

CAST IRON PIPE RESEARCH ASSOCIATION

HANDBOOK

Ductile Iron Pipe Cast Iron Pipe



Fourth Edition

CAST IRON PIPE RESEARCH ASSOCIATION

1301 W. 22nd St.

Oak Brook, Illinois 60521

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Oak Brook, Illinois

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PREFACE

The Cast Iron Pipe Research Association (CIPRA) is a non-profit corporation whose members are manufacturers of gray and ductile cast iron pressure pipe. Throughout its 60 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.

CIPRA'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, manuals and the Cast Iron Pipe News.

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

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. Unabridged ANSI and AWWA Standards are included, together with other helpful reference material.

Membership Directory

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Cast Iron Pipe Installed 1664 Versailles

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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-9Seine 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 installed cast iron mains.

Invention of Bell & Spigot Joint

The joints of these early cast iron lines were of the flanged type, with lead gaskets. These joints were used until Sir Thomas Simpson, engineer of the Chelsea Water Company, London, invented the bell and spigot joint in 1785. The bell and spigot 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. This joint was used extensively until recent years. Many of the original bell and spigot lines are still in use and apparently will serve for many more years.

Extensive Use of Cast Iron Pipe

There are more than 150 water and gas utilities in the United States that have cast iron distribution mains with continuous service records of more than 100 years.

Since the introduction of cast iron in this country, shortly after 1816, various other materials have been offered as suitable for water distribution mains. That none of these has proved able to supplant cast iron in the confidence and preference of water works engineers is demonstrated by a survey of the kinds of pipe in service in water distribution systems of the 100 largest U.S. cities. This survey revealed that cast iron pipe represented more than 90 percent of the pipe in service in these 100 cities.

Because of such strong evidence and the cumulative experience of generations of water works engineers, cast iron pipe remains more firmly entrenched than ever in its acknowledged position as the standard material for water distribution mains.

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 1930's.

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 compressed 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 VI).

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 20 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.

Manufacture of Cast Iron Pipe

The centrifugal casting methods used in manufacturing ductile and cast 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 characteristics 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.

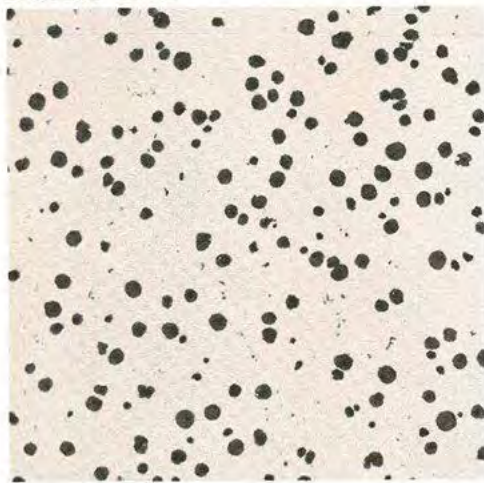
Microstructures

Gray Iron



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Ductile Iron



SECTION II

Gray Cast Iron Pipe

Introduction

Cast iron pipe is widely used for water transmission and distribution, gravity sewers and force mains, water and sewage treatment plants and industrial piping. Its characteristics make it an ideal piping material for underground, underwater and aboveground installations. It is available with a wide variety of joints, each suited for specific service conditions. Linings are available for protection against aggressive liquid; and external corrosion control measures can be provided where severe conditions prevail (see Section VIII).

Advantages of cast iron pipe include machineability, which provides ease of field cutting and tapping; convenient pipe lengths for ease of installation; and inherent corrosion resistance, assuring long service life.

Cast iron pressure pipe is designed in accordance with ANSI Standard A21.1 (AWWA C101) and manufactured in accordance with ANSI Standards A21.6 (AWWA C106), A21.8 (AWWA C108) and Federal Specifications WW-P-360b and WW-P-421c. The ANSI design and manufacturing Standards form a part of Federal Specification WW-P-421c by reference. Also referenced in this Specification are ANSI Standards A21.4 (AWWA C104) and A21.11 (AWWA C111) on linings and joints, respectively.

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.

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4 **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 is limited to 0.12 percent maximum in the current pipe standards.

Several other elements may be present and affect the physical properties. For this reason, the acceptance test requirements of cast iron pipe standards are based on the physical properties.

Quality Control

Modern metallurgical control enables the foundry to produce quality castings with the desired combination of properties. Tests carried out as a guide to metallurgical control include: 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 is the hydrostatic test to which every length is subjected. Correlation of the values obtained from all of these tests with service performance of the castings have enabled the cast iron pressure pipe industry to produce progressively better and more reliable cast iron pipe and fittings.

ANSI A21.1-1967
(AWWA C101-67)
(Formerly AWWA H1-67)
Reaffirmed w/o revision 1972

AMERICAN NATIONAL STANDARD
for
THICKNESS DESIGN OF CAST-IRON PIPE

With Tables of Pipe Thicknesses

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In Four Parts

- Sec. 1-1—Thickness Tables for Standard Conditions**
- Sec. 1-2—General Procedure for Thickness Determination**
- Sec. 1-3—Design Theory—Determination of Net Thickness,
Earth Load, and Truck Superload**
- Sec. 1-4—Thickness Determination for Pipe on Piers or Piling
Aboveground or Underground**

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AMERICAN WATER WORKS ASSOCIATION
NEW ENGLAND WATER WORKS ASSOCIATION

Approved by The American National Standard Institute, Nov. 10, 1967
Reaffirmed without revision Jul. 6, 1972

NOTICE

This Standard has been especially printed by the American Water Works Association for incorporation into this volume. It is current as of December 1, 1975. 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.

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

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Foreword

This foreword is provided for information only and is not a part of ANSI A21.1-1967 (AWWA C101-67).

History of Standard

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On Sep. 10, 1902, NEWWA adopted a "Standard Specification for Cast-Iron Pipe and Special Castings," covering bell-and-spigot pit-cast pipe and fittings of ten thickness classes. The thickness classes were based on allowable internal pressures varying by increments of 50 ft of head.

On May 12, 1908, AWWA adopted a "Standard Specification for Cast-Iron Pipe and Special Castings," covering bell-and-spigot pit-cast pipe and fittings of eight classes, A through H, with allowable working pressures varying by increments of 100 ft of head from 100 to 800 ft. Dimensions and weights were given for pipe and fittings.

In 1926, ASA Sectional Committee (now ANSI Standards Committee) A21 on Cast-Iron Pipe and Fittings was organized under the sponsorship of AGA, ASTM, AWWA, and NEWWA. The present scope of Committee A21 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.

Sectional Committee A21 sponsored many tests of pipe and fittings; these included subjection of pipe to combined earth load and internal pressures (which form the basis of pipe-thickness design), corrosion tests, measurement of hydraulic friction loss in fittings, and tests of bursting strengths of pipe and fittings. After exhaustive study of the test results and other research, the committee in 1939 issued A21.1, "American Standard Practice Manual for the Computation of Strength and Thickness of Cast-Iron Pipe." The manual included nomograms and thickness tables for pit-cast pipe with 11/31 * iron strength. As stated in the preface to that manual, however, the design method was applicable to pipe of any iron strength.

Discussions and interpretations^{1,2} of the method of design of cast-iron pipe were published in 1939 and presented to AWWA and AGA. As a result of these publications and because of the general acceptance of A21.1, a substantial volume of cast-iron pipe was designed by the new method and furnished to manufacturers' standards between 1939 and 1953. A standard (A21.2) for pit-cast pipe with 11/31 iron strength also was issued in 1939. Work on standards for centrifugally cast pipe with 18/40 iron strength was started after the design was completed in 1939, but, owing to the intervention of World War II and other causes, they were not formally issued until 1953.

* The first figure designates the bursting tensile strength in units of 1,000 psi and the second figure designates the ring modulus of rupture in units of 1,000 psi.

In 1957, a revision of A21.1 was issued. In that revision, designated ASA A21.1-1957 (AWWA H1-57) the major change was the addition of a method for computing earth loads on pipe laid under embankments and of nomograms and thickness tables for centrifugally cast pipe with 18/40 iron strength.

In 1958, Sectional 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 scope of Subcommittee 1—Pipe is:

To include the periodic review of all current A21 standards for pipe, the preparation of revisions or new standards when needed, as well as other matters pertaining to pipe standards.

As a result of the work of Subcommittee No. 1 on this assignment, revisions of the cast-iron pipe standards A21.6 (AWWA C106), A21.7, A21.8 (AWWA C108), and A21.9 were issued in 1962 and again in 1970. Revision of A21.1-1957 (AWWA H1-57) was delayed in order for the subcommittee to carry out a new assignment from the sectional committee to develop a design standard and pipe standards for ductile-iron pipe. Subsequently, the subcommittee completed its study and a revision of A21.1 was issued in 1967.

In 1971, Subcommittee No. 1 reviewed the 1967 edition and submitted a recommendation to Committee A21 that the standard be reaffirmed without change. Therefore, this reaffirmed edition is unchanged from the 1967 edition, except for the updating of this foreword. For convenience, the major features listed in the foreword of the 1967 edition are repeated here.

Major Features of 1967 Revision

Although ANSI A21.1-1967 (AWWA H1-67) contained no changes in the basic design method, a number of revisions were incorporated to simplify the design procedure and to reflect changes in technology. Major features of the 1967 revision are discussed.

1. *Format.* This revision is divided into four major sections: Sec. 1-1 gives thickness tables for standard conditions; Sec. 1-2 gives the general procedure for thickness determination; Sec. 1-3 gives design theory and provides methods for determining pipe thicknesses, earth loads, and truck superloads for both standard and special conditions; and Sec. 1-4 gives the design procedure for a special installation condition, pipe on piers aboveground or underground.

2. *Iron strength.* Thickness tables, nomograms, and other data for pit-cast pipe (11/31 iron strength) were deleted, as this type of pipe is seldom furnished today.

Centrifugally cast pipe covered under ANSI Standards A21.6 (AWWA C106), A21.7, A21.8 (AWWA C108), and A21.9 are specified to have an iron strength of not less than 18/40. Advances in production technology have enabled the manufacturers to furnish pipe with greater strength, and pipe with 21/45 iron strength has been available for many years. Thus, for the con-

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venience of users, tables and figures in the standard cover pipe with iron strengths of both 18/40 and 21/45.

3. *Laying conditions.* Laying conditions C, D, and E (also called "field conditions" in the 1957 revision) were deleted. Conditions C and D were for pipe laid on blocks, a method sometimes used in the 1920s and 1930s. This method has been recognized as undesirable and is seldom used today. Condition E was for pipe laid with special bedding but without tamping the backfill. It was felt that this combination would rarely be used today; when special bedding is used, the backfill is almost always tamped, giving laying condition F, which was retained in this revision.

4. *Earth loads.* Formulas and procedures were added (Sec. 1-3) for determining earth loads for standard and special conditions. Earth loads shown in Table 1-8 are the same as those given in the 1957 revision, except that loads for 20 and 24 ft of cover were added.

5. *Allowance for truck superloads.* Formulas and procedures were added (Sec. 1-3) for determining truck superloads for standard and special conditions. These procedures may be used to compute truck superloads for unpaved roads, flexible pavement, or rigid pavement; one truck or two passing trucks; and any wheel load and impact factor, including AASHO truck loadings. Truck superloads for standard conditions are shown in Table 1-8 and are the same as given in the 1957 revision, except that loads for 20 and 24 ft of cover were added.

6. *Allowance for surge pressure.* The allowances for surge pressure (water hammer), shown in Table 1-10, are unchanged from those given in the 1957 revision.

7. *Allowance for corrosion.* A standard allowance for soil corrosion of 0.08 in., based on judgment and experience of early engineers, was used in the 1939 manual and continued in the 1957 revision. The allowance of 0.08 in. was also retained in this edition. It is very conservative for many soils, and has proved to be adequate in most. In areas suspected or known to be highly corrosive, however, the designer should take special precautions. Where unusually corrosive soil conditions are anticipated, a soil survey is recommended.

8. *Pipe on piers.* A new section (Sec. 1-4) was added to provide procedures for computing thicknesses of pipe installed on piers or piling, a condition sometimes encountered in laying pipe in unstable soil, across streams or swamps, either aboveground or underground, and in installing pipe on bridges and other aboveground structures.

Standard Thicknesses of Pit-Cast Pipe

As stated in the foregoing, thickness tables for pit-cast pipe were deleted in the 1967 edition. During the review of this standard in 1971, it was determined that some standards and codes refer to the table of standard thickness classes for pit-cast pipe shown as Table 10 in the 1957 edition of A21.1. For reference, the contents of that table are reproduced on the next page:

AMERICAN NATIONAL STANDARD

Standard Thickness Classes for Pit-Cast Pipe*

Pipe Size in.	Pipe-Wall Thickness (in.) for Standard Thickness Class No.:													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
3	0.37	0.40	0.43	0.46	0.50	0.54	0.58	0.63	0.68	0.73	0.79	0.85	0.92	0.99
4	0.40	0.43	0.46	0.50	0.54	0.58	0.63	0.68	0.73	0.79	0.85	0.92	0.99	1.07
6	0.43	0.46	0.50	0.54	0.58	0.63	0.68	0.73	0.79	0.85	0.92	0.99	1.07	1.16
8	0.46	0.50	0.54	0.58	0.63	0.68	0.73	0.79	0.85	0.92	0.99	1.07	1.16	1.25
10	0.50	0.54	0.58	0.63	0.68	0.73	0.79	0.85	0.92	0.99	1.07	1.16	1.25	1.35
12	0.54	0.58	0.63	0.68	0.73	0.79	0.85	0.92	0.99	1.07	1.16	1.25	1.35	1.46
14	0.54	0.58	0.63	0.68	0.73	0.79	0.85	0.92	0.99	1.07	1.16	1.25	1.35	1.46
16	0.58	0.63	0.68	0.73	0.79	0.85	0.92	0.99	1.07	1.16	1.25	1.35	1.46	1.58
18	0.63	0.68	0.73	0.79	0.85	0.92	0.99	1.07	1.16	1.25	1.35	1.46	1.58	1.71
20	0.66	0.71	0.77	0.83	0.90	0.97	1.05	1.13	1.22	1.32	1.43	1.54	1.66	1.79
24	0.74	0.80	0.86	0.93	1.00	1.08	1.17	1.26	1.36	1.47	1.59	1.72	1.86	2.01
30	0.87	0.94	1.02	1.10	1.19	1.29	1.39	1.50	1.62	1.75	1.89	2.04	2.20	2.38
36	0.97	1.05	1.13	1.22	1.32	1.43	1.54	1.66	1.79	1.93	2.08	2.25	2.43	2.62
42	1.07	1.16	1.25	1.35	1.46	1.58	1.71	1.85	2.00	2.16	2.33	2.52	2.72	2.94
48	1.18	1.27	1.37	1.48	1.60	1.73	1.87	2.02	2.18	2.35	2.54	2.74	2.96	3.20
54	1.30	1.40	1.51	1.63	1.76	1.90	2.05	2.21	2.39	2.58	2.79	3.01	3.25	3.51
60	1.39	1.50	1.62	1.75	1.89	2.04	2.20	2.38	2.57	2.78	3.00	3.24	3.50	3.78

* Each class is made 8 per cent heavier than the preceding class, starting with the thinnest, i.e., minimum thickness, as the base class.

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Sec. 1-1—Thickness Tables for Standard Conditions

Sec. 1-1.1—General

Tables 1-1, 1-2, and 1-3, as applicable, permit the direct determination of the required thickness of cast-iron pipe limited to the following conditions:

a. Vertical-sided trench of width at top of pipe not greater than the nominal pipe diameter plus 2 ft

b. Unit weight of soil 120 lb/cu ft

c. $K\mu = 0.1924$, $K\mu' = 0.130$ (see Sec. 1-3.2 for definition)

d. Truck superload based on two passing trucks with adjacent wheels 3 ft apart, 9,000 lb wheel load, unpaved road or flexible pavement, 1.50 impact factor

e. Surge allowances as shown in Table 1-10

f. Iron strengths of 18/40 and 21/45*

g. The three most common laying conditions:

A—Pipe laid on flat-bottom trench, backfill not tamped

B—Pipe laid on flat-bottom trench, backfill tamped

* The first figure designates the bursting tensile strength (S) in units of 1,000 psi and the second figure designates the ring modulus of rupture (R) in units of 1,000 psi.

F—Pipe bedded in gravel or sand, backfill tamped

h. Allowances for casting tolerance as shown in Table 1-6

i. A corrosion allowance of 0.08 in.

Sec. 1-1.2—Trench Load and Internal Pressure

The required thickness of cast-iron pressure pipe is determined from a consideration of trench load and internal pressure in combination. Trench load is considered to consist of the earth load on the pipe plus any superload resulting from traffic over the trench. Internal pressure is considered to consist of the design working pressure plus an additional allowance for surge pressure. Two different combinations of trench load and internal pressure are considered in the design:

Case 1. Trench load (earth load but no truck superload) in combination with internal pressure (working pressure plus surge pressure) and with 2.5 factor of safety applied to both trench load and internal pressure

Case 2. Trench load (earth load plus truck superload) in combination with internal pressure (working pressure but no surge pressure) and with

a 2.5 factor of safety applied to both trench load and internal pressure.

Sec. 1-1.3—Traffic Superload and Surge Pressure

In designing water pipe it is customary to assume that neither traffic superload nor surge pressure will occur in important magnitude simultaneously. Thus, calculations for the required thickness of water pipe are made for both conditions independently, and the greater of the two thicknesses thus determined is chosen as the net thickness.

In designing gas pipe the procedure is the same, except that surge pressure is not a factor and only Case 2 is considered.

Sec. 1-1.4—Corrosion Allowance and Casting Tolerance

To the net thickness determined as explained above, a corrosion allowance and a casting tolerance are added to obtain the calculated thickness shown in Tables 1-1, 1-2, and 1-3. The standard thickness class and/or the nominal thickness for this class shown in Tables 1-1, 1-2, and 1-3 are used for specifying and ordering pipe.

For other than standard conditions the formulas, tables, and diagrams in Sec. 1-2 may be used. The design theory on which Tables 1-1, 1-2, and 1-3 are based is presented in Sec. 1-3. Procedures for determining the net thickness of pipe on piers or piling above- or belowground are presented in Sec. 1-4.

TABLE 1-1
Schedule of Barrel Thickness for Water Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thicknesses—in.						
Three-Inch Water Pipe									
A	2½	Calculated Thickness	.21*	.21*	.22*	.22*	.22*	.22*	.23*
		Use { Thickness Class Thickness	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32
	3½	Calculated Thickness	.21*	.21*	.22*	.22*	.22*	.22*	.23*
		Use { Thickness Class Thickness	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32
	5	Calculated Thickness	.21*	.21*	.22*	.22*	.23	.23	.24
		Use { Thickness Class Thickness	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32
8	Calculated Thickness	.22*	.23*	.23*	.24	.24	.24	.25	
	Use { Thickness Class Thickness	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	
12	Calculated Thickness	.24*	.25*	.25*	.26	.26	.27	.28	
	Use { Thickness Class Thickness	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	
16	Calculated Thickness	.27	.27	.28	.28	.28	.29	.29	
	Use { Thickness Class Thickness	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	
B	2½	Calculated Thickness	.21*	.21*	.22*	.22*	.22*	.22*	.23*
		Use { Thickness Class Thickness	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32
	3½	Calculated Thickness	.21*	.21*	.22*	.22*	.22*	.22*	.23*
		Use { Thickness Class Thickness	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32
	5	Calculated Thickness	.21*	.21*	.22*	.22*	.23	.23	.24
		Use { Thickness Class Thickness	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32
8	Calculated Thickness	.22*	.22*	.23*	.23*	.24	.24	.24	
	Use { Thickness Class Thickness	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	
12	Calculated Thickness	.24*	.24*	.25	.25	.26	.26	.27	
	Use { Thickness Class Thickness	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	
16	Calculated Thickness	.26	.26	.27	.27	.28	.28	.29	
	Use { Thickness Class Thickness	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	
F	2½	Calculated Thickness	.21*	.21*	.21*	.21*	.22*	.22*	.23
		Use { Thickness Class Thickness	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32
	3½	Calculated Thickness	.21*	.21*	.21*	.21*	.22*	.22*	.23
		Use { Thickness Class Thickness	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32
	5	Calculated Thickness	.21*	.21*	.21*	.22*	.22*	.22*	.23
		Use { Thickness Class Thickness	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32
8	Calculated Thickness	.21	.21	.22	.22	.23	.23	.24	
	Use { Thickness Class Thickness	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	
12	Calculated Thickness	.23	.23	.23	.24	.24	.24	.25	
	Use { Thickness Class Thickness	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	
16	Calculated Thickness	.24	.24	.25	.25	.26	.26	.27	
	Use { Thickness Class Thickness	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	.22 .32	

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-1 (Continued)
 Schedule of Barrel Thickness for Water Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thicknesses—in.						
Four-Inch Water Pipe									
A	2½	Calculated Thickness	.23*	.23*	.24*	.24*	.24*	.25*	.27
		Use { Thickness Class Thickness	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35
	3½	Calculated Thickness	.23*	.23*	.23*	.24	.24	.25	.27
		Use { Thickness Class Thickness	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35
	5	Calculated Thickness	.23*	.24*	.24*	.25	.26	.27	.28
		Use { Thickness Class Thickness	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35
8	Calculated Thickness	.25*	.26	.27	.28	.28	.29	.30	
	Use { Thickness Class Thickness	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	
12	Calculated Thickness	.29	.29	.30	.30	.31	.31	.32	
	Use { Thickness Class Thickness	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	
16	Calculated Thickness	.31	.31	.32	.32	.33	.33	.34	
	Use { Thickness Class Thickness	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	
B	2½	Calculated Thickness	.23*	.23*	.23*	.23*	.24*	.25	.27
		Use { Thickness Class Thickness	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35
	3½	Calculated Thickness	.23*	.23*	.23*	.24	.25	.26	.27
		Use { Thickness Class Thickness	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35
	5	Calculated Thickness	.23	.24	.24	.25	.26	.27	.28
		Use { Thickness Class Thickness	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35
8	Calculated Thickness	.25	.26	.27	.27	.28	.29	.29	
	Use { Thickness Class Thickness	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	
12	Calculated Thickness	.28	.28	.29	.30	.30	.31	.32	
	Use { Thickness Class Thickness	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	
16	Calculated Thickness	.30	.31	.31	.32	.32	.33	.33	
	Use { Thickness Class Thickness	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	
F	2½	Calculated Thickness	.23*	.23*	.23*	.24*	.24	.25	.26
		Use { Thickness Class Thickness	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35
	3½	Calculated Thickness	.23*	.23*	.23	.24	.24	.25	.26
		Use { Thickness Class Thickness	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35
	5	Calculated Thickness	.23	.23	.23	.24	.24	.25	.26
		Use { Thickness Class Thickness	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35
8	Calculated Thickness	.24	.24	.25	.25	.25	.26	.27	
	Use { Thickness Class Thickness	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	
12	Calculated Thickness	.25	.26	.27	.28	.28	.29	.30	
	Use { Thickness Class Thickness	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	
16	Calculated Thickness	.28	.28	.29	.29	.30	.30	.31	
	Use { Thickness Class Thickness	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-1 (Continued)
 Schedule of Barrel Thickness for Water Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thicknesses—in.						
Six-Inch Water Pipe									
A	2½	Calculated Thickness	.29*	.29*	.30*	.31*	.32*	.33*	.34
		Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38
	3½	Calculated Thickness	.28*	.28*	.29*	.30*	.31*	.32*	.34
		Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38
	5	Calculated Thickness	.29*	.29*	.30*	.31*	.33	.34	.35
		Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38
8	Calculated Thickness	.32	.33	.34	.35	.36	.37	.38	
	Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	
12	Calculated Thickness	.36	.37	.38	.38	.39	.40	.41	
	Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	
16	Calculated Thickness	.39	.40	.41	.42	.42	.43	.44	
	Use { Thickness Class Thickness	22 .38	23 .41	23 .41	23 .41	23 .41	23 .41	23 .41	
B	2½	Calculated Thickness	.28*	.28*	.29*	.30*	.31*	.32*	.33*
		Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38
	3½	Calculated Thickness	.27*	.28*	.28*	.29*	.30*	.32	.34
		Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38
	5	Calculated Thickness	.28*	.29	.30	.31	.32	.33	.34
		Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38
8	Calculated Thickness	.31	.32	.33	.34	.35	.36	.37	
	Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	
12	Calculated Thickness	.35	.35	.36	.37	.38	.39	.40	
	Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	
16	Calculated Thickness	.38	.38	.39	.40	.41	.42	.43	
	Use { Thickness Class Thickness	22 .38	22 .38	22 .38	23 .41	23 .41	23 .41	23 .41	
F	2½	Calculated Thickness	.26*	.27*	.28	.29	.30	.32	.34
		Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38
	3½	Calculated Thickness	.27	.27	.28	.29	.30	.32	.34
		Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38
	5	Calculated Thickness	.28	.28	.29	.29	.30	.32	.35
		Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38
8	Calculated Thickness	.29	.30	.31	.32	.33	.34	.35	
	Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	
12	Calculated Thickness	.32	.33	.34	.35	.36	.37	.38	
	Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	
16	Calculated Thickness	.35	.35	.36	.37	.38	.39	.40	
	Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-1 (Continued)
Schedule of Barrel Thickness for Water Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thicknesses—in.						
Eight-Inch Water Pipe									
A	2½	Calculated Thickness	.34*	.35*	.36*	.37*	.38*	.39*	.40*
		Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41
	3½	Calculated Thickness	.33*	.34*	.34*	.35*	.36*	.39	.41
		Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41
	5	Calculated Thickness	.34*	.35*	.36*	.37*	.39	.41	.43
		Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41
8	Calculated Thickness	.38	.39	.40	.41	.43	.44	.46	
	Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41
12	Calculated Thickness	.43	.44	.45	.46	.47	.49	.50	
	Use { Thickness Class Thickness	.23 .44	.23 .44	.23 .44	.24 .48	.24 .48	.24 .48	.24 .48	.24 .48
16	Calculated Thickness	.46	.47	.48	.49	.51	.52	.53	
	Use { Thickness Class Thickness	.24 .48	.24 .48	.24 .48	.24 .48	.25 .52	.25 .52	.25 .52	.25 .52
B	2½	Calculated Thickness	.32*	.33*	.34*	.35*	.36*	.38*	.39*
		Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41
	3½	Calculated Thickness	.32*	.33*	.33*	.34*	.36*	.38	.40
		Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41
	5	Calculated Thickness	.33*	.34*	.35	.36	.38	.40	.42
		Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41
8	Calculated Thickness	.36	.37	.38	.40	.41	.43	.45	
	Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41
12	Calculated Thickness	.41	.42	.43	.44	.46	.47	.48	
	Use { Thickness Class Thickness	.22 .41	.22 .41	.23 .44	.23 .44	.24 .48	.24 .48	.24 .48	.24 .48
16	Calculated Thickness	.44	.45	.46	.47	.48	.50	.51	
	Use { Thickness Class Thickness	.23 .44	.23 .44	.24 .48	.24 .48	.24 .48	.25 .52	.25 .52	.25 .52
F	2½	Calculated Thickness	.30*	.31*	.32*	.33*	.35	.37	.39
		Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41
	3½	Calculated Thickness	.29*	.30*	.31	.33	.35	.37	.39
		Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41
	5	Calculated Thickness	.30*	.31*	.32	.34	.36	.38	.40
		Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41
8	Calculated Thickness	.34	.35	.36	.37	.39	.41	.43	
	Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41
12	Calculated Thickness	.38	.39	.40	.41	.43	.44	.46	
	Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41
16	Calculated Thickness	.40	.41	.42	.43	.45	.46	.48	
	Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.23 .44	.23 .44	.24 .48	.24 .48	.24 .48

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-1 (Continued)
Schedule of Barrel Thickness for Water Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thicknesses—in.						
Ten-Inch Water Pipe									
A	2½	Calculated Thickness	.40*	.41*	.42*	.43*	.45*	.46*	.48*
		Use { Thickness Class Thickness	22 .44	22 .44	22 .44	22 .44	22 .44	23 .48	23 .48
	3½	Calculated Thickness	.39*	.40*	.41*	.42*	.44*	.46	.49
		Use { Thickness Class Thickness	22 .44	22 .44	22 .44	22 .44	22 .44	23 .48	23 .48
	5	Calculated Thickness	.40*	.41*	.42*	.44	.46	.48	.51
		Use { Thickness Class Thickness	22 .44	22 .44	22 .44	22 .44	23 .48	23 .48	24 .52
8	Calculated Thickness	.44	.46	.47	.49	.51	.53	.55	
	Use { Thickness Class Thickness	22 .44	23 .48	23 .48	23 .48	24 .52	24 .52	25 .56	
12	Calculated Thickness	.51	.52	.53	.55	.56	.58	.60	
	Use { Thickness Class Thickness	24 .52	24 .52	24 .52	25 .56	25 .56	26 .60	26 .60	
16	Calculated Thickness	.53	.54	.56	.57	.59	.60	.62	
	Use { Thickness Class Thickness	24 .52	25 .56	25 .56	25 .56	26 .60	26 .60	26 .60	
B	2½	Calculated Thickness	.38*	.39*	.40*	.41*	.43*	.45*	.47*
		Use { Thickness Class Thickness	22 .44	22 .44	22 .44	22 .44	22 .44	22 .44	23 .48
	3½	Calculated Thickness	.37*	.38*	.39*	.40*	.42*	.44	.48
		Use { Thickness Class Thickness	22 .44	22 .44	22 .44	22 .44	22 .44	22 .44	23 .48
	5	Calculated Thickness	.38*	.39*	.40*	.42	.45	.47	.50
		Use { Thickness Class Thickness	22 .44	22 .44	22 .44	22 .44	22 .44	23 .48	24 .52
8	Calculated Thickness	.41*	.44	.45	.47	.49	.51	.53	
	Use { Thickness Class Thickness	22 .44	22 .44	22 .44	23 .48	23 .48	24 .52	24 .52	
12	Calculated Thickness	.48	.49	.51	.52	.54	.56	.58	
	Use { Thickness Class Thickness	23 .48	23 .48	24 .52	24 .52	25 .56	25 .56	26 .60	
16	Calculated Thickness	.50	.52	.53	.54	.56	.58	.60	
	Use { Thickness Class Thickness	24 .52	24 .52	24 .52	25 .56	25 .56	26 .60	26 .60	
F	2½	Calculated Thickness	.35*	.36*	.37*	.38*	.41	.44	.47
		Use { Thickness Class Thickness	22 .44	22 .44	22 .44	22 .44	22 .44	22 .44	23 .48
	3½	Calculated Thickness	.34*	.35*	.36*	.38	.41	.44	.47
		Use { Thickness Class Thickness	22 .44	22 .44	22 .44	22 .44	22 .44	22 .44	23 .48
	5	Calculated Thickness	.35*	.36*	.38	.40	.42	.46	.48
		Use { Thickness Class Thickness	22 .44	22 .44	22 .44	22 .44	22 .44	23 .48	23 .48
8	Calculated Thickness	.39	.41	.42	.44	.46	.48	.51	
	Use { Thickness Class Thickness	22 .44	22 .44	22 .44	22 .44	23 .48	23 .48	24 .52	
12	Calculated Thickness	.44	.45	.46	.48	.50	.52	.54	
	Use { Thickness Class Thickness	22 .44	22 .44	23 .48	23 .48	24 .52	24 .52	25 .56	
16	Calculated Thickness	.46	.47	.49	.51	.52	.54	.56	
	Use { Thickness Class Thickness	23 .48	23 .48	23 .48	24 .52	24 .52	25 .56	25 .56	

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-1 (Continued)
Schedule of Barrel Thickness for Water Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thicknesses—in.						
Twelve-Inch Water Pipe									
A	2½	Calculated Thickness	.45*	.46*	.47*	.49*	.51*	.53*	.55*
		Use { Thickness Class Thickness	.22 .48	.22 .48	.22 .48	.22 .48	.23 .48	.23 .52	.24 .56
	3½	Calculated Thickness	.43*	.45*	.46*	.48*	.50*	.51	.55
		Use { Thickness Class Thickness	.22 .48	.22 .48	.22 .48	.22 .48	.23 .52	.23 .52	.24 .56
	5	Calculated Thickness	.45*	.46*	.47*	.49	.52	.54	.57
		Use { Thickness Class Thickness	.22 .48	.22 .48	.22 .48	.22 .48	.23 .52	.24 .56	.24 .56
8	Calculated Thickness	.50	.52	.53	.55	.57	.60	.62	
	Use { Thickness Class Thickness	.23 .52	.23 .52	.23 .52	.24 .56	.24 .56	.25 .60	.25 .60	
12	Calculated Thickness	.56	.57	.59	.60	.62	.64	.67	
	Use { Thickness Class Thickness	.24 .56	.24 .56	.25 .60	.25 .60	.25 .60	.26 .65	.26 .65	
16	Calculated Thickness	.59	.60	.61	.63	.65	.67	.69	
	Use { Thickness Class Thickness	.25 .60	.25 .60	.25 .60	.26 .60	.26 .65	.26 .65	.27 .70	
B	2½	Calculated Thickness	.42*	.44*	.45*	.46*	.48*	.50*	.53*
		Use { Thickness Class Thickness	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48	.23 .52	.23 .52
	3½	Calculated Thickness	.41*	.42*	.44*	.45*	.47*	.51	.55
		Use { Thickness Class Thickness	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48	.23 .52	.24 .56
	5	Calculated Thickness	.42*	.43*	.45*	.47	.50	.53	.56
		Use { Thickness Class Thickness	.22 .48	.22 .48	.22 .48	.22 .48	.23 .52	.23 .52	.24 .56
8	Calculated Thickness	.48	.49	.51	.53	.55	.57	.60	
	Use { Thickness Class Thickness	.22 .48	.22 .48	.23 .52	.23 .52	.24 .56	.24 .56	.25 .60	
12	Calculated Thickness	.53	.54	.56	.57	.59	.61	.64	
	Use { Thickness Class Thickness	.23 .52	.24 .56	.24 .56	.24 .56	.25 .60	.25 .60	.26 .65	
16	Calculated Thickness	.55	.57	.58	.60	.62	.64	.66	
	Use { Thickness Class Thickness	.24 .56	.24 .56	.25 .60	.25 .60	.25 .60	.26 .65	.26 .65	
F	2½	Calculated Thickness	.39*	.40*	.41*	.43*	.45*	.49	.53
		Use { Thickness Class Thickness	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48	.22 .52
	3½	Calculated Thickness	.38*	.39*	.40*	.42*	.45	.50	.53
		Use { Thickness Class Thickness	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48	.22 .52	.23 .52
	5	Calculated Thickness	.39*	.40*	.41*	.43*	.46	.50	.54
		Use { Thickness Class Thickness	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48	.23 .52	.23 .56
8	Calculated Thickness	.44	.45	.47	.49	.52	.55	.58	
	Use { Thickness Class Thickness	.22 .48	.22 .48	.22 .48	.22 .48	.23 .52	.24 .56	.24 .60	
12	Calculated Thickness	.48	.49	.51	.53	.55	.58	.61	
	Use { Thickness Class Thickness	.22 .48	.22 .48	.23 .52	.23 .52	.24 .56	.25 .60	.25 .60	
16	Calculated Thickness	.50	.52	.53	.55	.57	.59	.62	
	Use { Thickness Class Thickness	.23 .52	.23 .52	.23 .52	.24 .56	.24 .56	.25 .60	.25 .60	

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-1 (Continued)
Schedule of Barrel Thickness for Water Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thicknesses—in.						
Fourteen-Inch Water Pipe									
A	2½	Calculated Thickness	.51*	.52*	.54*	.55*	.58*	.60*	.62*
		Use { Thickness Class Thickness	22 .51	22 .51	23 .55	23 .55	24 .59	24 .59	25 .64
	3½	Calculated Thickness	.50*	.51*	.53*	.54*	.57*	.60	.64
		Use { Thickness Class Thickness	22 .51	22 .51	23 .55	23 .55	24 .59	24 .59	25 .64
	5	Calculated Thickness	.51*	.53*	.54*	.56*	.59	.62	.66
		Use { Thickness Class Thickness	22 .51	23 .55	23 .55	23 .55	24 .59	25 .64	25 .64
8	Calculated Thickness	.58	.60	.62	.64	.66	.69	.72	
	Use { Thickness Class Thickness	24 .59	24 .59	25 .64	25 .64	25 .64	26 .69	27 .75	
12	Calculated Thickness	.63	.65	.67	.69	.71	.74	.76	
	Use { Thickness Class Thickness	25 .64	25 .64	26 .69	26 .69	26 .69	27 .75	27 .75	
16	Calculated Thickness	.67	.68	.70	.72	.74	.76	.79	
	Use { Thickness Class Thickness	26 .69	26 .69	26 .69	27 .75	27 .75	27 .75	28 .81	
B	2½	Calculated Thickness	.47*	.49*	.51*	.52*	.54*	.57*	.62
		Use { Thickness Class Thickness	21 .48	21 .48	22 .51	22 .51	23 .55	24 .59	25 .64
	3½	Calculated Thickness	.46*	.47*	.49*	.51*	.54	.57	.63
		Use { Thickness Class Thickness	21 .48	21 .48	22 .51	22 .51	23 .55	24 .59	25 .64
	5	Calculated Thickness	.48*	.49*	.52	.54	.57	.61	.65
		Use { Thickness Class Thickness	21 .48	22 .51	22 .51	23 .55	24 .59	24 .59	25 .64
8	Calculated Thickness	.54	.56	.58	.61	.63	.66	.69	
	Use { Thickness Class Thickness	23 .55	23 .55	24 .59	24 .59	25 .64	25 .64	26 .69	
12	Calculated Thickness	.59	.61	.63	.65	.68	.70	.73	
	Use { Thickness Class Thickness	24 .59	24 .59	25 .64	25 .64	26 .69	26 .69	27 .75	
16	Calculated Thickness	.62	.64	.66	.68	.70	.73	.75	
	Use { Thickness Class Thickness	25 .64	25 .64	25 .64	26 .69	26 .69	27 .75	27 .75	
F	2½	Calculated Thickness	.44*	.45*	.47*	.49*	.52	.57	.61
		Use { Thickness Class Thickness	21 .48	21 .48	21 .48	21 .48	22 .51	24 .59	24 .59
	3½	Calculated Thickness	.44*	.45*	.47	.50	.53	.57	.62
		Use { Thickness Class Thickness	21 .48	21 .48	21 .48	22 .51	23 .55	24 .59	25 .64
	5	Calculated Thickness	.45	.47	.49	.52	.55	.59	.64
		Use { Thickness Class Thickness	21 .48	21 .48	21 .48	22 .51	23 .55	24 .59	25 .64
8	Calculated Thickness	.50	.52	.54	.57	.60	.64	.66	
	Use { Thickness Class Thickness	22 .51	22 .51	23 .55	24 .59	24 .59	25 .64	25 .64	
12	Calculated Thickness	.54	.56	.58	.61	.63	.66	.69	
	Use { Thickness Class Thickness	23 .55	23 .55	24 .59	24 .59	25 .64	25 .64	26 .69	
16	Calculated Thickness	.57	.58	.60	.63	.65	.68	.71	
	Use { Thickness Class Thickness	24 .59	24 .59	24 .59	25 .64	25 .64	26 .69	26 .69	

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-1 (Continued)
 Schedule of Barrel Thickness for Water Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thicknesses—in.						
Sixteen-Inch Water Pipe									
A	2½	Calculated Thickness	.54*	.56*	.58*	.60*	.62*	.65*	.68*
		Use { Thickness Class Thickness	22 .54	23 .58	23 .58	23 .58	24 .63	24 .63	25 .68
	3½	Calculated Thickness	.54*	.55*	.57*	.59*	.61	.65	.70
		Use { Thickness Class Thickness	22 .54	22 .54	23 .58	23 .58	24 .63	24 .63	25 .68
	5	Calculated Thickness	.56*	.57*	.59*	.61*	.64	.68	.72
		Use { Thickness Class Thickness	23 .58	23 .58	23 .58	24 .63	24 .63	25 .68	26 .73
8	Calculated Thickness	.62	.64	.66	.69	.72	.75	.78	
	Use { Thickness Class Thickness	24 .63	24 .63	25 .68	25 .68	26 .73	26 .73	27 .79	
12	Calculated Thickness	.68	.70	.72	.74	.77	.80	.83	
	Use { Thickness Class Thickness	25 .68	25 .68	26 .73	26 .73	27 .79	27 .79	28 .85	
16	Calculated Thickness	.72	.74	.76	.78	.81	.83	.86	
	Use { Thickness Class Thickness	26 .73	26 .73	27 .79	27 .79	27 .79	28 .85	28 .85	
B	2½	Calculated Thickness	.50*	.52*	.54*	.56*	.59*	.62*	.65*
		Use { Thickness Class Thickness	21 .50	22 .54	22 .54	23 .58	23 .58	24 .63	25 .68
	3½	Calculated Thickness	.50*	.52*	.53*	.56*	.59	.63	.68
		Use { Thickness Class Thickness	21 .50	22 .54	22 .54	23 .58	23 .58	24 .63	25 .68
	5	Calculated Thickness	.52*	.53*	.55*	.58	.62	.66	.70
		Use { Thickness Class Thickness	22 .54	22 .54	22 .54	23 .58	24 .63	25 .68	25 .68
8	Calculated Thickness	.58	.60	.62	.65	.68	.71	.75	
	Use { Thickness Class Thickness	23 .58	23 .58	24 .63	24 .63	25 .68	26 .73	26 .73	
12	Calculated Thickness	.63	.65	.68	.70	.73	.76	.79	
	Use { Thickness Class Thickness	24 .63	24 .63	25 .68	25 .68	26 .73	27 .79	27 .79	
16	Calculated Thickness	.67	.69	.71	.73	.76	.79	.82	
	Use { Thickness Class Thickness	25 .68	25 .68	26 .73	26 .73	27 .79	27 .79	28 .85	
F	2½	Calculated Thickness	.47*	.48*	.50*	.52*	.56	.61	.67
		Use { Thickness Class Thickness	21 .50	21 .50	21 .50	22 .54	23 .58	24 .63	25 .68
	3½	Calculated Thickness	.46*	.47*	.50	.53	.57	.62	.67
		Use { Thickness Class Thickness	21 .50	21 .50	21 .50	22 .54	23 .58	24 .63	25 .68
	5	Calculated Thickness	.48*	.50	.52	.56	.59	.64	.68
		Use { Thickness Class Thickness	21 .50	21 .50	22 .54	23 .58	23 .58	24 .63	25 .68
8	Calculated Thickness	.53	.55	.58	.61	.64	.68	.72	
	Use { Thickness Class Thickness	22 .54	22 .54	23 .58	24 .63	24 .63	25 .68	26 .73	
12	Calculated Thickness	.57	.59	.62	.65	.68	.71	.75	
	Use { Thickness Class Thickness	23 .58	23 .58	24 .63	24 .63	25 .68	26 .73	26 .73	
16	Calculated Thickness	.61	.63	.65	.68	.71	.74	.77	
	Use { Thickness Class Thickness	24 .63	24 .63	24 .63	25 .68	26 .73	26 .73	27 .79	

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-1 (Continued)
Schedule of Barrel Thickness for Water Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thicknesses—in.						
Eighteen-Inch Water Pipe									
A	2½	Calculated Thickness	.58*	.60*	.62*	.65*	.67*	.70*	.74*
		Use (Thickness Class Thickness)	.22 .58	.22 .58	.23 .63	.23 .63	.24 .68	.24 .68	.25 .73
	3½	Calculated Thickness	.58*	.59*	.62*	.64*	.67*	.70	.76
		Use (Thickness Class Thickness)	.22 .58	.22 .58	.23 .63	.23 .63	.24 .68	.24 .68	.26 .79
	5	Calculated Thickness	.60*	.62*	.64*	.67	.70	.75	.79
		Use (Thickness Class Thickness)	.22 .58	.23 .63	.23 .63	.24 .68	.24 .68	.25 .73	.26 .79
8	Calculated Thickness	.67	.69	.72	.74	.77	.81	.85	
	Use (Thickness Class Thickness)	.24 .68	.24 .68	.25 .73	.25 .73	.26 .79	.26 .79	.27 .85	
12	Calculated Thickness	.73	.75	.78	.80	.83	.86	.90	
	Use (Thickness Class Thickness)	.25 .73	.25 .73	.26 .79	.26 .79	.27 .85	.27 .85	.28 .92	
16	Calculated Thickness	.77	.80	.82	.85	.88	.91	.95	
	Use (Thickness Class Thickness)	.26 .79	.26 .79	.27 .85	.27 .85	.27 .85	.28 .92	.28 .92	
B	2½	Calculated Thickness	.54*	.56*	.58*	.60*	.63*	.67	.73
		Use (Thickness Class Thickness)	.21 .54	.22 .58	.22 .58	.22 .58	.23 .63	.24 .68	.25 .73
	3½	Calculated Thickness	.53*	.55*	.57*	.60	.64	.69	.75
		Use (Thickness Class Thickness)	.21 .54	.21 .54	.22 .58	.22 .58	.23 .63	.24 .68	.25 .73
	5	Calculated Thickness	.55*	.58*	.60	.63	.67	.72	.77
		Use (Thickness Class Thickness)	.21 .54	.22 .58	.22 .58	.23 .63	.24 .68	.25 .73	.26 .79
8	Calculated Thickness	.62	.64	.67	.70	.74	.77	.82	
	Use (Thickness Class Thickness)	.23 .63	.23 .63	.24 .68	.24 .68	.25 .73	.26 .79	.27 .85	
12	Calculated Thickness	.68	.70	.73	.75	.78	.82	.86	
	Use (Thickness Class Thickness)	.24 .68	.24 .68	.25 .73	.25 .73	.26 .79	.27 .85	.27 .85	
16	Calculated Thickness	.72	.74	.76	.79	.82	.85	.89	
	Use (Thickness Class Thickness)	.25 .73	.25 .73	.26 .79	.26 .79	.27 .85	.27 .85	.28 .92	
F	2½	Calculated Thickness	.50*	.51*	.53*	.56*	.61	.67	.73
		Use (Thickness Class Thickness)	.21 .54	.21 .54	.21 .54	.22 .58	.23 .63	.24 .68	.25 .73
	3½	Calculated Thickness	.49*	.51	.53	.57	.62	.67	.73
		Use (Thickness Class Thickness)	.21 .54	.21 .54	.21 .54	.22 .58	.23 .63	.24 .68	.25 .73
	5	Calculated Thickness	.51*	.53	.57	.60	.65	.70	.75
		Use (Thickness Class Thickness)	.21 .54	.21 .54	.22 .58	.22 .58	.23 .63	.24 .68	.25 .73
8	Calculated Thickness	.57	.59	.62	.65	.69	.74	.78	
	Use (Thickness Class Thickness)	.22 .58	.22 .58	.23 .63	.23 .63	.24 .68	.25 .73	.26 .79	
12	Calculated Thickness	.61	.64	.67	.70	.73	.77	.81	
	Use (Thickness Class Thickness)	.23 .63	.23 .63	.24 .68	.24 .68	.25 .73	.26 .79	.26 .79	
16	Calculated Thickness	.65	.67	.69	.72	.76	.80	.84	
	Use (Thickness Class Thickness)	.23 .63	.24 .68	.24 .68	.25 .73	.26 .79	.26 .79	.27 .85	

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-1 (Continued)
Schedule of Barrel Thickness for Water Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thicknesses—in.						
Twenty-Inch Water Pipe									
A	2½	Calculated Thickness	.62*	.65*	.67*	.70*	.73*	.76*	.80*
		Use { Thickness Class Thickness	22 .62	23 .67	23 .67	24 .72	24 .72	25 .78	25 .78
	3½	Calculated Thickness	.62*	.64*	.66*	.69*	.72*	.76*	.80
		Use { Thickness Class Thickness	22 .62	22 .62	23 .67	23 .67	24 .72	25 .78	26 .84
	5	Calculated Thickness	.65*	.67*	.69*	.72*	.75*	.80	.85
		Use { Thickness Class Thickness	23 .67	23 .67	23 .67	24 .72	25 .78	25 .78	26 .84
8	Calculated Thickness	.71	.73	.76	.79	.83	.87	.91	
	Use { Thickness Class Thickness	24 .72	24 .72	25 .78	25 .78	26 .84	26 .84	27 .91	
12	Calculated Thickness	.78	.80	.83	.86	.89	.93	.97	
	Use { Thickness Class Thickness	25 .78	25 .78	26 .84	26 .84	27 .91	27 .91	28 .98	
16	Calculated Thickness	.83	.86	.88	.91	.94	.97	1.01	
	Use { Thickness Class Thickness	26 .84	26 .84	27 .91	27 .91	27 .91	28 .98	28 .98	
B	2½	Calculated Thickness	.57*	.59*	.62*	.65*	.68*	.72	.78
		Use { Thickness Class Thickness	21 .57	21 .57	22 .62	23 .67	23 .67	24 .72	25 .78
	3½	Calculated Thickness	.57*	.58*	.62*	.64*	.68	.74	.80
		Use { Thickness Class Thickness	21 .57	21 .57	22 .62	22 .62	23 .67	24 .72	25 .78
	5	Calculated Thickness	.59*	.61*	.64*	.67	.72	.77	.82
		Use { Thickness Class Thickness	21 .57	22 .62	22 .62	23 .67	24 .72	25 .78	26 .84
8	Calculated Thickness	.65	.68	.71	.74	.78	.82	.87	
	Use { Thickness Class Thickness	23 .67	23 .67	24 .72	24 .72	25 .78	26 .84	26 .84	
12	Calculated Thickness	.71	.74	.77	.80	.84	.87	.92	
	Use { Thickness Class Thickness	24 .72	24 .72	25 .78	25 .78	26 .84	26 .84	27 .91	
16	Calculated Thickness	.76	.78	.81	.84	.87	.91	.95	
	Use { Thickness Class Thickness	25 .78	25 .78	26 .84	26 .84	26 .84	27 .91	28 .98	
F	2½	Calculated Thickness	.51*	.53*	.57*	.60*	.64	.70	.77
		Use { Thickness Class Thickness	21 .57	21 .57	21 .57	22 .62	22 .62	24 .72	25 .78
	3½	Calculated Thickness	.52	.54	.57	.61	.66	.72	.78
		Use { Thickness Class Thickness	21 .57	21 .57	21 .57	22 .62	23 .67	24 .72	25 .78
	5	Calculated Thickness	.53	.56	.60	.64	.69	.74	.80
		Use { Thickness Class Thickness	21 .57	21 .57	22 .62	22 .62	23 .67	24 .72	25 .78
8	Calculated Thickness	.60	.62	.65	.69	.73	.78	.83	
	Use { Thickness Class Thickness	22 .62	22 .62	23 .67	23 .67	24 .72	25 .78	26 .84	
12	Calculated Thickness	.65	.68	.71	.74	.78	.82	.87	
	Use { Thickness Class Thickness	23 .67	23 .67	24 .72	24 .72	25 .78	26 .84	26 .84	
16	Calculated Thickness	.69	.71	.74	.77	.81	.85	.90	
	Use { Thickness Class Thickness	23 .67	24 .72	24 .72	25 .78	26 .84	26 .84	27 .91	

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-1 (Continued)
Schedule of Barrel Thickness for Water Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thicknesses—in.						
Twenty-four-Inch Water Pipe									
A	2½	Calculated Thickness	.69*	.72*	.75*	.78*	.82*	.86*	.91*
		Use { Thickness Class Thickness	22 .68	23 .73	23 .73	24 .79	25 .85	25 .85	26 .92
	3½	Calculated Thickness	.69*	.71*	.74*	.78*	.81*	.86	.93
		Use { Thickness Class Thickness	22 .68	23 .73	23 .73	24 .79	24 .79	25 .85	26 .92
	5	Calculated Thickness	.72*	.75*	.78*	.81*	.85*	.91	.96
		Use { Thickness Class Thickness	23 .73	23 .73	24 .79	24 .79	25 .85	26 .92	27 .99
8	Calculated Thickness	.80	.82	.86	.90	.94	.99	1.04	
	Use { Thickness Class Thickness	24 .79	25 .85	25 .85	26 .92	26 .92	27 .99	28 1.07	
12	Calculated Thickness	.88	.91	.94	.98	1.02	1.06	1.10	
	Use { Thickness Class Thickness	25 .85	26 .92	26 .92	27 .99	27 .99	28 1.07	28 1.07	
16	Calculated Thickness	.94	.97	1.00	1.03	1.07	1.11	1.15	
	Use { Thickness Class Thickness	26 .92	27 .99	27 .99	28 1.07	28 1.07	28 1.07	29 1.16	
B	2½	Calculated Thickness	.63*	.65*	.68*	.72*	.76*	.82	.90
		Use { Thickness Class Thickness	21 .63	21 .63	22 .68	23 .73	24 .79	25 .85	26 .92
	3½	Calculated Thickness	.62*	.65*	.68*	.71*	.77	.84	.91
		Use { Thickness Class Thickness	21 .63	21 .63	22 .68	23 .73	24 .79	25 .85	26 .92
	5	Calculated Thickness	.65*	.67*	.71*	.76	.81	.88	.94
		Use { Thickness Class Thickness	21 .63	22 .68	23 .73	24 .79	24 .79	25 .85	26 .92
8	Calculated Thickness	.72	.75	.79	.83	.88	.94	.99	
	Use { Thickness Class Thickness	23 .73	23 .73	24 .79	25 .85	25 .85	26 .92	27 .99	
12	Calculated Thickness	.79	.82	.86	.90	.94	.99	1.04	
	Use { Thickness Class Thickness	24 .79	25 .85	25 .85	26 .92	26 .92	27 .99	28 1.07	
16	Calculated Thickness	.85	.88	.91	.95	.99	1.03	1.08	
	Use { Thickness Class Thickness	25 .85	25 .85	26 .92	26 .92	27 .99	28 1.07	28 1.07	
F	2½	Calculated Thickness	.56*	.58*	.63*	.67*	.73	.81	.89
		Use { Thickness Class Thickness	21 .63	21 .63	21 .63	22 .68	23 .73	24 .79	26 .92
	3½	Calculated Thickness	.56*	.59	.63	.69	.75	.82	.90
		Use { Thickness Class Thickness	21 .63	21 .63	21 .63	22 .68	23 .73	25 .85	26 .92
	5	Calculated Thickness	.59	.63	.67	.72	.78	.84	.92
		Use { Thickness Class Thickness	21 .63	21 .63	22 .68	23 .73	24 .79	25 .85	26 .92
8	Calculated Thickness	.66	.69	.73	.77	.83	.89	.95	
	Use { Thickness Class Thickness	22 .68	22 .68	23 .73	24 .79	25 .85	26 .92	26 .92	
12	Calculated Thickness	.72	.75	.79	.83	.88	.93	.99	
	Use { Thickness Class Thickness	23 .73	23 .73	24 .79	25 .85	25 .85	26 .92	27 .99	
16	Calculated Thickness	.77	.80	.83	.87	.91	.96	1.02	
	Use { Thickness Class Thickness	24 .79	24 .79	25 .85	25 .85	26 .92	27 .99	27 .99	

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-1 (Continued)
Schedule of Barrel Thickness for Water Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thicknesses—in.						
Thirty-Inch Water Pipe									
A	2½	Calculated Thickness Use { Thickness Class Thickness	.83* 23 .85	.86* 23 .85	.90* 24 .92	.94* 24 .92	.98* 25 .99	1.04* 26 1.07	1.10 26 1.07
	3½	Calculated Thickness Use { Thickness Class Thickness	.82* 23 .85	.85* 23 .85	.89* 24 .92	.93* 24 .92	.98* 25 .99	1.04 26 1.07	1.12 27 1.16
	5	Calculated Thickness Use { Thickness Class Thickness	.86* 23 .85	.90* 24 .92	.93* 24 .92	.97* 25 .99	1.03 26 1.07	1.10 26 1.07	1.18 27 1.16
	8	Calculated Thickness Use { Thickness Class Thickness	.94* 24 .92	.98 25 .99	1.02 25 .99	1.07 26 1.07	1.12 27 1.16	1.19 27 1.16	1.25 28 1.25
	12	Calculated Thickness Use { Thickness Class Thickness	1.05 26 1.07	1.08 26 1.07	1.12 27 1.16	1.17 27 1.16	1.22 28 1.25	1.28 28 1.25	1.33 29 1.35
	16	Calculated Thickness Use { Thickness Class Thickness	1.13 27 1.16	1.17 27 1.16	1.20 27 1.16	1.25 28 1.25	1.29 28 1.25	1.35 29 1.35	1.40 29 1.35
B	2½	Calculated Thickness Use { Thickness Class Thickness	.74* 21 .73	.77* 22 .79	.81* 22 .79	.85* 23 .85	.90* 24 .92	.99 25 .99	1.09 26 1.07
	3½	Calculated Thickness Use { Thickness Class Thickness	.73* 21 .73	.76* 22 .79	.80* 22 .79	.85* 23 .85	.92 24 .99	1.01 25 .99	1.10 26 1.07
	5	Calculated Thickness Use { Thickness Class Thickness	.77* 22 .79	.80* 22 .79	.84* 23 .85	.90 24 .92	.97 25 .99	1.05 26 1.07	1.13 27 1.16
	8	Calculated Thickness Use { Thickness Class Thickness	.84 23 .85	.88 23 .85	.93 24 .92	.98 25 .99	1.05 26 1.07	1.11 26 1.07	1.18 27 1.16
	12	Calculated Thickness Use { Thickness Class Thickness	.93 24 .92	.97 25 .99	1.01 25 .99	1.06 26 1.07	1.12 27 1.16	1.18 27 1.16	1.25 28 1.25
	16	Calculated Thickness Use { Thickness Class Thickness	1.00 25 .99	1.04 26 1.07	1.08 26 1.07	1.13 27 1.16	1.18 27 1.16	1.24 28 1.25	1.30 29 1.35
F	2½	Calculated Thickness Use { Thickness Class Thickness	.66* 21 .73	.70* 21 .73	.74* 21 .73	.79* 22 .79	.88 23 .85	.98 25 .99	1.08 26 1.07
	3½	Calculated Thickness Use { Thickness Class Thickness	.66* 21 .73	.70* 21 .73	.74* 21 .73	.80 22 .79	.90 24 .92	1.00 25 .99	1.10 26 1.07
	5	Calculated Thickness Use { Thickness Class Thickness	.70* 21 .73	.73* 21 .73	.79 22 .79	.86 23 .85	.93 24 .92	1.01 25 .99	1.11 26 1.07
	8	Calculated Thickness Use { Thickness Class Thickness	.77 22 .79	.81 22 .79	.86 23 .85	.93 24 .92	1.00 25 .99	1.07 26 1.07	1.15 27 1.16
	12	Calculated Thickness Use { Thickness Class Thickness	.85 23 .85	.89 24 .92	.94 24 .92	.99 25 .99	1.05 26 1.07	1.12 27 1.16	1.20 27 1.16
	16	Calculated Thickness Use { Thickness Class Thickness	.91 24 .92	.95 24 .92	.99 25 .99	1.04 26 1.07	1.10 26 1.07	1.16 27 1.16	1.23 28 1.25

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-1 (Continued)
Schedule of Barrel Thickness for Water Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thicknesses—in.						
Thirty-six-Inch Water Pipe									
A	2½	Calculated Thickness Use { Thickness Class Thickness	.94* 23 .94	.98* 24 1.02	1.02* 24 1.02	1.07* 25 1.10	1.13* 25 1.10	1.19* 26 1.19	1.27 27 1.29
	3½	Calculated Thickness Use { Thickness Class Thickness	.93* 23 .94	.97* 23 .94	1.02* 24 1.02	1.07* 25 1.10	1.12* 25 1.10	1.19 26 1.19	1.31 27 1.29
	5	Calculated Thickness Use { Thickness Class Thickness	.98* 24 1.02	1.02* 24 1.02	1.07* 25 1.10	1.12* 25 1.10	1.17* 26 1.19	1.26 27 1.29	1.35 28 1.39
	8	Calculated Thickness Use { Thickness Class Thickness	1.07* 25 1.10	1.11* 25 1.10	1.16 26 1.19	1.22 26 1.19	1.28 27 1.29	1.36 27 1.39	1.44 28 1.39
	12	Calculated Thickness Use { Thickness Class Thickness	1.19 26 1.19	1.24 27 1.29	1.28 27 1.29	1.34 28 1.39	1.40 28 1.39	1.47 29 1.50	1.54 29 1.50
	1	Calculated Thickness Use { Thickness Class Thickness	1.29 27 1.29	1.33 27 1.29	1.38 28 1.39	1.43 28 1.39	1.49 29 1.50	1.55 29 1.50	1.62 30 1.62
B	2½	Calculated Thickness Use { Thickness Class Thickness	.82* 21 .81	.86* 22 .87	.91* 23 .94	.97* 23 .94	1.03* 24 1.02	1.14 25 1.10	1.26 27 1.29
	3½	Calculated Thickness Use { Thickness Class Thickness	.81* 21 .81	.85* 22 .87	.90* 22 .87	.96* 23 .94	1.04 24 1.02	1.15 26 1.19	1.28 27 1.29
	5	Calculated Thickness Use { Thickness Class Thickness	.86* 22 .87	.90* 22 .87	.94* 23 .94	1.01 24 1.02	1.10 25 1.10	1.20 26 1.19	1.30 27 1.29
	8	Calculated Thickness Use { Thickness Class Thickness	.94 23 .94	.99 24 1.02	1.05 24 1.02	1.11 25 1.10	1.18 26 1.19	1.27 27 1.29	1.36 28 1.39
	12	Calculated Thickness Use { Thickness Class Thickness	1.05 24 1.02	1.09 25 1.10	1.14 25 1.10	1.20 26 1.19	1.27 27 1.29	1.34 28 1.39	1.43 28 1.39
	16	Calculated Thickness Use { Thickness Class Thickness	1.12 25 1.10	1.17 26 1.19	1.22 26 1.19	1.27 27 1.29	1.34 28 1.39	1.40 28 1.39	1.48 29 1.50
F	2½	Calculated Thickness Use { Thickness Class Thickness	.73* 21 .81	.79* 21 .81	.84* 22 .87	.89 22 .87	1.01 24 1.02	1.13 25 1.10	1.25 27 1.29
	3½	Calculated Thickness Use { Thickness Class Thickness	.73* 21 .81	.78* 21 .81	.83* 21 .81	.92 23 .94	1.03 24 1.02	1.14 25 1.10	1.26 27 1.29
	5	Calculated Thickness Use { Thickness Class Thickness	.78* 21 .81	.82* 21 .81	.89 22 .87	.97 23 .94	1.07 25 1.10	1.17 26 1.19	1.28 27 1.29
	8	Calculated Thickness Use { Thickness Class Thickness	.86 22 .87	.91 23 .94	.97 23 .94	1.04 24 1.02	1.13 25 1.10	1.22 26 1.19	1.33 27 1.29
	12	Calculated Thickness Use { Thickness Class Thickness	.95 23 .94	1.00 24 1.02	1.06 25 1.10	1.12 25 1.10	1.20 26 1.19	1.28 27 1.29	1.37 28 1.39
	16	Calculated Thickness Use { Thickness Class Thickness	1.02 24 1.02	1.07 25 1.10	1.12 25 1.10	1.18 26 1.19	1.25 27 1.29	1.33 27 1.29	1.42 28 1.39

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-1 (Continued)
Schedule of Barrel Thickness for Water Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thicknesses—in.						
Forty-two-Inch Water Pipe									
A	2½	Calculated Thickness	1.04*	1.08*	1.14*	1.20*	1.27*	1.34*	1.43
		Use { Thickness Class Thickness	23 1.05	23 1.05	24 1.13	25 1.22	26 1.32	26 1.32	27 1.43
	3½	Calculated Thickness	1.04*	1.08*	1.14*	1.20*	1.27*	1.33	1.46
		Use { Thickness Class Thickness	23 1.05	23 1.05	24 1.13	25 1.22	26 1.32	26 1.32	27 1.43
	5	Calculated Thickness	1.09*	1.14*	1.19*	1.25*	1.32*	1.43	1.52
		Use { Thickness Class Thickness	24 1.13	24 1.13	25 1.22	25 1.22	26 1.32	27 1.43	28 1.54
8	Calculated Thickness	1.19*	1.24*	1.30	1.37	1.45	1.53	1.63	
	Use { Thickness Class Thickness	25 1.22	25 1.22	26 1.32	26 1.32	27 1.43	28 1.54	29 1.66	
12	Calculated Thickness	1.33	1.38	1.44	1.50	1.58	1.65	1.74	
	Use { Thickness Class Thickness	26 1.32	27 1.43	27 1.43	28 1.54	28 1.54	29 1.66	30 1.79	
16	Calculated Thickness	1.46	1.51	1.56	1.62	1.68	1.75	1.83	
	Use { Thickness Class Thickness	27 1.43	28 1.54	28 1.54	29 1.66	29 1.66	30 1.79	30 1.79	
B	2½	Calculated Thickness	.89*	.94*	1.00*	1.07*	1.14	1.28	1.42
		Use { Thickness Class Thickness	21 .90	22 .97	22 .97	23 1.05	24 1.13	26 1.32	27 1.43
	3½	Calculated Thickness	.89*	.94*	1.00*	1.07*	1.17	1.30	1.43
		Use { Thickness Class Thickness	21 .90	22 .97	22 .97	23 1.05	24 1.13	26 1.32	27 1.43
	5	Calculated Thickness	.94*	.98*	1.04*	1.13	1.23	1.34	1.47
		Use { Thickness Class Thickness	22 .97	22 .97	23 1.05	24 1.13	25 1.22	26 1.32	27 1.43
8	Calculated Thickness	1.04	1.09	1.16	1.23	1.32	1.42	1.53	
	Use { Thickness Class Thickness	23 1.05	24 1.13	24 1.13	25 1.22	26 1.32	27 1.43	28 1.54	
12	Calculated Thickness	1.15	1.21	1.27	1.33	1.42	1.51	1.60	
	Use { Thickness Class Thickness	24 1.13	25 1.22	26 1.32	26 1.32	27 1.43	28 1.54	29 1.66	
16	Calculated Thickness	1.25	1.30	1.36	1.43	1.50	1.58	1.67	
	Use { Thickness Class Thickness	25 1.22	26 1.32	26 1.32	27 1.43	28 1.54	28 1.54	29 1.66	
F	2½	Calculated Thickness	.80*	.86*	.92*	1.00	1.15	1.28	1.42
		Use { Thickness Class Thickness	21 .90	21 .90	21 .90	22 .97	24 1.13	26 1.32	27 1.43
	3½	Calculated Thickness	.80*	.86*	.92*	1.04	1.17	1.29	1.43
		Use { Thickness Class Thickness	21 .90	21 .90	21 .90	23 1.05	24 1.13	26 1.32	27 1.43
	5	Calculated Thickness	.85*	.90*	.98	1.08	1.19	1.32	1.45
		Use { Thickness Class Thickness	21 .90	21 .90	22 .97	23 1.05	25 1.22	26 1.32	27 1.43
8	Calculated Thickness	.94	1.00	1.08	1.16	1.26	1.36	1.49	
	Use { Thickness Class Thickness	22 .97	22 .97	23 1.05	24 1.13	25 1.22	26 1.32	28 1.54	
12	Calculated Thickness	1.05	1.10	1.17	1.25	1.34	1.43	1.54	
	Use { Thickness Class Thickness	23 1.05	24 1.13	24 1.13	25 1.22	26 1.32	27 1.43	28 1.54	
16	Calculated Thickness	1.13	1.18	1.24	1.32	1.40	1.49	1.59	
	Use { Thickness Class Thickness	24 1.13	25 1.22	25 1.22	26 1.32	27 1.43	28 1.54	28 1.54	

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-1 (Continued)
Schedule of Barrel Thickness for Water Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thicknesses—in.						
Forty-eight-Inch Water Pipe									
A	2½	Calculated Thickness	1.14*	1.19*	1.25*	1.32*	1.40*	1.46*	1.61
		Use { Thickness Class Thickness	23 1.14	24 1.23	24 1.23	25 1.33	26 1.44	26 1.44	27 1.56
	3½	Calculated Thickness	1.14*	1.20*	1.26*	1.33*	1.40*	1.50	1.66
		Use { Thickness Class Thickness	23 1.14	24 1.23	24 1.23	25 1.33	26 1.44	27 1.56	28 1.68
	5	Calculated Thickness	1.22*	1.27*	1.32*	1.39*	1.47	1.58	1.71
		Use { Thickness Class Thickness	24 1.23	24 1.23	25 1.33	26 1.44	26 1.44	27 1.56	28 1.68
8	Calculated Thickness	1.33*	1.38*	1.44	1.53	1.61	1.71	1.83	
	Use { Thickness Class Thickness	25 1.33	25 1.33	26 1.44	27 1.56	27 1.56	28 1.68	29 1.81	
12	Calculated Thickness	1.49	1.55	1.61	1.69	1.77	1.85	1.96	
	Use { Thickness Class Thickness	26 1.44	27 1.56	27 1.56	28 1.68	29 1.81	29 1.81	30 1.95	
16	Calculated Thickness	1.63	1.68	1.74	1.81	1.89	1.98	2.08	
	Use { Thickness Class Thickness	28 1.68	28 1.68	28 1.68	29 1.81	30 1.95	30 1.95		
B	2½	Calculated Thickness	.97*	1.03*	1.09*	1.17*	1.28	1.43	1.59
		Use { Thickness Class Thickness	21 .98	22 1.06	22 1.06	23 1.14	25 1.33	26 1.44	27 1.56
	3½	Calculated Thickness	.98*	1.03*	1.10*	1.17	1.31	1.45	1.61
		Use { Thickness Class Thickness	21 .98	22 1.06	23 1.14	23 1.14	25 1.33	26 1.44	27 1.56
	5	Calculated Thickness	1.03*	1.09*	1.15*	1.25	1.37	1.50	1.65
		Use { Thickness Class Thickness	22 1.06	22 1.06	23 1.14	24 1.23	25 1.33	27 1.56	28 1.68
8	Calculated Thickness	1.13	1.20	1.28	1.37	1.47	1.58	1.72	
	Use { Thickness Class Thickness	23 1.14	24 1.23	25 1.33	25 1.33	26 1.44	27 1.56	28 1.68	
12	Calculated Thickness	1.28	1.34	1.41	1.49	1.58	1.69	1.80	
	Use { Thickness Class Thickness	25 1.33	25 1.33	26 1.44	26 1.44	27 1.56	28 1.68	29 1.81	
16	Calculated Thickness	1.38	1.43	1.50	1.58	1.67	1.77	1.87	
	Use { Thickness Class Thickness	25 1.33	26 1.44	27 1.56	27 1.56	28 1.68	29 1.81	29 1.81	
F	2½	Calculated Thickness	.88*	.93*	1.00*	1.12	1.27	1.43	1.59
		Use { Thickness Class Thickness	21 .98	21 .98	21 .98	23 1.14	24 1.23	26 1.44	27 1.56
	3½	Calculated Thickness	.88*	.94*	1.01*	1.14	1.29	1.44	1.60
		Use { Thickness Class Thickness	21 .98	21 .98	21 .98	23 1.14	25 1.33	26 1.44	27 1.56
	5	Calculated Thickness	.93*	.99*	1.08	1.20	1.33	1.48	1.63
		Use { Thickness Class Thickness	21 .98	21 .98	22 1.06	24 1.23	25 1.33	26 1.44	28 1.68
8	Calculated Thickness	1.03	1.10	1.19	1.28	1.40	1.52	1.67	
	Use { Thickness Class Thickness	22 1.06	23 1.14	24 1.23	25 1.33	26 1.44	27 1.56	28 1.68	
12	Calculated Thickness	1.15	1.22	1.29	1.39	1.48	1.60	1.73	
	Use { Thickness Class Thickness	23 1.14	24 1.23	25 1.33	26 1.44	26 1.44	27 1.56	28 1.68	
16	Calculated Thickness	1.25	1.31	1.38	1.46	1.56	1.67	1.78	
	Use { Thickness Class Thickness	24 1.23	25 1.33	25 1.33	26 1.44	27 1.56	28 1.68	29 1.81	

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-2

Schedule of Barrel Thickness for Water Pipe of 21/45 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thickness—in.						
Three-Inch Water Pipe									
A	2½	Calculated Thickness Use { Thickness Class Thickness	0.20* 22 0.32	0.20* 22 0.32	0.20* 22 0.32	0.20* 22 0.32	0.21* 22 0.32	0.21* 22 0.32	0.21 22 0.32
	3½	Calculated Thickness Use { Thickness Class Thickness	0.20* 22 0.32	0.20* 22 0.32	0.20* 22 0.32	0.21* 22 0.32	0.21* 22 0.32	0.22* 22 0.32	0.22 22 0.32
	5	Calculated Thickness Use { Thickness Class Thickness	0.21 22 0.32	0.21 22 0.32	0.21 22 0.32	0.22 22 0.32	0.22 22 0.32	0.23 22 0.32	0.23 22 0.32
	8	Calculated Thickness Use { Thickness Class Thickness	0.22 22 0.32	0.23 22 0.32	0.23 22 0.32	0.23 22 0.32	0.24 22 0.32	0.24 22 0.32	0.25 22 0.32
	12	Calculated Thickness Use { Thickness Class Thickness	0.24 22 0.32	0.25 22 0.32	0.25 22 0.32	0.25 22 0.32	0.26 22 0.32	0.26 22 0.32	0.26 22 0.32
	16	Calculated Thickness Use { Thickness Class Thickness	0.26 22 0.32	0.26 22 0.32	0.27 22 0.32	0.27 22 0.32	0.27 22 0.32	0.28 22 0.32	0.28 22 0.32
B	2½	Calculated Thickness Use { Thickness Class Thickness	0.19* 22 0.32	0.20* 22 0.32	0.20* 22 0.32	0.20* 22 0.32	0.21 22 0.32	0.22 22 0.32	0.22 22 0.32
	3½	Calculated Thickness Use { Thickness Class Thickness	0.19* 22 0.32	0.20* 22 0.32	0.20 22 0.32	0.21 22 0.32	0.21 22 0.32	0.22 22 0.32	0.22 22 0.32
	5	Calculated Thickness Use { Thickness Class Thickness	0.21 22 0.32	0.21 22 0.32	0.21 22 0.32	0.21 22 0.32	0.22 22 0.32	0.22 22 0.32	0.23 22 0.32
	8	Calculated Thickness Use { Thickness Class Thickness	0.22 22 0.32	0.22 22 0.32	0.22 22 0.32	0.23 22 0.32	0.23 22 0.32	0.24 22 0.32	0.24 22 0.32
	12	Calculated Thickness Use { Thickness Class Thickness	0.24 22 0.32	0.24 22 0.32	0.24 22 0.32	0.25 22 0.32	0.25 22 0.32	0.25 22 0.32	0.26 22 0.32
	16	Calculated Thickness Use { Thickness Class Thickness	0.25 22 0.32	0.26 22 0.32	0.26 22 0.32	0.26 22 0.32	0.27 22 0.32	0.27 22 0.32	0.27 22 0.32
F	2½	Calculated Thickness Use { Thickness Class Thickness	0.19* 22 0.32	0.19* 22 0.32	0.19 22 0.32	0.20 22 0.32	0.20 22 0.32	0.21 22 0.32	0.22 22 0.32
	3½	Calculated Thickness Use { Thickness Class Thickness	0.19* 22 0.32	0.19 22 0.32	0.19 22 0.32	0.20 22 0.32	0.20 22 0.32	0.21 22 0.32	0.22 22 0.32
	5	Calculated Thickness Use { Thickness Class Thickness	0.19 22 0.32	0.20 22 0.32	0.20 22 0.32	0.21 22 0.32	0.21 22 0.32	0.22 22 0.32	0.22 22 0.32
	8	Calculated Thickness Use { Thickness Class Thickness	0.21 22 0.32	0.21 22 0.32	0.21 22 0.32	0.22 22 0.32	0.22 22 0.32	0.23 22 0.32	0.23 22 0.32
	12	Calculated Thickness Use { Thickness Class Thickness	0.22 22 0.32	0.22 22 0.32	0.23 22 0.32	0.23 22 0.32	0.24 22 0.32	0.24 22 0.32	0.25 22 0.32
	16	Calculated Thickness Use { Thickness Class Thickness	0.24 22 0.32	0.24 22 0.32	0.24 22 0.32	0.25 22 0.32	0.25 22 0.32	0.25 22 0.32	0.26 22 0.32

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-2 (Continued)
Schedule of Barrel Thickness for Water Pipe of 21/45 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thickness—in.						
Four-Inch Water Pipe									
4 2 A	2½	Calculated Thickness Use { Thickness Class Thickness	0.22* 22 0.35	0.23* 22 0.35	0.23* 22 0.35	0.24* 22 0.35	0.24* 22 0.35	0.25* 22 0.35	0.25* 22 0.35
	3½	Calculated Thickness Use { Thickness Class Thickness	0.22* 22 0.35	0.22* 22 0.35	0.23* 22 0.35	0.23* 22 0.35	0.24 22 0.35	0.25 22 0.35	0.26 22 0.35
	5	Calculated Thickness Use { Thickness Class Thickness	0.23* 22 0.35	0.23* 22 0.35	0.24* 22 0.35	0.24* 22 0.35	0.25 22 0.35	0.26 22 0.35	0.26 22 0.35
	8	Calculated Thickness Use { Thickness Class Thickness	0.25 22 0.35	0.26 22 0.35	0.26 22 0.35	0.27 22 0.35	0.27 22 0.35	0.28 22 0.35	0.28 22 0.35
	12	Calculated Thickness Use { Thickness Class Thickness	0.28 22 0.35	0.28 22 0.35	0.29 22 0.35	0.29 22 0.35	0.29 22 0.35	0.30 22 0.35	0.31 22 0.35
	16	Calculated Thickness Use { Thickness Class Thickness	0.30 22 0.35	0.30 22 0.35	0.31 22 0.35	0.31 22 0.35	0.32 22 0.35	0.32 22 0.35	0.33 22 0.35
B	2½	Calculated Thickness Use { Thickness Class Thickness	0.22* 22 0.35	0.22* 22 0.35	0.23* 22 0.35	0.23* 22 0.35	0.24* 22 0.35	0.24* 22 0.35	0.24 22 0.35
	3½	Calculated Thickness Use { Thickness Class Thickness	0.22* 22 0.35	0.22* 22 0.35	0.22* 22 0.35	0.23* 22 0.35	0.24 22 0.35	0.24 22 0.35	0.25 22 0.35
	5	Calculated Thickness Use { Thickness Class Thickness	0.22 22 0.35	0.23 22 0.35	0.23 22 0.35	0.24 22 0.35	0.25 22 0.35	0.25 22 0.35	0.26 22 0.35
	8	Calculated Thickness Use { Thickness Class Thickness	0.25 22 0.35	0.25 22 0.35	0.25 22 0.35	0.26 22 0.35	0.27 22 0.35	0.28 22 0.35	0.28 22 0.35
	12	Calculated Thickness Use { Thickness Class Thickness	0.27 22 0.35	0.27 22 0.35	0.28 22 0.35	0.28 22 0.35	0.29 22 0.35	0.29 22 0.35	0.30 22 0.35
	16	Calculated Thickness Use { Thickness Class Thickness	0.29 22 0.35	0.29 22 0.35	0.30 22 0.35	0.30 22 0.35	0.31 22 0.35	0.31 22 0.35	0.32 22 0.35
F	2½	Calculated Thickness Use { Thickness Class Thickness	0.21* 22 0.35	0.21* 22 0.35	0.21* 22 0.35	0.22* 22 0.35	0.23 22 0.35	0.24 22 0.35	0.25 22 0.35
	3½	Calculated Thickness Use { Thickness Class Thickness	0.20* 22 0.35	0.21 22 0.35	0.21 22 0.35	0.22 22 0.35	0.23 22 0.35	0.24 22 0.35	0.25 22 0.35
	5	Calculated Thickness Use { Thickness Class Thickness	0.21 22 0.35	0.22 22 0.35	0.22 22 0.35	0.23 22 0.35	0.24 22 0.35	0.25 22 0.35	0.25 22 0.35
	8	Calculated Thickness Use { Thickness Class Thickness	0.23 22 0.35	0.24 22 0.35	0.24 22 0.35	0.25 22 0.35	0.25 22 0.35	0.26 22 0.35	0.27 22 0.35
	12	Calculated Thickness Use { Thickness Class Thickness	0.25 22 0.35	0.26 22 0.35	0.26 22 0.35	0.27 22 0.35	0.27 22 0.35	0.28 22 0.35	0.28 22 0.35
	16	Calculated Thickness Use { Thickness Class Thickness	0.27 22 0.35	0.27 22 0.35	0.28 22 0.35	0.28 22 0.35	0.29 22 0.35	0.29 22 0.35	0.30 22 0.35

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-2 (Continued)
Schedule of Barrel Thickness for Water Pipe of 21/45 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thickness—in.						
Six-Inch Water Pipe									
A	2½	Calculated Thickness Use { Thickness Class Thickness	0.28* 21 0.35	0.28* 21 0.35	0.29* 21 0.35	0.30* 21 0.35	0.30* 21 0.35	0.31* 21 0.35	0.32* 21 0.35
	3½	Calculated Thickness Use { Thickness Class Thickness	0.27* 21 0.35	0.27* 21 0.35	0.28* 21 0.35	0.29* 21 0.35	0.29* 21 0.35	0.30* 21 0.35	0.32 21 0.35
	5	Calculated Thickness Use { Thickness Class Thickness	0.28* 21 0.35	0.28* 21 0.35	0.29 21 0.35	0.30 21 0.35	0.31 21 0.35	0.32 21 0.35	0.33 21 0.35
	8	Calculated Thickness Use { Thickness Class Thickness	0.31 21 0.35	0.31 21 0.35	0.32 21 0.35	0.33 21 0.35	0.34 21 0.35	0.35 21 0.35	0.36 21 0.35
	12	Calculated Thickness Use { Thickness Class Thickness	0.34 21 0.35	0.35 21 0.35	0.36 21 0.35	0.36 21 0.35	0.37 22 0.38	0.38 22 0.38	0.39 22 0.38
	16	Calculated Thickness Use { Thickness Class Thickness	0.38 22 0.38	0.38 22 0.38	0.39 22 0.38	0.39 22 0.38	0.40 23 0.41	0.41 23 0.41	0.42 23 0.41
B	2½	Calculated Thickness Use { Thickness Class Thickness	0.27* 21 0.35	0.27* 21 0.35	0.28* 21 0.35	0.29* 21 0.35	0.29* 21 0.35	0.30* 21 0.35	0.31* 21 0.35
	3½	Calculated Thickness Use { Thickness Class Thickness	0.26* 21 0.35	0.27* 21 0.35	0.27* 21 0.35	0.28* 21 0.35	0.29* 21 0.35	0.30 21 0.35	0.31 21 0.35
	5	Calculated Thickness Use { Thickness Class Thickness	0.27* 21 0.35	0.27* 21 0.35	0.28* 21 0.35	0.29 21 0.35	0.30 21 0.35	0.31 21 0.35	0.32 21 0.35
	8	Calculated Thickness Use { Thickness Class Thickness	0.30 21 0.35	0.30 21 0.35	0.31 21 0.35	0.32 21 0.35	0.33 21 0.35	0.34 21 0.35	0.35 21 0.35
	12	Calculated Thickness Use { Thickness Class Thickness	0.33 21 0.35	0.34 21 0.35	0.34 21 0.35	0.35 21 0.35	0.36 21 0.35	0.37 22 0.38	0.38 22 0.38
	16	Calculated Thickness Use { Thickness Class Thickness	0.36 21 0.35	0.37 22 0.38	0.37 22 0.38	0.38 22 0.38	0.39 22 0.38	0.39 22 0.38	0.40 23 0.41
F	2½	Calculated Thickness Use { Thickness Class Thickness	0.25* 21 0.35	0.26* 21 0.35	0.26* 21 0.35	0.27* 21 0.35	0.28* 21 0.35	0.29* 21 0.35	0.30 21 0.35
	3½	Calculated Thickness Use { Thickness Class Thickness	0.24* 21 0.35	0.25* 21 0.35	0.25 21 0.35	0.26 21 0.35	0.28 21 0.35	0.29 21 0.35	0.31 21 0.35
	5	Calculated Thickness Use { Thickness Class Thickness	0.25 21 0.35	0.26 21 0.35	0.27 21 0.35	0.28 21 0.35	0.29 21 0.35	0.30 21 0.35	0.31 21 0.35
	8	Calculated Thickness Use { Thickness Class Thickness	0.28 21 0.35	0.28 21 0.35	0.29 21 0.35	0.30 21 0.35	0.31 21 0.35	0.32 21 0.35	0.33 21 0.35
	12	Calculated Thickness Use { Thickness Class Thickness	0.31 21 0.35	0.31 21 0.35	0.32 21 0.35	0.33 21 0.35	0.34 21 0.35	0.34 21 0.35	0.35 21 0.35
	16	Calculated Thickness Use { Thickness Class Thickness	0.33 21 0.35	0.34 21 0.35	0.34 21 0.35	0.35 21 0.35	0.36 21 0.35	0.37 22 0.38	0.38 22 0.38

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. - See Sec. 1-2.1.

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TABLE 1-2 (Continued)
Schedule of Barrel Thickness for Water Pipe of 21/45 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thickness—in.						
Eight-Inch Water Pipe									
A	2½	Calculated Thickness	0.33*	0.33*	0.34*	0.35*	0.36*	0.37*	0.38*
		Use { Thickness Class Thickness	20 0.35	20 0.35	20 0.35	20 0.35	20 0.35	21 0.38	21 0.38
	3½	Calculated Thickness	0.32*	0.32*	0.33*	0.34*	0.35*	0.36*	0.38
		Use { Thickness Class Thickness	20 0.35	20 0.35	20 0.35	20 0.35	20 0.35	20 0.35	21 0.38
	5	Calculated Thickness	0.32*	0.33*	0.34*	0.35	0.36	0.38	0.39
		Use { Thickness Class Thickness	20 0.35	20 0.35	20 0.35	20 0.35	20 0.35	21 0.38	21 0.38
8	Calculated Thickness	0.36	0.37	0.38	0.39	0.40	0.41	0.43	
	Use { Thickness Class Thickness	20 0.35	21 0.38	21 0.38	21 0.38	22 0.41	22 0.41	23 0.44	
12	Calculated Thickness	0.41	0.42	0.43	0.44	0.45	0.46	0.47	
	Use { Thickness Class Thickness	22 0.41	22 0.41	23 0.44	23 0.44	23 0.44	24 0.48	24 0.48	
16	Calculated Thickness	0.44	0.45	0.46	0.47	0.47	0.48	0.50	
	Use { Thickness Class Thickness	23 0.44	23 0.44	24 0.48	24 0.48	24 0.48	24 0.48	25 0.52	
B	2½	Calculated Thickness	0.31*	0.32*	0.33*	0.34*	0.35*	0.36*	0.37*
		Use { Thickness Class Thickness	20 0.35	20 0.35	20 0.35	20 0.35	20 0.35	20 0.35	21 0.38
	3½	Calculated Thickness	0.30*	0.31*	0.32*	0.33*	0.34*	0.35	0.37
		Use { Thickness Class Thickness	20 0.35	20 0.35	20 0.35	20 0.35	20 0.35	20 0.35	21 0.38
	5	Calculated Thickness	0.31*	0.32*	0.33	0.34	0.35	0.37	0.38
		Use { Thickness Class Thickness	20 0.35	20 0.35	20 0.35	20 0.35	20 0.35	21 0.38	21 0.38
8	Calculated Thickness	0.35	0.35	0.36	0.37	0.39	0.40	0.41	
	Use { Thickness Class Thickness	20 0.35	20 0.35	20 0.35	21 0.38	21 0.38	22 0.41	22 0.41	
12	Calculated Thickness	0.39	0.40	0.41	0.42	0.43	0.44	0.45	
	Use { Thickness Class Thickness	21 0.38	22 0.41	22 0.41	22 0.41	23 0.44	23 0.44	23 0.44	
16	Calculated Thickness	0.42	0.43	0.44	0.44	0.45	0.46	0.48	
	Use { Thickness Class Thickness	22 0.41	23 0.44	23 0.44	23 0.44	23 0.44	24 0.48	24 0.48	
F	2½	Calculated Thickness	0.29*	0.30*	0.30*	0.31*	0.32*	0.34	0.36
		Use { Thickness Class Thickness	20 0.35	20 0.35	20 0.35	20 0.35	20 0.35	20 0.35	20 0.35
	3½	Calculated Thickness	0.28*	0.29*	0.30*	0.31*	0.33	0.35	0.36
		Use { Thickness Class Thickness	20 0.35	20 0.35	20 0.35	20 0.35	20 0.35	20 0.35	20 0.35
	5	Calculated Thickness	0.29*	0.30	0.31	0.32	0.34	0.36	0.37
		Use { Thickness Class Thickness	20 0.35	20 0.35	20 0.35	20 0.35	20 0.35	20 0.35	21 0.38
8	Calculated Thickness	0.32	0.33	0.34	0.35	0.36	0.38	0.39	
	Use { Thickness Class Thickness	20 0.35	20 0.35	20 0.35	20 0.35	20 0.35	21 0.38	21 0.38	
12	Calculated Thickness	0.36	0.37	0.38	0.39	0.40	0.41	0.42	
	Use { Thickness Class Thickness	20 0.35	21 0.38	21 0.38	21 0.38	22 0.41	22 0.41	22 0.41	
16	Calculated Thickness	0.38	0.39	0.40	0.41	0.42	0.43	0.44	
	Use { Thickness Class Thickness	21 0.38	21 0.38	22 0.41	22 0.41	22 0.41	23 0.44	23 0.44	

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-2 (Continued)
Schedule of Barrel Thickness for Water Pipe of 21/45 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure— <i>psi</i>						
			50	100	150	200	250	300	350
			Barrel Thickness— <i>in.</i>						
Ten-Inch Water Pipe									
A	2½	Calculated Thickness Use { Thickness Class Thickness	0.38* 20 0.38	0.39* 20 0.38	0.40* 21 0.41	0.41* 21 0.41	0.42* 21 0.41	0.44* 22 0.44	0.45* 22 0.44
	3½	Calculated Thickness Use { Thickness Class Thickness	0.37* 20 0.38	0.38* 20 0.38	0.39* 20 0.38	0.40* 21 0.41	0.41* 21 0.41	0.43* 22 0.44	0.44 22 0.44
	5	Calculated Thickness Use { Thickness Class Thickness	0.38* 20 0.38	0.39* 20 0.38	0.40* 21 0.41	0.41 21 0.41	0.43 22 0.44	0.44 22 0.44	0.46 23 0.48
	8	Calculated Thickness Use { Thickness Class Thickness	0.42 21 0.41	0.44 22 0.44	0.45 22 0.44	0.46 23 0.48	0.47 23 0.48	0.49 23 0.48	0.51 24 0.52
	12	Calculated Thickness Use { Thickness Class Thickness	0.48 23 0.48	0.49 23 0.48	0.50 24 0.52	0.51 24 0.52	0.53 24 0.52	0.54 25 0.56	0.56 25 0.56
	16	Calculated Thickness Use { Thickness Class Thickness	0.51 24 0.52	0.52 24 0.52	0.53 24 0.52	0.54 25 0.56	0.55 25 0.56	0.56 25 0.56	0.58 26 0.60
B	2½	Calculated Thickness Use { Thickness Class Thickness	0.36* 20 0.38	0.37* 20 0.38	0.38* 20 0.38	0.39* 20 0.38	0.41* 21 0.41	0.42* 21 0.41	0.44* 22 0.44
	3½	Calculated Thickness Use { Thickness Class Thickness	0.35* 20 0.38	0.36* 20 0.38	0.37* 20 0.38	0.39* 20 0.38	0.40* 21 0.41	0.41 21 0.41	0.44 22 0.44
	5	Calculated Thickness Use { Thickness Class Thickness	0.36* 20 0.38	0.37* 20 0.38	0.38* 20 0.38	0.40 21 0.41	0.41 21 0.41	0.43 22 0.44	0.46 23 0.48
	8	Calculated Thickness Use { Thickness Class Thickness	0.40 21 0.41	0.42 21 0.41	0.43 22 0.44	0.44 22 0.44	0.46 23 0.48	0.47 23 0.48	0.49 23 0.48
	12	Calculated Thickness Use { Thickness Class Thickness	0.46 23 0.48	0.47 23 0.48	0.48 23 0.48	0.49 23 0.48	0.50 24 0.52	0.52 24 0.52	0.53 24 0.52
	16	Calculated Thickness Use { Thickness Class Thickness	0.48 23 0.48	0.49 23 0.48	0.50 24 0.52	0.51 24 0.52	0.52 24 0.52	0.54 25 0.56	0.55 25 0.56
F	2½	Calculated Thickness Use { Thickness Class Thickness	0.33* 20 0.38	0.34* 20 0.38	0.35* 20 0.38	0.37* 20 0.38	0.38* 20 0.38	0.40 21 0.41	0.43 22 0.44
	3½	Calculated Thickness Use { Thickness Class Thickness	0.33* 20 0.38	0.33* 20 0.38	0.35* 20 0.38	0.36* 20 0.38	0.38 20 0.38	0.40 21 0.41	0.43 22 0.44
	5	Calculated Thickness Use { Thickness Class Thickness	0.33* 20 0.38	0.34 20 0.38	0.36 20 0.38	0.38 20 0.38	0.40 21 0.41	0.42 21 0.41	0.44 22 0.44
	8	Calculated Thickness Use { Thickness Class Thickness	0.37 20 0.38	0.38 20 0.38	0.40 21 0.41	0.41 21 0.41	0.43 22 0.44	0.45 22 0.44	0.47 23 0.48
	12	Calculated Thickness Use { Thickness Class Thickness	0.42 21 0.41	0.43 22 0.44	0.44 22 0.44	0.45 22 0.44	0.47 23 0.48	0.48 23 0.48	0.50 24 0.52
	16	Calculated Thickness Use { Thickness Class Thickness	0.44 22 0.44	0.45 22 0.44	0.46 23 0.48	0.47 23 0.48	0.48 23 0.48	0.50 24 0.52	0.52 24 0.52

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-2 (Continued)
Schedule of Barrel Thickness for Water Pipe of 21/45 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thickness—in.						
Twelve-Inch Water Pipe									
A	2½	Calculated Thickness	0.43*	0.44*	0.45*	0.47*	0.48*	0.49*	0.51*
		Use { Thickness Class Thickness	21 0.44	21 0.44	21 0.44	22 0.48	22 0.48	22 0.48	23 0.52
	3½	Calculated Thickness	0.42*	0.43*	0.44*	0.45*	0.47*	0.48*	0.50*
		Use { Thickness Class Thickness	20 0.41	21 0.44	21 0.44	21 0.44	22 0.48	22 0.48	23 0.52
	5	Calculated Thickness	0.43*	0.44*	0.45*	0.46*	0.48	0.50	0.52
		Use { Thickness Class Thickness	21 0.44	21 0.44	21 0.44	22 0.48	22 0.48	23 0.52	23 0.52
8	Calculated Thickness	0.48	0.49	0.50	0.52	0.54	0.55	0.57	
	Use { Thickness Class Thickness	22 0.48	22 0.48	23 0.52	23 0.52	24 0.56	24 0.56	24 0.56	
12	Calculated Thickness	0.53	0.54	0.56	0.57	0.58	0.60	0.62	
	Use { Thickness Class Thickness	23 0.52	24 0.56	24 0.56	24 0.56	25 0.60	25 0.60	25 0.60	
16	Calculated Thickness	0.56	0.57	0.58	0.60	0.61	0.63	0.64	
	Use { Thickness Class Thickness	24 0.56	24 0.56	25 0.60	25 0.60	25 0.60	26 0.65	26 0.65	
B	2½	Calculated Thickness	0.41*	0.42*	0.43*	0.44*	0.46*	0.47*	0.49*
		Use { Thickness Class Thickness	20 0.41	20 0.41	21 0.44	21 0.44	22 0.48	22 0.48	22 0.48
	3½	Calculated Thickness	0.39*	0.40*	0.42*	0.43*	0.45*	0.46*	0.49
		Use { Thickness Class Thickness	20 0.41	20 0.41	20 0.41	21 0.44	21 0.44	22 0.48	22 0.48
	5	Calculated Thickness	0.40*	0.41*	0.42*	0.44*	0.46	0.48	0.51
		Use { Thickness Class Thickness	20 0.41	20 0.41	20 0.41	21 0.44	22 0.48	22 0.48	23 0.52
8	Calculated Thickness	0.45	0.46	0.48	0.49	0.51	0.53	0.55	
	Use { Thickness Class Thickness	21 0.44	22 0.48	22 0.48	22 0.48	23 0.52	23 0.52	24 0.56	
12	Calculated Thickness	0.50	0.51	0.52	0.54	0.56	0.57	0.59	
	Use { Thickness Class Thickness	23 0.52	23 0.52	23 0.52	24 0.56	24 0.56	24 0.56	25 0.60	
16	Calculated Thickness	0.52	0.54	0.55	0.56	0.58	0.60	0.61	
	Use { Thickness Class Thickness	23 0.52	24 0.56	24 0.56	24 0.56	25 0.60	25 0.60	25 0.60	
F	2½	Calculated Thickness	0.37*	0.38*	0.39*	0.41*	0.42*	0.44*	0.48
		Use { Thickness Class Thickness	20 0.41	20 0.41	20 0.41	20 0.41	20 0.41	21 0.44	22 0.48
	3½	Calculated Thickness	0.36*	0.37*	0.38*	0.40*	0.42	0.45	0.48
		Use { Thickness Class Thickness	20 0.41	20 0.41	20 0.41	20 0.41	20 0.41	21 0.44	22 0.48
	5	Calculated Thickness	0.37*	0.38*	0.39*	0.42	0.44	0.47	0.49
		Use { Thickness Class Thickness	20 0.41	20 0.41	20 0.41	20 0.41	21 0.44	22 0.48	22 0.48
8	Calculated Thickness	0.41	0.43	0.44	0.46	0.48	0.50	0.53	
	Use { Thickness Class Thickness	20 0.41	21 0.44	21 0.44	22 0.48	22 0.48	23 0.52	23 0.52	
12	Calculated Thickness	0.45	0.47	0.48	0.50	0.52	0.54	0.56	
	Use { Thickness Class Thickness	21 0.44	22 0.48	22 0.48	23 0.52	23 0.52	24 0.56	24 0.56	
16	Calculated Thickness	0.48	0.49	0.50	0.52	0.54	0.55	0.57	
	Use { Thickness Class Thickness	22 0.48	22 0.48	23 0.52	23 0.52	24 0.56	24 0.56	24 0.56	

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-2 (Continued)
Schedule of Barrel Thickness for Water Pipe of 21/45 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thickness—in.						
Fourteen-Inch Water Pipe									
A	2½	Calculated Thickness Use {Thickness Class Thickness	0.48* 21 0.48	0.50* 22 0.51	0.51* 22 0.51	0.53* 23 0.55	0.54* 23 0.55	0.56* 23 0.55	0.58* 24 0.59
	3½	Calculated Thickness Use {Thickness Class Thickness	0.47* 21 0.48	0.49* 21 0.48	0.50* 22 0.51	0.52* 22 0.51	0.53* 23 0.55	0.55* 23 0.55	0.58 24 0.59
	5	Calculated Thickness Use {Thickness Class Thickness	0.49* 21 0.48	0.51* 22 0.51	0.52* 22 0.51	0.53* 23 0.55	0.55* 23 0.55	0.58 24 0.59	0.60 24 0.59
	8	Calculated Thickness Use {Thickness Class Thickness	0.55 23 0.55	0.56 23 0.55	0.58 24 0.59	0.60 24 0.59	0.62 25 0.64	0.64 25 0.64	0.66 25 0.64
	12	Calculated Thickness Use {Thickness Class Thickness	0.60 24 0.59	0.61 24 0.59	0.63 25 0.64	0.65 25 0.64	0.67 26 0.69	0.68 26 0.69	0.71 26 0.69
	16	Calculated Thickness Use {Thickness Class Thickness	0.63 25 0.64	0.65 25 0.64	0.66 25 0.64	0.68 26 0.69	0.69 26 0.69	0.71 26 0.69	0.73 27 0.75
B	2½	Calculated Thickness Use {Thickness Class Thickness	0.45* 21 0.48	0.47* 21 0.48	0.48* 21 0.48	0.50* 22 0.51	0.51* 22 0.51	0.53* 23 0.55	0.56* 23 0.55
	3½	Calculated Thickness Use {Thickness Class Thickness	0.44* 21 0.48	0.46* 21 0.48	0.47* 21 0.48	0.49* 21 0.48	0.51* 22 0.51	0.53 23 0.55	0.57 24 0.59
	5	Calculated Thickness Use {Thickness Class Thickness	0.46* 21 0.48	0.47* 21 0.48	0.49* 21 0.48	0.50 22 0.51	0.53 23 0.55	0.56 23 0.55	0.59 24 0.59
	8	Calculated Thickness Use {Thickness Class Thickness	0.52 22 0.51	0.53 23 0.55	0.55 23 0.55	0.57 24 0.59	0.59 24 0.59	0.61 24 0.59	0.64 25 0.64
	12	Calculated Thickness Use {Thickness Class Thickness	0.56 23 0.55	0.57 24 0.59	0.59 24 0.59	0.61 24 0.59	0.63 25 0.64	0.65 25 0.64	0.67 26 0.69
	16	Calculated Thickness Use {Thickness Class Thickness	0.59 24 0.59	0.60 24 0.59	0.62 25 0.64	0.64 25 0.64	0.65 25 0.64	0.67 26 0.69	0.70 26 0.69
F	2½	Calculated Thickness Use {Thickness Class Thickness	0.42* 21 0.48	0.43* 21 0.48	0.44* 21 0.48	0.46* 21 0.48	0.48* 21 0.48	0.51 22 0.51	0.55 23 0.55
	3½	Calculated Thickness Use {Thickness Class Thickness	0.41* 21 0.48	0.42* 21 0.48	0.44* 21 0.48	0.45* 21 0.48	0.48 21 0.48	0.52 22 0.51	0.56 23 0.55
	5	Calculated Thickness Use {Thickness Class Thickness	0.42* 21 0.48	0.43* 21 0.48	0.45 21 0.48	0.48 21 0.48	0.51 22 0.51	0.54 23 0.55	0.57 24 0.59
	8	Calculated Thickness Use {Thickness Class Thickness	0.47 21 0.48	0.49 21 0.48	0.51 22 0.51	0.53 23 0.55	0.55 23 0.55	0.58 24 0.59	0.61 24 0.59
	12	Calculated Thickness Use {Thickness Class Thickness	0.51 22 0.51	0.53 23 0.55	0.54 23 0.55	0.56 23 0.55	0.59 24 0.59	0.61 24 0.59	0.63 25 0.64
	16	Calculated Thickness Use {Thickness Class Thickness	0.54 23 0.55	0.55 23 0.55	0.57 24 0.59	0.59 24 0.59	0.61 24 0.59	0.63 25 0.64	0.65 25 0.64

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-2 (Continued)
Schedule of Barrel Thickness for Water Pipe of 21/45 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thickness—in.						
Twenty-Inch Water Pipe									
A	2½	Calculated Thickness Use { Thickness Class Thickness	0.59* 21 0.57	0.61* 22 0.62	0.63* 22 0.62	0.65* 23 0.67	0.68* 23 0.67	0.71* 24 0.72	0.74* 24 0.72
	3½	Calculated Thickness Use { Thickness Class Thickness	0.59* 21 0.57	0.61* 22 0.62	0.63* 22 0.62	0.65* 23 0.67	0.68* 23 0.67	0.70* 24 0.72	0.73* 24 0.72
	5	Calculated Thickness Use { Thickness Class Thickness	0.62* 22 0.62	0.64* 22 0.62	0.65* 23 0.67	0.67* 23 0.67	0.70* 24 0.72	0.73 24 0.72	0.77 25 0.78
	8	Calculated Thickness Use { Thickness Class Thickness	0.67* 23 0.67	0.69 23 0.67	0.71 24 0.72	0.74 24 0.72	0.77 25 0.78	0.80 25 0.78	0.83 26 0.84
	12	Calculated Thickness Use { Thickness Class Thickness	0.74 24 0.72	0.76 25 0.78	0.78 25 0.78	0.80 25 0.78	0.83 26 0.84	0.86 26 0.84	0.89 27 0.91
	16	Calculated Thickness Use { Thickness Class Thickness	0.78 25 0.78	0.80 25 0.78	0.83 26 0.84	0.85 26 0.84	0.87 26 0.84	0.90 27 0.91	0.93 27 0.91
B	2½	Calculated Thickness Use { Thickness Class Thickness	0.55* 21 0.57	0.56* 21 0.57	0.58* 21 0.57	0.61* 22 0.62	0.63* 22 0.67	0.66* 23 0.67	0.70* 24 0.72
	3½	Calculated Thickness Use { Thickness Class Thickness	0.54* 21 0.57	0.56* 21 0.57	0.58* 21 0.57	0.60* 22 0.62	0.63* 22 0.62	0.66* 23 0.67	0.71* 24 0.72
	5	Calculated Thickness Use { Thickness Class Thickness	0.57* 21 0.57	0.58* 21 0.57	0.60* 22 0.62	0.63* 22 0.62	0.66 23 0.67	0.70 24 0.72	0.74 24 0.72
	8	Calculated Thickness Use { Thickness Class Thickness	0.62 22 0.62	0.64 22 0.62	0.66 23 0.67	0.69 23 0.67	0.72 24 0.72	0.76 24 0.78	0.79 25 0.78
	12	Calculated Thickness Use { Thickness Class Thickness	0.68 23 0.67	0.70 24 0.72	0.72 24 0.72	0.75 25 0.78	0.77 25 0.78	0.81 26 0.84	0.84 26 0.84
	16	Calculated Thickness Use { Thickness Class Thickness	0.72 24 0.72	0.74 24 0.72	0.76 25 0.78	0.78 25 0.78	0.81 25 0.84	0.84 26 0.84	0.87 26 0.84
F	2½	Calculated Thickness Use { Thickness Class Thickness	0.50* 21 0.57	0.52* 21 0.57	0.54* 21 0.57	0.56* 21 0.57	0.59* 21 0.57	0.64 22 0.62	0.69 23 0.67
	3½	Calculated Thickness Use { Thickness Class Thickness	0.49* 21 0.57	0.51* 21 0.57	0.53* 21 0.57	0.56* 21 0.57	0.60 22 0.62	0.65 23 0.67	0.70 24 0.72
	5	Calculated Thickness Use { Thickness Class Thickness	0.51* 21 0.57	0.53 21 0.57	0.55 21 0.57	0.59 21 0.57	0.63 22 0.62	0.67 23 0.67	0.72 24 0.72
	8	Calculated Thickness Use { Thickness Class Thickness	0.56 21 0.57	0.59 21 0.57	0.61 22 0.62	0.64 22 0.62	0.68 23 0.67	0.72 24 0.72	0.76 25 0.78
	12	Calculated Thickness Use { Thickness Class Thickness	0.61 22 0.62	0.64 22 0.62	0.66 23 0.67	0.69 23 0.67	0.72 24 0.72	0.75 25 0.78	0.79 25 0.78
	16	Calculated Thickness Use { Thickness Class Thickness	0.65 23 0.67	0.67 23 0.67	0.70 24 0.72	0.72 24 0.72	0.75 25 0.78	0.78 25 0.78	0.82 26 0.84

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-2 (Continued)
Schedule of Barrel Thickness for Water Pipe of 21/45 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thickness—in.						
Twenty-four-Inch Water Pipe									
A	2½	Calculated Thickness	0.66*	0.68*	0.71*	0.73*	0.76*	0.80*	0.84*
		Use { Thickness Class Thickness	22 0.68	22 0.68	23 0.73	23 0.73	24 0.79	24 0.79	25 0.85
	3½	Calculated Thickness	0.66*	0.68*	0.70*	0.73*	0.76*	0.79*	0.83*
		Use { Thickness Class Thickness	22 0.68	22 0.68	22 0.68	23 0.73	24 0.79	24 0.79	25 0.85
	5	Calculated Thickness	0.69*	0.71*	0.74*	0.76*	0.79*	0.83	0.88
		Use { Thickness Class Thickness	22 0.68	23 0.73	23 0.73	24 0.79	24 0.79	25 0.85	25 0.85
8	Calculated Thickness	0.75*	0.77	0.80	0.83	0.87	0.91	0.95	
	Use { Thickness Class Thickness	23 0.73	24 0.79	24 0.79	25 0.85	25 0.85	26 0.92	26 0.92	
12	Calculated Thickness	0.83	0.85	0.88	0.91	0.94	0.98	1.01	
	Use { Thickness Class Thickness	25 0.85	25 0.85	25 0.85	26 0.92	26 0.92	27 0.99	27 0.99	
16	Calculated Thickness	0.89	0.91	0.94	0.96	0.99	1.03	1.06	
	Use { Thickness Class Thickness	26 0.92	26 0.92	26 0.92	27 0.99	27 0.99	28 1.07	28 1.07	
B	2½	Calculated Thickness	0.60*	0.62*	0.65*	0.67*	0.71*	0.74*	0.80
		Use { Thickness Class Thickness	21 0.63	21 0.63	21 0.68	22 0.68	23 0.73	23 0.73	24 0.79
	3½	Calculated Thickness	0.59*	0.62*	0.64*	0.67*	0.70*	0.75	0.81
		Use { Thickness Class Thickness	21 0.63	21 0.63	21 0.63	22 0.68	22 0.68	23 0.73	24 0.79
	5	Calculated Thickness	0.62*	0.65*	0.67*	0.70	0.74	0.79	0.85
		Use { Thickness Class Thickness	21 0.63	21 0.63	22 0.68	22 0.68	23 0.73	24 0.79	25 0.85
8	Calculated Thickness	0.68	0.71	0.74	0.77	0.81	0.85	0.90	
	Use { Thickness Class Thickness	22 0.68	23 0.73	23 0.73	24 0.79	24 0.79	25 0.85	26 0.92	
12	Calculated Thickness	0.75	0.78	0.80	0.83	0.87	0.91	0.95	
	Use { Thickness Class Thickness	23 0.73	24 0.79	24 0.79	25 0.85	25 0.85	26 0.92	26 0.92	
16	Calculated Thickness	0.80	0.82	0.85	0.88	0.91	0.95	0.99	
	Use { Thickness Class Thickness	24 0.79	25 0.85	25 0.85	25 0.85	26 0.92	26 0.92	27 0.99	
F	2½	Calculated Thickness	0.54*	0.57*	0.59*	0.62*	0.66*	0.72	0.79
		Use { Thickness Class Thickness	21 0.63	21 0.62	21 0.63	21 0.63	22 0.68	23 0.73	24 0.79
	3½	Calculated Thickness	0.54*	0.56*	0.59*	0.62*	0.67	0.73	0.80
		Use { Thickness Class Thickness	21 0.63	21 0.63	21 0.63	21 0.63	22 0.68	23 0.72	24 0.79
	5	Calculated Thickness	0.57*	0.59*	0.62	0.66	0.71	0.76	0.82
		Use { Thickness Class Thickness	21 0.63	21 0.63	21 0.63	22 0.68	23 0.73	24 0.79	25 0.85
8	Calculated Thickness	0.62	0.65	0.68	0.72	0.76	0.81	0.86	
	Use { Thickness Class Thickness	21 0.63	21 0.63	22 0.68	23 0.73	24 0.79	24 0.79	25 0.85	
12	Calculated Thickness	0.68	0.71	0.74	0.77	0.81	0.85	0.90	
	Use { Thickness Class Thickness	22 0.68	23 0.73	23 0.73	24 0.79	24 0.79	25 0.85	26 0.92	
16	Calculated Thickness	0.72	0.75	0.78	0.81	0.85	0.89	0.93	
	Use { Thickness Class Thickness	23 0.73	23 0.73	24 0.79	24 0.79	25 0.85	25 0.92	26 0.92	

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-2 (Continued)
Schedule of Barrel Thickness for Water Pipe of 21/45 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thickness—in.						
Thirty-Inch Water Pipe									
A	2½	Calculated Thickness Use {Thickness Class Thickness	0.79* 22 0.79	0.81* 22 0.79	0.84* 23 0.85	0.88* 23 0.85	0.92* 24 0.92	0.96* 25 0.99	1.01* 25 0.99
	3½	Calculated Thickness Use {Thickness Class Thickness	0.78* 22 0.79	0.81* 22 0.79	0.84* 23 0.85	0.87* 23 0.85	0.91* 24 0.92	0.95* 24 0.92	1.00 25 0.99
	5	Calculated Thickness Use {Thickness Class Thickness	0.82* 23 0.85	0.85* 23 0.85	0.88* 23 0.85	0.91* 24 0.92	0.94 24 0.92	1.00 25 0.99	1.06 26 1.01
	8	Calculated Thickness Use {Thickness Class Thickness	0.89* 24 0.92	0.92 24 0.92	0.95 24 0.92	0.99 25 0.99	1.04 26 1.07	1.09 26 1.07	1.14 27 1.16
	12	Calculated Thickness Use {Thickness Class Thickness	0.99 25 0.99	1.02 25 0.99	1.05 26 1.07	1.09 26 1.07	1.13 27 1.16	1.17 27 1.16	1.22 28 1.25
	16	Calculated Thickness Use {Thickness Class Thickness	1.06 26 1.07	1.09 26 1.07	1.12 27 1.16	1.16 27 1.16	1.20 27 1.16	1.24 28 1.25	1.29 25 1.29
B	2½	Calculated Thickness Use {Thickness Class Thickness	0.70* 20 0.68	0.73* 21 0.73	0.76* 22 0.79	0.80* 22 0.79	0.84* 23 0.85	0.89* 24 0.92	0.88 25 0.99
	3½	Calculated Thickness Use {Thickness Class Thickness	0.69* 20 0.68	0.72* 21 0.73	0.75* 21 0.73	0.79* 22 0.79	0.83* 23 0.85	0.90 24 0.92	0.98 25 0.99
	5	Calculated Thickness Use {Thickness Class Thickness	0.73* 21 0.73	0.76* 22 0.79	0.79* 22 0.79	0.83* 23 0.85	0.88 23 0.85	0.95 24 0.92	1.02 25 0.99
	8	Calculated Thickness Use {Thickness Class Thickness	0.79 22 0.79	0.83 23 0.85	0.86 23 0.85	0.91 24 0.92	0.96 25 0.99	1.01 25 0.99	1.07 26 1.07
	12	Calculated Thickness Use {Thickness Class Thickness	0.88 23 0.85	0.91 24 0.92	0.95 24 0.92	0.99 25 0.99	1.03 26 1.07	1.08 26 1.07	1.14 27 1.16
	16	Calculated Thickness Use {Thickness Class Thickness	0.94 24 0.92	0.97 25 0.99	1.01 25 0.99	1.05 26 1.07	1.09 26 1.07	1.13 27 1.16	1.18 27 1.16
F	2½	Calculated Thickness Use {Thickness class Thickness	0.64* 20 0.68	0.67* 20 0.68	0.70* 20 0.68	0.74* 21 0.73	0.79* 22 0.79	0.87 23 0.85	0.96 25 0.99
	3½	Calculated Thickness Use {Thickness Class Thickness	0.63* 20 0.68	0.66* 20 0.68	0.69* 20 0.68	0.73* 21 0.73	0.81 22 0.79	0.88 23 0.85	0.97 25 0.99
	5	Calculated Thickness Use {Thickness Class Thickness	0.66* 20 0.68	0.69* 20 0.68	0.73 21 0.73	0.78 22 0.79	0.85 23 0.85	0.92 24 0.92	0.99 25 0.99
	8	Calculated Thickness Use {Thickness Class Thickness	0.72 21 0.73	0.76 22 0.79	0.80 22 0.79	0.85 23 0.85	0.90 24 0.92	0.96 25 0.99	1.03 26 1.07
	12	Calculated Thickness Use {Thickness Class Thickness	0.80 22 0.79	0.84 23 0.85	0.87 23 0.85	0.91 24 0.92	0.96 25 0.99	1.02 25 0.99	1.08 26 1.07
	16	Calculated Thickness Use {Thickness Class Thickness	0.85 23 0.85	0.89 24 0.92	0.92 24 0.92	0.96 25 0.99	1.01 25 0.99	1.06 26 1.07	1.12 27 1.91

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-2 (Continued)
Schedule of Barrel Thickness for Water Pipe of 21/45 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thickness—in.						
Thirty-six-Inch Water Pipe									
A	2½	Calculated Thickness	0.89*	0.92*	0.96*	1.00*	1.05*	1.10*	1.16*
		Use { Thickness Class Thickness	22 0.87	23 0.94	23 0.94	24 1.02	24 1.02	25 1.10	26 1.19
	3½	Calculated Thickness	0.88*	0.92*	0.95*	1.00*	1.04*	1.10*	1.15
		Use { Thickness Class Thickness	22 0.87	23 0.94	23 0.94	24 1.02	24 1.02	25 1.10	26 1.19
	5	Calculated Thickness	0.93*	0.96*	1.00*	1.04*	1.09*	1.14	1.22
		Use { Thickness Class Thickness	23 0.94	23 0.94	24 1.02	24 1.02	25 1.10	25 1.10	26 1.19
8	Calculated Thickness	1.01*	1.04*	1.08	1.13	1.18	1.24	1.31	
	Use { Thickness Class Thickness	24 1.02	24 1.02	25 1.10	25 1.10	26 1.19	27 1.29	27 1.29	
12	Calculated Thickness	1.13	1.16	1.20	1.25	1.30	1.35	1.41	
	Use { Thickness Class Thickness	25 1.10	26 1.19	26 1.19	27 1.29	27 1.29	28 1.39	28 1.39	
16	Calculated Thickness	1.22	1.25	1.29	1.33	1.38	1.43	1.48	
	Use { Thickness Class Thickness	26 1.19	27 1.29	27 1.29	27 1.29	28 1.39	28 1.39	29 1.50	
B	2½	Calculated Thickness	0.78*	0.81*	0.85*	0.90*	0.95*	1.01*	1.12
		Use { Thickness Class Thickness	21 0.81	21 0.81	22 0.87	22 0.87	23 0.94	24 1.02	25 1.10
	3½	Calculated Thickness	0.77*	0.81*	0.85*	0.89*	0.95*	1.03	1.12
		Use { Thickness Class Thickness	20 0.75	21 0.81	22 0.87	22 0.87	23 0.94	24 1.02	25 1.10
	5	Calculated Thickness	0.81*	0.85*	0.89*	0.93*	1.00	1.08	1.16
		Use { Thickness Class Thickness	21 .81	22 .87	22 .87	23 .94	24 1.02	25 1.10	26 1.19
8	Calculated Thickness	0.88	0.92	0.97	1.02	1.08	1.15	1.22	
	Use { Thickness Class Thickness	22 0.87	23 0.94	23 0.94	24 1.02	25 1.10	26 1.19	26 1.19	
12	Calculated Thickness	0.99	1.02	1.07	1.12	1.17	1.23	1.30	
	Use { Thickness Class Thickness	24 1.02	24 1.02	25 1.10	25 1.10	26 1.19	26 1.19	27 1.29	
16	Calculated Thickness	1.06	1.10	1.14	1.19	1.24	1.29	1.35	
	Use { Thickness Class Thickness	25 1.10	25 1.10	25 1.10	26 1.19	27 1.29	27 1.29	28 1.39	
F	2½	Calculated Thickness	0.71*	0.74*	0.78*	0.83*	0.90	1.00	1.10
		Use { Thickness Class Thickness	20 0.75	20 0.75	21 0.81	21 0.81	22 0.87	24 1.02	25 1.10
	3½	Calculated Thickness	0.70*	0.74*	0.78*	0.83	0.92	1.01	1.11
		Use { Thickness Class Thickness	20 0.75	20 0.75	21 0.81	21 0.81	23 0.94	24 1.02	25 1.10
	5	Calculated Thickness	0.74*	0.77*	0.82	0.88	0.96	1.05	1.14
		Use { Thickness Class Thickness	20 0.75	20 0.75	21 0.81	22 0.87	23 0.94	24 1.02	25 1.10
8	Calculated Thickness	0.81	0.85	0.90	0.96	1.02	1.10	1.18	
	Use { Thickness Class Thickness	21 0.81	22 0.87	22 0.87	23 0.94	24 1.02	25 1.10	26 1.19	
12	Calculated Thickness	0.90	0.94	0.98	1.04	1.09	1.16	1.23	
	Use { Thickness Class Thickness	22 0.87	23 0.94	24 1.02	24 1.02	25 1.10	26 1.19	26 1.19	
16	Calculated Thickness	0.96	1.00	1.04	1.09	1.15	1.21	1.28	
	Use { Thickness Class Thickness	23 0.94	24 1.02	24 1.02	25 1.10	26 1.19	26 1.19	27 1.29	

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-2 (Continued)
Schedule of Barrel Thickness for Water Pipe of 21/45 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thickness—in.						
Forty-two-Inch Water Pipe									
A	2½	Calculated Thickness	0.99*	1.02*	1.07*	1.12*	1.17*	1.24*	1.31*
		Use { Thickness Class Thickness	22 0.97	23 1.05	23 1.05	24 1.13	24 1.13	25 1.22	26 1.32
	3½	Calculated Thickness	0.99*	1.02*	1.07*	1.12*	1.17*	1.24*	1.30
		Use { Thickness Class Thickness	22 0.97	23 1.05	23 1.05	24 1.13	24 1.13	25 1.22	26 1.32
	5	Calculated Thickness	1.04*	1.08*	1.12*	1.17*	1.22*	1.28*	1.37
		Use { Thickness Class Thickness	23 1.05	23 1.05	24 1.13	24 1.13	25 1.22	26 1.32	26 1.32
8	Calculated Thickness	1.13*	1.17*	1.21	1.27	1.33	1.40	1.48	
	Use { Thickness Class Thickness	24 1.13	24 1.13	25 1.22	26 1.32	26 1.32	27 1.43	27 1.43	
12	Calculated Thickness	1.26	1.30	1.35	1.40	1.46	1.52	1.59	
	Use { Thickness Class Thickness	25 1.22	26 1.32	26 1.32	27 1.43	27 1.43	28 1.54	28 1.54	
16	Calculated Thickness	1.37	1.41	1.46	1.51	1.56	1.62	1.68	
	Use { Thickness Class Thickness	26 1.32	27 1.43	27 1.43	28 1.54	28 1.54	29 1.66	29 1.66	
B	2½	Calculated Thickness	0.85*	0.89*	0.94*	0.99*	1.05*	1.13	1.25
		Use { Thickness Class Thickness	20 0.83	21 0.90	22 0.97	22 0.97	23 1.05	24 1.13	25 1.22
	3½	Calculated Thickness	0.85*	0.89*	0.94*	0.99*	1.05	1.15	1.27
		Use { Thickness Class Thickness	20 0.83	21 0.90	22 0.97	22 0.97	23 1.05	24 1.13	26 1.32
	5	Calculated Thickness	0.89*	0.93*	0.98*	1.03*	1.11	1.21	1.31
		Use { Thickness Class Thickness	21 0.90	21 0.90	22 0.97	23 1.05	24 1.13	25 1.22	26 1.32
8	Calculated Thickness	0.97	1.02	1.07	1.13	1.21	1.29	1.37	
	Use { Thickness Class Thickness	22 0.97	23 1.05	23 1.05	24 1.13	25 1.22	26 1.32	26 1.32	
12	Calculated Thickness	1.09	1.13	1.18	1.24	1.30	1.38	1.45	
	Use { Thickness Class Thickness	24 1.13	24 1.13	25 1.22	25 1.22	26 1.32	27 1.43	27 1.43	
16	Calculated Thickness	1.18	1.22	1.27	1.32	1.38	1.45	1.52	
	Use { Thickness Class Thickness	25 1.22	25 1.22	26 1.32	26 1.32	27 1.43	27 1.43	28 1.54	
F	2½	Calculated Thickness	0.77*	0.81*	0.86*	0.92*	1.00	1.12	1.24
		Use { Thickness Class Thickness	20 0.83	20 0.83	20 0.83	21 0.90	22 0.97	24 1.13	25 1.22
	3½	Calculated Thickness	0.77*	0.81*	0.86*	0.92*	1.02	1.14	1.25
		Use { Thickness Class Thickness	20 0.83	20 0.83	20 0.83	21 0.90	23 1.05	24 1.13	25 1.22
	5	Calculated Thickness	0.81*	0.85*	0.90	0.98	1.07	1.17	1.28
		Use { Thickness Class Thickness	20 0.83	20 0.83	21 0.90	22 0.97	23 1.05	24 1.13	26 1.32
8	Calculated Thickness	0.89	0.94	0.99	1.06	1.14	1.23	1.33	
	Use { Thickness Class Thickness	21 0.90	22 0.97	22 0.97	23 1.05	24 1.13	25 1.22	26 1.32	
12	Calculated Thickness	0.99	1.03	1.09	1.15	1.22	1.30	1.39	
	Use { Thickness Class Thickness	22 0.97	23 1.05	24 1.13	24 1.13	25 1.22	26 1.32	27 1.43	
16	Calculated Thickness	1.07	1.11	1.16	1.21	1.28	1.36	1.44	
	Use { Thickness Class Thickness	23 1.05	24 1.13	24 1.13	25 1.22	26 1.32	26 1.32	27 1.43	

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-2 (Continued)
Schedule of Barrel Thickness for Water Pipe of 21/45 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi						
			50	100	150	200	250	300	350
			Barrel Thickness—in.						
Forty-eight-Inch Water Pipe									
A	2½	Calculated Thickness Use {Thickness Class Thickness	1.08* 22 1.06	1.12* 23 1.14	1.17* 23 1.14	1.23* 24 1.23	1.29* 25 1.33	1.37* 25 1.33	1.45* 26 1.44
	3½	Calculated Thickness Use {Thickness Class Thickness	1.09* 22 1.06	1.13* 23 1.14	1.18* 23 1.14	1.24* 24 1.23	1.30* 25 1.33	1.37* 25 1.33	1.46 26 1.44
	5	Calculated Thickness Use {Thickness Class Thickness	1.15* 23 1.14	1.19* 24 1.23	1.24* 24 1.23	1.30* 25 1.33	1.36* 25 1.33	1.43 26 1.44	1.53 27 1.56
	8	Calculated Thickness Use {Thickness Class Thickness	1.25* 24 1.23	1.29* 25 1.33	1.34 25 1.33	1.41 26 1.44	1.48 26 1.44	1.56 27 1.56	1.65 28 1.68
	12	Calculated Thickness Use {Thickness Class Thickness	1.41 26 1.44	1.45 26 1.44	1.51 27 1.56	1.57 27 1.56	1.63 28 1.68	1.70 28 1.68	1.77 29 1.81
	16	Calculated Thickness Use {Thickness Class Thickness	1.53 27 1.56	1.58 27 1.56	1.63 28 1.68	1.68 28 1.68	1.75 29 1.81	1.81 29 1.81	1.89 30 1.95
B	2½	Calculated Thickness Use {Thickness Class Thickness	0.92* 20 0.91	0.97* 21 0.98	1.02* 22 1.06	1.08* 22 1.06	1.16* 23 1.14	1.26 24 1.23	1.40 26 1.44
	3½	Calculated Thickness Use {Thickness Class Thickness	0.93* 20 0.91	0.97* 21 0.98	1.03* 22 1.06	1.09* 22 1.06	1.17 23 1.14	1.29 25 1.33	1.42 26 1.44
	5	Calculated Thickness Use {Thickness Class Thickness	0.98* 21 0.98	1.02* 22 1.06	1.08* 22 1.06	1.14 23 1.14	1.23 24 1.23	1.34 25 1.33	1.46 26 1.44
	8	Calculated Thickness Use {Thickness Class Thickness	1.06 22 1.06	1.12 23 1.14	1.18 23 1.14	1.25 24 1.23	1.34 25 1.33	1.43 26 1.44	1.53 27 1.56
	12	Calculated Thickness Use {Thickness Class Thickness	1.20 24 1.23	1.25 24 1.23	1.31 25 1.33	1.37 25 1.33	1.45 26 1.44	1.53 27 1.56	1.62 28 1.68
	16	Calculated Thickness Use {Thickness Class Thickness	1.30 25 1.33	1.35 25 1.33	1.41 26 1.44	1.47 26 1.44	1.54 27 1.56	1.61 27 1.56	1.70 28 1.68
F	2½	Calculated Thickness Use {Thickness Class Thickness	0.83* 20 0.91	0.88* 20 0.91	0.94* 20 0.91	1.01* 21 0.98	1.12 23 1.14	1.25 24 1.23	1.39 26 1.44
	3½	Calculated Thickness Use {Thickness Class Thickness	0.84* 20 0.91	0.89* 20 0.91	0.94* 20 0.91	1.02 22 1.06	1.14 23 1.14	1.27 24 1.23	1.40 26 1.44
	5	Calculated Thickness Use {Thickness Class Thickness	0.88* 20 0.91	0.93* 20 0.91	0.99 21 0.98	1.08 22 1.06	1.19 24 1.23	1.30 25 1.33	1.43 26 1.44
	8	Calculated Thickness Use {Thickness Class Thickness	0.97 21 0.98	1.03 22 1.06	1.09 22 1.06	1.17 23 1.14	1.27 24 1.23	1.37 25 1.33	1.48 26 1.44
	12	Calculated Thickness Use {Thickness Class Thickness	1.09 22 1.06	1.14 23 1.14	1.20 24 1.23	1.27 24 1.23	1.35 25 1.33	1.45 26 1.44	1.55 27 1.56
	16	Calculated Thickness Use {Thickness Class Thickness	1.17 23 1.14	1.23 24 1.23	1.28 25 1.33	1.35 25 1.33	1.43 26 1.44	1.51 27 1.56	1.60 27 1.56

* Asterisk following total calculated thickness indicates that truck superload (Case 2) is the controlling factor. When total calculated thickness is not followed by asterisk, surge pressure (Case 1) is the controlling factor. See Sec. 1-2.1.

TABLE 1-3
Schedule of Barrel Thickness for Gas Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi					
			10	50	100	150	200	250
			Barrel Thicknesses—in.					
Four-Inch Gas Pipe								
A	2½	Calculated Thickness	.23	.23	.23	.24	.24	.24
		Use (Thickness Class Thickness)	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35
	3½	Calculated Thickness	.22	.23	.23	.23	.23	.23
		Use (Thickness Class Thickness)	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35
	5	Calculated Thickness	.23	.23	.24	.24	.24	.25
		Use (Thickness Class Thickness)	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35
8	Calculated Thickness	.25	.25	.25	.26	.26	.27	
	Use (Thickness Class Thickness)	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	
12	Calculated Thickness	.27	.28	.28	.29	.29	.29	
	Use (Thickness Class Thickness)	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	
16	Calculated Thickness	.30	.30	.30	.31	.31	.32	
	Use (Thickness Class Thickness)	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	
B	2½	Calculated Thickness	.23	.23	.23	.23	.23	.24
		Use (Thickness Class Thickness)	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35
	3½	Calculated Thickness	.22	.23	.23	.23	.24	.24
		Use (Thickness Class Thickness)	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35
	5	Calculated Thickness	.23	.23	.23	.23	.24	.24
		Use (Thickness Class Thickness)	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35
8	Calculated Thickness	.24	.24	.24	.25	.25	.26	
	Use (Thickness Class Thickness)	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	
12	Calculated Thickness	.28	.29	.29	.29	.30	.30	
	Use (Thickness Class Thickness)	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	
16	Calculated Thickness	.29	.29	.29	.30	.30	.31	
	Use (Thickness Class Thickness)	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	
F	2½	Calculated Thickness	.22	.22	.22	.22	.23	.23
		Use (Thickness Class Thickness)	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35
	3½	Calculated Thickness	.22	.22	.22	.22	.23	.23
		Use (Thickness Class Thickness)	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35
	5	Calculated Thickness	.22	.22	.22	.22	.23	.23
		Use (Thickness Class Thickness)	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35
8	Calculated Thickness	.23	.23	.23	.24	.24	.24	
	Use (Thickness Class Thickness)	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	
12	Calculated Thickness	.24	.24	.25	.25	.26	.27	
	Use (Thickness Class Thickness)	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	
16	Calculated Thickness	.26	.26	.27	.28	.28	.29	
	Use (Thickness Class Thickness)	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	.22 .35	

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TABLE 1-3 (Continued)
Schedule of Barrel Thickness for Gas Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi					
			10	50	100	150	200	250
			Barrel Thicknesses—in.					
Six-Inch Gas Pipe								
A	2½	Calculated Thickness	.28	.29	.29	.30	.30	.32
		Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38
	3½	Calculated Thickness	.27	.28	.28	.29	.30	.31
		Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38
	5	Calculated Thickness	.28	.29	.29	.30	.31	.32
		Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38
8	Calculated Thickness	.31	.31	.32	.33	.33	.34	
	Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	
12	Calculated Thickness	.34	.35	.35	.36	.37	.38	
	Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	
16	Calculated Thickness	.38	.38	.39	.39	.40	.41	
	Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	23 .41	23 .41	
B	2½	Calculated Thickness	.27	.28	.28	.29	.30	.31
		Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38
	3½	Calculated Thickness	.27	.27	.28	.28	.29	.30
		Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38
	5	Calculated Thickness	.28	.28	.28	.29	.30	.31
		Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38
8	Calculated Thickness	.29	.30	.31	.31	.32	.33	
	Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	
12	Calculated Thickness	.33	.34	.34	.35	.35	.36	
	Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	
16	Calculated Thickness	.36	.36	.37	.38	.38	.39	
	Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	
F	2½	Calculated Thickness	.26	.26	.27	.27	.28	.29
		Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38
	3½	Calculated Thickness	.26	.26	.26	.27	.28	.29
		Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38
	5	Calculated Thickness	.26	.27	.27	.28	.28	.29
		Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38
8	Calculated Thickness	.28	.28	.29	.29	.30	.31	
	Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	
12	Calculated Thickness	.30	.31	.31	.32	.33	.34	
	Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	
16	Calculated Thickness	.33	.33	.34	.35	.35	.36	
	Use { Thickness Class Thickness	22 .38	22 .38	22 .38	22 .38	22 .38	22 .38	

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TABLE 1-3 (Continued)
Schedule of Barrel Thickness for Gas Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover <i>ft</i>	Thickness Specifications	Internal Pressure— <i>psi</i>					
			10	50	100	150	200	250
			Barrel Thicknesses— <i>in.</i>					
Eight-Inch Gas Pipe								
A	2½	Calculated Thickness	.33	.34	.35	.36	.37	.38
		Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41
	3½	Calculated Thickness	.32	.33	.34	.34	.35	.36
		Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41
	5	Calculated Thickness	.33	.34	.35	.36	.37	.38
		Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41
8	Calculated Thickness	.36	.37	.37	.38	.39	.40	
	Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	
12	Calculated Thickness	.41	.42	.42	.43	.44	.45	
	Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.23 .44	.23 .44	.23 .44	
16	Calculated Thickness	.44	.45	.45	.46	.47	.48	
	Use { Thickness Class Thickness	.23 .44	.23 .44	.23 .44	.24 .48	.24 .48	.24 .48	
B	2½	Calculated Thickness	.32	.32	.33	.34	.35	.36
		Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41
	3½	Calculated Thickness	.31	.32	.33	.33	.34	.36
		Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41
	5	Calculated Thickness	.32	.33	.34	.34	.35	.37
		Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41
8	Calculated Thickness	.35	.35	.36	.37	.38	.39	
	Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	
12	Calculated Thickness	.39	.39	.40	.41	.42	.43	
	Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	
16	Calculated Thickness	.42	.42	.43	.44	.45	.46	
	Use { Thickness Class Thickness	.22 .41	.22 .41	.23 .44	.23 .44	.23 .44	.24 .48	
F	2½	Calculated Thickness	.29	.30	.31	.32	.33	.34
		Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41
	3½	Calculated Thickness	.29	.29	.30	.30	.31	.33
		Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41
	5	Calculated Thickness	.29	.30	.31	.32	.33	.34
		Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41
8	Calculated Thickness	.32	.33	.33	.34	.35	.36	
	Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	
12	Calculated Thickness	.35	.36	.37	.37	.38	.39	
	Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	
16	Calculated Thickness	.38	.38	.39	.40	.41	.42	
	Use { Thickness Class Thickness	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	.22 .41	

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TABLE 1-3 (Continued)
 Schedule of Barrel Thickness for Gas Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi					
			10	50	100	150	200	250
			Barrel Thicknesses—in.					
Ten-Inch Gas Pipe								
A	2½	Calculated Thickness	.39	.40	.41	.42	.43	.45
		Use { Thickness Class Thickness	.22 .44	.22 .44	.22 .44	.22 .44	.22 .44	.22 .44
	3½	Calculated Thickness	.38	.39	.40	.41	.42	.44
		Use { Thickness Class Thickness	.22 .44	.22 .44	.22 .44	.22 .44	.22 .44	.22 .44
	5	Calculated Thickness	.39	.40	.41	.42	.43	.44
		Use { Thickness Class Thickness	.22 .44	.22 .44	.22 .44	.22 .44	.22 .44	.22 .44
8	Calculated Thickness	.43	.43	.44	.46	.47	.48	
	Use { Thickness Class Thickness	.22 .44	.22 .44	.22 .44	.23 .48	.23 .48	.23 .48	
12	Calculated Thickness	.48	.49	.49	.50	.51	.52	
	Use { Thickness Class Thickness	.23 .48	.23 .48	.23 .48	.24 .52	.24 .52	.24 .52	
16	Calculated Thickness	.50	.51	.52	.53	.54	.56	
	Use { Thickness Class Thickness	.24 .52	.24 .52	.24 .52	.24 .52	.25 .56	.25 .56	
B	2½	Calculated Thickness	.37	.38	.39	.40	.41	.43
		Use { Thickness Class Thickness	.22 .44	.22 .44	.22 .44	.22 .44	.22 .44	.22 .44
	3½	Calculated Thickness	.36	.37	.38	.39	.40	.42
		Use { Thickness Class Thickness	.22 .44	.22 .44	.22 .44	.22 .44	.22 .44	.22 .44
	5	Calculated Thickness	.37	.38	.39	.40	.41	.43
		Use { Thickness Class Thickness	.22 .44	.22 .44	.22 .44	.22 .44	.22 .44	.22 .44
8	Calculated Thickness	.40	.41	.42	.43	.44	.46	
	Use { Thickness Class Thickness	.22 .44	.22 .44	.22 .44	.22 .44	.22 .44	.23 .48	
12	Calculated Thickness	.45	.46	.47	.48	.49	.50	
	Use { Thickness Class Thickness	.22 .44	.23 .48	.23 .48	.23 .48	.23 .48	.24 .52	
16	Calculated Thickness	.47	.48	.49	.50	.51	.53	
	Use { Thickness Class Thickness	.23 .48	.23 .48	.23 .48	.24 .52	.24 .52	.24 .52	
F	2½	Calculated Thickness	.34	.35	.36	.37	.38	.40
		Use { Thickness Class Thickness	.22 .44	.22 .44	.22 .44	.22 .44	.22 .44	.22 .44
	3½	Calculated Thickness	.33	.34	.35	.36	.37	.39
		Use { Thickness Class Thickness	.22 .44	.22 .44	.22 .44	.22 .44	.22 .44	.22 .44
	5	Calculated Thickness	.34	.35	.36	.37	.38	.40
		Use { Thickness Class Thickness	.22 .44	.22 .44	.22 .44	.22 .44	.22 .44	.22 .44
8	Calculated Thickness	.36	.37	.38	.39	.41	.42	
	Use { Thickness Class Thickness	.22 .44	.22 .44	.22 .44	.22 .44	.22 .44	.22 .44	
12	Calculated Thickness	.41	.42	.43	.44	.45	.46	
	Use { Thickness Class Thickness	.22 .44	.22 .44	.22 .44	.22 .44	.22 .44	.23 .48	
16	Calculated Thickness	.43	.44	.45	.46	.47	.48	
	Use { Thickness Class Thickness	.22 .44	.22 .44	.22 .44	.23 .48	.23 .48	.23 .48	

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TABLE 1-3 (Continued)
 Schedule of Barrel Thickness for Gas Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi					
			10	50	100	150	200	250
			Barrel Thicknesses—in.					
Twelve-Inch Gas Pipe								
A	2½	Calculated Thickness	.44	.45	.46	.47	.49	.51
		Use { Thickness Class Thickness	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48	.23 .52
	3½	Calculated Thickness	.43	.43	.45	.46	.48	.50
		Use { Thickness Class Thickness	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48	.23 .52
	5	Calculated Thickness	.44	.45	.46	.47	.48	.50
		Use { Thickness Class Thickness	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48	.23 .52
8	Calculated Thickness	.48	.49	.50	.52	.53	.55	
	Use { Thickness Class Thickness	.22 .48	.22 .48	.23 .52	.23 .52	.23 .52	.24 .56	.25 .56
12	Calculated Thickness	.53	.54	.55	.57	.58	.59	
	Use { Thickness Class Thickness	.23 .52	.24 .56	.24 .56	.24 .56	.25 .60	.25 .60	.25 .60
16	Calculated Thickness	.56	.56	.58	.59	.60	.62	
	Use { Thickness Class Thickness	.24 .56	.24 .56	.25 .60	.25 .60	.25 .60	.25 .60	.25 .60
B	2½	Calculated Thickness	.41	.42	.44	.45	.46	.48
		Use { Thickness Class Thickness	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48
	3½	Calculated Thickness	.40	.41	.42	.44	.45	.47
		Use { Thickness Class Thickness	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48
	5	Calculated Thickness	.41	.42	.43	.45	.46	.48
		Use { Thickness Class Thickness	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48
8	Calculated Thickness	.45	.46	.47	.49	.50	.52	
	Use { Thickness Class Thickness	.22 .48	.22 .48	.22 .48	.22 .48	.23 .52	.23 .52	.23 .52
12	Calculated Thickness	.50	.51	.52	.53	.55	.56	
	Use { Thickness Class Thickness	.23 .52	.23 .52	.23 .52	.23 .52	.24 .56	.24 .56	.24 .56
16	Calculated Thickness	.52	.53	.54	.56	.57	.59	
	Use { Thickness Class Thickness	.23 .52	.23 .52	.24 .56	.24 .56	.24 .56	.25 .60	.25 .60
F	2½	Calculated Thickness	.38	.39	.40	.41	.43	.45
		Use { Thickness Class Thickness	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48
	3½	Calculated Thickness	.37	.38	.39	.40	.42	.44
		Use { Thickness Class Thickness	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48
	5	Calculated Thickness	.38	.39	.40	.41	.43	.45
		Use { Thickness Class Thickness	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48
8	Calculated Thickness	.41	.42	.43	.45	.46	.48	
	Use { Thickness Class Thickness	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48	.22 .48
12	Calculated Thickness	.45	.46	.47	.48	.50	.52	
	Use { Thickness Class Thickness	.22 .48	.22 .48	.22 .48	.22 .48	.23 .52	.23 .52	.23 .52
16	Calculated Thickness	.47	.48	.49	.50	.52	.53	
	Use { Thickness Class Thickness	.22 .48	.22 .48	.22 .48	.23 .52	.23 .52	.23 .52	.23 .52

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TABLE 1-3 (Continued)
Schedule of Barrel Thickness for Gas Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi					
			10	50	100	150	200	250
			Barrel Thicknesses—in.					
Sixteen-Inch Gas Pipe								
A	2½	Calculated Thickness	.53	.54	.56	.58	.60	
		Use { Thickness Class Thickness	.22 .54	.22 .54	.23 .58	.23 .58	.23 .58	.23 .58
	3½	Calculated Thickness	.52	.54	.55	.57	.59	
		Use { Thickness Class Thickness	.22 .54	.22 .54	.22 .54	.23 .58	.23 .58	.23 .58
	5	Calculated Thickness	.54	.55	.57	.59	.61	
		Use { Thickness Class Thickness	.22 .54	.22 .54	.23 .58	.23 .58	.24 .63	.24 .63
8	Calculated Thickness	.60	.61	.63	.65	.67		
	Use { Thickness Class Thickness	.23 .58	.24 .63	.24 .63	.24 .63	.25 .68	.25 .68	
12	Calculated Thickness	.65	.66	.67	.69	.71		
	Use { Thickness Class Thickness	.24 .63	.25 .68	.25 .68	.25 .68	.26 .73	.26 .73	
16	Calculated Thickness	.68	.69	.71	.73	.75		
	Use { Thickness Class Thickness	.25 .68	.25 .68	.26 .73	.26 .73	.26 .73	.26 .73	
B	2½	Calculated Thickness	.49	.50	.52	.54	.56	
		Use { Thickness Class Thickness	.21 .50	.21 .50	.22 .54	.22 .54	.23 .58	.23 .58
	3½	Calculated Thickness	.49	.50	.52	.53	.56	
		Use { Thickness Class Thickness	.21 .50	.21 .50	.22 .54	.22 .54	.23 .58	.23 .58
	5	Calculated Thickness	.51	.51	.53	.55	.57	
		Use { Thickness Class Thickness	.21 .50	.21 .50	.22 .54	.22 .54	.23 .58	.23 .58
8	Calculated Thickness	.55	.56	.58	.60	.62		
	Use { Thickness Class Thickness	.22 .54	.23 .58	.23 .58	.23 .58	.24 .63	.24 .63	
12	Calculated Thickness	.60	.61	.62	.64	.66		
	Use { Thickness Class Thickness	.23 .58	.24 .63	.24 .63	.24 .63	.25 .68	.25 .68	
16	Calculated Thickness	.63	.64	.66	.67	.69		
	Use { Thickness Class Thickness	.24 .63	.24 .63	.25 .68	.25 .68	.25 .68	.25 .68	
F	2½	Calculated Thickness	.46	.47	.48	.50	.52	
		Use { Thickness Class Thickness	.21 .50	.21 .50	.21 .50	.21 .50	.22 .54	.22 .54
	3½	Calculated Thickness	.45	.46	.47	.49	.52	
		Use { Thickness Class Thickness	.21 .50	.21 .50	.21 .50	.21 .50	.22 .54	.22 .54
	5	Calculated Thickness	.47	.48	.49	.51	.53	
		Use { Thickness Class Thickness	.21 .50	.21 .50	.21 .50	.21 .50	.22 .54	.22 .54
8	Calculated Thickness	.51	.52	.53	.55	.57		
	Use { Thickness Class Thickness	.21 .50	.22 .54	.22 .54	.22 .54	.23 .58	.23 .58	
12	Calculated Thickness	.54	.55	.57	.59	.61		
	Use { Thickness Class Thickness	.22 .54	.22 .54	.23 .58	.23 .58	.24 .63	.24 .63	
16	Calculated Thickness	.57	.58	.59	.61	.63		
	Use { Thickness Class Thickness	.23 .58	.23 .58	.23 .58	.24 .63	.24 .63	.24 .63	

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TABLE 1-3 (Continued)
Schedule of Barrel Thickness for Gas Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi					
			10	50	100	150	200	250
			Barrel Thicknesses—in.					
Twenty-Inch Gas Pipe								
A	2½	Calculated Thickness	.61	.62	.65	.67	.70	
		Use { Thickness Class Thickness	.22 .62	.22 .62	.23 .67	.23 .67	.24 .72	.23 .72
	3½	Calculated Thickness	.61	.62	.64	.66	.69	
		Use { Thickness Class Thickness	.22 .62	.22 .62	.22 .62	.23 .67	.23 .67	.23 .67
	5	Calculated Thickness	.63	.65	.67	.69	.72	
		Use { Thickness Class Thickness	.22 .62	.23 .67	.23 .67	.23 .67	.24 .72	.24 .72
8	Calculated Thickness	.69	.70	.72	.75	.77		
	Use { Thickness Class Thickness	.23 .67	.24 .72	.24 .72	.25 .78	.25 .78	.25 .78	
12	Calculated Thickness	.74	.76	.78	.80	.83		
	Use { Thickness Class Thickness	.24 .72	.25 .78	.25 .78	.25 .78	.26 .84	.26 .84	
16	Calculated Thickness	.79	.80	.82	.84	.87		
	Use { Thickness Class Thickness	.25 .78	.25 .78	.26 .84	.26 .84	.26 .84	.26 .84	
B	2½	Calculated Thickness	.56	.57	.59	.62	.65	
		Use { Thickness Class Thickness	.21 .57	.21 .57	.21 .57	.22 .62	.23 .67	.23 .67
	3½	Calculated Thickness	.55	.57	.59	.62	.64	
		Use { Thickness Class Thickness	.21 .57	.21 .57	.21 .57	.22 .62	.22 .62	.22 .62
	5	Calculated Thickness	.58	.59	.61	.64	.67	
		Use { Thickness Class Thickness	.21 .57	.21 .57	.22 .62	.22 .62	.23 .67	.23 .67
8	Calculated Thickness	.63	.64	.66	.69	.71		
	Use { Thickness Class Thickness	.22 .62	.22 .62	.23 .67	.23 .67	.24 .72	.24 .72	
12	Calculated Thickness	.68	.69	.71	.73	.76		
	Use { Thickness Class Thickness	.23 .67	.23 .67	.24 .72	.24 .72	.25 .78	.25 .78	
16	Calculated Thickness	.71	.73	.75	.77	.80		
	Use { Thickness Class Thickness	.24 .72	.24 .72	.25 .78	.25 .78	.25 .78	.25 .78	
F	2½	Calculated Thickness	.50	.51	.53	.57	.60	
		Use { Thickness Class Thickness	.21 .57	.21 .57	.21 .57	.21 .57	.22 .62	.22 .62
	3½	Calculated Thickness	.50	.51	.53	.57	.60	
		Use { Thickness Class Thickness	.21 .57	.21 .57	.21 .57	.21 .57	.22 .62	.22 .62
	5	Calculated Thickness	.52	.54	.56	.58	.62	
		Use { Thickness Class Thickness	.21 .57	.21 .57	.21 .57	.21 .57	.22 .62	.22 .62
8	Calculated Thickness	.56	.58	.60	.62	.65		
	Use { Thickness Class Thickness	.21 .57	.21 .57	.22 .62	.22 .62	.23 .67	.23 .67	
12	Calculated Thickness	.61	.62	.64	.67	.70		
	Use { Thickness Class Thickness	.22 .62	.22 .62	.22 .62	.23 .67	.23 .72	.24 .72	
16	Calculated Thickness	.64	.66	.68	.70	.72		
	Use { Thickness Class Thickness	.22 .62	.23 .67	.23 .67	.24 .72	.24 .72	.24 .72	

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TABLE 1-3 (Continued)
 Schedule of Barrel Thickness for Gas Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi					
			10	50	100	150	200	250
			Barrel Thicknesses—in.					
Twenty-four-Inch Gas Pipe								
A	2½	Calculated Thickness	.67	.69	.72	.75	.78	
		Use (Thickness Class	22	22	23	23	24	
		Thickness	.68	.68	.73	.73	.79	
	3½	Calculated Thickness	.67	.69	.71	.74	.78	
		Use (Thickness Class	22	22	23	23	24	
		Thickness	.68	.68	.73	.73	.79	
5	Calculated Thickness	.71	.72	.75	.78	.81		
	Use (Thickness Class	23	23	23	24	24		
	Thickness	.73	.73	.73	.79	.79		
8	Calculated Thickness	.77	.79	.81	.84	.87		
	Use (Thickness Class	24	24	24	25	25		
	Thickness	.79	.79	.79	.85	.85		
12	Calculated Thickness	.84	.86	.88	.91	.94		
	Use (Thickness Class	25	25	25	26	26		
	Thickness	.85	.85	.85	.92	.92		
16	Calculated Thickness	.90	.91	.94	.97	1.00		
	Use (Thickness Class	26	26	26	27	27		
	Thickness	.92	.92	.92	.99	.99		
B	2½	Calculated Thickness	.61	.63	.65	.68	.72	
		Use (Thickness Class	21	21	21	22	23	
		Thickness	.63	.63	.63	.68	.73	
	3½	Calculated Thickness	.59	.62	.65	.68	.71	
		Use (Thickness Class	21	21	21	22	23	
		Thickness	.63	.63	.63	.68	.73	
5	Calculated Thickness	.63	.65	.67	.71	.75		
	Use (Thickness Class	21	21	22	23	23		
	Thickness	.63	.63	.68	.73	.73		
8	Calculated Thickness	.69	.71	.73	.76	.79		
	Use (Thickness Class	22	23	23	24	24		
	Thickness	.68	.73	.73	.79	.79		
12	Calculated Thickness	.75	.77	.79	.82	.85		
	Use (Thickness Class	23	24	24	25	25		
	Thickness	.73	.79	.79	.85	.85		
16	Calculated Thickness	.80	.81	.84	.87	.90		
	Use (Thickness Class	24	24	25	25	26		
	Thickness	.79	.79	.85	.85	.92		
F	2½	Calculated Thickness	.55	.56	.58	.63	.67	
		Use (Thickness Class	21	21	21	21	22	
		Thickness	.63	.63	.63	.63	.68	
	3½	Calculated Thickness	.54	.56	.58	.62	.66	
		Use (Thickness Class	21	21	21	21	22	
		Thickness	.63	.63	.63	.63	.68	
5	Calculated Thickness	.57	.58	.62	.65	.68		
	Use (Thickness Class	21	21	21	21	22		
	Thickness	.63	.63	.63	.63	.68		
8	Calculated Thickness	.62	.64	.67	.70	.73		
	Use (Thickness Class	21	21	22	22	23		
	Thickness	.63	.63	.68	.68	.73		
12	Calculated Thickness	.67	.69	.72	.75	.78		
	Use (Thickness Class	22	22	23	23	24		
	Thickness	.68	.68	.73	.73	.79		
16	Calculated Thickness	.71	.73	.76	.79	.82		
	Use (Thickness Class	23	23	24	24	25		
	Thickness	.73	.73	.79	.79	.85		

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TABLE 1-3 (Continued)
 Schedule of Barrel Thickness for Gas Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi					
			10	50	100	150	200	250
			Barrel Thicknesses—in.					
Thirty-Inch Gas Pipe								
A	2½	Calculated Thickness	.80	.83	.86	.90		
		Use { Thickness Class Thickness	.22 .79	.23 .85	.23 .85	.24 .92		
	3½	Calculated Thickness	.79	.82	.85	.89		
		Use { Thickness Class Thickness	.22 .79	.23 .85	.23 .85	.24 .92		
	5	Calculated Thickness	.84	.86	.90	.93		
		Use { Thickness Class Thickness	.23 .85	.23 .85	.24 .92	.24 .92		
8	Calculated Thickness	.92	.94	.97	1.01			
	Use { Thickness Class Thickness	.24 .92	.24 .92	.25 .99	.25 .99			
12	Calculated Thickness	1.01	1.03	1.06	1.09			
	Use { Thickness Class Thickness	.25 .99	.26 1.07	.26 1.07	.26 1.07			
16	Calculated Thickness	1.07	1.09	1.12	1.15			
	Use { Thickness Class Thickness	.26 1.07	.26 1.07	.27 1.16	.27 1.16			
B	2½	Calculated Thickness	.69	.74	.77	.81		
		Use { Thickness Class Thickness	.21 .73	.21 .73	.22 .79	.22 .79		
	3½	Calculated Thickness	.69	.73	.76	.80		
		Use { Thickness Class Thickness	.21 .73	.21 .73	.22 .79	.22 .79		
	5	Calculated Thickness	.75	.77	.80	.85		
		Use { Thickness Class Thickness	.21 .73	.22 .79	.22 .79	.23 .85		
8	Calculated Thickness	.81	.83	.86	.90			
	Use { Thickness Class Thickness	.22 .79	.23 .85	.23 .85	.24 .92			
12	Calculated Thickness	.88	.90	.93	.97			
	Use { Thickness Class Thickness	.23 .85	.24 .92	.24 .92	.25 .99			
16	Calculated Thickness	.94	.96	.99	1.03			
	Use { Thickness Class Thickness	.24 .92	.25 .99	.25 .99	.26 1.07			
F	2½	Calculated Thickness	.63	.66	.70	.74		
		Use { Thickness Class Thickness	.21 .73	.21 .73	.21 .73	.21 .73		
	3½	Calculated Thickness	.63	.66	.70	.74		
		Use { Thickness Class Thickness	.21 .73	.21 .73	.21 .73	.21 .73		
	5	Calculated Thickness	.68	.70	.73	.77		
		Use { Thickness Class Thickness	.21 .73	.21 .73	.21 .73	.22 .79		
8	Calculated Thickness	.73	.75	.79	.83			
	Use { Thickness Class Thickness	.21 .73	.21 .73	.22 .79	.23 .85			
12	Calculated Thickness	.79	.81	.85	.88			
	Use { Thickness Class Thickness	.22 .79	.22 .79	.23 .85	.23 .85			
16	Calculated Thickness	.84	.86	.90	.93			
	Use { Thickness Class Thickness	.23 .85	.23 .85	.24 .92	.24 .92			

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TABLE 1-3 (Continued)
 Schedule of Barrel Thickness for Gas Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover <i>f</i>	Thickness Specifications	Internal Pressure— <i>psi</i>					
			10	50	100	150	200	250
			Barrel Thicknesses— <i>in.</i>					
Thirty-six-Inch Gas Pipe								
A	2½	Calculated Thickness Use { Thickness Class Thickness	.91 23 .94	.94 23 .94	.98 24 1.02	1.02 24 1.02		
	3½	Calculated Thickness Use { Thickness Class Thickness	.90 22 .87	.93 23 .94	.97 23 .94	1.02 24 1.02		
	5	Calculated Thickness Use { Thickness Class Thickness	.95 23 .94	.98 24 1.02	1.02 24 1.02	1.07 25 1.10		
	8	Calculated Thickness Use { Thickness Class Thickness	1.04 24 1.02	1.07 25 1.10	1.11 25 1.10	1.15 26 1.19		
	12	Calculated Thickness Use { Thickness Class Thickness	1.15 26 1.19	1.17 26 1.19	1.21 26 1.19	1.25 27 1.29		
	16	Calculated Thickness Use { Thickness Class Thickness	1.23 26 1.19	1.26 27 1.29	1.29 27 1.29	1.33 27 1.29		
B	2½	Calculated Thickness Use { Thickness Class Thickness	.79 21 .81	.82 21 .81	.86 22 .87	.91 23 .94		
	3½	Calculated Thickness Use { Thickness Class Thickness	.79 21 .81	.81 21 .81	.85 22 .87	.90 22 .87		
	5	Calculated Thickness Use { Thickness Class Thickness	.83 21 .81	.86 22 .87	.90 22 .87	.94 23 .94		
	8	Calculated Thickness Use { Thickness Class Thickness	.90 22 .87	.93 23 .94	.96 23 .94	1.01 24 1.02		
	12	Calculated Thickness Use { Thickness Class Thickness	.99 24 1.02	1.01 24 1.02	1.05 24 1.02	1.10 25 1.10		
	16	Calculated Thickness Use { Thickness Class Thickness	1.06 25 1.10	1.08 25 1.10	1.13 25 1.10	1.17 26 1.19		
F	2½	Calculated Thickness Use { Thickness Class Thickness	.71 21 .81	.73 21 .81	.79 21 .81	.84 22 .87		
	3½	Calculated Thickness Use { Thickness Class Thickness	.71 21 .81	.73 21 .81	.78 21 .81	.83 21 .81		
	5	Calculated Thickness Use { Thickness Class Thickness	.75 21 .81	.78 21 .81	.82 21 .81	.87 22 .87		
	8	Calculated Thickness Use { Thickness Class Thickness	.81 21 .81	.84 22 .87	.88 22 .87	.93 23 .94		
	12	Calculated Thickness Use { Thickness Class Thickness	.89 22 .87	.91 23 .94	.95 23 .94	1.00 24 1.02		
	16	Calculated Thickness Use { Thickness Class Thickness	.95 23 .94	.97 23 .94	1.01 24 1.02	1.06 25 1.10		

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TABLE 1-3 (Continued)
 Schedule of Barrel Thickness for Gas Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi					
			10	50	100	150	200	250
			Barrel Thicknesses—in.					
Forty-two-Inch Gas Pipe								
A	2½	Calculated Thickness Use { Thickness Class Thickness	1.01 23 1.05	1.04 23 1.05	1.08 23 1.05	1.14 24 1.13		
	3½	Calculated Thickness Use { Thickness Class Thickness	1.01 23 1.05	1.04 23 1.05	1.08 23 1.05	1.14 24 1.13		
	5	Calculated Thickness Use { Thickness Class Thickness	1.07 23 1.05	1.09 24 1.13	1.14 24 1.13	1.19 25 1.22		
	8	Calculated Thickness Use { Thickness Class Thickness	1.16 24 1.13	1.19 25 1.22	1.24 25 1.22	1.29 26 1.32		
	12	Calculated Thickness Use { Thickness Class Thickness	1.29 26 1.32	1.32 26 1.32	1.36 26 1.32	1.41 27 1.43		
	16	Calculated Thickness Use { Thickness Class Thickness	1.39 27 1.43	1.42 27 1.43	1.46 27 1.43	1.51 28 1.54		
B	2½	Calculated Thickness Use { Thickness Class Thickness	.86 21 .90	.89 21 .90	.94 22 .97	1.00 22 .97		
	3½	Calculated Thickness Use { Thickness Class Thickness	.86 21 .90	.89 21 .90	.94 22 .97	1.00 22 .97		
	5	Calculated Thickness Use { Thickness Class Thickness	.91 21 .90	.94 22 .97	.98 22 .97	1.04 23 1.05		
	8	Calculated Thickness Use { Thickness Class Thickness	.99 22 .97	1.02 23 1.05	1.07 23 1.05	1.12 24 1.13		
	12	Calculated Thickness Use { Thickness Class Thickness	1.10 24 1.13	1.13 24 1.13	1.17 24 1.13	1.22 25 1.22		
	16	Calculated Thickness Use { Thickness Class Thickness	1.18 25 1.22	1.21 25 1.22	1.25 25 1.22	1.30 26 1.32		
F	2½	Calculated Thickness Use { Thickness Class Thickness	.77 21 .90	.80 21 .90	.86 21 .90	.92 21 .90		
	3½	Calculated Thickness Use { Thickness Class Thickness	.77 21 .90	.80 21 .90	.86 21 .90	.92 21 .90		
	5	Calculated Thickness Use { Thickness Class Thickness	.82 21 .90	.85 21 .90	.90 21 .90	.96 22 .97		
	8	Calculated Thickness Use { Thickness Class Thickness	.89 21 .90	.92 21 .90	.97 22 .97	1.03 23 1.05		
	12	Calculated Thickness Use { Thickness Class Thickness	.98 22 .97	1.01 23 1.05	1.06 23 1.05	1.11 24 1.13		
	16	Calculated Thickness Use { Thickness Class Thickness	1.06 23 1.05	1.08 23 1.05	1.13 24 1.13	1.18 25 1.22		

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TABLE 1-3 (Continued)
 Schedule of Barrel Thickness for Gas Pipe of 18/40 Iron Strength

Laying Condition	Depth of Cover ft	Thickness Specifications	Internal Pressure—psi					
			10	50	100	150	200	250
			Barrel Thicknesses—in.					
Forty-eight-Inch Gas Pipe								
A	2½	Calculated Thickness Use { Thickness Class Thickness	1.10 23 1.14	1.14 23 1.14	1.19 24 1.23	1.25 24 1.23		
	3½	Calculated Thickness Use { Thickness Class Thickness	1.11 23 1.14	1.14 23 1.14	1.20 24 1.23	1.26 24 1.23		
	5	Calculated Thickness Use { Thickness Class Thickness	1.18 23 1.14	1.22 24 1.23	1.27 24 1.23	1.32 25 1.33		
	8	Calculated Thickness Use { Thickness Class Thickness	1.29 25 1.33	1.33 25 1.33	1.38 25 1.33	1.43 26 1.44		
	12	Calculated Thickness Use { Thickness Class Thickness	1.43 26 1.44	1.47 26 1.44	1.52 27 1.56	1.57 27 1.56		
	16	Calculated Thickness Use { Thickness Class Thickness	1.55 27 1.56	1.58 27 1.56	1.63 28 1.68	1.69 28 1.68		
B	2½	Calculated Thickness Use { Thickness Class Thickness	.93 21 .98	.97 21 .98	1.03 22 1.06	1.09 22 1.06		
	3½	Calculated Thickness Use { Thickness Class Thickness	.94 21 .98	.98 21 .98	1.03 22 1.06	1.10 23 1.14		
	5	Calculated Thickness Use { Thickness Class Thickness	.99 21 .98	1.03 22 1.06	1.09 22 1.06	1.15 23 1.14		
		Calculated Thickness Use { Thickness Class Thickness	1.09 22 1.06	1.12 23 1.14	1.17 23 1.14	1.24 24 1.23		
	12	Calculated Thickness Use { Thickness Class Thickness	1.21 24 1.23	1.25 24 1.23	1.30 25 1.33	1.35 25 1.33		
	16	Calculated Thickness Use { Thickness Class Thickness	1.30 25 1.33	1.34 25 1.33	1.38 25 1.33	1.44 26 1.44		
F	2½	Calculated Thickness Use { Thickness Class Thickness	.84 21 .98	.88 21 .98	.93 21 .98	1.00 21 .98		
	3½	Calculated Thickness Use { Thickness Class Thickness	.84 21 .98	.88 21 .98	.94 21 .98	1.01 21 .98		
	5	Calculated Thickness Use { Thickness Class Thickness	.90 21 .98	.93 21 .98	.99 21 .98	1.06 22 1.06		
	8	Calculated Thickness Use { Thickness Class Thickness	.97 21 .98	1.01 21 .98	1.07 22 1.06	1.13 23 1.14		
	12	Calculated Thickness Use { Thickness Class Thickness	1.08 22 1.06	1.12 23 1.14	1.16 23 1.14	1.23 24 1.23		
	16	Calculated Thickness Use { Thickness Class Thickness	1.15 23 1.14	1.20 24 1.23	1.25 24 1.23	1.31 25 1.33		

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Sec. 1-2—General Procedure for Thickness Determination

Sec. 1-2.1—Scope

This section gives the general method for determining the thicknesses of cast-iron pressure pipe. Thickness nomograms (Fig. 1-1 through 1-5) are included for two commonly used iron strengths (18/40 and 21/45); thicknesses for other iron strengths may be computed by the method presented in Sec. 1-3.1.

The required thickness of cast-iron pipe is determined by considering trench load and internal pressure in combination, and calculations of net thickness are made for two cases, namely:

Case 1. Trench load (earth load but no truck superload) in combination with internal pressure (working pressure plus surge pressure) and with a 2.5 factor of safety applied to both trench load and internal pressure

Case 2. Trench load (earth load plus truck superload) in combination with internal pressure (working pressure but no surge pressure) and with a 2.5 factor of safety applied to both trench load and internal pressure.

The larger thickness thus determined is chosen as the net thickness (only Case 2 is used for gas pipe). To the net thickness is added a corrosion allowance to obtain the minimum manufacturing thickness and a casting tolerance to obtain the total calculated thickness. Finally, the thickness for specifying and ordering is selected from a table of standard class thicknesses.

An example of this method is shown in Sec. 1-2.3.

Sec. 1-2.2—Procedure for Thickness Determination

This section gives the procedure for determining total calculated thick-

nesses and standard class thicknesses for pipe. This procedure was used in calculating the values shown in Sec. 1-1, Tables 1-1, 1-2 and 1-3.

1-2.2.1—Determination of Net Thickness

The net thickness for the more usual conditions may be readily determined using Tables 1-4 and 1-5 and the nomograms in Fig. 1-1 through 1-5. The bases for these tables and nomograms are described in Sec. 1-3. The three most commonly used methods of laying pipe, called "laying conditions," are defined below:

Laying Condition	Description
A	Pipe laid on flat-bottom trench, backfill not tamped
B	Pipe laid on flat-bottom trench, backfill tamped
F	Pipe bedded in gravel or sand, backfill tamped

After the pipe size, working pressure, iron strength, laying condition, and depth of cover have been established, the procedure for determining net thickness is as follows:

a. From Table 1-4, select for both Case 1 and Case 2 the value of w , which is the ring test load equivalent of trench load including a 2.5 safety factor (see Sec. 1-3.1 for definition of ring test load equivalent).

b. From Table 1-5, select for both Case 1 and Case 2 the value of p , which is the internal pressure including a 2.5 safety factor.

c. Thickness nomograms are provided in Fig. 1-1 through 1-5 for iron strengths of 18/40* and 21/45.* Se-

* The first figure designates the bursting tensile strength in 1,000 psi and the second figure designates the ring modulus of rupture in 1,000 psi.

lect the nomogram for the desired iron strength and range of loads and pressures. Locate the values of w and p for Case 1 on the vertical scales. Connect these values with a straightedge and read the required thickness for Case 1.

d. Repeat this procedure using the above values of w and p for Case 2 and read the required thickness for Case 2.

e. The larger thickness, as determined for Cases 1 and 2, is the net thickness for water pipe. (For gas pipe, only Case 2 is applicable.)

1-2.2.2—*Addition of Allowances to Net Thickness*

a. A corrosion allowance of 0.08 in. is added to the net thickness. The resulting thickness is the minimum manufacturing thickness. Where severe corrosion is anticipated, an analysis of the condition should be made.

b. A casting tolerance from Table 1-6 is added to the minimum manufacturing thickness and the resulting thickness is the total calculated thickness.

1-2.2.3—*Selection of Standard Thickness*

Refer to Table 1-7 and select the standard class thickness nearest to the total calculated thickness. When the calculated thickness is halfway between two standard thicknesses, the larger of these is selected. When the calculated thickness is less than the smallest standard thickness, the smallest standard thickness is selected.

Sec. 1-2.3—Example for Determining Thickness of 18-in. Water Pipe

Determine the thickness for 18-in. cast-iron pipe laid on flat-bottom trench with tamped backfill (laying condition B), under 5 ft of cover for a working pressure of 200 psi. Iron strength is 18/40.

1-2.3.1—*Step 1—Determination of Net Thickness*

a. From Table 1-4, the ring test load equivalents of trench load, including a safety factor of 2.5, are

For Case 1, $w = 2,786$ lb/lin ft

For Case 2, $w = 3,876$ lb/lin ft

b. From Table 1-5, the internal pressures, including a safety factor of 2.5, are

For Case 1, $p = 750$ psi

For Case 2, $p = 500$ psi

c. Using Fig. 1-1, locate $w = 2,786$ and $p = 750$ on the vertical scales. Connect these values with a straightedge and read the thickness for Case 1, which is 0.47 in.

d. Using Fig. 1-1, locate $w = 3,876$ and $p = 500$ and read the thickness for Case 2, which is 0.46 in.

e. The larger of these two thicknesses is the net thickness. The controlling one in this example is 0.47 in. (Case 1).

1-2.3.2—*Step 2—Addition of Allowances to Net Thickness*

The total calculated thickness, as shown in Table 1-1, is determined as follows:

Net thickness	0.47 in.
Corrosion allowance	0.08 in.
Minimum manufacturing thickness	0.55 in.
Casting tolerance (Table 1-6)	0.08 in.
<i>Total calculated thickness</i>	0.63 in.

1-2.3.3—*Step 3—Selection of Standard Thickness*

From Table 1-7, the total calculated thickness of 0.63 in. is exactly the same as Class 23. Therefore, Class 23 is the standard thickness class for the pipe in this example.

In ordering or specifying, the foregoing pipe is identified as 18-in. size, thickness Class 23, conforming to ANSI Standard A21.6 or A21.8 as applicable.

THICKNESS DESIGN OF CAST-IRON PIPE

TABLE 1-4

Ring Test Load Equivalents (w) of Trench Loads—lb/lin ft*

Laying Condition	Pipe Size in.	Depth of Cover—ft							
		2½	3½	5	8	12	16	20	24
Case 1—Ring Test Load Equivalent of Earth Load (Use With Surge Pressure)									
A	3	396	565	817	1,324	2,000	2,674	3,343	4,026
	4	491	704	1,024	1,663	2,515	3,367	4,222	5,074
	6	672	974	1,428	2,337	3,548	4,756	5,487	5,754
	8	826	1,211	1,791	2,948	4,491	5,635	6,120	6,446
	10	974	1,448	2,157	3,576	5,376	6,198	6,770	7,163
	12	1,111	1,674	2,520	4,239	5,839	6,774	7,433	7,902
	14	1,235	1,887	2,865	4,822	6,304	7,356	8,115	8,659
	16	1,341	2,085	3,196	5,176	6,776	7,954	8,804	9,433
	18	1,446	2,265	3,513	5,506	7,250	8,548	9,509	10,224
	20	1,552	2,433	3,815	5,839	7,728	9,150	10,224	11,033
	24	1,770	2,730	4,372	6,509	8,693	10,378	11,678	12,680
	30	2,093	3,167	5,087	7,520	10,161	12,256	13,915	15,237
	36	2,437	3,626	5,713	8,537	11,643	14,167	16,220	17,882
	42	2,761	4,083	6,341	9,556	13,078	16,104	18,554	20,560
	48	3,102	4,550	6,991	10,580	14,646	18,061	20,928	23,354
	54	3,437	5,022	7,650	11,609	16,161	20,039	23,346	26,161
	60	3,778	5,493	8,313	12,643	17,815	22,028	25,776	28,998
	B	3	355	508	734	1,189	1,797	2,402	3,004	3,617
4		438	628	913	1,483	2,242	3,002	3,764	4,523
6		585	848	1,244	2,036	3,091	4,144	4,780	5,014
8		709	1,039	1,537	2,530	3,855	4,836	5,252	5,531
10		824	1,224	1,823	3,024	4,546	5,241	5,724	6,057
12		926	1,395	2,100	3,533	4,866	5,645	6,194	6,586
14		1,007	1,539	2,337	3,933	5,142	6,000	6,618	7,062
16		1,079	1,677	2,570	4,163	5,449	6,397	7,080	7,586
18		1,147	1,797	2,786	4,367	5,750	6,779	7,541	8,109
20		1,214	1,903	2,985	4,568	6,046	7,158	7,998	8,631
24		1,339	2,066	3,307	4,924	6,577	7,852	8,836	9,593
30		1,524	2,305	3,703	5,473	7,396	8,921	10,128	11,090
36		1,709	2,543	4,006	5,986	8,165	9,935	11,373	12,540
42		1,879	2,778	4,315	6,503	8,899	10,959	12,626	14,015
48		2,074	3,042	4,674	7,074	9,792	12,076	13,993	15,615
54		2,259	3,300	5,027	7,629	10,620	13,169	15,342	17,191
60		2,455	3,569	5,401	8,215	11,575	14,312	16,747	18,841
F		3	261	374	540	875	1,322	1,767	2,210	2,661
	4	323	463	673	1,093	1,653	2,213	2,774	3,334
	6	434	629	923	1,510	2,292	3,073	3,545	3,718
	8	528	774	1,144	1,883	2,869	3,600	3,910	4,118
	10	612	910	1,355	2,247	3,378	3,895	4,254	4,502
	12	691	1,041	1,566	2,635	3,630	4,211	4,620	4,912
	14	755	1,154	1,753	2,949	3,856	4,500	4,964	5,297
	16	812	1,262	1,934	3,133	4,101	4,815	5,329	5,709
	18	861	1,350	2,093	3,281	4,320	5,093	5,666	6,092
	20	915	1,435	2,250	3,444	4,558	5,396	6,029	6,506
	24	1,018	1,570	2,514	3,742	4,999	5,968	6,715	7,291
	30	1,157	1,751	2,812	4,157	5,618	6,776	7,693	8,424
	36	1,310	1,949	3,070	4,588	6,257	7,613	8,716	9,610
	42	1,443	2,134	3,315	4,996	6,837	8,418	9,699	10,766
	48	1,586	2,326	3,573	5,408	7,485	9,231	10,697	11,937
	54	1,726	2,522	3,842	5,830	8,116	10,063	11,724	13,138
	60	1,881	2,735	4,139	6,295	8,869	10,967	12,832	14,436

*A safety factor of 2.5 is included. These ring test load equivalents are based on the earth loads in Table 1-8.

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TABLE 1-4 (Continued)
Ring Test Load Equivalents (w) of Trench Loads—lb/lin ft*

Laying Condition	Pipe Size in.	Depth of Cover—ft							
		2½	3½	5	8	12	16	20	24
Case 2—Ring Test Load Equivalent of Earth Load Plus Truck Superload (Use Without Surge Pressure)†									
A	3	748	741	935	1,411	2,059	2,704	3,363	4,041
	4	1,137	1,057	1,200	1,780	2,602	3,426	4,261	5,104
	6	1,904	1,678	1,839	2,541	3,696	4,843	5,543	5,798
	8	2,528	2,267	2,437	3,270	4,696	5,752	6,198	6,506
	10	3,087	2,798	2,978	3,987	5,611	6,346	6,867	7,239
	12	3,635	3,317	3,517	4,767	6,104	6,950	7,548	7,991
	14	3,880	3,641	4,039	5,409	6,598	7,561	8,250	8,763
	16	4,183	3,996	4,478	5,880	7,128	8,220	8,980	9,567
	18	4,489	4,361	4,887	6,298	7,661	8,841	9,702	10,374
	20	4,865	4,772	5,400	6,730	8,198	9,502	10,456	11,213
	24	5,383	5,250	6,043	7,513	9,250	10,761	11,930	12,876
	30	6,278	6,115	7,083	8,746	10,865	12,726	14,226	15,476
	36	7,180	7,054	8,083	9,911	12,465	14,724	16,587	18,167
	42	7,878	7,887	9,035	11,115	14,076	16,778	19,000	20,939
	48	8,596	8,728	10,035	12,350	15,761	18,824	21,432	23,743
	54	9,165	9,483	10,967	13,563	17,452	20,861	23,902	26,572
	60	9,789	10,237	11,904	14,783	19,193	22,909	26,393	29,437
	B	3	672	666	840	1,268	1,850	2,430	3,021	3,631
4		1,014	942	1,070	1,587	2,320	3,054	3,798	4,550
6		1,659	1,462	1,602	2,214	3,220	4,220	4,830	5,051
8		2,170	1,946	2,091	2,806	4,030	4,937	5,319	5,584
10		2,610	2,366	2,518	3,371	4,744	5,366	5,807	6,121
12		3,029	2,765	2,931	3,973	5,087	5,792	6,290	6,659
14		3,165	2,970	3,294	4,411	5,381	6,166	6,729	7,147
16		3,364	3,213	3,601	4,729	5,733	6,610	7,222	7,694
18		3,560	3,459	3,876	4,995	6,076	7,012	7,695	8,228
20		3,806	3,733	4,225	5,265	6,413	7,434	8,180	8,772
24		4,072	3,972	4,572	5,684	6,998	8,141	9,026	9,742
30		4,570	4,451	5,155	6,366	7,908	9,263	10,354	11,264
36		5,035	4,947	5,668	6,950	8,741	10,325	11,631	12,739
42		5,361	5,367	6,148	7,564	9,578	11,417	12,929	14,248
48		5,747	5,836	6,709	8,257	10,538	12,586	14,330	15,875
54		6,023	6,232	7,207	8,913	11,469	13,709	15,707	17,461
60		6,360	6,651	7,734	9,604	12,470	14,884	17,148	19,126
F		3	494	490	618	932	1,361	1,787	2,223	2,671
	4	747	694	789	1,170	1,710	2,251	2,800	3,354
	6	1,230	1,084	1,188	1,642	2,388	3,129	3,581	3,746
	8	1,615	1,449	1,557	2,089	3,000	3,675	3,960	4,157
	10	1,940	1,758	1,872	2,505	3,526	3,988	4,316	4,549
	12	2,260	2,062	2,187	2,964	3,795	4,320	4,692	4,968
	14	2,374	2,227	2,471	3,309	4,036	4,625	5,046	5,360
	16	2,532	2,418	2,711	3,559	4,315	4,975	5,436	5,791
	18	2,675	2,598	2,912	3,752	4,565	5,268	5,781	6,181
	20	2,869	2,814	3,185	3,969	4,835	5,604	6,167	6,613
	24	3,095	3,019	3,475	4,320	5,319	6,188	6,860	7,404
	30	3,471	3,381	3,916	4,835	6,007	7,036	7,865	8,556
	36	3,859	3,791	4,343	5,326	6,698	7,912	8,914	9,763
	42	4,118	4,123	4,723	5,810	7,358	8,771	9,932	10,945
	48	4,393	4,461	5,129	6,312	8,055	9,621	10,954	12,136
	54	4,603	4,762	5,508	6,811	8,764	10,476	12,003	13,344
	60	4,874	5,097	5,927	7,360	9,556	11,405	13,140	14,655

*A safety factor of 2.5 is included. These ring test load equivalents are based on the earth loads and truck superloads in Table 1-8.

† Truck superload is based on two passing trucks with adjacent wheels 3 ft apart, having a 9,000-lb wheel load on unpaved road or flexible pavement and an impact factor of 1.50 (see Sec. 1-3.3).

THICKNESS DESIGN OF CAST-IRON PIPE

TABLE 1-5
Internal Pressures (p)*

Pipe Size in.	Rated Working Pressure—psi							
	10	50	100	150	200	250	300	350
Case 1—Internal Pressure With Surge Pressure Allowances†								
3	—	425	550	675	800	925	1,050	1,175
4	—	425	550	675	800	925	1,050	1,175
6	—	425	550	675	800	925	1,050	1,175
8	—	425	550	675	800	925	1,050	1,175
10	—	425	550	675	800	925	1,050	1,175
12	—	400	525	650	775	900	1,025	1,150
14	—	400	525	650	775	900	1,025	1,150
16	—	375	500	625	750	875	1,000	1,125
18	—	375	500	625	750	875	1,000	1,125
20	—	350	475	600	725	850	975	1,100
24	—	338	463	588	713	838	963	1,088
30	—	325	450	575	700	825	950	1,075
36	—	313	438	563	688	813	938	1,063
42	—	300	425	550	675	800	925	1,050
48	—	300	425	550	675	800	925	1,050
54	—	300	425	550	675	800	925	1,050
60	—	300	425	550	675	800	925	1,050
Case 2—Internal Pressure Without Surge Pressure Allowances								
3-60 all	25	125	250	375	500	625	750	875

* Safety factor of 2.5 included.

† For surge pressure allowances, see Table 1-10.

TABLE 1-6
Allowances For Casting Tolerance

Pipe Size in.	Casting Tolerance in.	Pipe Size in.	Casting Tolerance in.
3-8	0.05	14-24	0.08
10-12	0.06	30-48	0.10

AMERICAN NATIONAL STANDARD

TABLE 1-7—Standard Thickness Classes of Cast-Iron Pipe
(See note on facing page)

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

7
3

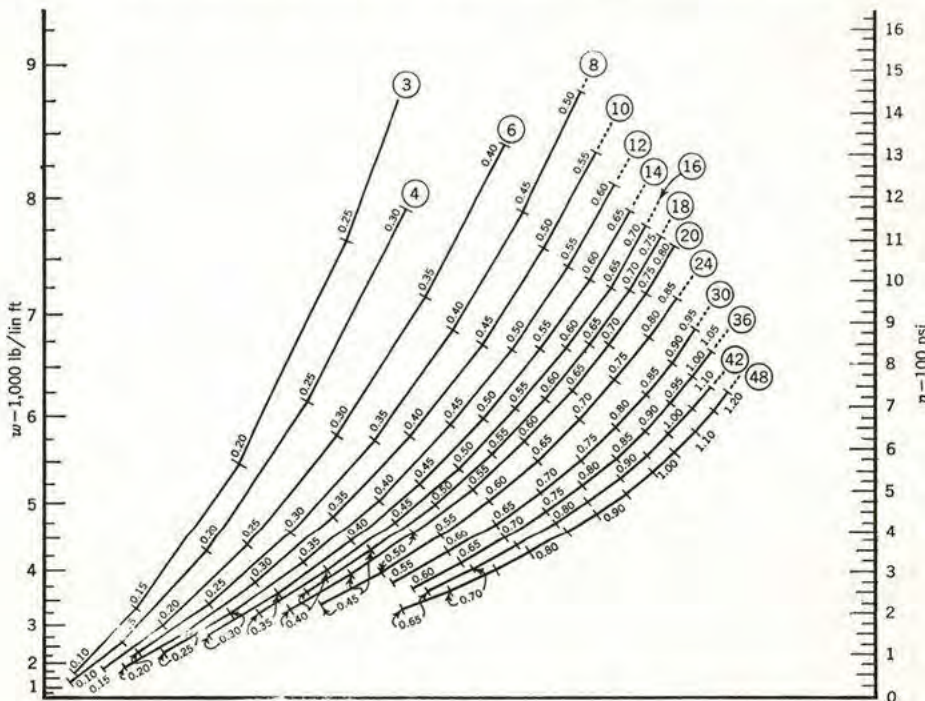


Fig. 1-1. Thickness Nomogram for Pipe of 18/40 Iron Strength, Low-Range Load
Thicknesses are net, and computations are made using nominal pipe diameter for inside diameter. S equals 18,000, R equals 40,000. The encircled values at the end of each curve are for pipe size, in inches.

THICKNESS DESIGN OF CAST-IRON PIPE

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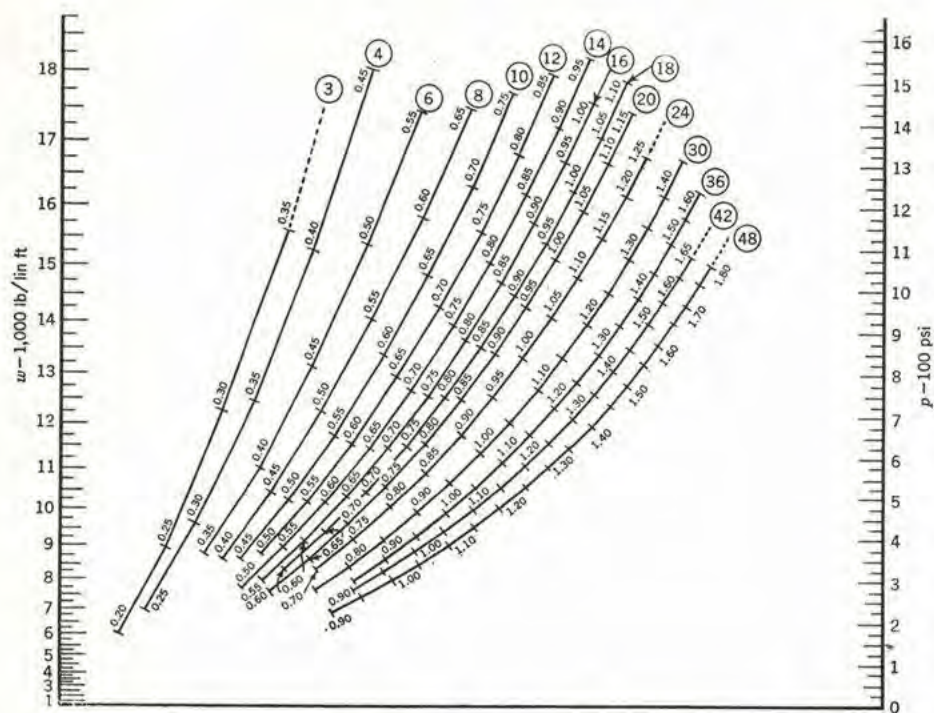


Fig. 1-2. Thickness Nomogram for Pipe of 18/40 Iron Strength, High-Range Load

Thicknesses are net, and computations are made using nominal pipe diameter for inside diameter. S equals 18,000, R equals 40,000. The encircled values at the end of each curve are for pipe size, in inches.

Explanatory Note to Table 1-7

Irrespective of calculated thickness, standard thicknesses are not made less than certain minimums, which are the smallest thickness classes shown in the table. They have been chosen by judgment based on experience with the shocks received by pipe in handling and transporting. ANSI Standards A21.6, A21.7, A21.8, and A21.9 are based on iron strength of 18/40. The recommended minimum nominal thicknesses for such pipe are shown in boldface type. Pipe of 21/45 iron strength for water service may have thicknesses less than those pipe of 18/40 iron strength. Pipe of such reduced thickness should be used only after consideration of possible adverse conditions of installation and environment. The recommended minimum nominal thicknesses for such pipe are shown with an asterisk. Pipe with 21/45 iron strength in Thickness Class 20 are sometimes used in sizes 14-24 in., when the calculated thicknesses permit and where provisions are made for special handling.

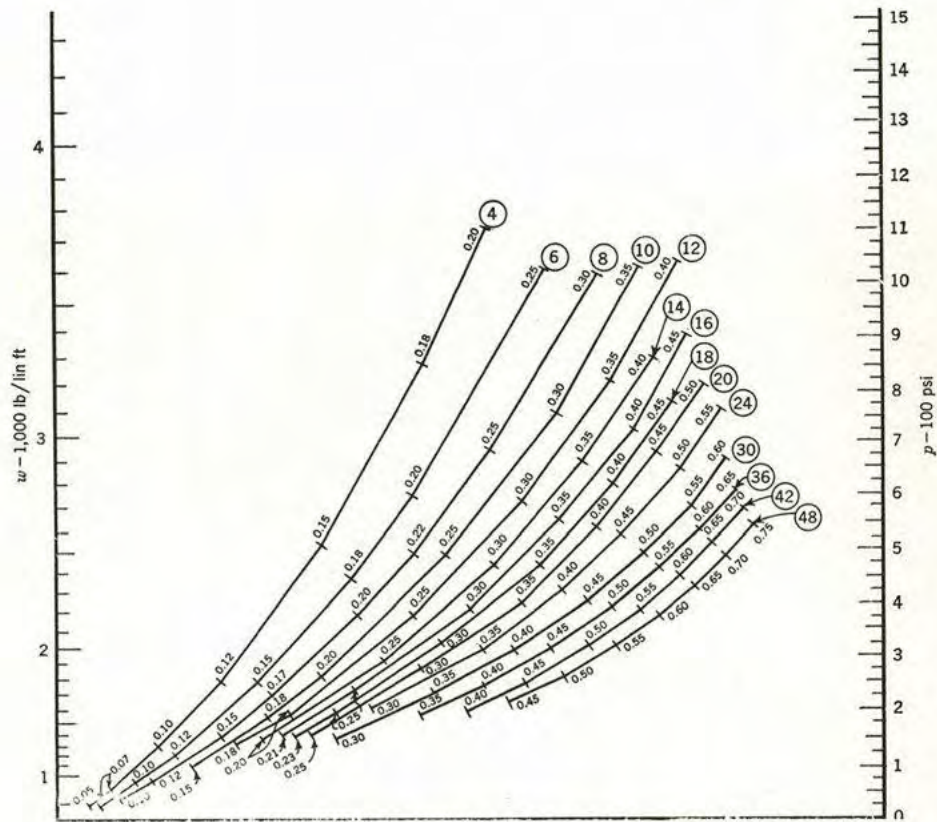


Fig. 1-3. Thickness Nomogram for Pipe of 21/45 Iron Strength, Low-Range Load

Thicknesses are net, and computations are made using nominal pipe diameter for inside diameter. S equals 21,000, R equals 45,000. The encircled values at the end of each curve are for pipe size, in inches.

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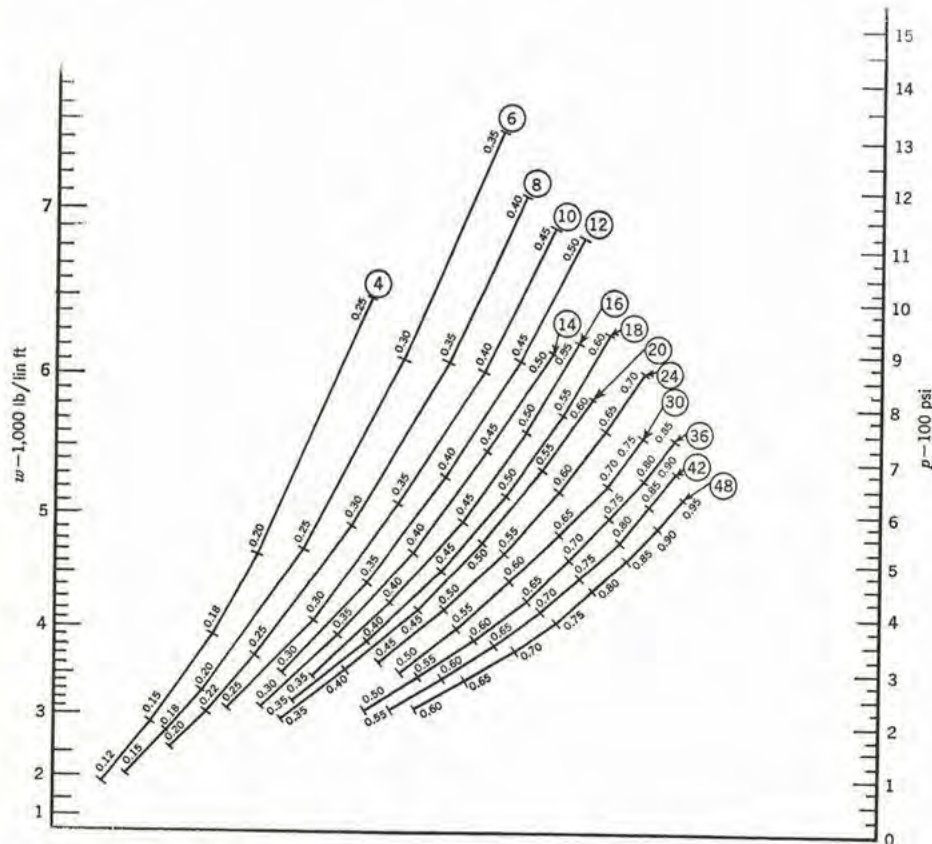


Fig. 1-4. Thickness Nomogram for Pipe of 21/45 Iron Strength, Medium-Range Load
 Thicknesses are net, and computations are made using nominal pipe diameter for inside diameter. S equals 21,000, R equals 45,000. The encircled values at the end of each curve are for pipe size, in inches.

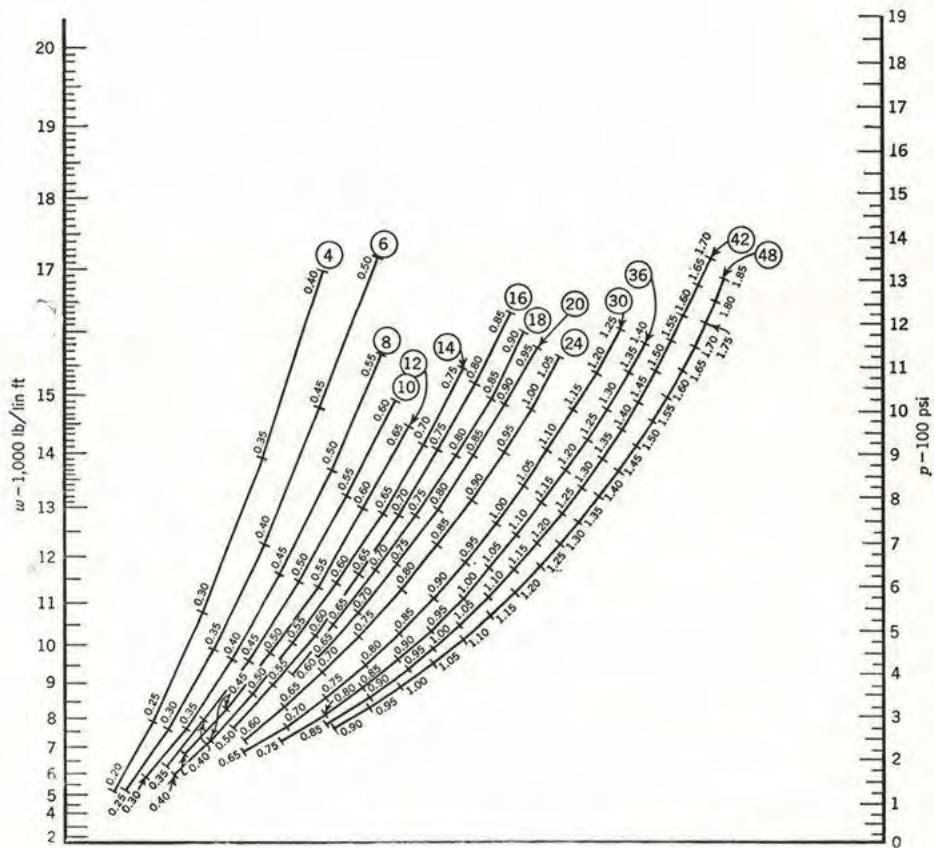


Fig. 1-5. Thickness Nomogram for Pipe of 21/45 Iron Strength, High-Range Load

Thicknesses are net, and computations are made using nominal pipe diameter for inside diameter. S equals 21,000, R equals 45,000. The encircled values at the end of each curve are for pipe size, in inches.

Sec. 1-3—Design Theory—Determination of Net Thickness, Earth Load, and Truck Superload

Sec. 1-3.1—Determination of Net Thickness

Tests made for ANSI Committee A21* showed that, when a pipe has both an external load applied in three-edge bearing (such as the laboratory ring test) and an internal pressure, the relation between external load and internal pressure at the point of breaking can be represented, with sufficient accuracy, by a parabola drawn as in Fig. 1-6.

The mathematical relationships expressed by the formula for the load-pressure curve are the basis for the whole system of pipe thickness calculations used in this standard.

The equation of the load-pressure parabola is

$$w = W \sqrt{\frac{P - p}{P}} \quad (1)$$

in which:

W = ring test crushing load with no internal pressure (lb/lin ft)

P = bursting pressure with no external load (psi)

p and w are any combination of internal pressure and external load that will just cause fracture.

The values of W and P are calculated as follows:

$$W = \frac{Rt^2}{0.0795(d + t)} \quad (2)$$

$$P = \frac{2St}{d} \quad (3)$$

in which:

R = ring modulus of rupture (psi)

S = bursting tensile strength (psi)

t = net thickness (in.)

d = nominal pipe size (in.).

The symbols S and R denote the strength of the iron in the pipe and are based on periodic full-length bursting tests and ring tests specified in ANSI Standards A 5 (AWWA C106), A21.7, A21.8 (AWWA C108), and A21.9.

The design values of w to be used in solving Eq 1, either by nomogram or by trial calculation, are determined as follows:

For Case 1,

$$w = \frac{2.5W_e}{L_f} \quad (4)$$

For Case 2,

$$w = \frac{2.5(W_e + W_t)}{L_f} \quad (5)$$

in which:

w = ring test load equivalent of trench load (lb/lin ft), including a 2.5 safety factor

W_e = earth load (lb/ft) (Table 1-8 and Sec. 1-3.2)

W_t = truck superload (lb/ft) (Table 1-8 and Sec. 1-3.3)

L_f = load factor dependent on laying condition (Table 1-9)

2.5 = safety factor.

The load factor L_f converts the trench load (earth load only or earth

* See Ref. 3, "Foreword," p. x.

load plus truck superload) to an equivalent load in the laboratory ring test. Table 1-4 gives values of w computed from Eq 4 and 5 for standard depths of cover using the earth loads and truck superloads in Table 1-8 and the load factors in Table 1-9.

The design values of p to be used in solving Eq 1, either by nomogram or by trial calculation, are determined as follows:

For Case 1,

$$p = 2.5 (p_w + p_s) \quad (6)$$

For Case 2,

$$p = 2.5 p_w \quad (7)$$

in which:

- p = internal pressure (psi), including a 2.5 safety factor
- p_w = working pressure (psi)
- p_s = allowance for surge pressure (psi) (Table 1-10)
- 2.5 = safety factor.

Table 1-5 gives values of p computed by Eq 6 and 7 for standard working pressures using the allowances for surge pressure in Table 1-10.

As described in Sec. 1-2.2, calculations for net thickness for water pipe are made for two conditions of combined loading: Case 1, which includes surge pressure but not truck superload; and Case 2, which includes truck superload but not surge pressure. The larger of the two thicknesses is used for design. Truck superload and surge pressure are transient and occasional loads, and it is considered extremely unlikely that they will occur simultaneously.

When Eq 2 and 3 are substituted in Eq 1, the result is a high-order equation which cannot be solved directly for the net thickness t by conventional mathematical procedure. It is necessary to resort to graphical solution

or to successive approximation. The more convenient method for routine work is to use a nomogram as shown in Fig. 1-1 through 1-5. Such nomograms are prepared by the following steps:

a. Using the appropriate iron strength values of S and R , calculate W and P for a series of thicknesses for each pipe size by means of Eq 2 and 3.

b. For each thickness select two values of p and compute the corresponding values of w using Eq 1.

c. Set up parallel scales for w and p , using linear increments for the p scale and increments proportional to the square of the load for the w scale.

d. Using a straightedge to connect the corresponding values of w and p , locate and mark the intersection of the two lines determined by the two sets of values for each thickness.

e. Repeat for the full series of thicknesses to lay out the curve for each pipe size.

If it is desired to determine net thickness for iron strengths or loads and pressures not covered in the nomograms in Fig. 1-1 through 1-5, a trial calculation method may be used to solve Eq 1, as follows:

a. Based on the values of w and p corresponding to the design conditions, assume a trial value of t .

b. Using the known iron strength values S and R and the trial value of t , calculate W and P from Eq 2 and 3.

c. Using these values of W and P and the design value of p , solve Eq 1 for w .

d. Compare this calculated value of w to the design value of w and assume a smaller or larger value of t , as required, for the second trial calculation.

e. Continue until a change in assumed thickness of less than 0.01 in. results in a calculated w equal to or greater than the design w .

Saturated top soil, maximum	0.150
Clay, ordinary maximum	0.130
Saturated clay, maximum	0.110

of p' and H/B_d have been determined as follows:

$$p' = h/B_d$$

h = depth of cover in trench from top of pipe to subgrade (ft)

H = total height of fill from top of pipe to top of embankment (ft)

B_d = width of subgrade trench at top of pipe (ft)

1-3.2.2—Positive-Projection Embankment

The positive-projection condition may be encountered with pipe laid on top of a subgrade and covered with fill for highway or dam construction. The earth load is calculated from Eq 9 using Eq 12a for calculation of C_c when standard values of $r_{sd}p$ and $K\mu$ are used. For such standard values the load may also be read directly from Fig. 1-12 which was constructed from loads computed by Eq 9. The loads in Fig. 1-12 are based on soil weighing 110 lb/cu ft and may be adjusted to soil of 120 lb/cu ft by multiplying the graph load by 120/110. For calculation of pipe thicknesses, special load factors are used for positive projection embankment condition as shown in Table 1-9.

1-3.2.3—Negative-Projection Embankment Condition

The negative-projection embankment condition may be encountered in highway or dam construction when the pipe is laid in a relatively narrow trench cut in the subgrade, a more desirable method than installation directly on top of the subgrade. Loads for negative projection are calculated as follows.

$$W_e = C_n w B_d^2 \quad (14)$$

in which:

C_n = calculation coefficient (negative projection condition).

Other terms are as defined for Eq 8 and 9.

The calculation coefficient, C_n , is read from Fig. 1-14 after the values

Equation 14 is considered to give the maximum load that could occur on pipe laid in trenches under embankment conditions such as the case of embankment or additional fill added at some time, generally years, after the pipe was laid as a ditch conduit and backfill placed. In many embankment cases, Eq 14 may give loads which are too conservative.

In cases where pipe is laid in a subgrade trench with the embankment completed shortly thereafter, the load may be closer to that given by Eq 8 for ditch condition, and the embankment fill above the subgrade trench may be considered as equivalent to an increase of the trench width above the top of the pipe without significant effect on the earth load.

For other cases the load may lie somewhere between those given by Eq 8 and Eq 14. The correct load depends largely on relative soil compaction in the subgrade trench and overlying embankment and selection of the proper load for pipe design will be governed by engineering judgment based on the specific factors in each installation.

1-3.2.4—Sample Calculation of Earth Load

Determine earth load on 12-in. cast-iron pipe with 5 ft of cover. Pipe laid

in a flat-bottom trench ($d + 2$) ft wide.

Step 1. Calculate earth load for ditch condition using Eq 8.

$$C_d = \frac{1 - e^{-2K\mu' \frac{H}{B_d}}}{2K\mu'} \quad (10)$$

$$K\mu' = 0.130$$

$$H = 5 \text{ ft}$$

$$B_d = \frac{12}{12} + 2 = 3 \text{ ft}$$

$$C_d = \frac{1 - e^{-2(0.130) \left(\frac{5}{3}\right)}}{2(0.130)} = \frac{0.3516}{0.260} = 1.35$$

$$W_s = C_d w B_d^2 \quad (8)$$

$$= 1.35(120)(3)^2$$

$$= 1,460 \text{ lb/ft}$$

Step 2. Calculate earth load for projection condition using Eq 9.

$$H_e = 1.75 B_e = 1.75 \left(\frac{13.20}{12}\right)$$

$$= 1.75(1.10) = 1.92 \text{ ft}$$

H is greater than H_e , therefore use Eq 12 or 12a to calculate C_e . Using Eq 12a:

$$C_e = 1.961 \frac{H}{B_e} - 0.934 \quad (12a)$$

$$= 1.961 \left(\frac{5}{1.10}\right) - 0.934$$

$$= 7.98$$

$$W_s = C_e w B_e^2 \quad (9)$$

$$= 7.98 (120)(1.10)^2$$

$$= 1,159 \text{ lb/ft}$$

Step 3. Select lesser load from Step 1 or 2. The load for projection condition is the lesser. Therefore, the earth load, W_s , is 1,159 lb/ft. This load is shown in Table 1-8.

Sec. 1-3.3—Truck Superloads (W_t)

The procedures in this section may be used to compute truck superloads

for unpaved roads, flexible pavement or rigid pavement; one truck or two passing trucks; and any wheel load and impact factor. For unpaved road or flexible pavement Eq 15 is used. For rigid pavement Eq 16 is used.

$$W_t = CRPF \quad (15)$$

$$W_t = KB_ePF \quad (16)$$

in which:

W_t = Truck superload (lb/lin ft)

C = Surface load factor for unpaved road or flexible pavement (for one truck, see Table 1-11; for two trucks, see Table 1-12).

R = Reduction factor which takes account of the fact that the part of the pipe directly below the wheels receives the truck superload in its full intensity but is aided in carrying the load by adjacent parts of the pipe that receive little or no load from the truck. (See Table 1-13.)

P = Wheel load (lb)

F = Impact factor

K = Surface load factor for rigid pavement (see Table 1-14).

B_e = Outside diameter of pipe (ft) (see Table 1-15).

Equations 15 and 16 may be used in computing AASHO truck loading which is described in "Standard Specifications for Highway Bridges," American Assn. of State Highway Officials, 1961. The wheel loads and impact factors to be used in the equations are given in Art. 1.2.5 and

1.2.12 of the AASHO specification, as follows:

AASHO Truck	Gross Weight	Wheel Load, P
H-10	10 tons	8,000 lb
H-15	15 tons	12,000 lb
H-20	20 tons	16,000 lb

Depth of Cover	Impact Factor, F
0 ft to 1 ft, 0 in.	1.30
1 ft, 1 in., to 2 ft, 0 in.	1.20
2 ft, 1 in., to 2 ft, 11 in.	1.10
3 ft, 0 in., or more	1.00

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The truck superload allowances given in Tables 1-4 and 1-8 are intended for standard conditions.

They are based on two passing trucks with adjacent wheels 3 ft apart, 9,000-lb wheel load, unpaved road or flexible pavement, 1.50 impact factor. These loads in most cases equal or exceed the static load from a single AASHO H-20 truck with 16,000 lb on each rear wheel. These truck superloads are based on having the design depth of cover over the pipe. 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.

TABLE 1-8
Earth Loads (W_e) and Truck Superloads (W_t)—lb/lin ft*

Pipe Size in.	Depth of Cover—ft															
	2½		3½		5		8		12		16		20		24	
	W_e	W_t	W_e	W_t	W_e	W_t	W_e	W_t	W_e	W_t	W_e	W_t	W_e	W_t	W_e	W_t
3	182	162	260	81	376	54	609	40	920	27	1,230	14	1,538	9	1,852	7
4	226	297	324	162	471	81	765	54	1,157	40	1,549	27	1,942	18	2,334	14
6	309	567	448	324	657	189	1,075	94	1,632	68	2,188	40	2,524	26	2,647	20
8	380	783	557	486	824	297	1,356	148	2,066	94	2,592	54	2,815	36	2,965	28
10	448	972	666	621	992	378	1,645	189	2,473	108	2,851	68	3,114	45	3,295	35
12	511	1,161	770	756	1,159	459	1,950	243	2,686	122	3,116	81	3,419	53	3,635	41
14	568	1,217	868	807	1,318	540	2,218	270	2,900	135	3,384	94	3,733	62	3,983	48
16	617	1,307	959	879	1,470	590	2,381	324	3,117	162	3,659	122	4,050	81	4,339	62
18	665	1,400	1,042	964	1,616	632	2,533	364	3,335	189	3,932	135	4,374	89	4,703	69
20	714	1,524	1,119	1,076	1,755	729	2,686	410	3,555	216	4,209	162	4,703	107	5,075	83
24	814	1,662	1,256	1,159	2,011	769	2,994	462	3,999	256	4,774	176	5,372	116	5,833	90
30	963	1,925	1,457	1,356	2,340	918	3,459	564	4,674	324	5,638	216	6,401	143	7,009	110
36	1,121	2,182	1,668	1,577	2,628	1,090	3,977	632	5,356	378	6,517	256	7,461	169	8,226	131
42	1,270	2,354	1,878	1,750	2,917	1,239	4,396	717	6,016	459	7,408	310	8,535	205	9,474	158
48	1,427	2,527	2,093	1,922	3,216	1,400	4,867	814	6,737	513	8,308	351	9,627	232	10,743	179
54	1,581	2,635	2,310	2,052	3,519	1,526	5,340	899	7,434	594	9,218	378	10,739	256	12,034	189
60	1,738	2,765	2,527	2,182	3,824	1,652	5,816	984	8,195	634	10,133	405	11,857	284	13,339	202

* Earth loads are based on the following conditions: trench width (B_e) equal to nominal pipe diameter plus 2 ft; unit weight of soil, 120 lb/cu ft; K_u equal to 0.1924 and K_d equal to 0.130. Truck superloads are based on two passing trucks with adjacent wheels 3 ft apart, having a 9,000-lb wheel load on unpaved road or flexible pavement and a 1.50 impact factor.

THICKNESS DESIGN OF CAST-IRON PIPE

TABLE 1-9
Load Factors for Cast-Iron Pipe in Ditch and Embankment Conditions

Pipe Size in.	$\frac{H^*}{B_e}$	Laying Condition			Pipe Size in.	$\frac{H^*}{B_e}$	Laying Condition		
		A	B	F			A	B	F
		Load Factor (L_f)					Load Factor (L_f)		
Ditch and Negative Projection Conditions†					Ditch and Negative Projection Conditions† (Continued)				
3		1.15	1.28	1.74	54		1.15	1.75	2.29
4		1.15	1.29	1.75	60		1.15	1.77	2.31
6		1.15	1.32	1.78	Positive-Projection Condition†				
8		1.15	1.34	1.80		0.5	1.50	2.16	
10		1.15	1.36	1.83		1.0	1.36	1.84	
12		1.15	1.38	1.85		1.5	1.29	1.74	
14		1.15	1.41	1.88		2.0	1.26	1.68	
16		1.15	1.43	1.90		3.0	1.26	1.64	
18		1.15	1.45	1.93		5.0	1.26	1.60	
20		1.15	1.47	1.95		10.0	1.26	1.58	
24		1.15	1.52	2.00					
30		1.15	1.58	2.08					
36		1.15	1.64	2.14					
42		1.15	1.69	2.20					
48		1.15	1.72	2.25					

* H is depth of cover to top of pipe, in feet; B_e is outside diameter of pipe, in feet (see Table 1-15).
† See Fig. 1-7 and See Sec. 1-3.2.

TABLE 1-10
Allowances for Surge Pressure

Pipe Size in.	Surge Pressure psi	Pipe Size in.	Surge Pressure psi
3-10	120	24	85
12-14	110	30	80
16-18	100	36	75
20	90	42-60	70

TABLE 1-11
Surface Load Factors (C) for One Truck on Unpaved Road or Flexible Pavement*

Pipe Size in.	Depth of Cover—ft												
	2	2½	3	3½	4	5	6	8	10	12	16	20	24
	Surface Load Factor												
3	0.028	0.020	0.014	0.011	0.009	0.006	0.004	0.002	0.0015	0.001	0.0006	0.0004	0.0002
4	0.034	0.024	0.017	0.013	0.011	0.007	0.005	0.003	0.002	0.0015	0.0008	0.0005	0.0003
6	0.048	0.034	0.025	0.020	0.015	0.010	0.007	0.004	0.003	0.002	0.001	0.0007	0.0004
8	0.062	0.044	0.033	0.026	0.020	0.013	0.009	0.006	0.0035	0.0025	0.0013	0.0008	0.0005
10	0.074	0.054	0.040	0.031	0.025	0.016	0.012	0.007	0.004	0.003	0.0016	0.001	0.0006
12	0.087	0.063	0.048	0.036	0.030	0.019	0.014	0.008	0.005	0.0035	0.002	0.0012	0.0007
14	0.099	0.072	0.055	0.042	0.034	0.022	0.016	0.010	0.006	0.004	0.0025	0.0015	0.0008
16	0.110	0.082	0.061	0.047	0.038	0.025	0.018	0.011	0.007	0.005	0.003	0.0017	0.001
18	0.122	0.090	0.068	0.052	0.042	0.028	0.020	0.012	0.008	0.0055	0.0035	0.002	0.0012
20	0.132	0.098	0.075	0.058	0.046	0.031	0.022	0.013	0.009	0.006	0.004	0.0025	0.0015
24	0.150	0.113	0.087	0.068	0.054	0.037	0.026	0.015	0.010	0.007	0.0045	0.003	0.0017
30	0.171	0.132	0.102	0.081	0.065	0.045	0.031	0.019	0.012	0.009	0.005	0.0035	0.002
36	0.188	0.148	0.117	0.093	0.076	0.052	0.037	0.022	0.015	0.010	0.006	0.004	0.0025
42	0.200	0.160	0.129	0.103	0.085	0.059	0.043	0.025	0.017	0.012	0.007	0.0045	0.003
48	0.210	0.170	0.139	0.113	0.093	0.066	0.048	0.029	0.019	0.013	0.008	0.005	0.0033
54	0.216	0.178	0.147	0.120	0.101	0.072	0.053	0.032	0.021	0.015	0.0085	0.0055	0.0036
60	0.222	0.184	0.153	0.126	0.107	0.077	0.057	0.035	0.023	0.016	0.009	0.006	0.004

* These factors are for a single concentrated wheel load centered over an effective pipe length of 3 ft. They were computed by the methods explained in Article 24.20 and Chap. 16 of M. G. Spangler's *Soil Engineering* (2nd ed., 1960; International Textbook Co., Scranton, Pa.).

TABLE 1-12
Surface Load Factors (C) for Two Passing Trucks on Unpaved Road or Flexible Pavement*

Pipe Size in.	Depth of Cover—ft												
	2	2½	3	3½	4	5	6	8	10	12	16	20	24
	Surface Load Factor												
3	0.019	0.012	0.008	0.006	0.005	0.004	0.0035	0.003	0.0025	0.002	0.001	0.0007	0.0005
4	0.032	0.022	0.016	0.012	0.009	0.006	0.005	0.004	0.0035	0.003	0.002	0.0013	0.0010
6	0.058	0.042	0.032	0.024	0.020	0.014	0.010	0.007	0.006	0.005	0.003	0.0019	0.0015
8	0.076	0.058	0.044	0.036	0.030	0.022	0.017	0.011	0.009	0.007	0.004	0.0027	0.0021
10	0.092	0.072	0.056	0.046	0.039	0.028	0.021	0.014	0.011	0.008	0.005	0.0033	0.0026
12	0.108	0.086	0.070	0.056	0.047	0.034	0.027	0.018	0.012	0.009	0.006	0.0039	0.0030
14	0.122	0.098	0.078	0.065	0.055	0.040	0.031	0.020	0.014	0.010	0.007	0.0046	0.0036
16	0.136	0.110	0.090	0.074	0.062	0.046	0.036	0.024	0.016	0.012	0.009	0.0060	0.0046
18	0.149	0.122	0.101	0.084	0.070	0.052	0.041	0.027	0.019	0.014	0.010	0.0066	0.0051
20	0.162	0.136	0.115	0.096	0.080	0.060	0.048	0.032	0.022	0.016	0.012	0.0079	0.0061
24	0.185	0.152	0.126	0.106	0.091	0.067	0.053	0.036	0.026	0.019	0.013	0.0086	0.0067
30	0.212	0.176	0.146	0.124	0.107	0.080	0.064	0.044	0.032	0.024	0.016	0.0106	0.0081
36	0.235	0.202	0.169	0.146	0.127	0.095	0.075	0.052	0.038	0.028	0.019	0.0125	0.0097
42	0.251	0.218	0.188	0.162	0.140	0.108	0.087	0.059	0.044	0.034	0.023	0.0152	0.0117
48	0.264	0.234	0.205	0.178	0.157	0.122	0.097	0.067	0.050	0.038	0.026	0.0172	0.0132
54	0.274	0.244	0.216	0.190	0.170	0.133	0.108	0.074	0.057	0.044	0.028	0.0190	0.0140
60	0.281	0.256	0.228	0.202	0.181	0.144	0.117	0.081	0.061	0.047	0.030	0.0210	0.0150

* The factors are for two trucks with 6-ft rear wheel spacing passing with inside rear wheels 3 ft apart. Effective pipe length is 3 ft, coinciding with the distance between the adjacent inside wheels. The factors were computed by the methods explained in Sec. 24.20 and Chap. 16 of M. G. Spangler's *Soil Engineering* (2nd ed., 1960; International Textbook Co., Scranton, Pa.)

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TABLE 1-13
Reduction Factors (R)

Pipe Size in.	Depth of Cover—ft				Pipe Size in.	Depth of Cover—ft			
	2½-3½	4-7	8-10	>10		2½-3½	4-7	8-10	>10
	Reduction Factor					Reduction Factor			
3-12	1.00	1.00	1.00	1.00	20	0.83	0.90	0.95	1.00
14	0.92	1.00	1.00	1.00	24-30	0.81	0.85	0.95	1.00
16	0.88	0.95	1.00	1.00	36-60	0.80	0.85	0.90	1.00
18	0.85	0.90	1.00	1.00					

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TABLE 1-14
Surface Load Factors (K) For One Truck and Two Passing Trucks on Rigid Pavement*

Depth of Cover ft	One Truck				Two Passing Trucks			
	Pavement Thickness—in.				Pavement Thickness—in.			
	4	6	8	10	4	6	8	10
Surface Load Factor								
2	0.0244	0.0149	0.0101	0.0076	0.0410	0.0263	0.0186	0.0142
2½	0.0213	0.0139	0.0097	0.0072	0.0364	0.0246	0.0177	0.0136
3	0.0186	0.0126	0.0090	0.0070	0.0333	0.0228	0.0167	0.0129
3½	0.0164	0.0114	0.0085	0.0066	0.0290	0.0206	0.0156	0.0122
4	0.0144	0.0102	0.0079	0.0061	0.0262	0.0187	0.0146	0.0117
5	0.0114	0.0084	0.0066	0.0054	0.0210	0.0156	0.0123	0.0102
6	0.0093	0.0071	0.0057	0.0047	0.0170	0.0133	0.0107	0.0088
8	0.0065	0.0052	0.0043	0.0036	0.0114	0.0097	0.0081	0.0069
10	0.0046	0.0039	0.0033	0.0029	0.0080	0.0070	0.0062	0.0055
12	0.0034	0.0030	0.0026	0.0023	0.0059	0.0054	0.0049	0.0045
16	0.0022	0.0019	0.0017	0.0016	0.0034	0.0032	0.0030	0.0028
20	0.0013	0.0011	0.0010	0.0009	0.0024	0.0023	0.0022	0.0021
24	0.0008	0.0007	0.0006	0.0005	0.0015	0.0014	0.0013	0.0012

* These factors were computed by the methods explained in "Vertical Pressure on Culverts under Wheel Loads on Concrete-Pavement Slabs", Bull. ST65, Portland Cement Assn., Chicago, Ill. In Bulletin ST65, K if expressed as c/L^3 . These factors are based on a modulus of subgrade reaction of 100 lb/cu in. and a modulus of elasticity of 4,000,000 psi for the pavement concrete. The factors for two passing trucks are based on the inside rear wheels passing 3 ft apart.

THICKNESS DESIGN OF CAST-IRON PIPE

TABLE 1-15
Outside Diameters of Cast-Iron Pipe

Pipe Size in.	Outside Diameter in.	Outside Diameter (B_o) ft	Pipe Size in.	Outside Diameter in.	Outside Diameter (B_o) ft
3	3.96	0.330	20	21.60	1.800
4	4.80	0.400	24	25.80	2.150
6	6.90	0.575	30	32.00	2.667
8	9.05	0.754	36	38.30	3.192
10	11.10	0.925	42	44.50	3.708
12	13.20	1.100	48	50.80	4.233
14	15.30	1.275	54	57.10	4.758
16	17.40	1.450	60	63.40	5.283
18	19.50	1.625			

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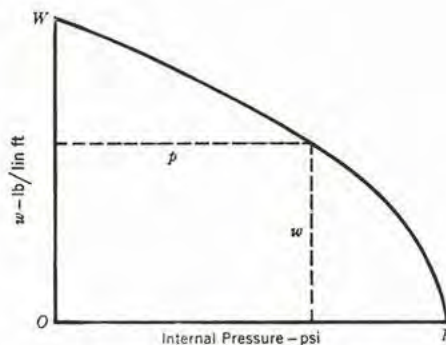


Fig. 1-6. Load-Pressure Curve

The parabola represents the relation between external load and internal pressure at the point of breaking.

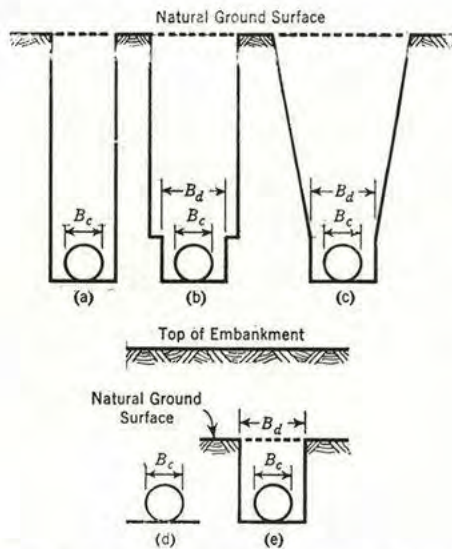


Fig. 1-7. Installation Conditions for Earth Load Calculations

Fig. 1-7(a)-(c) are for ditch conditions; Fig. 1-7(d) and (e) are for positive and negative projection embankment conditions, respectively.

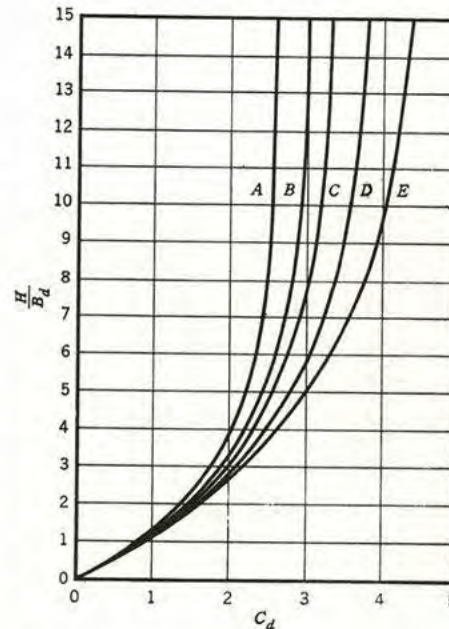


Fig. 1-8. Calculation Coefficients (C_d) for Ditch Condition

Curve A is for C_d for K_μ and K_μ' of 0.1924, the minimum for granular materials without cohesion; Curve B, C_d for K_μ and K_μ' of 0.165, the maximum for sand and gravel; Curve C, C_d for K_μ and K_μ' of 0.150, the maximum for saturated topsoil; Curve D, C_d for K_μ and K_μ' of 0.130, the ordinary maximum for clay; and Curve E, C_d for K_μ and K_μ' of 0.110, the maximum for saturated clay.

THICKNESS DESIGN OF CAST-IRON PIPE

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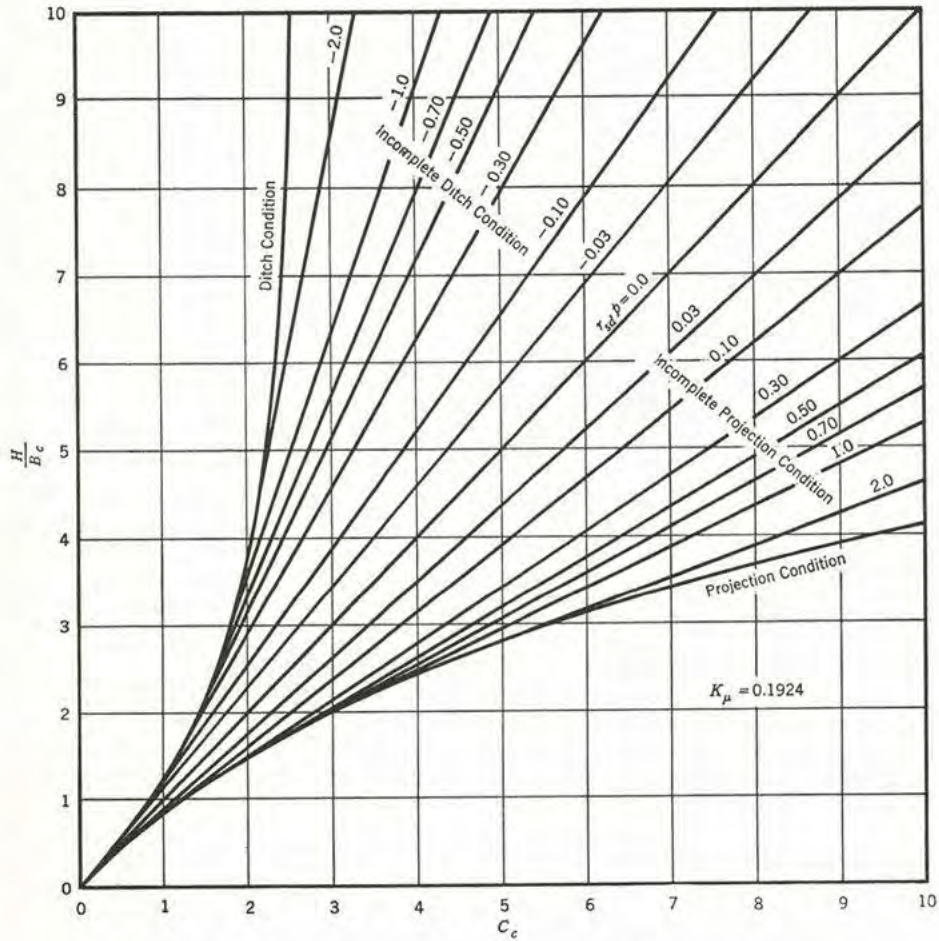


Fig. 1-9. Calculation Coefficients (C_c) for Positive-Projection Condition
 The values of C_c may also be determined by Eq 11 or Eq 12, given in the text.

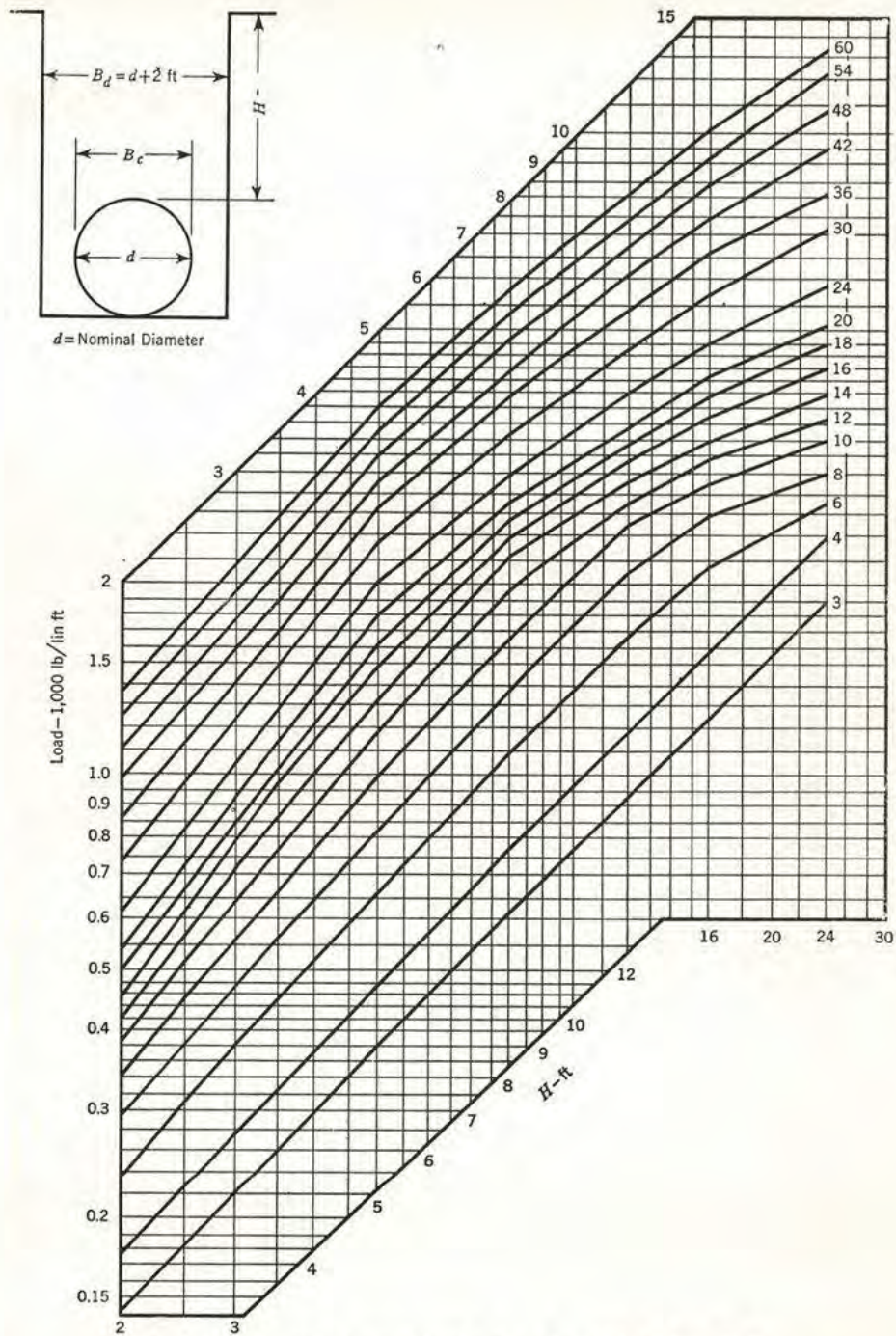


Fig. 1-10. Earth Loads on Pipe for Trench Width of $(d + 2)$ ft

Values associated with each curve are for pipe size, in inches. It is assumed that the unit weight of fill is 120 lb/cu ft; that K_{μ} equals 0.1924 and K_{μ}' equals 0.130, and that r_{ndp} is 0.75 for all sizes. B_c is pipe OD. For 3- and 8-60-in. pipe, OD is as shown in Table 1-15. OD of 4- and 6-in. pipe is 5.00 and 7.10 in., respectively.

THICKNESS DESIGN OF CAST-IRON PIPE

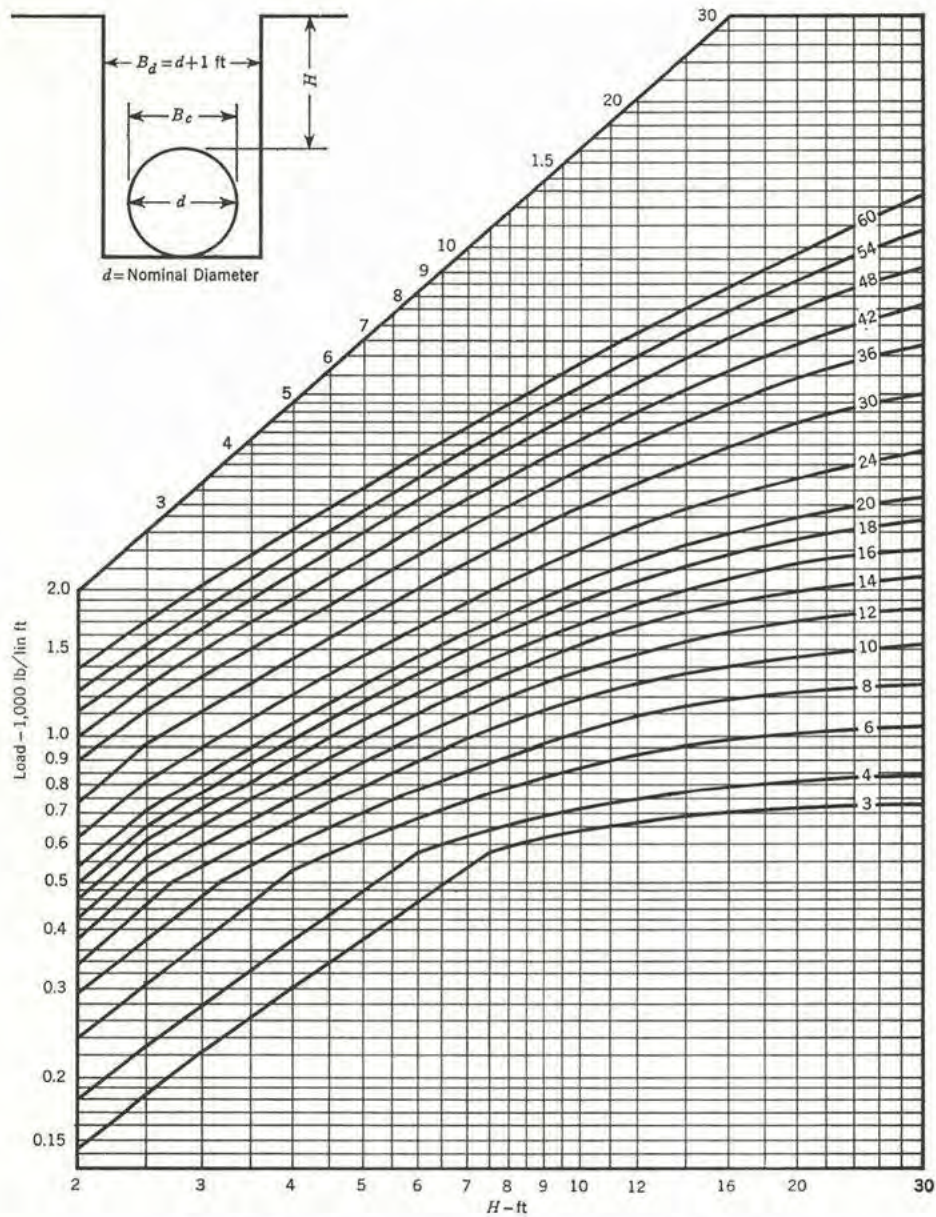


Fig. 1-11. Earth Loads on Pipe for Trench Width of $(d + 1)$ ft

Values associated with each curve are for pipe size, in inches. It is assumed that the unit weight of fill is 120 lb/cu ft, that K_{μ} equals 0.1924 and K_{μ}' equals 0.130. For wide ditches, r_{top} is 0.75. B_c is pipe OD. For 3- and 8-60-in. pipe, OD is as shown in Table 1-15. OD of 4- and 6-in. pipe is 5.00 and 7.10 in., respectively.

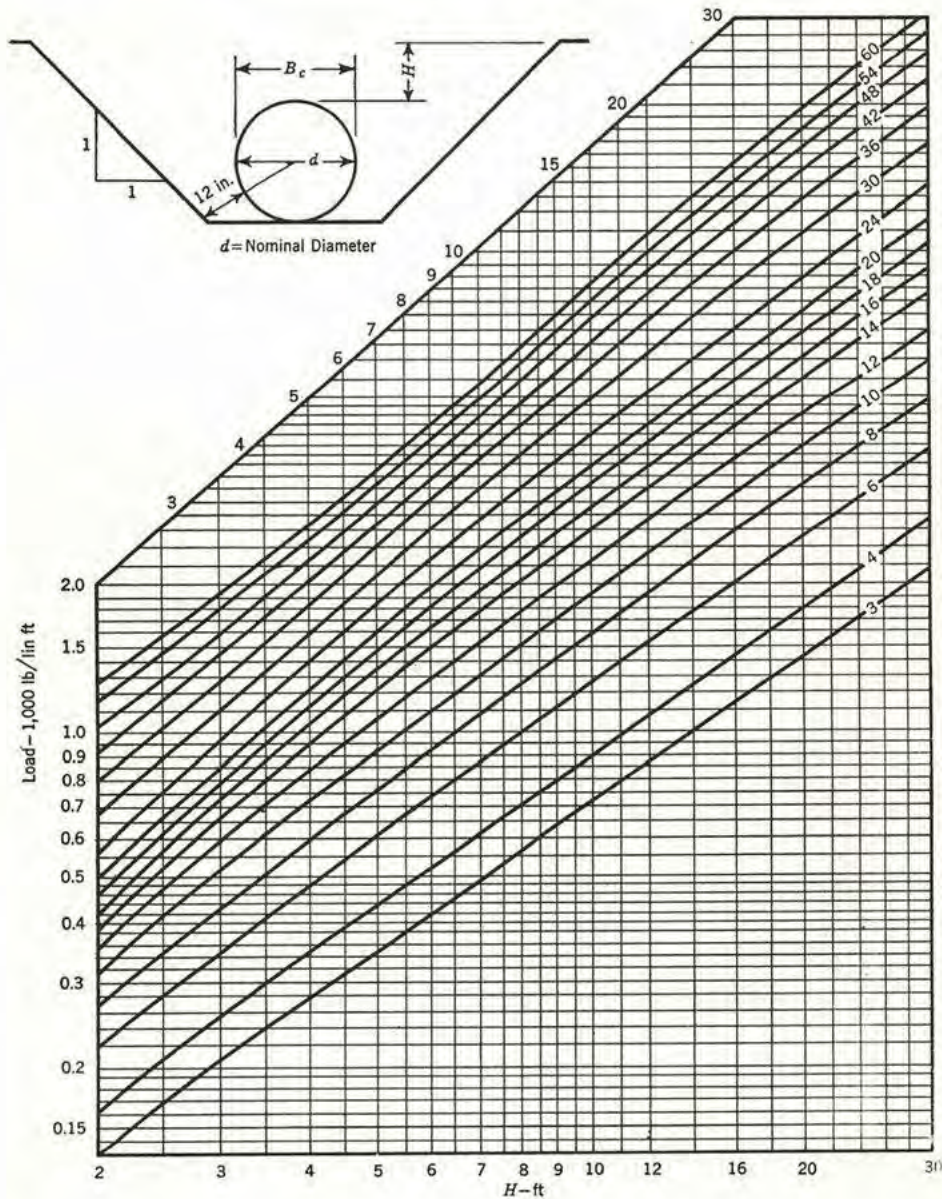


Fig. 1-12. Earth Loads on Pipe in Trench With 1:1 Side Slopes

Values associated with each curve are for pipe size, in inches. It is assumed that the unit weight of fill is 110 lb/cu ft; this load may be adjusted to soil of 120 lb/cu ft by multiplying the graph load by 120/110. For wide ditches, r_{ndP} is 0.75. K_{μ} equals 0.1924, K_{μ}' equals 0.130. B_c is pipe OD. For 3- and 8-60-in. pipe, OD is as shown in Table 1-15. OD of 4- and 6-in. pipe is 5.00 and 7.10 in., respectively.

THICKNESS DESIGN OF CAST-IRON PIPE

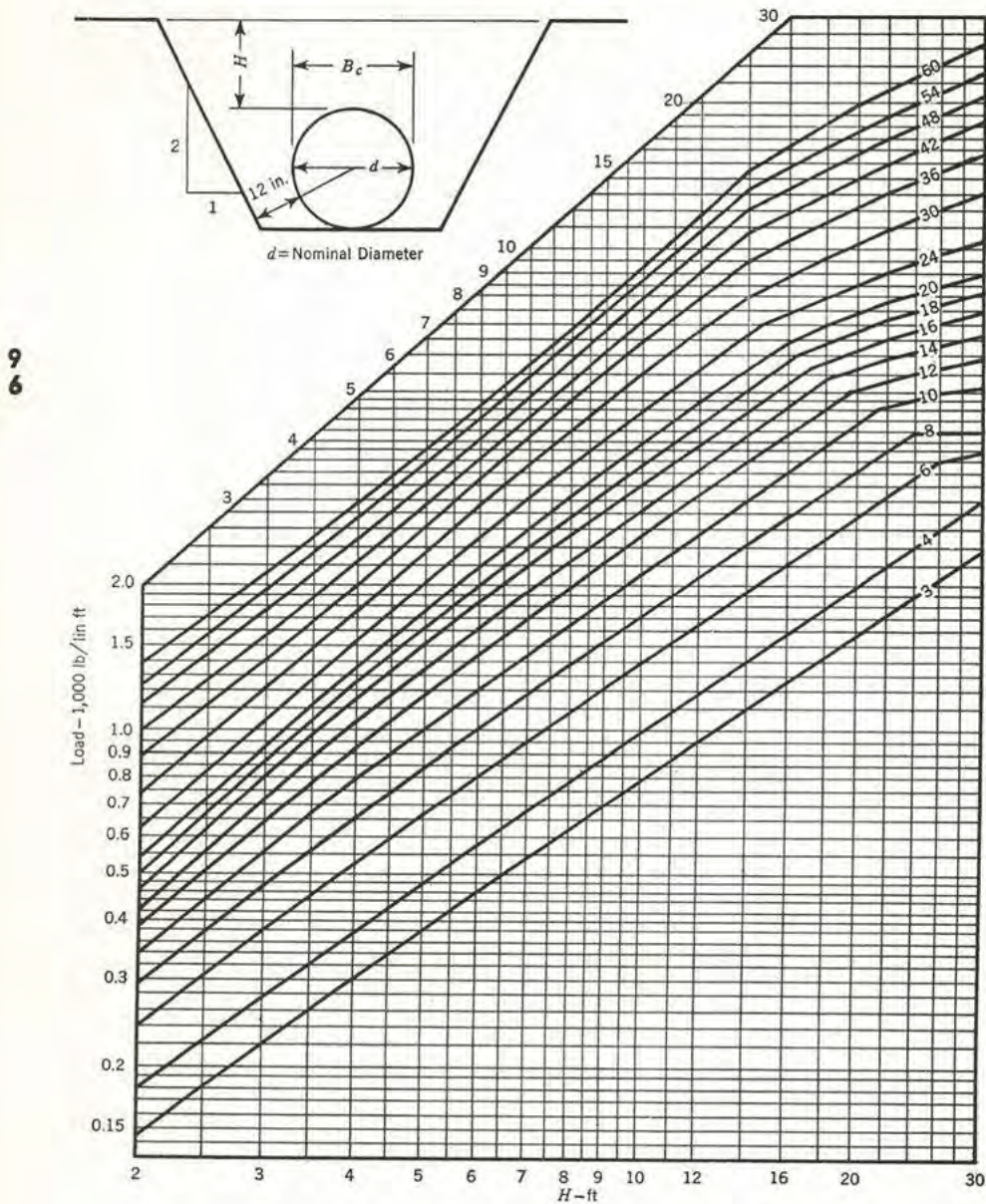


Fig. 1-13. Earth Loads on Pipe in Trench With 2:1 Side Slopes

Values associated with each curve are for pipe size, in inches. It is assumed that the unit weight of fill is 120 lb/cu ft. For wide ditches, r_{adp} equals 0.75. K_{μ} equals 0.1924, K_{μ}' equals 0.130. B_c is pipe OD. For 3- and 8-60-in. pipe, OD is as shown in Table 1-15. OD of 4- and 6-in. pipe is 5.00 and 7.10 in., respectively.

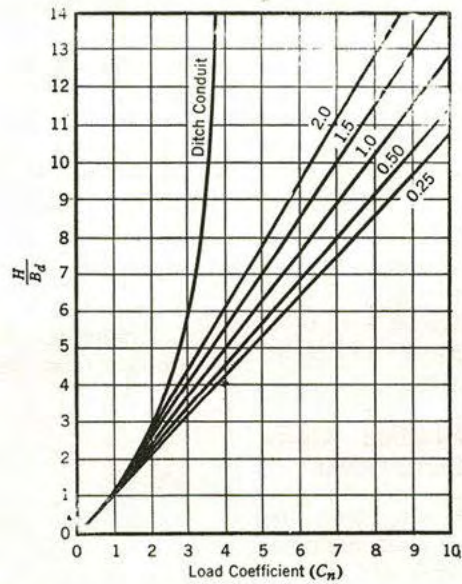


Fig. 1-14. Calculation Coefficients (C_n) for Negative-Projection Conditions

The values associated with the five curves to the right are for ν' . $K\mu'$ equals 0.130. r_{sdP} equals 0.0.

Sec. 1-4—Thickness Determination for Pipe on Piers or Piling Aboveground or Underground

Sec. 1-4.1—Scope

This section gives the procedures for determining the net thickness of cast-iron pipe supported at intervals rather than continuously. These procedures are applicable to pipe installed on piling bents and piers, with or without earth cover, as well as to pipe installed on bridges and other structures with hangers and other types of spaced supports.

Sec. 1-4.2—Pipe Installed Aboveground Without Earth Cover

a. Determine the ring test load equivalent of external load, including 2.5 safety factor, as follows:

$$w = \frac{2.5(W_p + W_w)}{L_f} \quad (17)$$

in which:

- w = ring test load equivalent (lb/ft)
- W_p = weight of pipe (lb/ft) (see Table 1-16)
- W_w = weight of contained water (lb/ft) (see Table 1-16)
- L_f = load factor (see Table 1-17)

b. Select the internal pressure for Case 1 from Table 1-5 which includes surge pressure and 2.5 safety factor.

c. Enter the above values of ring test load equivalent and internal pressure in the appropriate nomogram and read the net thickness. To obtain total calculated thickness, corrosion allowance and casting tolerance are added to this net thickness as described in Sec. 1-2.2.

Sec. 1-4.3—Pipe Installed Underground With Earth Cover

Thicknesses are computed for two cases as described in Sec. 1-2.2 and the larger of the two thicknesses is used for design.

Case 1:

a. Determine the ring test load equivalent from the following formula:

$$w = \frac{2.5W_e}{L_f} \quad (18)$$

in which:

- w = ring test load equivalent (lb/ft)
- W_e = earth load (see Table 1-8)
- L_f = load factor (see Table 1-17)

b. Select the internal pressure to Case 1 from Table 1-5 which includes surge pressure and 2.5 safety factor.

c. Enter the above values of ring test load equivalent and internal pressure in the appropriate nomogram and read the net thickness.

Case 2:

a. Determine the ring test load equivalent from the following formula:

$$w = \frac{2.5(W_e + W_t)}{L_f} \quad (19)$$

in which W_t is the truck superload in pounds per foot (see Table 1-8) and other factors are as defined for Eq 18.

b. Select the internal pressure for Case 2 from Table 1-5 which includes a safety factor of 2.5.

c. Enter the values of ring test load equivalent and internal pressure in the appropriate nomogram and read the net thickness.

The net thickness is selected from Case 1 or Case 2, whichever gives the greater computed thickness. To obtain total calculated thickness, corrosion allowance and casting tolerance are added to this net thickness as described in Sec. 1-2.2.

Sec. 1-4.4—Design Examples

a. Calculate the thickness of 24-in. cast-iron pipe, 18/40 iron strength, installed aboveground on piers spaced 18 ft apart on centers with 60-deg saddle support. Working pressure is 150 psi.

Load factor (Table 1-17),

$$L_f = 0.29 \times 1.55$$

$$= 0.45$$

Ring test load equivalent,

$$w = \frac{2.5(177 + 196)}{0.45}$$

$$= 2,071 \text{ lb/ft}$$

Internal pressure (Table 1-5),

$$p = 588 \text{ psi}$$

Using the above values of w and p in the nomogram, Fig. 1-1, the net thickness is determined to be 0.49 in. Adding 0.08 in. corrosion allowance and 0.08 in. casting tolerance, the total calculated thickness is determined to be 0.65 in.

b. Calculate the thickness of 16-in. cast-iron pipe, 18/40 iron strength, installed underground on piers spaced 18 ft apart on centers with 120-deg saddle support, with 5-ft cover. Working pressure is 150 psi.

Case 1:

Load factor (Table 1-17),

$$L_f = 0.24 \times 2.13$$

$$= 0.51$$

Ring test load equivalent,

$$w = \frac{2.5 \times 1470}{0.51}$$

$$= 7,206 \text{ lb/ft}$$

Internal pressure (Table 1-5),

$$p = 625 \text{ psi}$$

Using the above values of w and p in the nomogram, Fig. 1-1, the net thickness is determined to be 0.57 in.

Case 2:

Ring test load equivalent,

$$w = \frac{2.5(1,470 + 590)}{0.51}$$

$$= 10,980 \text{ lb/ft}$$

Internal pressure (Table 1-5),

$$p = 375 \text{ psi}$$

Using the above values of w and p in the nomogram, Fig. 1-2, the net thickness is determined to be 0.65 in.

Case 2 gives the larger computed thickness, 0.65 in., which is selected as the net thickness. Adding 0.08 in. corrosion allowance and 0.08 in. casting tolerance, the total calculated thickness is determined to be 0.81 in.

Sec. 1-4.5—Calculation of Beam Stress and Deflection

For small-diameter pipe, generally 3 in. through 8 in., a check of the beam stress may be required. If the calculated beam stress exceeds 14,000 psi, the thickness is increased or the span between supports is decreased to limit the beam stress to 14,000 psi. In

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THICKNESS DESIGN OF CAST-IRON PIPE

some types of installations, such as gravity flow sewers, beam deflection may be a significant factor in the design. Beam stress and deflection are calculated from the following two formulas:

$$f = \frac{15.28WDL^2}{D^4 - d^4} \quad (20)$$

$$y = \frac{30fL^2}{DE} \quad (21)$$

in which:

f = beam stress (14,000 psi maximum)

W = external load, lb per ft (for aboveground pipe $W = W_p + W_w$; for underground pipe, $W = W_e + W_l$)

L = distance on centers between supports (ft)

D = outside diameter of pipe (in.)

d = inside diameter ($D-2t$) (in.)

t = net thickness (in.)

y = deflection at mid-span (in.)

E = modulus of elasticity, 15,000,000 psi.

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TABLE 1-16

Weights of Pipe and Contained Water for Design of Aboveground Pipe

Pipe Size in.	Weight—lb/ft		Pipe Size in.	Weight—lb/ft	
	Pipe (W_p)*	Water (W_w)†		Pipe (W_p)*	Water (W_w)†
3	12	3	18	114	110
4	16	6	20	135	136
6	26	12	24	177	196
8	37	22	30	257	307
10	49	34	36	339	442
12	63	49	42	439	601
14	78	67	48	545	785
16	94	88			

* Based on Class 22 pipe. Although the computed thickness may differ from that given for Class 22, the effect of the difference in pipe weight usually will not have a significant effect on the computed thickness and recalculation usually will not be necessary.

† Based on nominal pipe size.

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TABLE 1-17
Load Factors for Pipe on Spaced Supports Aboveground and Underground

Pipe Size in.	Distance on Centers Between Supports—ft							
	6	8	9	10	12	16	18	20
Load Factor for Flat Support								
3	0.19	0.14	0.13	0.11	0.10	0.07	0.06	0.06
4	0.22	0.17	0.15	0.13	0.11	0.08	0.07	0.07
6	0.31	0.23	0.21	0.19	0.16	0.12	0.10	0.09
8	0.40	0.30	0.27	0.24	0.20	0.15	0.13	0.12
10	0.50	0.38	0.33	0.30	0.25	0.19	0.17	0.15
12	0.60	0.45	0.40	0.36	0.30	0.23	0.20	0.18
14	0.67	0.50	0.45	0.40	0.33	0.25	0.22	0.20
16	0.73	0.55	0.49	0.44	0.36	0.27	0.24	0.22
18	0.78	0.59	0.52	0.47	0.39	0.29	0.26	0.23
20	0.81	0.61	0.54	0.49	0.40	0.30	0.27	0.24
24	0.87	0.65	0.58	0.52	0.43	0.33	0.29	0.26
30	0.93	0.70	0.62	0.56	0.46	0.35	0.31	0.28
36	0.96	0.72	0.64	0.58	0.48	0.36	0.32	0.29
42	0.98	0.73	0.65	0.59	0.49	0.37	0.33	0.29
48	0.99	0.74	0.66	0.60	0.50	0.37	0.33	0.30

Explanatory Note. 1. Load factor for saddle support is obtained by multiplying the load factor for flat support by the following modifiers:

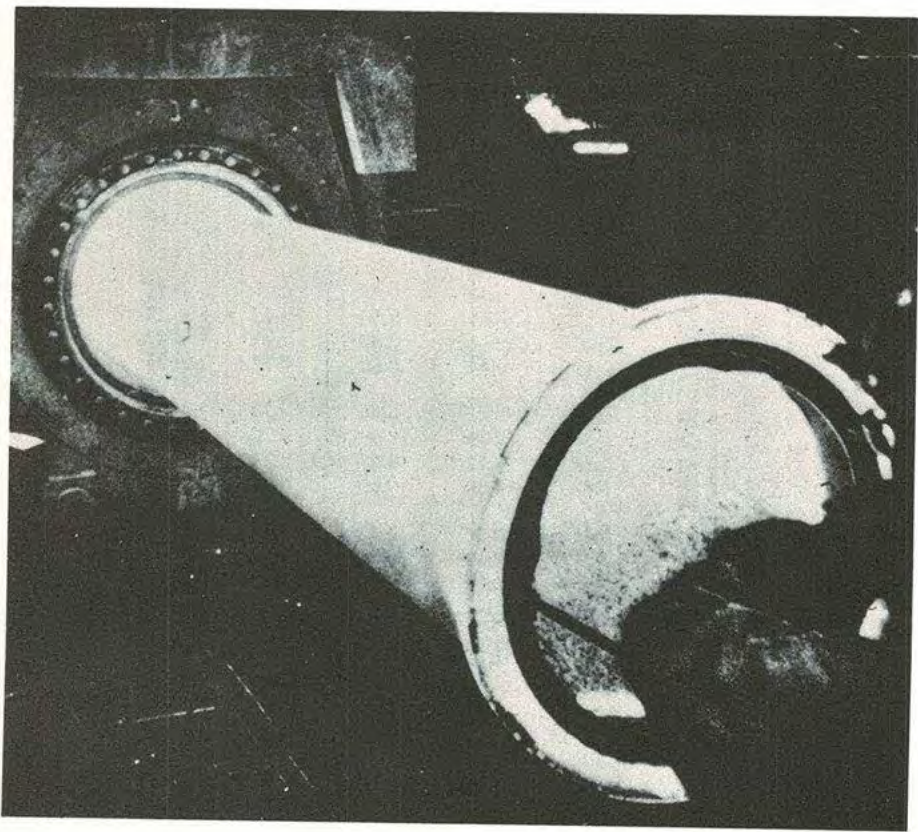
Saddle Angle deg.	Modifier
30	1.25
45	1.40
60	1.55
90	1.87
120	2.13
180	2.35

2. Load factors for other distances between supports or for other saddle angles may be obtained by interpolation between tabulated values.

3. The load factor for flat support is equal to the load factor for laying condition C, A21.1-1957, multiplied by the ratio of 6-ft, the block spacing of laying condition C, to the distance between supports. The modifier for saddle support is obtained from Table 2 of Stresses in Pressure Pipelines and Protective Casing Pipes [M. G. Spangler, *J. Struct. Div. ASCE*, Vol. 82, No. ST5 (Sep. 1956)], by dividing K_b for 180 deg load and 0 deg support by K_b for 180 deg load and a support angle equal to the saddle angle.

4. The recommended minimum axial bearing length of supports, for underground pipe is 6 in. for 3-8-in. pipe, 12 in. for 10-24-in. pipe, and 18 in. for 30-48-in. pipe.

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**ANSI A21.6-1975
(AWWA C106-75)**

Revision of
A21.6-1970
(AWWA C106-70)

AMERICAN NATIONAL STANDARD
for
**CAST-IRON PIPE CENTRIFUGALLY CAST
IN METAL MOLDS,
FOR WATER OR OTHER LIQUIDS**

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ADMINISTRATIVE SECRETARIAT
AMERICAN WATER WORKS ASSOCIATION

CO-SECRETARIATS
AMERICAN GAS ASSOCIATION
NEW ENGLAND WATER WORKS ASSOCIATION

Revised edition approved by American National Standards Institute, Inc., May 28, 1975.

NOTICE

This Standard has been especially printed by the American Water Works Association for incorporation into this volume. It is current as of December 1, 1975. 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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American National Standard

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Foreword

This foreword is provided for information only and is not a part of ANSI A21.6-1975 (AWWA C106-75).

I—History of Standard

On Sep. 10, 1902, NEWWA adopted a "Standard Specification for Cast-Iron Pipe and Special Castings," covering bell-and-spigot pit-cast pipe and fittings of ten thickness classes. The thickness classes were based on allowable internal pressures varying by increments of 50 ft of head.

On May 12, 1908, AWWA adopted a "Standard Specification for Cast-Iron Pipe and Special Castings," covering bell-and-spigot pit-cast pipe and fittings of eight classes, A through H, with allowable working pressures varying by increments of 100 ft of head from 100 to 800 ft. Dimensions and weights were given for pipe and fittings.

In 1926, ASA Sectional Committee (now American National Standards Committee) A21 on Cast-Iron Pipe and Fittings was organized under the sponsorship of A.G.A., ASTM, AWWA, and NEWWA and was assigned the following scope:

Unification of specifications for cast-iron pipe, including materials; dimensions; pressure ratings; methods of manufacture (including such new developments as centrifugal casting) insofar as they may be necessary to secure satisfactory specifications; elimination of unnecessary sizes and varieties; consideration of the possibility of developing a coordinated scheme of metallic pipe and fittings applicable to all common mediums; and methods of making up joints insofar as they are determining as to the dimensional design of cast-iron pipe.

The types of cast-iron pipe [are] to include bell-and-spigot pipe, flanged pipe, flanged and bell mouth fittings and wall castings, pipe elbows, tees, wyes, return bends, and other fittings not now included in standard lists; cast-iron pipe threaded for flanges or couplings. The standardization is not to include methods of installing pipe and similar matters, except as to the making up of joints in its relationship to the dimensional standardization of pipe and fittings, as noted above.

Sectional Committee A21 sponsored many tests of pipe and fittings; these included subjection of pipe to combined earth load and internal pressures (which form the basis of pipe thickness design), corrosion tests, measurement of hydraulic friction loss in fittings, and tests of bursting strengths of pipe and fittings. After exhaustive study of the test results and other research, the committee in 1939 issued A21.1, "American Standard Practice Manual for the Computation of Strength and Thickness of Cast Iron Pipe." The manual included nomograms and thickness tables for pit-cast pipe with 11/31* iron strength. As stated in the preface to that manual, however, the design method was applicable to pipe of any iron strength.

Discussions and interpretations of the method of design of cast-iron pipe

* The first figure designates the bursting tensile strength in units of 1 000 psi and the second figure designates the ring modulus of rupture in units of 1 000 psi.

were published in 1939 and presented to AWWA and A.G.A. As a result of these publications and because of the general acceptance of A21.1, a substantial volume of cast-iron pipe was designed by the new method and furnished to manufacturers' standards between 1939 and 1953. A standard (A21.2) for pit-cast pipe with 11/31 iron strength also was issued in 1939. Work on standards for centrifugally cast pipe with 18/40 iron strength was started after the design was completed in 1939, but, owing to the intervention of World War II and other causes, they were not formally issued until 1953.

In 1957, a revision of A21.1 was issued. In that revision, designated ASA A21.1-1957 (AWWA H1-57) the major change was the addition of a method for computing earth loads on pipe laid under embankments and of nomograms and thickness tables for centrifugally cast pipe with 18/40 iron strength.

In 1958, Sectional 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 subcommittee on pipe (Subcommittee No. 1) was organized with the following assignment:

The scope of the committee activity shall include an examination of all present A21 standards for pipe to determine what is needed to bring these up to date. The examination shall include A21.1, A21.2, A21.3, A21.6, A21.7, A21.8, and A21.9, as well as any other matters pertaining to pipe standards.

As a result of the work of Subcommittee No. 1 on this assignment, revisions of the cast-iron pipe standards A21.6 (AWWA C106), A21.7, A21.8 (AWWA C108) and A21.9 were issued in 1962. A revision of A21.1-1957 (AWWA H1-57) was issued in 1967

and reaffirmed without revision in 1972. Revisions of the 1962 cast-iron pipe standards were issued in 1970. The major revisions of A21.6-1970 were: pipe with push-on joints were added; laying conditions C and D were deleted and condition F was added; and, the tables were revised to include the pipe lengths then being produced.

In 1974, Subcommittee 1 reviewed the 1970 edition and recommended minor editorial changes. Therefore, this edition is unchanged from the 1970 edition except for minor editorial changes and the updating of this foreword.

The tables and strength test requirements in this standard are for pipe with 18/40 iron strength. Advances in production technology have enabled the manufacturers to furnish pipe with greater strength. Pipe with 21/45 iron strength has been furnished for many years. Design details and standard thicknesses for pipe with 21/45 iron strength are shown in A21.1-1957 (AWWA C101-67), reaffirmed in 1972.

II—Acceptance Tests

Acceptance tests were established as routine control measures to ensure the design burst and ring strengths. The acceptance tests specified in this standard are the Talbot strip test and the hardness test. In establishing the acceptance values for the Talbot strip test, A21 Committee in the 1940s reviewed detailed data, including burst, ring, and Talbot strip tests on more than 400 pipe centrifugally cast in metal molds. Correlations of the data showed that the Talbot strip modulus of rupture and secant modulus of elasticity values specified in this standard represent acceptable pipe which meet the design burst and ring strengths.

The hardness test was specified as a means of assuring the ferritic matrix which is characteristic of the microstructure of pipe cast in metal molds. The specified acceptance values for the Talbot strip test provide additional control of the microstructure to ensure satisfactory machinability.

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 pipe required. The following summarizes these 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 lengths (Tables)
2. Special joints (Sec. 6-1)
3. Certification by manufacturer (Sec. 6-4)
4. Inspection by purchaser (Sec. 6-5)
5. Cement lining (Sec. 6-8.2) 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.
6. Special coatings and linings (Sec. 6-8.4)
7. Special marking on pipe (Sec. 6-10)
8. Written transcripts of foundry records (Sec. 6-15)
9. Special tests (Sec. 6-16).

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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

ROBERT S. BRYANT
FRANK E. DOLSON
GEORGE F. KEENAN
LEONARD ORLANDO JR.
JOHN E. PERRY

Producer Members

W. D. GOODE
CARL A. HENRIKSON
THOMAS D. HOLMES
SIDNEY P. TEAGUE

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

LLOYD W. WELLER, *Chairman*
CARL A. HENRIKSON, *Vice-Chairman*
JAMES B. RAMSEY, *Secretary*

<i>Organization Represented</i>	<i>Name of Representative</i>
American Gas Association	LEONARD ORLANDO JR.
American Society of Civil Engineers	KENNETH W. HENDERSON
American Society of Mechanical Engineers	JAMES S. VANICK
American Society for Testing and Materials	ALBERT H. SMITH JR.
American Water Works Association	ARNOLD M. TINKEY
	LLOYD W. WELLER
Cast Iron Pipe Research Association	CARL A. HENRIKSON
	EDWARD C. SEARS
	W. HARRY SMITH
Individual Producer	ALFRED F. CASE
Manufacturers' Standardization Society of the Valve and Fittings Industry	ABRAHAM FENSTER
New England Water Works Association	WALTER AMORY
Naval Facilities Engineering Command	STANLEY C. BAKER
Underwriters' Laboratories, Inc.	JOHN E. PERRY
Canadian Standards Association	W. F. SEMENCHUK*

* Liaison representative without vote.

ANSI A21.6-1975
(AWWA C106-75)

Revision of
A21.6-1970
(AWWA C106-70)

American National Standard for

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

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Sec. 6-1—Scope

This standard covers 3-in. through 24-in. cast-iron pipe centrifugally cast in metal molds for water or other liquids. Characteristics of such pipe with push-on joints, mechanical joints and bell-and-spigot joints are given in the tables. This standard may be used for pipe with such other types of joints as may be agreed upon at the time of purchase. The thicknesses, weights, and strength test requirements shown in this standard are for pipe with 18/40 iron strength (18 000 psi minimum bursting tensile and 40 000 psi minimum ring modulus of rupture).

Sec. 6-2—Definitions

Under this standard, the following definitions shall apply:

6-2.1. *Purchaser.* The party entering into a contract or agreement to purchase pipe according to this standard.

6-2.2. *Manufacturer.* The party that produces the pipe.

6-2.3. *Inspector.* The representative of the purchaser, authorized to inspect in behalf of the purchaser to determine whether or not the pipe meet this standard.

6-2.4. *Cast iron.* The unqualified term *cast iron* shall apply to gray cast iron which is a 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.

6-2.5. *Push-on joint.* The single rubber-gasket joint as described in ANSI A21.11 (AWWA C111) of latest revision.

6-2.6. *Mechanical joint.* The gasketed and bolted joint as detailed in ANSI A21.11 (AWWA C111) of latest revision.

6-2.7. *Bell-and-spigot joint.* The poured or caulked joint as detailed in Table 6.6.

Sec. 6-3—General Requirements

6-3.1. Pipe with push-on joints, mechanical joints, and bell-and-spigot joints shall conform to the applicable dimensions and weights shown in the tables in this standard and to the applicable requirements of ANSI A21.11 (AWWA C111) of latest revision. 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.

6-3.2. The nominal laying length of the pipe shall be as shown in the tables. A maximum of 10 per cent of the total number of pipe of each size specified in an order may be furnished by as much as 24 in. shorter than the nominal laying length, and an additional 10 per cent may be furnished by as much as 3 in. shorter than nominal laying length.

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Sec. 6-4—Inspection and Certification by Manufacturer

6-4.1. The manufacturer shall establish the necessary quality control and inspection practice to assure compliance with this standard.

6-4.2. 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 standard.

6-4.3. All pipe shall be clean and sound without defects which 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 standard.

Sec. 6-5—Inspection by Purchaser

6-5.1. 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.

6-5.2. The inspector shall have free access to those parts of the manufacturer's plant that are necessary to assure compliance with this standard. 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 the handling of pipe.

Sec. 6-6—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. 6-7—Tolerances or Permitted Variations

6-7.1. *Dimensions.* The spigot end, bell, and socket of the pipe and the accessories shall be gaged with suitable gages 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 gages. Other socket dimensions shall be gaged as appropriate.

6-7.2. *Thickness.* Minus thickness tolerances of pipe and bell shall not exceed those shown below:

Pipe Size in.	Minus Tolerance in.
3-8	0.05
10-12	0.06
14-24	0.08

NOTE: An additional tolerance of 0.02 in. shall be permitted over areas not exceeding 8 in. in any direction.

6-7.3. *Weight.* The weight of any single pipe shall not be less than the tabulated weight by more than 5 per cent for pipe 12 in. or smaller in diameter, nor by more than 4 per cent for pipe larger than 12 in. in diameter.

Sec. 6-8—Coatings and Linings

6-8.1. *Outside coating.* The outside coating for use under normal conditions shall be a bituminous coating approximately 1 mil 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.

6-8.2. *Cement-mortar linings.* Cement linings shall be in accordance with ANSI A21.4 (AWWA C104) of latest revision. If desired, cement linings shall be specified in the invitation for bids and on the purchase order.

6-8.3. *Inside coating.* Unless otherwise specified, the inside coating for pipe not cement lined shall be a bituminous material as thick as practicable (at least 1 mil) and conforming to all appropriate requirements for seal coat in ANSI A21.4 of latest revision.

6-8.4. *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. 6-9—Hydrostatic Test

Each pipe shall be subjected to a hydrostatic test of not less than 500 psi. This test may be made either before or after the outside coating and the 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. 6-10—Marking Pipe

The weight, class or nominal thickness, and sampling period shall be shown on each pipe. The manufacturer's mark and the year in which the pipe was produced 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 8 in. and larger shall be not less than $\frac{1}{2}$ in. in height.

Sec. 6-11—Weighing Pipe

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

Sec. 6-12—Acceptance Tests

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

6-12.1. *Talbot strip tests.* Talbot strip tests shall be used to determine the acceptability of 3-24 in. pipe for modulus of rupture and secant modulus of elasticity.

6-12.1.1. *Sampling.* At least one sample shall be taken during each period of approximately 3 hr. The sample for the first period shall be taken during the first hour, or if casting is direct from the melting unit, from the first ladle. Samples shall be

be so placed that the vertical deformation at the two ends of the ring shall be approximately equal. If the ring is not uniform in thickness, it shall be so placed that the thick and thin portions are near the ends of the horizontal diameter.

For purposes of Sec. 6-15, a record of the breaking load of each ring tested shall be made. The modulus of rupture is computed from the formula

$$R = 0.954 \frac{W(d+t)}{bt^2}$$

in which R is the modulus of rupture (psi); W , the breaking load (lb); d , the average inside diameter (in.) of the ring; t , the average thickness (in.) of metal along the line of fracture; and b , the length (in.) of the ring.

6-13.3. *Burst test method.* The bursting tensile strength shall be determined by testing full-length pipe (less the amount cut off for ring and strip test specimens) to destruction by hydraulic pressure. Bells may be removed to facilitate testing. A suitable means for holding the end thrust shall be used which will not subject the pipe to endwise tension or compression, or other parasitic stresses. A calibrated pressure gage shall be used for determining the bursting pressure. The gage shall be connected to the interior of the test pipe by a separate connection from that which supplies water for the test. The unit tensile strength in bursting shall be obtained by the use of the formula

$$S = \frac{Pd}{2t}$$

in which S is the bursting tensile strength (psi) of the iron; P , the internal pressure (psi) at bursting; d , the average inside diameter (in.) of the pipe; and t , the minimum average

thickness (in.) of the pipe along the principal line of break.

Measurements of thickness shall be taken along the principal line of break at 1-ft intervals.

The minimum average thickness along the principal line of break shall be obtained by averaging the measurements at the thinnest section at a weight of two and at the adjacent sections on each side at a weight of one each; or, if the thinnest section is at the end of the break, by averaging the thinnest-section measurement at a weight of two and the measurements of the adjacent section and the next section at a weight of one each.

Sec. 6-14—Chemical Analyses

Analyses of the iron shall be made at sufficiently frequent intervals to determine compliance with the following limits:

Substance	Maximum Limit per cent
Phosphorus	0.90
Sulfur	0.12

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

Sec. 6-15—Foundry Records

The results of the following tests shall be recorded and retained for one year and shall be available to the purchaser at the foundry. Written transcripts of the results of these tests shall be furnished when specified on the purchase order:

- 6-15.1. Talbot strip tests (see Sec. 6-12.1)
- 6-15.2. Hardness tests (see Sec. 6-12.2)

6-15.3. Ring tests and full-length bursting tests (see Sec. 6-13)

6-15.4. Chemical analyses (see Sec. 6-14).

Sec. 6-16—Additional Tests Required by Purchaser

When 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.

Sec. 6-17—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 sampling period as the specimen which failed. Both of the additional speci-

mens shall meet the prescribed tests to qualify the pipe produced in that sampling period.

Sec. 6-18—Rejection of Pipe

When any routine chemical analysis fails to meet the requirements of Sec. 6-14 or when any physical acceptance test fails to meet the requirements of Sec. 6-12.1, 6-12.2, or 6-17, the pipe cast in the same sampling period shall be rejected except as subject to the provision of Sec. 6-19.

Sec. 6-19—Determining Rejection

The manufacturer may determine the amount of rejection by making similar additional tests of pipe of the same size as that rejected 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 sampling period, the acceptability of pipe of different sizes from that same period may be established by making the routine acceptance tests for these sizes.

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AMERICAN NATIONAL STANDARD

TABLE 6.1

Selection Table for Push-On Joint Cast-Iron Pipes‡

These thicknesses and weights are for pipe laid without blocks, on flat-bottom trench, with tamped backfill (laying condition B), under 5 ft of cover. For other conditions see tables 6.3 and 6.4 hereof and ANSI A21.1 (AWWA C101).

Size	Thickness	OD	Weight Based on 18-ft Laying Length		Weight Based on 20-ft Laying Length	
			Per Length†	Avg. per Foot‡	Per Length†	Avg. per Foot‡
in.			lb			
Working Pressure 50 psi—115 ft Head						
3*	0.32	3.96	215	12.0	240	11.9
4	0.35	4.80	290	16.1	320	16.0
6	0.38	6.90	460	25.6	510	25.6
8	0.41	9.05	665	36.9	735	36.8
10	0.44	11.10	880	49.0	975	48.7
12	0.48	13.20	1,140	63.4	1,260	63.1
14	0.48	15.30	1,335	74.1	1,470	73.6
16	0.54	17.40	1,700	94.5	1,880	94.0
18	0.54	19.50	1,920	106.7	2,120	106.1
20	0.57	21.60	2,250	124.9	2,485	124.2
24	0.63	25.80	2,975	165.3	3,285	164.4
Working Pressure 100 psi—231 ft Head						
3*	0.32	3.96	215	12.0	240	11.9
4	0.35	4.80	290	16.1	320	16.0
6	0.38	6.90	460	25.6	510	25.6
8	0.41	9.05	665	36.9	735	36.8
10	0.44	11.10	880	49.0	975	48.7
12	0.48	13.20	1,140	63.4	1,260	63.1
14	0.51	15.30	1,410	78.2	1,555	77.8
16	0.54	17.40	1,700	94.5	1,880	94.0
18	0.58	19.50	2,050	113.9	2,265	113.3
20	0.62	21.60	2,430	134.9	2,685	134.2
24	0.68	25.80	3,190	177.3	3,525	176.4
Working Pressure 150 psi—346 ft Head						
3*	0.32	3.96	215	12.0	240	11.9
4	0.35	4.80	290	16.1	320	16.0
6	0.38	6.90	460	25.6	510	25.6
8	0.41	9.05	665	36.9	735	36.8
10	0.44	11.10	880	49.0	975	48.7
12	0.48	13.20	1,140	63.4	1,260	63.1
14	0.51	15.30	1,410	78.2	1,555	77.8
16	0.54	17.40	1,700	94.5	1,880	94.0
18	0.58	19.50	2,050	113.9	2,265	113.3
20	0.62	21.60	2,430	134.9	2,685	134.2
24	0.73	25.80	3,410	189.4	3,765	188.4
Working Pressure 200 psi—462 ft Head						
3*	0.32	3.96	215	12.0	240	11.9
4	0.35	4.80	290	16.1	320	16.0
6	0.38	6.90	460	25.6	510	25.6
8	0.41	9.05	665	36.9	735	36.8
10	0.44	11.10	880	49.0	975	48.7
12	0.48	13.20	1,140	63.4	1,260	63.1
14	0.55	15.30	1,510	83.8	1,670	83.4
16	0.58	17.40	1,815	100.9	2,010	100.4
18	0.63	19.50	2,210	122.8	2,445	122.2
20	0.67	21.60	2,610	144.9	2,885	144.2
24	0.79	25.80	3,665	203.6	4,055	202.6

* Pipe of 3-in. size also available in 12-ft laying length. Weight per length† is 150 lb; average weight per foot‡ is 12.5 lb for all working pressures and heads.

† 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.

§ Weights shown for push-on joint pipe are also applicable to bell-and-spigot joint pipe.

PIPE CENTRIFUGALLY CAST IN METAL MOLDS

TABLE 6.1—(contd.)

Selection Table for Push-On Joint Cast-Iron Pipe§

These thicknesses and weights are for pipe laid without blocks, on flat-bottom trench, with tamped backfill (Laying Condition B), under 5 ft of cover. For other conditions see Tables 6.3 and 6.4 hereof and ANSI A21.1 (AWWA C101).

Size	Thickness	OD	Weight Based on 18-ft Laying Length		Weight Based on 20-ft Laying Length	
			Per Length†	Avg. per Foot‡	Per Length†	Avg. per Foot‡
in.			lb			
Working Pressure 250 psi—577 ft Head						
3*	0.32	3.96	215	12.0	240	11.9
4	0.35	4.80	290	16.1	320	16.0
6	0.38	6.90	460	25.6	510	25.6
8	0.41	9.05	665	36.9	735	36.8
10	0.44	11.10	880	49.0	975	48.7
12	0.52	13.20	1,230	68.3	1,360	67.9
14	0.59	15.30	1,610	89.5	1,780	89.0
16	0.63	17.40	1,960	109.0	2,170	108.4
18	0.68	19.50	2,370	131.8	2,620	131.1
20	0.72	21.60	2,785	154.8	3,080	154.0
24	0.79	25.80	3,665	203.6	4,055	202.6
Working Pressure 300 psi—693 ft Head						
3*	0.32	3.96	215	12.0	240	11.9
4	0.35	4.80	290	16.1	320	16.0
6	0.38	6.90	460	25.6	510	25.6
8	0.41	9.05	665	36.9	735	36.8
10	0.48	11.10	955	53.0	1,055	52.7
12	0.52	13.20	1,230	68.3	1,360	67.9
14	0.59	15.30	1,610	89.5	1,780	89.0
16	0.68	17.40	2,100	116.8	2,325	116.2
18	0.73	19.50	2,530	140.6	2,800	140.0
20	0.78	21.60	3,000	166.6	3,315	165.8
24	0.85	25.80	3,920	217.8	4,335	216.8
Working Pressure 350 psi—808 ft Head						
3*	0.32	3.96	215	12.0	240	11.9
4	0.35	4.80	290	16.1	320	16.0
6	0.38	6.90	460	25.6	510	25.6
8	0.41	9.05	665	36.9	735	36.8
10	0.52	11.10	1,025	56.9	1,130	56.6
12	0.56	13.20	1,315	73.1	1,455	72.7
14	0.64	15.30	1,735	96.3	1,920	95.9
16	0.68	17.40	2,100	116.8	2,325	116.2
18	0.79	19.50	2,720	151.2	3,010	150.6
20	0.84	21.60	3,210	178.4	3,550	177.6
24	0.92	25.80	4,220	234.4	4,665	233.4

* Pipe of 3-in. size also available in 12-ft laying length. Weight per length† is 150 lb; average weight per foot‡ is 12.5 lb for all working pressures and heads.

† 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.

§ Weights shown for push-on joint pipe are also applicable to bell-and-spigot joint pipe.

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TABLE 6.2

Selection Table for Mechanical-Joint Cast-Iron Pipe

These thicknesses and weights are for pipe laid without blocks, on flat-bottom trench, with tamped backfill (Laying Condition B), under 5 ft of cover. For other conditions see Tables 6.3 and 6.5 hereof and ANSI A21.1 (AWWA C101).

Size	Thickness	OD	Weight Based on 18-ft Laying Length		Weight Based on 20-ft Laying Length	
			Per Length†	Avg. per Foot‡	Per Length†	Avg. per Foot‡
in.			lb			
Working Pressure 50 psi—115 ft Head						
3*	0.32	3.96	215	12.0	240	11.9
4	0.35	4.80	290	16.2	320	16.1
6	0.38	6.90	460	25.5	510	25.4
8	0.41	9.05	655	36.4	725	36.2
10	0.44	11.10	870	48.2	960	48.0
12	0.48	13.20	1,125	62.6	1,245	62.3
14	0.48	15.30	1,335	74.0	1,470	73.6
16	0.54	17.40	1,700	94.5	1,880	94.0
18	0.54	19.50	1,920	106.7	2,120	106.0
20	0.57	21.60	2,250	124.9	2,485	124.2
24	0.63	25.80	2,975	165.2	3,285	164.2
Working Pressure 100 psi—231 ft Head						
3*	0.32	3.96	215	12.0	240	11.9
4	0.35	4.80	290	16.2	320	16.1
6	0.38	6.90	460	25.5	510	25.4
8	0.41	9.05	655	36.4	725	36.2
10	0.44	11.10	870	48.2	960	48.0
12	0.48	13.20	1,125	62.6	1,245	62.3
14	0.51	15.30	1,410	78.2	1,555	77.8
16	0.54	17.40	1,700	94.5	1,880	94.0
18	0.58	19.50	2,050	113.9	2,265	113.2
20	0.62	21.60	2,430	134.9	2,685	134.2
24	0.68	25.80	3,190	177.2	3,525	176.2
Working Pressure 150 psi—346 ft Head						
3*	0.32	3.96	215	12.0	240	11.9
4	0.35	4.80	290	16.2	320	16.1
6	0.38	6.90	460	25.5	510	25.4
8	0.41	9.05	655	36.4	725	36.2
10	0.44	11.10	870	48.2	960	48.0
12	0.48	13.20	1,125	62.6	1,245	62.3
14	0.51	15.30	1,410	78.2	1,555	77.8
16	0.54	17.40	1,700	94.5	1,880	94.0
18	0.58	19.50	2,050	113.9	2,265	113.2
20	0.62	21.60	2,430	134.9	2,685	134.2
24	0.73	25.80	3,405	189.2	3,765	188.2
Working Pressure 200 psi—462 ft Head						
3*	0.32	3.96	215	12.0	240	11.9
4	0.35	4.80	290	16.2	320	16.1
6	0.38	6.90	460	25.5	510	25.4
8	0.41	9.05	655	36.4	725	36.2
10	0.44	11.10	870	48.2	960	48.0
12	0.48	13.20	1,125	62.6	1,245	62.3
14	0.55	15.30	1,510	83.8	1,670	83.4
16	0.58	17.40	1,815	100.9	2,005	100.3
18	0.63	19.50	2,210	122.8	2,445	122.2
20	0.67	21.60	2,610	144.9	2,885	144.2
24	0.79	25.80	3,665	203.5	4,050	202.6

* Pipe of 3-in. size also available in 12-ft laying length. Weight per length† is 150 lb; average weight per foot‡ is 12.3 lb for all working pressures and heads.

† 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.

PIPE CENTRIFUGALLY CAST IN METAL MOLDS

TABLE 6.2—(contd.)

Selection Table for Mechanical-Joint Cast-Iron Pipe

These thicknesses and weights are for pipe laid without blocks, on flat-bottom trench, with tamped backfill (Laying Condition B), under 5 ft of cover. For other conditions see Tables 6.3 and 6.5 hereof and ANSI A21.1 (AWWA C101).

Size	Thickness	OD	Weight Based on 18-ft Laying Length		Weight Based on 20-ft Laying Length	
			Per Length†	Avg. per Foot‡	Per Length†	Avg. per Foot‡
in.			lb			
Working Pressure 250 psi—577 ft Head						
3*	0.32	3.96	215	12.0	240	11.9
4	0.35	4.80	290	16.2	320	16.1
6	0.38	6.90	460	25.5	510	25.4
8	0.41	9.05	655	36.4	725	36.2
10	0.44	11.10	870	48.2	960	48.0
12	0.52	13.20	1,215	67.4	1,340	67.1
14	0.59	15.30	1,610	89.4	1,780	89.0
16	0.63	17.40	1,960	108.9	2,165	108.3
18	0.68	19.50	2,370	131.7	2,620	131.0
20	0.72	21.60	2,785	154.8	3,080	154.1
24	0.79	25.80	3,665	203.5	4,050	202.6
Working Pressure 300 psi—693 ft Head						
3*	0.32	3.96	215	12.0	240	11.9
4	0.35	4.80	290	16.2	320	16.1
6	0.38	6.90	460	25.5	510	25.4
8	0.41	9.05	655	36.4	725	36.2
10	0.48	11.10	940	52.2	1,040	52.0
12	0.52	13.20	1,215	67.4	1,340	67.1
14	0.59	15.30	1,610	89.4	1,780	89.0
16	0.68	17.40	2,100	116.7	2,325	116.2
18	0.73	19.50	2,530	140.6	2,800	140.0
20	0.78	21.60	3,000	166.6	3,320	165.9
24	0.85	25.80	3,920	217.7	4,335	216.8
Working Pressure 350 psi—808 ft Head						
3*	0.32	3.96	215	12.0	240	11.9
4	0.35	4.80	290	16.2	320	16.1
6	0.38	6.90	460	25.5	510	25.4
8	0.41	9.05	655	36.4	725	36.2
10	0.52	11.10	1,010	56.1	1,120	55.9
12	0.56	13.20	1,300	72.2	1,440	71.9
14	0.64	15.30	1,735	96.3	1,920	95.9
16	0.68	17.40	2,100	116.7	2,325	116.2
18	0.79	19.50	2,720	151.2	3,010	150.6
20	0.84	21.60	3,210	178.3	3,550	177.6
24	0.92	25.80	4,215	234.2	4,665	233.2

* Pipe of 3-in. size also available in 12-ft laying length. Weight per length† is 150 lb; average weight per foot is 12.3 lb for all working pressures and heads.

† 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.

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TABLE 6.3

Standard Thickness* Selection Table for Cast-Iron Pipe

Laying Condition A—flat-bottom trench, without blocks, untamped backfill

Laying Condition B—flat-bottom trench, without blocks, tamped backfill

Laying Condition F—pipe laid on gravel or sand bedding, backfill tamped

Size in.	Working Pressure psi	3½-ft Cover			5-ft Cover			8-ft Cover		
		Laying Condition			Laying Condition			Laying Condition		
		A	B	F	A	B	F	A	B	F
		Thickness*—in.								
3	50	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
	100	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
	150	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
	200	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
	250	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
	300	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
4	50	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
	100	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
	150	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
	200	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
	250	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
	300	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
6	50	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
	100	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
	150	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
	200	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
	250	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
	300	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
8	50	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
	100	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
	150	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
	200	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
	250	0.41	0.41	0.41	0.41	0.41	0.41	0.44	0.41	0.41
	300	0.41	0.41	0.41	0.41	0.41	0.41	0.44	0.44	0.41
10	50	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44
	100	0.44	0.44	0.44	0.44	0.44	0.44	0.48	0.44	0.44
	150	0.44	0.44	0.44	0.44	0.44	0.44	0.48	0.44	0.44
	200	0.44	0.44	0.44	0.44	0.44	0.44	0.48	0.48	0.44
	250	0.44	0.44	0.44	0.48	0.44	0.44	0.52	0.48	0.48
	300	0.48	0.44	0.44	0.48	0.48	0.48	0.52	0.52	0.48
12	50	0.48	0.48	0.48	0.48	0.48	0.48	0.52	0.48	0.48
	100	0.48	0.48	0.48	0.48	0.48	0.48	0.52	0.48	0.48
	150	0.48	0.48	0.48	0.48	0.48	0.48	0.52	0.52	0.48
	200	0.48	0.48	0.48	0.48	0.48	0.48	0.56	0.52	0.48
	250	0.52	0.48	0.48	0.52	0.52	0.48	0.56	0.56	0.52
	300	0.52	0.52	0.52	0.56	0.52	0.52	0.60	0.56	0.56
14	50	0.51	0.48	0.48	0.51	0.48	0.48	0.59	0.55	0.51
	100	0.51	0.48	0.48	0.55	0.51	0.48	0.59	0.55	0.51
	150	0.55	0.51	0.48	0.55	0.51	0.48	0.64	0.59	0.55
	200	0.55	0.51	0.51	0.55	0.55	0.51	0.64	0.59	0.59
	250	0.59	0.55	0.55	0.59	0.59	0.55	0.64	0.64	0.59
	300	0.59	0.59	0.59	0.64	0.59	0.59	0.69	0.64	0.64
350	0.64	0.64	0.64	0.64	0.64	0.64	0.75	0.69	0.64	

* Thicknesses include allowances for foundry practice, corrosion, and either water hammer or truck load.

PIPE CENTRIFUGALLY CAST IN METAL MOLDS

TABLE 6.3—(contd.)

Standard Thickness* Selection Table for Cast-Iron Pipe

Laying Condition A—flat-bottom trench, without blocks, untamped backfill
 Laying Condition B—flat-bottom trench, without blocks, tamped backfill
 Laying Condition F—pipe laid on gravel or sand bedding, backfill tamped

Size in.	Working Pressure psi	3½-ft Cover			5-ft Cover			8-ft Cover		
		Laying Condition			Laying Condition			Laying Condition		
		A	B	F	A	B	F	A	B	F
		Thickness*—in.								
16	50	0.54	0.50	0.50	0.58	0.54	0.50	0.63	0.58	0.54
	100	0.54	0.54	0.50	0.58	0.54	0.50	0.63	0.58	0.54
	150	0.58	0.54	0.50	0.58	0.54	0.54	0.68	0.63	0.58
	200	0.58	0.58	0.54	0.63	0.58	0.58	0.68	0.63	0.63
	250	0.63	0.58	0.58	0.63	0.63	0.58	0.73	0.68	0.63
	300	0.63	0.63	0.63	0.68	0.68	0.63	0.73	0.73	0.68
	350	0.68	0.68	0.68	0.73	0.68	0.68	0.79	0.73	0.73
18	50	0.58	0.54	0.54	0.58	0.54	0.54	0.68	0.63	0.58
	100	0.58	0.54	0.54	0.63	0.58	0.54	0.68	0.63	0.58
	150	0.63	0.58	0.54	0.63	0.58	0.58	0.73	0.68	0.63
	200	0.63	0.58	0.58	0.68	0.63	0.58	0.73	0.68	0.63
	250	0.68	0.63	0.63	0.68	0.68	0.63	0.79	0.73	0.68
	300	0.68	0.68	0.68	0.73	0.73	0.68	0.79	0.79	0.73
	350	0.79	0.73	0.73	0.79	0.79	0.73	0.85	0.85	0.79
20	50	0.62	0.57	0.57	0.67	0.57	0.57	0.72	0.67	0.62
	100	0.62	0.57	0.57	0.67	0.62	0.57	0.72	0.67	0.62
	150	0.67	0.62	0.57	0.67	0.62	0.62	0.78	0.72	0.67
	200	0.67	0.62	0.62	0.72	0.67	0.62	0.78	0.72	0.67
	250	0.72	0.67	0.67	0.78	0.72	0.67	0.84	0.78	0.72
	300	0.78	0.72	0.72	0.78	0.78	0.72	0.84	0.84	0.78
	350	0.84	0.78	0.78	0.84	0.84	0.78	0.91	0.84	0.84
24	50	0.68	0.63	0.63	0.73	0.63	0.63	0.79	0.73	0.68
	100	0.73	0.63	0.63	0.73	0.68	0.63	0.85	0.73	0.68
	150	0.73	0.68	0.63	0.79	0.73	0.68	0.85	0.79	0.73
	200	0.79	0.73	0.68	0.79	0.79	0.73	0.92	0.85	0.79
	250	0.79	0.79	0.73	0.85	0.79	0.79	0.92	0.85	0.85
	300	0.85	0.85	0.85	0.92	0.85	0.85	0.99	0.92	0.92
	350	0.92	0.92	0.92	0.99	0.92	0.92	1.07	0.99	0.92

* Thicknesses include allowances for foundry practice, corrosion, and either water hammer or truck load.

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TABLE 6.4

Standard Dimensions and Weights of Push-On Joint Cast-Iron Pipe^{||}

Size in.	Thick- ness Class	Thick- ness	OD [†]	Weight of Barrel per Foot	Weight of Bell	Weight Based on 18-ft Laying Length		Weight Based on 20-ft Laying Length	
						Per Length [‡]	Avg. per Foot [§]	Per Length [‡]	Avg. per Foot [§]
						in.		lb	
3*	22	0.32	3.96	11.4	11	215	12.0	240	11.9
	23	0.35	3.96	12.4	11	235	13.0	260	12.9
	24	0.38	3.96	13.3	11	250	13.9	275	13.8
4	22	0.35	4.80	15.3	14	290	16.1	320	16.0
	23	0.38	4.80	16.5	14	310	17.3	345	17.2
	24	0.41	4.80	17.6	14	330	18.4	365	18.3
	25	0.44	4.80	18.8	14	350	19.5	390	19.5
6	22	0.38	6.90	24.3	25	460	25.6	510	25.6
	23	0.41	6.90	26.1	25	495	27.5	545	27.4
	24	0.44	6.90	27.9	25	525	29.3	585	29.2
	25	0.48	6.90	30.2	25	570	31.7	630	31.4
	26	0.52	6.90	32.5	25	610	33.9	675	33.8
8	22	0.41	9.05	34.7	41	665	36.9	735	36.8
	23	0.44	9.05	37.1	41	710	39.4	785	39.2
	24	0.48	9.05	40.3	41	765	42.6	845	42.4
	25	0.52	9.05	43.5	41	825	45.8	910	45.6
	26	0.56	9.05	46.6	41	880	48.9	975	48.6
	27	0.60	9.05	49.7	41	935	52.0	1,035	51.8
10	22	0.44	11.10	46.0	54	880	49.0	975	48.7
	23	0.48	11.10	50.0	54	955	53.0	1,055	52.7
	24	0.52	11.10	53.9	54	1,025	56.9	1,130	56.6
	25	0.56	11.10	57.9	54	1,095	60.9	1,210	60.6
	26	0.60	11.10	61.8	54	1,165	64.8	1,290	64.5
	27	0.65	11.10	66.6	54	1,255	69.6	1,385	69.3
12	22	0.48	13.20	59.8	66	1,140	63.4	1,260	63.1
	23	0.52	13.20	64.6	66	1,230	68.3	1,360	67.9
	24	0.56	13.20	69.4	66	1,315	73.1	1,455	72.7
	25	0.60	13.20	74.1	66	1,400	77.8	1,550	77.4
	26	0.65	13.20	80.0	66	1,505	83.7	1,665	83.3
	27	0.70	13.20	85.8	66	1,610	89.5	1,780	89.1
	28	0.76	13.20	92.7	66	1,735	96.4	1,920	96.0

* Pipe of 3-in. size also available in 12-ft laying length. Weight (lb) per length[‡] for thickness class 22 is 150; for 23, 160; for 24, 170. Average weight (lb) per foot[§] for thickness class 22 is 12.5; for 23, 13.5; for 24, 14.3.

† 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.

§ Tolerances of OD of spigot end: 3-12 in., ±0.06 in.; 14-24 in., +0.05 in., -0.08 in.

|| Weights shown for push-on joint pipe are also applicable to bell-and-spigot joint pipe.

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PIPE CENTRIFUGALLY CAST IN METAL MOLDS

TABLE 6.4—(contd.)

Standard Dimensions and Weights of Push-On Joint Cast-Iron Pipe

Size in.	Thick- ness Class	Thick- ness	OD†	Weight of Barrel per Foot	Weight of Bell	Weight Based on 18-ft Laying Length		Weight Based on 20-ft Laying Length	
						Per Length‡	Avg. per Foot§	Per Length‡	Avg. per Foot§
						in.			lb
14	21	0.48	15.30	69.7	78	1,335	74.1	1,470	73.6
	22	0.51	15.30	73.9	78	1,410	78.2	1,555	77.8
	23	0.55	15.30	79.5	78	1,510	83.8	1,670	83.4
	24	0.59	15.30	85.1	78	1,610	89.5	1,780	89.0
	25	0.64	15.30	92.0	78	1,735	96.3	1,920	95.9
	26	0.69	1.530	98.8	78	1,855	103.1	2,055	102.7
	27	0.75	15.30	107.0	78	2,005	111.3	2,220	110.9
	28	0.81	15.30	115.0	78	2,150	119.3	2,380	118.9
16	21	0.50	17.40	82.8	96	1,585	88.1	1,750	87.6
	22	0.54	17.40	89.2	96	1,700	94.5	1,880	94.0
	23	0.58	17.40	95.6	96	1,815	100.9	2,010	100.4
	24	0.63	17.40	103.6	96	1,960	109.0	2,170	108.4
	25	0.68	17.40	111.4	96	2,100	116.8	2,325	116.2
	26	0.73	17.40	119.3	96	2,245	124.6	2,480	124.1
	27	0.79	17.40	128.6	96	2,410	133.9	2,670	133.4
	28	0.85	17.40	137.9	96	2,580	143.2	2,855	142.7
18	21	0.54	19.50	100.4	114	1,920	106.7	2,120	106.1
	22	0.58	19.50	107.6	114	2,050	113.9	2,265	113.3
	23	0.63	19.50	116.5	114	2,210	122.8	2,445	122.2
	24	0.68	19.50	125.4	114	2,370	131.8	2,620	131.1
	25	0.73	19.50	134.3	114	2,530	140.6	2,800	140.0
	26	0.79	19.50	144.9	114	2,720	151.2	3,010	150.6
	27	0.85	19.50	155.4	114	2,910	161.7	3,220	161.1
	28	0.92	19.50	167.5	114	3,130	173.8	3,465	173.2
20	21	0.57	21.60	117.5	133	2,250	124.9	2,485	124.2
	22	0.62	21.60	127.5	133	2,430	134.9	2,685	134.2
	23	0.67	21.60	137.5	133	2,610	144.9	2,885	144.2
	24	0.72	21.60	147.4	133	2,785	154.8	3,080	154.0
	25	0.78	21.60	159.2	133	3,000	166.6	3,315	165.8
	26	0.84	21.60	170.9	133	3,210	178.4	3,550	177.6
	27	0.91	21.60	184.5	133	3,455	191.9	3,825	191.2
	28	0.98	21.60	198.1	133	3,700	205.5	4,095	204.8
24	21	0.63	25.80	155.4	179	2,975	165.3	3,285	164.4
	22	0.68	25.80	167.4	179	3,190	177.3	3,525	176.4
	23	0.73	25.80	179.4	179	3,410	189.4	3,765	188.4
	24	0.79	25.80	193.7	179	3,665	203.6	4,055	202.6
	25	0.85	25.80	207.9	179	3,920	217.8	4,335	216.8
	26	0.92	25.80	224.4	179	4,220	234.4	4,665	233.4
	27	0.99	25.80	240.8	179	4,515	250.7	4,995	249.8
	28	1.07	25.80	259.4	179	4,850	269.3	5,365	268.4

‡ 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.

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

|| Weights shown for push-on joint pipe are also applicable to bell-and-spigot joint pipe.

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TABLE 6.5

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

Size in.	Thick- ness Class	Thick- ness	OD†	Weight of Barrel per Foot	Weight of Bell	Weight Based on 18-ft Laying Length		Weight Based on 20-ft Laying Length	
						Per Length‡	Avg. per Foot§	Per Length‡	Avg. per Foot§
						in.			lb
3*	22	0.32	3.96	11.4	11	215	12.0	240	11.9
	23	0.35	3.96	12.4	11	235	13.0	260	12.9
	24	0.38	3.96	13.3	11	250	13.9	275	13.8
4	22	0.35	4.80	15.3	16	290	16.2	320	16.1
	23	0.38	4.80	16.5	16	315	17.4	345	17.3
	24	0.41	4.80	17.6	16	335	18.5	370	18.4
	25	0.44	4.80	18.8	16	355	19.7	390	19.6
6	22	0.38	6.90	24.3	22	460	25.5	510	25.4
	23	0.41	6.90	26.1	22	490	27.3	545	27.2
	24	0.44	6.90	27.9	22	525	29.1	580	29.0
	25	0.48	6.90	30.2	22	565	31.4	625	31.3
	26	0.52	6.90	32.5	22	605	33.7	670	33.6
8	22	0.41	9.05	34.7	30	655	36.4	725	36.2
	23	0.44	9.05	37.1	30	700	38.8	770	38.6
	24	0.48	9.05	40.3	30	755	42.0	835	41.8
	25	0.52	9.05	43.5	30	815	45.2	900	45.0
	26	0.56	9.05	46.6	30	870	48.3	960	48.1
	27	0.60	9.05	49.7	30	925	51.4	1,025	51.2
10	22	0.44	11.10	46.0	40	870	48.2	960	48.0
	23	0.48	11.10	50.0	40	940	52.2	1,040	52.0
	24	0.52	11.10	53.9	40	1,010	56.1	1,120	55.9
	25	0.56	11.10	57.9	40	1,080	60.1	1,200	59.9
	26	0.60	11.10	61.8	40	1,150	64.0	1,275	63.8
	27	0.65	11.10	66.6	40	1,240	68.8	1,370	68.6
12	22	0.48	13.20	59.8	50	1,125	62.6	1,245	62.3
	23	0.52	13.20	64.6	50	1,215	67.4	1,340	67.1
	24	0.56	13.20	69.4	50	1,300	72.2	1,440	71.9
	25	0.60	13.20	74.1	50	1,385	76.9	1,530	76.6
	26	0.65	13.20	80.0	50	1,490	82.8	1,650	82.5
	27	0.70	13.20	85.8	50	1,595	88.6	1,765	88.3
	28	0.76	13.20	92.7	50	1,720	95.5	1,905	95.2

* Pipe of 3-in. size also available in 12-ft laying length. Weight (lb) per length‡ for thickness class 22 is 150; for 23, 160; for 24, 170. Average weight (lb) per foot§ for thickness class 22 is 12.3; for 23, 13.3; for 24, 14.2.

† 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.

§ Tolerances of OD of spigot end: 3-12 in., ±0.06 in.; 14-24 in., ±0.05 in.; ≥26 in., ±0.08 in.

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PIPE CENTRIFUGALLY CAST IN METAL MOLDS

TABLE 6.5—(contd.)

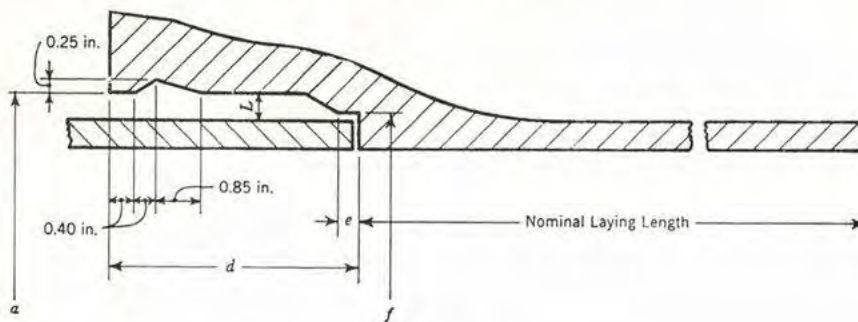
Standard Dimensions and Weights of Mechanical-Joint Cast-Iron Pipe

Size in.	Thick- ness Class	Thick- ness	OD†	Weight of Barrel per Foot	Weight of Bell	Weight Based on 18-ft Laying Length		Weight Based on 20-ft Laying Length	
						Per Length‡	Avg. per Foot§	Per Length‡	Avg. per Foot§
						in.		lb	
14	21	0.48	15.30	69.7	78	1,335	74.0	1,470	73.6
	22	0.51	15.30	73.9	78	1,410	78.2	1,555	77.8
	23	0.55	15.30	79.5	78	1,510	83.8	1,670	83.4
	24	0.59	15.30	85.1	78	1,610	89.4	1,780	89.0
	25	0.64	15.30	92.0	78	1,735	96.3	1,920	95.9
	26	0.69	15.30	98.8	78	1,855	103.1	2,055	102.7
	27	0.75	15.30	107.0	78	2,005	111.3	2,220	110.9
	28	0.81	15.30	115.0	78	2,150	119.3	2,380	118.9
16	21	0.50	17.40	82.8	95	1,585	88.1	1,750	87.6
	22	0.54	17.40	89.2	95	1,700	94.5	1,880	94.0
	23	0.58	17.40	95.6	95	1,815	100.9	2,005	100.3
	24	0.63	17.40	103.6	95	1,960	108.9	2,165	108.3
	25	0.68	17.40	111.4	95	2,100	116.7	2,325	116.2
	26	0.73	17.40	119.3	95	2,240	124.6	2,480	124.0
	27	0.79	17.40	128.6	95	2,410	133.9	2,665	133.3
	28	0.85	17.40	137.9	95	2,575	143.2	2,855	142.7
18	21	0.54	19.50	100.4	113	1,920	106.7	2,120	106.0
	22	0.58	19.50	107.6	113	2,050	113.9	2,265	113.2
	23	0.63	19.50	116.5	113	2,210	122.8	2,445	122.2
	24	0.68	19.50	125.4	113	2,370	131.7	2,620	131.0
	25	0.73	19.50	134.3	113	2,530	140.6	2,800	140.0
	26	0.79	19.50	144.9	113	2,720	151.2	3,010	150.6
	27	0.85	19.50	155.4	113	2,910	161.7	3,220	161.0
	28	0.92	19.50	167.5	113	3,130	173.8	3,465	173.2
20	21	0.57	21.60	117.5	134	2,250	124.9	2,485	124.2
	22	0.62	21.60	127.5	134	2,430	134.9	2,685	134.2
	23	0.67	21.60	137.5	134	2,610	144.9	2,885	144.2
	24	0.72	21.60	147.4	134	2,785	154.8	3,080	154.1
	25	0.78	21.60	159.2	134	3,000	166.6	3,320	165.9
	26	0.84	21.60	170.9	134	3,210	178.3	3,550	177.6
	27	0.91	21.60	184.5	134	3,455	191.9	3,825	191.2
	28	0.98	21.60	198.1	134	3,700	205.5	4,095	204.8
24	21	0.63	25.80	155.4	177	2,975	165.2	3,285	164.2
	22	0.68	25.80	167.4	177	3,190	177.2	3,525	176.2
	23	0.73	25.80	179.4	177	3,405	189.2	3,765	188.2
	24	0.79	25.80	193.7	177	3,665	203.5	4,050	202.6
	25	0.85	25.80	207.9	177	3,920	217.7	4,335	216.8
	26	0.92	25.80	224.4	177	4,215	234.2	4,665	233.2
	27	0.99	25.80	240.8	177	4,510	250.6	4,995	249.7
	28	1.07	25.80	259.4	177	4,845	269.2	5,365	268.2

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‡ 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.
 † Tolerances of OD of spigot end: 3-12 in., +0.06 in.; 14-24 in., +0.05 in.; -0.08 in.

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TABLE 6.6

Standard Bell-and-Spigot Joint Dimensions

For weights of bell-and-spigot joint pipe see Tables 6.1 and 6.4.

Size	Pipe OD†	Socket Diam. a †	Thickness of Joint L	Socket Depth d	Centering Shoulder	
					Depth e	ID f †
<i>in.</i>						
3	3.96	4.76	0.40	3.30	0.30	4.10
4	4.80	5.60	0.40	3.30	0.30	4.94
6	6.90	7.70	0.40	3.88	0.38	7.06
8	9.05	9.85	0.40	4.38	0.38	9.21
10	11.10	11.90	0.40	4.38	0.38	11.28
12	13.20	14.00	0.40	4.38	0.38	13.38
14	15.30	16.10	0.40	4.50	0.50	15.52
16	17.40	18.40	0.50	4.50	0.50	17.62
18	19.50	20.50	0.50	4.50	0.50	19.72
20	21.60	22.60	0.50	4.50	0.50	21.82
24	25.80	26.80	0.50	4.50	0.50	26.02

† Tolerances for outside diameter of spigot ends, socket diameter a , and centering shoulder inside diameter shall be ± 0.06 in. for sizes 3-12 in.; ± 0.08 in. for sizes 14-24 in.

**ANSI A21.8-1975
(AWWA C108-75)**

Revision of
A21.8-1970
(AWWA C108-70)

AMERICAN NATIONAL STANDARD
for
**CAST-IRON PIPE CENTRIFUGALLY CAST
IN SAND-LINED MOLDS, FOR WATER
OR OTHER LIQUIDS**

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ADMINISTRATIVE SECRETARIAT
AMERICAN WATER WORKS ASSOCIATION

Co-SECRETARIATS
AMERICAN GAS ASSOCIATION
NEW ENGLAND WATER WORKS ASSOCIATION

Revised edition approved by American National Standards Institute, Inc., May 28, 1975

NOTICE

This Standard has been especially printed by the American Water Works Association for incorporation into this volume. It is current as of December 1, 1975. 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

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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*

<i>User Members</i>	<i>Producer Members</i>
ROBERT S. BRYANT	W. D. GOODE
FRANK E. DOLSON	CARL A. HENRIKSON
GEORGE F. KEENAN	THOMAS D. HOLMES
LEONARD ORLANDO JR.	SIDNEY P. TEAGUE
JOHN E. PERRY	

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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:

LLOYD W. WELLER, *Chairman*
CARL A. HENRIKSON, *Vice-Chairman*
JAMES B. RAMSEY, *Secretary*

<i>Organization Represented</i>	<i>Name of Representative</i>
American Gas Association	LEONARD ORLANDO JR.
American Society of Civil Engineers	KENNETH W. HENDERSON
American Society of Mechanical Engineers	JAMES S. VANICK
American Society for Testing and Materials	ALBERT H. SMITH JR.
American Water Works Association	ARNOLD M. TINKEY
	LLOYD W. WELLER
Cast Iron Pipe Research Association	CARL A. HENRIKSON
	EDWARD C. SEARS
	W. HARRY SMITH
Individual Producer	ALFRED F. CASE
Manufacturers' Standardization Society of the Valve and Fittings Industry	ABRAHAM FENSTER
New England Water Works Association	WALTER AMORY
Naval Facilities Engineering Command	STANLEY C. BAKER
Underwriters' Laboratories, Inc.	JOHN E. PERRY
Canadian Standards Association	W. F. SEMENCHUK*

* Liaison representative without vote.

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Foreword

This foreword is provided for information only and is not a part of ANSI A21.8-1975 (AWWA C108-75).

I—History of Standard

On Sep. 10, 1902, NEWWA adopted a "Standard Specification for Cast-Iron Pipe and Special Castings," covering bell-and-spigot pit-cast pipe and fittings of ten thickness classes. The thickness classes were based on allowable internal pressures varying by increments of 50 ft of head.

On May 12, 1908, AWWA adopted a "Standard Specification for Cast-Iron Pipe and Special Castings," covering bell-and-spigot pit-cast pipe and fittings of eight classes, A through H, with allowable working pressures varying by increments of 100 ft of head from 100 to 800 ft. Dimensions and weights were given for pipe and fittings.

In 1926, ASA Sectional Committee (now American National Standards Committee) A21 on Cast-Iron Pipe and Fittings was organized under the sponsorship of A.G.A., ASTM, AWWA, and NEWWA and was assigned the following scope:

Unification of specifications for cast-iron pipe, including materials; dimensions; pressure ratings; methods of manufacture (including such new developments as centrifugal casting) insofar as they may be necessary to secure satisfactory specifications; elimination of unnecessary sizes and varieties; consideration of the possibility of developing a coordinated scheme of metallic pipe and fittings applicable to all common mediums; and methods of making up joints insofar as they are determining as to the dimensional design of cast-iron pipe.

The types of cast-iron pipe [are] to include bell-and-spigot pipe, flanged pipe, flanged and bell mouth fittings and wall castings, pipe elbows, tees, wyes, return bends, and other fittings not now included in standard lists; cast-iron pipe threaded for flanges or couplings. The standardization is not to include methods of installing pipe and similar matters, except as to the making up of joints in its relationship to the dimensional standardization of pipe and fittings, as noted above.

Sectional Committee A21 sponsored many tests of pipe and fittings; these included subjection of pipe to combined earth load and internal pressures (which form the basis of pipe thickness design), corrosion tests, measurement of hydraulic friction loss in fittings, and tests of bursting strengths of pipe and fittings. After exhaustive study of the test results and other research, the committee in 1939 issued A21.1, "American Standard Practice Manual for the Computation of Strength and Thickness of Cast Iron Pipe." The manual included nomograms and thickness tables for pit-cast pipe with 11/31 * iron strength. As stated in the preface to that manual, however, the design method was applicable to pipe of any iron strength.

Discussions and interpretations of the method of design of cast-iron pipe were published in 1939 and presented

* The first figure designates the bursting tensile strength in units of 1 000 psi and the second figure designates the ring modulus of rupture in units of 1 000 psi.

to AWWA and A.G.A. As a result of these publications and because of the general acceptance of A21.1, a substantial volume of cast-iron pipe was designed by the new method and furnished to manufacturers' standards between 1939 and 1953. A standard (A21.2) for pit-cast pipe with 11/31 iron strength also was issued in 1939. Work on standards for centrifugally cast pipe with 18/40 iron strength was started after the design was completed in 1939, but, owing to the intervention of World War II and other causes, they were not formally issued until 1953.

In 1957, a revision of A21.1 was issued. In that revision, designated ASA A21.1-1957 (AWWA H1-57) the major change was the addition of a method for computing earth loads on pipe laid under embankments and of nomograms and thickness tables for centrifugally cast pipe with 18/40 iron strength.

In 1958, Sectional 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 subcommittee on pipe (Subcommittee No. 1) was organized with the following assignment:

The scope of the committee activity shall include an examination of all present A21 standards for pipe to determine what is needed to bring these up to date. The examination shall include A21.1, A21.2, A21.3, A21.6, A21.7, A21.8, and A21.9, as well as any other matters pertaining to pipe standards.

As a result of the work of Subcommittee No. 1 on this assignment, revisions of the cast-iron pipe standards A21.6 (AWWA C106), A21.7, A21.8 (AWWA C108) and A21.9 were issued in 1962. A revision of A21.1-1957 (AWWA H1-57) was issued in

1967 and reaffirmed without revision in 1972. Revisions of the 1962 cast-iron pipe standards were issued in 1970. The major revisions of A21.8-1970 were: pipe with push-on joints were added; laying conditions C and D were deleted and condition F was added; the tables were revised to include the pipe lengths then being produced.

In 1974, Subcommittee 1 reviewed the 1970 edition and recommended minor editorial changes. Therefore, this edition is unchanged from the 1970 edition except for minor editorial changes and the updating of this foreword.

The tables and strength test requirements in this standard are for pipe with 18/40 iron strength. Advances in production technology have enabled the manufacturers to furnish pipe with greater strength. Pipe with 21/45 iron strength has been furnished for many years. Design details and standard thicknesses for pipe with 21/45 iron strength are shown in A21.1-1967 (AWWA C101-67) reaffirmed in 1972.

II—Acceptance Tests

Acceptance tests were established as routine control measures to assure the design burst and ring strengths. The acceptance tests specified in this standard are the Talbot strip test for 3-24 in. pipe and either the test bar test or the Talbot strip test for 30-48 in. pipe. In establishing the acceptance values for the Talbot strip test and the test bar test, A21 Committee in the 1940s reviewed detailed data, including burst, ring, and Talbot strip tests, on more than 400 pipe centrifugally cast in sand-lined molds. Of these, 216 were 30-48 in. pipe for which test bar test data were also included. Correlations of the data showed that the Talbot

strip modulus of rupture and secant modulus of elasticity values and the test bar load and deflection values specified in this standard represent acceptable pipe which meet the design burst and ring strengths.

A hardness test is not specified in this standard. The characteristic pearlitic matrix microstructure of this pipe is formed in the sand-lined mold. This metal structure is readily machinable. Long service experience with pearlitic cast irons did not in the 1940s indicate to the A21 Committee a need for hardness tests on pipe cast in sand-lined molds and subsequent experience has confirmed this. Also, the specified acceptance values for the Talbot strip and test bar tests provide effective control of the microstructure to assure satisfactory machinability.

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 pipe required. The following summarizes these 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 lengths (Tables)
2. Special joints (Sec. 8-1)
3. Certification by manufacturer (Sec. 8-4)
4. Inspection by purchaser (Sec. 8-5)
5. Cement lining (Sec. 8-8.2) 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.
6. Special coatings and linings (Sec. 8-8.4)
7. Special marking on pipe (Sec. 8-10)
8. Written transcripts of foundry records (Sec. 8-15)
9. Special tests (Sec. 8-16).

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American National Standard for

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

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Sec. 8-1—Scope

This standard covers 3-in. through 48-in. cast-iron pipe centrifugally cast in sand-lined molds for water or other liquids. Characteristics of such pipe with push-on joints, mechanical joints, and bell-and-spigot joints are given in the tables. This standard may be used for pipe with such other types of joints as may be agreed upon at the time of purchase. The thicknesses, weights, and strength test requirements shown in this standard are for pipe with 18/40 iron strength (18 000 psi minimum bursting tensile and 40 000 psi minimum ring modulus of rupture).

Sec. 8-2—Definitions

Under this standard, the following definitions shall apply:

8-2.1. *Purchaser.* The party entering into a contract or agreement to purchase pipe according to this standard.

8-2.2. *Manufacturer.* The party that produces the pipe.

8-2.3. *Inspector.* The representative of the purchaser, authorized to inspect in behalf of the purchaser to determine whether or not the pipe meet this standard.

8-2.4. *Cast iron.* The unqualified term *cast iron* shall apply to gray cast iron which is a 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.

8-2.5. *Push-on joint.* The single rubber-gasket joint as described in ANSI A21.11 (AWWA C111) of latest revision.

8-2.6. *Mechanical joint.* The gasketed and bolted joint as detailed in ANSI A21.11 (AWWA C111) of latest revision.

8-2.7. *Bell-and-spigot joint.* The poured or caulked joint as detailed in Table 8.6.

Sec. 8-3—General Requirements

8-3.1. Pipe with push-on joints, mechanical joints, and bell-and-spigot joints shall conform to the applicable dimensions and weights shown in the tables in this standard and to the applicable requirements of ANSI A21.11 (AWWA C111) of latest revision. 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.

8-3.2. The nominal laying length of the pipe shall be as shown in the tables. A maximum of 10 per cent of the total number of pipe of each size specified in an order may be furnished by as much as 24 in. shorter than the nominal laying length, and an additional 10 per cent may be furnished by as much as 3 in. shorter than nominal laying length.

Sec. 8-4—Inspection and Certification by Manufacturer

8-4.1. The manufacturer shall establish the necessary quality control and inspection practice to assure compliance with this standard.

8-4.2. 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 standard.

8-4.3. All pipe shall be clean and sound without defects which 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 standard.

Sec. 8-5—Inspection by Purchaser

8-5.1. 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.

8-5.2. The inspector shall have free access to those parts of the manufacturer's plant that are necessary to assure compliance with this standard. The manufacturer shall make available for the inspector's use such gages as are necessary for inspection. The manufacturer shall provide the in-

spector with assistance as necessary for the handling of pipe.

Sec. 8-6—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. 8-7—Tolerances or Permitted Variations

8-7.1. *Dimensions.* The spigot end, bell, and socket of the pipe and the accessories shall be gaged with suitable gages at sufficiently frequent intervals to assure 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 gages. Other socket dimensions shall be gaged as appropriate.

8-7.2. *Thickness.* Minus thickness tolerances of pipe and bell shall not exceed those shown below:

Pipe Size in.	Minus Tolerance in.
3- 8	0.05
10-12	0.06
14-24	0.08
30-48	0.10

NOTE: An additional tolerance of 0.02 in. shall be permitted over areas not exceeding 8 in. in any direction.

8-7.3. *Weight.* The weight of any single pipe shall not be less than the tabulated weight by more than 5 per cent for pipe 12 in. or smaller in diameter, nor by more than 4 per cent for pipe larger than 12 in. in diameter.

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Sec. 8-8—Coatings and Linings

8-8.1. *Outside coating.* The outside coating for use under normal conditions shall be a bituminous coating approximately 1 mil 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.

8-8.2. *Cement-mortar linings.* Cement linings shall be in accordance with ANSI A21.4 (AWWA C104) of latest revision. If desired, cement linings shall be specified in the invitation for bids and on the purchase order.

8-8.3. *Inside coating.* Unless otherwise specified, the inside coating for pipe not cement lined shall be a bituminous material as thick as practicable (at least 1 mil) and conforming to all appropriate requirements for seal coat in ANSI A21.4 of latest revision.

8-8.4. *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. 8-9—Hydrostatic Test

Each pipe shall be subjected to a hydrostatic test of not less than the pressure shown below:

Pipe Size—in.	Test Pressure psi
3-24 (all thicknesses)	500
30-48 (Class 23 and thinner)	400
(Class 24 and thicker)	500

This test may be made either before or after the outside coating and the 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 re-tested, at the manufacturer's option, after application of such lining.

Sec. 8-10—Marking Pipe

The weight, class or nominal thickness, and sampling period shall be shown on each pipe. The manufacturer's mark and the year in which the pipe was produced 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 8 in. and larger shall be not less than 1/2 in. in height.

Sec. 8-11—Weighing Pipe

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

Sec. 8-12—Acceptance Tests

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

8-12.1. *Talbot strip tests.* Talbot strip tests shall be used to determine the acceptability of 3-24 in. pipe for modulus of rupture and secant modulus of elasticity.

8-12.1.1. *Sampling.* At least one sample shall be taken during each period of approximately 3 hr. The sam-

ple for the first period shall be taken during the first hour, or if casting is direct from the melting unit, from the first ladle. Samples shall be taken so that each size of pipe continuously cast for 2 hr or longer and each source of iron continuously used for 2 hr or longer shall be fairly represented.

8-12.1.2. *Acceptance values.* The modulus of rupture as determined by Talbot strip test shall be 40 000 psi minimum.

The secant modulus of elasticity value shall not exceed 250 times the actual value of the modulus of rupture. (For example: when the modulus of rupture is 40 000 psi, the secant modulus of elasticity shall not exceed 10 000 000 psi.)

8-12.1.3. *Test method.* Talbot strips (Fig. 8.1) shall be machined longitudinally from each pipe specimen selected for testing by this method. The Talbot strips may be cut from a part of the ring little stressed in the ring test—that is, near one of the elements marked *a* in the illustration of the ring test (Fig. 8.2). The strips in any case will be in cross section as indicated in Fig. 8.1—that is, will have for their width the thickness of the pipe and for their depth 0.50 in. Their length shall be at least 10½ in. These strips shall be tested as beams on supports 10 in. apart with loads applied perpendicularly to the machined faces at two points 3¼ in. from the supports. The breaking load and the deflection shall be observed and recorded.

The strip shall be accurately calibrated at the point of rupture and the

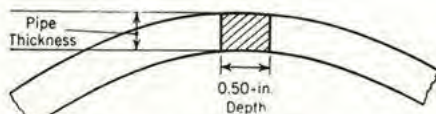


Fig. 8.1. Position From Which Talbot Strip is Cut

modulus of rupture, R , shall be calculated by the usual beam formula, which for this case reduces to the expression

$$R = \frac{10W}{td^2}$$

The secant modulus of elasticity, E_s , in pounds per square inch, shall be computed by the formula

$$E_s = \frac{21.3R}{dy}$$

In the above formulas, R is the modulus of rupture (psi); E_s the secant modulus of elasticity (psi); W , the breaking load (lb); d , the depth (in.) of the strip (intended to be 0.50 in.); t , the width (in.) of the strip (pipe thickness); and y , the deflection (in.) of the strip at the center at breaking load.

Deflection measurements shall be that of the specimen and shall not include any compression of the supports or loading blocks, or backlash or distortion of the testing machine.

8-12.2. *Test bar tests.* At the manufacturer's option, test bar tests or Talbot strip tests shall be used to determine the acceptability of 30-48 in. pipe. Test bar tests shall be made in accordance with ASTM A438-68 using vertically cast 2-in. diameter bars, 27 in. plus or minus 1 in. long. If Talbot strips are tested, they shall meet the requirements of Sec. 8-12.1.

Test bar samples shall be taken during each period of approximately 3 hr. The sample for the first period shall be taken from the first ladle. Metal for the bars shall be taken from the main ladle from which the pipe is to be poured after all alloys and other additional metal, except cast-iron pipe scrap for cooling, have been added and become melted.

Test bar test values, corrected to

2.00-in. standard nominal diameter, and tested on 24-in. supports, shall be: minimum breaking load, 6 000 lb; minimum deflection, 0.15 in. plus 0.01 in. for each 500 lb that the breaking load exceeds 6 000 lb.

Sec. 8-13—Ring Tests and Full-Length Bursting Tests

8-13.1. The manufacturer shall make bursting tests and ring tests in conjunction with strip tests so that he can certify the design values of the modulus of rupture (40 000 psi) and the bursting tensile strength of the iron in the pipe (18 000 psi). These tests shall be made in accordance with dimensions and methods given in Sec. 8-13.2 and Sec. 8-13.3. At least one pipe sample for the ring and bursting tests shall be selected from each of the following size groups from each calendar month's cast:

Group	Size in.
1	6, 8
2	10, 12
3	14, 16, 18
4	20, 24
5	30, 36, 42, 48

When no pipe in a size group are manufactured during the calendar month, no tests on these sizes are required. Ring tests and bursting tests are not required on 3- and 4-in. pipe. At least three Talbot strips shall be tested from each pipe selected for bursting. Tests and records shall include the modulus of rupture of each strip and ring, and the modulus of elasticity of each strip.

For 30-48 in. pipe, one ring and one Talbot strip shall be cut and tested from each 200 pieces, and from at least one pipe of each size each calendar month. These tests shall meet the requirements of this section for rings, and Sec. 8-12.1.2 for Talbot strips.

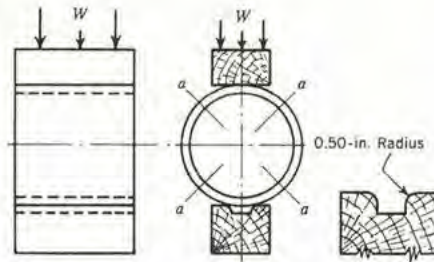


Fig. 8.2. Assembly for Ring Test

8-13.2. *Ring test method.* The maximum length of any ring shall not exceed 12 in.; for pipe 14 in. and larger, the minimum length shall be 10½ in.; for pipe 12 in. and smaller, the minimum length shall be one half the nominal diameter of the pipe. Each ring shall be tested by the three-edge bearing method as indicated in Fig. 8.2. The lower bearing for the ring shall consist of two strips with vertical sides having their interior top edges rounded to a radius of approximately ½ in. The strips shall be of hard wood or of metal. If of metal, a piece of fabric or leather approximately ⅜ in. thick shall be laid over them. They shall be straight and shall be securely fastened to a rigid block, with their interior vertical faces the following distances apart:

Pipe Size in.	Bearing Strip Spacing in.
6-12	½
14-24	1
30-48	2

The upper bearing shall be a hard wood block, straight and true from end to end. The upper and lower bearings shall extend the full length of the ring. The ring shall be placed symmetrically between the two bearings, and the center of application of the load shall be so placed that the vertical deformation at the two ends of the ring shall be approximately equal. If the ring

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is not uniform in thickness, it shall be so placed that the thick and thin portions are near the ends of the horizontal diameter.

For purposes of Sec. 8-15, a record of the breaking load of each ring tested shall be made. The modulus of rupture is computed from the formula

$$R = 0.954 \frac{W(d+t)}{bt^2}$$

in which R is the modulus of rupture (psi); W , the breaking load (lb); d , the average inside diameter (in.) of the ring; t , the average thickness (in.) of metal along the line of fracture; and b , the length (in.) of the ring.

8-13.3. *Burst test method.* The bursting tensile strength shall be determined by testing full-length pipe (less the amount cut off for ring and strip test specimens) to destruction by hydraulic pressure. Bells may be removed to facilitate testing. A suitable means for holding the end thrust shall be used which will not subject the pipe to endwise tension or compression, or other parasitic stresses. A calibrated pressure gage shall be used for determining the bursting pressure. The gage shall be connected to the interior of the test pipe by a separate connection from that which supplies water for the test. The unit tensile strength in bursting shall be obtained by the use of the formula

$$S = \frac{Pd}{2t}$$

in which S is the bursting tensile strength (psi) of the iron; P , the internal pressure (psi) at bursting; d , the average inside diameter (in.) of the pipe; and t , the minimum average thickness (in.) of the pipe along the principal line of break.

Measurements of thickness shall be

taken along the principal line of break at 1-ft intervals.

The minimum average thickness along the principal line of break shall be obtained by averaging the measurements at the thinnest section at a weight of two and at the adjacent sections on each side at a weight of one each; or, if the thinnest section is at the end of the break, by averaging the thinnest-section measurement at a weight of two and the measurements of the adjacent section and the next section at a weight of one each.

Sec. 8-14—Chemical Analyses

Analyses of the iron shall be made at sufficiently frequent intervals to determine compliance with the following limits:

Substance	Maximum Limit per cent
Phosphorus	0.90
Sulfur	0.12

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

Sec. 8-15—Foundry Records

The results of the following tests shall be recorded and retained for one year and shall be available to the purchaser at the foundry. Written transcripts of the results of these tests shall be furnished when specified on the purchase order:

8-15.1. *Talbot strip tests.* (see Sec. 8-12.1.)

8-15.2. *Test bar tests.* (see Sec. 8-12.2.)

8-15.3. *Ring tests and full-length bursting tests.* (see Sec. 8-13.)

8-15.4. *Chemical analyses.* (see Sec. 8-14.)

Sec. 8-16—Additional Tests Required by Purchaser

When 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.

Sec. 8-17—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 sampling period as the specimen which failed. Both of the additional specimens shall meet the prescribed tests to qualify the pipe produced in that sampling period.

If a routine test bar fails to meet the requirements, the manufacturer shall have the right to substitute a

Talbot strip cut from a pipe cast with iron represented by the failed test bar tests. If the strip test meets the requirements, the pipe for that period shall be acceptable.

Sec. 8-18—Rejection of Pipe

When any routine chemical analysis fails to meet the requirements of Sec. 8-14 or when any physical acceptance test fails to meet the requirements of Sec. 8-12.1, 8-12.2, or 8-17, the pipe cast in the same sampling period shall be rejected except as subject to the provision of Sec. 8-19.

Sec. 8-19—Determining Rejection

The manufacturer may determine the amount of rejection by making similar additional tests of pipe of the same size as that rejected 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 sampling period, the acceptability of pipe of different sizes from that same period may be established by making the routine acceptance tests for these sizes.

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TABLE 8.1

Selection Table for Push-On Joint Cast-Iron Pipes

These thicknesses and weights are for pipe laid without blocks on flat-bottom trench, with tamped backfill (Laying Condition B), under 5 ft of cover. For other conditions see Tables 8.3 and 8.4 hereof and ANSI A21.1 (AWWA C101).

Size	Thickness	OD	Weight Based on 16-ft Laying Length		Weight Based on 18-ft Laying Length*		Weight Based on 20-ft Laying Length	
			Per Length†	Avg. per Foot‡	Per Length†	Avg. per Foot‡	Per Length†	Avg. per Foot‡
in.			lb					
Working Pressure 50 psi—115-ft Head								
3*	0.32	3.96			150	12.7		
4	0.35	4.80			295	16.4		
6	0.38	6.90			465	25.7		
8	0.41	9.05			660	36.8		
10	0.44	11.10			880	48.8		
12	0.48	13.20			1,140	63.3	1,260	63.0
14	0.48	15.30					1,475	73.7
16	0.54	17.40					1,880	94.0
18	0.54	19.50					2,125	106.2
20	0.57	21.60					2,485	124.2
24	0.63	25.80					3,280	164.0
30	0.79	32.00	4,110	257.0				
36	0.87	38.30	5,415	338.6				
42	0.97	44.50	7,020	438.9				
48	1.06	50.80	8,720	544.9				
Working Pressure 100 psi—231-ft Head								
3*	0.32	3.96			150	12.7		
4	0.35	4.80			295	16.4		
6	0.38	6.90			465	25.7		
8	0.41	9.05			660	36.8		
10	0.44	11.10			880	48.8		
12	0.48	13.20			1,140	63.3	1,260	63.0
14	0.51	15.30					1,555	77.8
16	0.54	17.40					1,880	94.0
18	0.58	19.50					2,265	113.3
20	0.62	21.60					2,685	134.2
24	0.68	25.80					3,520	176.0
30	0.79	32.00	4,110	257.0				
36	0.87	38.30	5,415	338.6				
42	0.97	44.50	7,020	438.9				
48	1.06	50.80	8,720	544.9				
Working Pressure 150 psi—346-ft Head								
3*	0.32	3.96			150	12.7		
4	0.35	4.80			295	16.4		
6	0.38	6.90			465	25.7		
8	0.41	9.05			660	36.8		
10	0.44	11.10			880	48.8		
12	0.48	13.20			1,140	63.3	1,260	63.0
14	0.51	15.30					1,555	77.8
16	0.54	17.40					1,880	94.0
18	0.58	19.50					2,265	113.3
20	0.62	21.60					2,685	134.2
24	0.73	25.80					3,760	188.0
30	0.85	32.00	4,395	274.8				
36	0.94	38.30	5,815	363.6				
42	1.05	44.50	7,555	472.2				
48	1.14	50.80	9,330	583.0				

* Pipe of 3-in. size have 12-ft laying length.

† 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.

§ Weights shown for push-on joint pipe are also applicable to bell-and-spigot joint pipe.

PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

TABLE 8.1—(contd.)

Selection Table for Push-On Joint Cast-Iron Pipes

Size	Thickness	OD	Weight Based on 16-ft Laying Length		Weight Based on 18-ft Laying Length*		Weight Based on 20-ft Laying Length	
			Per Length†	Avg. per Foot‡	Per Length†	Avg. per Foot‡	Per Length†	Avg. per Foot‡
in.			lb					
Working Pressure 200 psi—462-ft Head								
3*	0.32	3.96			150	12.7		
4	0.35	4.80			295	16.4		
6	0.38	6.90			465	25.7		
8	0.41	9.05			660	36.8		
10	0.44	11.10			880	48.8		
12	0.48	13.20			1,140	63.3	1,260	63.0
14	0.55	15.30					1,670	83.4
16	0.58	17.40					2,010	100.4
18	0.63	19.50					2,445	122.2
20	0.67	21.60					2,885	144.2
24	0.79	25.80					4,065	203.2
30	0.92	32.00	4,755	297.2				
36	1.02	38.30	6,315	394.8				
42	1.13	44.50	8,145	509.2				
48	1.23	50.80	10,135	633.4				
Working Pressure 250 psi—577-ft Head								
3*	0.32	3.96			150	12.7		
4	0.35	4.80			295	16.4		
6	0.38	6.90			465	25.7		
8	0.41	9.05			660	36.8		
10	0.44	11.10			880	48.8		
12	0.52	13.20			1,225	68.1	1,355	67.8
14	0.59	15.30					1,790	89.4
16	0.63	17.40					2,180	108.9
18	0.68	19.50					2,635	131.7
20	0.72	21.60					3,095	154.7
24	0.79	25.80					4,065	203.2
30	0.99	32.00	5,085	317.8				
36	1.10	38.30	6,770	423.2				
42	1.22	44.50	8,740	546.4				
48	1.33	50.80	10,890	680.7				
Working Pressure 300 psi—693-ft Head								
3*	0.32	3.96			150	12.7		
4	0.35	4.80			295	16.4		
6	0.38	6.90			465	25.7		
8	0.41	9.05			660	36.8		
10	0.48	11.10			950	52.8		
12	0.52	13.20			1,225	68.1	1,355	67.8
14	0.59	15.30					1,790	89.4
16	0.68	17.40					2,335	116.7
18	0.73	19.50					2,815	140.7
20	0.78	21.60					3,335	166.7
24	0.85	25.80					4,350	217.5
Working Pressure 350 psi—808-ft Head								
3*	0.32	3.96			150	12.7		
4	0.35	4.80			295	16.4		
6	0.38	6.90			465	25.7		
8	0.41	9.05			660	36.8		
10	0.52	11.10			1,025	57.0		
12	0.56	13.20			1,320	73.3	1,460	73.0
14	0.64	15.30					1,930	96.4
16	0.68	17.40					2,335	116.7
18	0.79	19.50					3,025	151.3
20	0.84	21.60					3,565	178.3
24	0.92	25.80					4,680	234.0

* Pipe of 3-in. size have 12-ft laying length.

† 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.

§ Weights shown for push-on joint pipe are also applicable to bell-and-spigot joint pipe.

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TABLE 8.2

Selection Table for Mechanical-Joint Cast-Iron Pipe

These thicknesses and weights are for pipe laid without blocks, on flat-bottom trench, with tamped backfill (Laying Condition B), under 5 ft of cover. For other conditions see Tables 8.3 and 8.5 hereof and ANSI A21.1 (AWWA C101).

Size	Thickness	OD	Weight Based on 16-ft Laying Length		Weight Based on 18-ft Laying Length*		Weight Based on 20-ft Laying Length	
			Per Length†	Avg. per Foot‡	Per Length†	Avg. per Foot‡	Per Length†	Avg. per Foot‡
in.			lb					
Working Pressure 50 psi—115 ft Head								
3*	0.32	3.96			150	12.3		
4	0.35	4.80			290	16.2		
6	0.38	6.90			460	25.5		
8	0.41	9.05			655	36.4		
10	0.44	11.10			870	48.2		
12	0.48	13.20			1,125	62.6	1,245	62.3
14	0.48	15.30					1,470	73.6
16	0.54	17.40					1,880	94.0
18	0.54	19.50					2,120	106.0
20	0.57	21.60					2,485	124.2
24	0.63	25.80					3,285	164.2
30	0.79	32.00	4,150	259.5				
36	0.87	38.30	5,500	343.9				
42	0.97	44.50	7,130	445.7				
48	1.06	50.80	8,915	557.1				
Working Pressure 100 psi—231 ft Head								
3*	0.32	3.96			150	12.3		
4	0.35	4.80			290	16.2		
6	0.38	6.90			460	25.5		
8	0.41	9.05			655	36.4		
10	0.44	11.10			870	48.2		
12	0.48	13.20			1,125	62.6	1,245	62.3
14	0.51	15.30					1,555	77.8
16	0.54	17.40					1,880	94.0
18	0.58	19.50					2,265	113.2
20	0.62	21.60					2,685	134.2
24	0.68	25.80					3,525	176.2
30	0.79	32.00	4,150	259.5				
36	0.87	38.30	5,500	343.9				
42	0.97	44.50	7,130	445.7				
48	1.06	50.80	8,915	557.1				
Working Pressure 150 psi—346 ft Head								
3*	0.32	3.96			150	12.3		
4	0.35	4.80			290	16.2		
6	0.38	6.90			460	25.5		
8	0.41	9.05			655	36.4		
10	0.44	11.10			870	48.2		
12	0.48	13.20			1,125	62.6	1,245	62.3
14	0.51	15.30					1,555	77.8
16	0.54	17.40					1,880	94.0
18	0.58	19.50					2,265	113.2
20	0.62	21.60					2,685	134.2
24	0.73	25.80					3,765	188.2
30	0.85	32.00	4,435	277.3				
36	0.94	38.30	5,900	368.9				
42	1.05	44.50	7,665	479.1				
48	1.14	50.80	9,525	595.2				

* Pipe of 3-in. size have 12-ft laying length.

† 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.

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PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

TABLE 8.2—(contd.)

Selection Table for Mechanical-Joint Cast-Iron Pipe

These thicknesses and weights are for pipe laid without blocks, on flat-bottom trench, with tamped backfill (Laying Condition B), under 5 ft of cover. For other conditions see Tables 8.3 and 8.5 hereof and ANSI A21.1 (AWWA C101).

Size	Thickness	OD	Weight Based on 16-ft Laying Length		Weight Based on 18-ft Laying Length*		Weight Based on 20-ft Laying Length	
			Per Length†	Avg. per Foot‡	Per Length†	Avg. per Foot‡	Per Length†	Avg. per Foot‡
in.			lb					
Working Pressure 200 psi—462 ft Head								
3*	0.32	3.96			150	12.3		
4	0.35	4.80			290	16.2		
6	0.38	6.90			460	25.5		
8	0.41	9.05			655	36.4		
10	0.44	11.10			870	48.2		
12	0.48	13.20			1,125	62.6	1,245	62.3
14	0.55	15.30					1,670	83.4
16	0.58	17.40					2,005	100.3
18	0.63	19.50					2,445	122.2
20	0.67	21.60					2,885	144.2
24	0.79	25.80					4,050	202.6
30	0.92	32.00	4,770	298.1				
36	1.02	38.30	6,360	397.4				
42	1.13	44.50	8,195	512.3				
48	1.23	50.80	10,205	637.9				
Working Pressure 250 psi—577 ft Head								
3*	0.32	3.96			150	12.3		
4	0.35	4.80			290	16.2		
6	0.38	6.90			460	25.5		
8	0.41	9.05			655	36.4		
10	0.44	11.10			870	48.2		
12	0.52	13.20			1,215	67.4	1,340	67.1
14	0.59	15.30					1,780	89.0
16	0.63	17.40					2,165	108.3
18	0.68	19.50					2,620	131.0
20	0.72	21.60					3,080	154.1
24	0.79	25.80					4,050	202.6
30	0.99	32.00	5,100	318.7				
36	1.10	38.30	6,815	425.8				
42	1.22	44.50	8,790	549.5				
48	1.33	50.80	10,965	685.2				
Working Pressure 300 psi—693 ft Head								
3*	0.32	3.96			150	12.3		
4	0.35	4.80			290	16.2		
6	0.38	6.90			460	25.5		
8	0.41	9.05			655	36.4		
10	0.48	11.10			940	52.2		
12	0.52	13.20			1,215	67.4	1,340	67.1
14	0.59	15.30					1,780	89.0
16	0.68	17.40					2,325	116.2
18	0.73	19.50					2,800	140.0
20	0.78	21.60					3,320	165.9
24	0.85	25.80					4,335	216.8
Working Pressure 350 psi—808 ft Head								
3*	0.32	3.96			150	12.3		
4	0.35	4.80			290	16.2		
6	0.38	6.90			460	25.5		
8	0.41	9.05			655	36.4		
10	0.52	11.10			1,010	56.1		
12	0.56	13.20			1,300	72.2	1,440	71.9
14	0.64	15.30					1,920	95.9
16	0.68	17.40					2,325	116.2
18	0.79	19.50					3,010	150.6
20	0.84	21.60					3,550	177.6
24	0.92	25.80					4,665	233.2

* Pipe of 3-in. size have 12-ft laying length.

† 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 8.3

Standard Thickness* Selection Table for Cast-Iron Pipe

Laying Condition A—flat-bottom trench, without blocks, untamped backfill

Laying Condition B—flat-bottom trench, without blocks, tamped backfill

Laying Condition F—pipe laid on gravel or sand bedding, backfill tamped

Size in.	Working Pressure psi	3½-ft Cover			5-ft Cover			8-ft Cover		
		Laying Condition			Laying Condition			Laying Condition		
		A	B	F	A	B	F	A	B	F
Thickness*—in.										
3	50	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
	100	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
	150	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
	200	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
	250	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
	350	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
4	50	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
	100	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
	150	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
	200	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
	250	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
	350	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
6	50	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
	100	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
	150	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
	200	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
	250	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
	350	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
8	50	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
	100	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
	150	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
	200	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
	250	0.41	0.41	0.41	0.41	0.41	0.41	0.44	0.41	0.41
	350	0.41	0.41	0.41	0.52	0.41	0.41	0.44	0.44	0.41
10	50	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44
	100	0.44	0.44	0.44	0.44	0.44	0.44	0.48	0.44	0.44
	150	0.44	0.44	0.44	0.44	0.44	0.44	0.48	0.44	0.44
	200	0.44	0.44	0.44	0.44	0.44	0.44	0.48	0.48	0.44
	250	0.44	0.44	0.44	0.48	0.44	0.44	0.52	0.48	0.48
	350	0.48	0.44	0.44	0.48	0.48	0.48	0.52	0.52	0.48
12	50	0.48	0.48	0.48	0.48	0.48	0.48	0.52	0.48	0.48
	100	0.48	0.48	0.48	0.48	0.48	0.48	0.52	0.48	0.48
	150	0.48	0.48	0.48	0.48	0.48	0.48	0.52	0.52	0.48
	200	0.48	0.48	0.48	0.48	0.48	0.48	0.56	0.52	0.48
	250	0.52	0.48	0.48	0.52	0.52	0.48	0.56	0.56	0.52
	350	0.52	0.52	0.52	0.56	0.52	0.52	0.60	0.56	0.56
14	50	0.51	0.48	0.48	0.51	0.48	0.48	0.59	0.55	0.51
	100	0.51	0.48	0.48	0.55	0.51	0.48	0.59	0.55	0.51
	150	0.55	0.51	0.48	0.55	0.51	0.48	0.64	0.59	0.55
	200	0.55	0.51	0.51	0.55	0.55	0.51	0.64	0.59	0.59
	250	0.59	0.55	0.55	0.59	0.59	0.52	0.64	0.64	0.59
	350	0.59	0.59	0.59	0.64	0.59	0.59	0.69	0.64	0.64
14	50	0.64	0.64	0.64	0.64	0.64	0.64	0.75	0.69	0.64

* Thicknesses include allowances for foundry practice, corrosion, and either water hammer or truck load.

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PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

TABLE 8.3—(contd.)

Standard Thickness* Selection Table for Cast-Iron Pipe

Laying Condition A—flat-bottom trench, without blocks, untamped backfill

Laying Condition B—flat-bottom trench, without blocks, tamped backfill

Laying Condition F—pipe laid on gravel or sand bedding, backfill tamped

Size in.	Working Pressure psi	3½-ft Cover			5-ft Cover			8-ft Cover		
		Laying Condition			Laying Condition			Laying Condition		
		A	B	F	A	B	F	A	B	F
		Thickness*—in.								
16	50	0.54	0.50	0.50	0.58	0.54	0.50	0.63	0.58	0.54
	100	0.54	0.54	0.50	0.58	0.54	0.50	0.63	0.58	0.54
	150	0.58	0.54	0.50	0.58	0.54	0.54	0.68	0.63	0.58
	200	0.58	0.58	0.54	0.63	0.58	0.58	0.68	0.63	0.63
	250	0.63	0.58	0.58	0.63	0.63	0.58	0.73	0.68	0.63
	300	0.63	0.63	0.63	0.68	0.68	0.63	0.73	0.73	0.68
18	350	0.68	0.68	0.68	0.73	0.68	0.68	0.79	0.73	0.73
	50	0.58	0.54	0.54	0.58	0.54	0.54	0.68	0.63	0.58
	100	0.58	0.54	0.54	0.63	0.58	0.54	0.68	0.63	0.58
	150	0.63	0.58	0.54	0.63	0.58	0.58	0.73	0.68	0.63
	200	0.63	0.58	0.58	0.68	0.63	0.58	0.73	0.68	0.63
	250	0.68	0.63	0.63	0.68	0.68	0.63	0.79	0.73	0.68
20	300	0.68	0.68	0.68	0.73	0.73	0.68	0.79	0.79	0.73
	350	0.79	0.73	0.73	0.79	0.79	0.73	0.85	0.85	0.79
	50	0.62	0.57	0.57	0.67	0.57	0.57	0.72	0.67	0.62
	100	0.62	0.57	0.57	0.67	0.62	0.57	0.72	0.67	0.62
	150	0.67	0.62	0.57	0.67	0.62	0.62	0.78	0.72	0.67
	200	0.67	0.62	0.62	0.72	0.67	0.62	0.78	0.72	0.67
24	250	0.72	0.67	0.67	0.78	0.72	0.67	0.84	0.78	0.72
	300	0.78	0.72	0.72	0.78	0.78	0.72	0.84	0.84	0.78
	350	0.84	0.78	0.78	0.84	0.84	0.78	0.91	0.84	0.84
	50	0.68	0.63	0.63	0.73	0.63	0.63	0.79	0.73	0.68
	100	0.73	0.63	0.63	0.73	0.68	0.63	0.85	0.73	0.68
	150	0.73	0.68	0.63	0.79	0.73	0.68	0.85	0.79	0.73
30	200	0.79	0.73	0.68	0.79	0.79	0.73	0.92	0.85	0.79
	250	0.79	0.79	0.73	0.85	0.79	0.79	0.92	0.85	0.79
	300	0.85	0.85	0.85	0.92	0.85	0.85	0.99	0.92	0.85
	350	0.92	0.92	0.92	0.99	0.92	0.92	1.07	0.99	0.92
	50	0.85	0.73	0.73	0.85	0.79	0.73	0.92	0.85	0.79
	100	0.85	0.79	0.73	0.92	0.79	0.73	0.99	0.85	0.79
36	150	0.92	0.79	0.73	0.92	0.85	0.79	0.99	0.92	0.85
	200	0.92	0.85	0.79	0.99	0.92	0.85	1.07	0.99	0.92
	250	0.99	0.92	0.92	1.07	0.99	0.92	1.16	1.07	0.99
	50	0.94	0.81	0.81	1.02	0.87	0.81	1.10	0.94	0.87
	100	0.94	0.87	0.81	1.02	0.87	0.81	1.10	1.02	0.94
	150	1.02	0.87	0.81	1.10	0.94	0.87	1.19	1.02	0.94
42	200	1.10	0.94	0.94	1.10	1.02	0.94	1.19	1.10	1.02
	250	1.10	1.02	1.02	1.19	1.10	1.10	1.29	1.19	1.10
	50	1.05	0.90	0.90	1.13	0.97	0.90	1.22	1.05	0.97
	100	1.05	0.97	0.90	1.13	0.97	0.90	1.22	1.13	0.97
	150	1.13	0.97	0.90	1.22	1.05	0.97	1.32	1.13	1.05
	200	1.22	1.05	1.05	1.22	1.13	1.05	1.32	1.22	1.13
48	250	1.32	1.13	1.13	1.32	1.22	1.22	1.43	1.32	1.22
	50	1.14	0.98	0.98	1.23	1.06	0.98	1.33	1.14	1.06
	100	1.23	1.06	0.98	1.23	1.06	0.98	1.33	1.23	1.14
	150	1.23	1.14	0.98	1.33	1.14	1.06	1.44	1.33	1.23
	200	1.33	1.14	1.14	1.44	1.23	1.23	1.56	1.33	1.33
	250	1.44	1.33	1.33	1.44	1.33	1.33	1.56	1.44	1.44

* Thicknesses include allowances for foundry practice, corrosion, and either water hammer or truck load.

AMERICAN NATIONAL STANDARD

TABLE 8.4
Standard Dimensions and Weights of Push-On Joint Cast-Iron Pipe^{||}

Size in.	Thickness Class	Thickness	OD [†]	Weight of Barrel per Foot	Weight of Bell	Weight Based on 18-ft Laying Length*		Weight Based on 20-ft Laying Length	
						Per Length [‡]	Avg. per Foot [§]	Per Length [‡]	Avg. per Foot [§]
						in.		lb	
3*	22	0.32	3.96	11.4	15	150	12.7		
	23	0.35	3.96	12.4	15	165	13.7		
	24	0.38	3.96	13.3	15	175	14.6		
4	22	0.35	4.80	15.3	19	295	16.4		
	23	0.38	4.80	16.5	19	315	17.6		
	24	0.41	4.80	17.6	19	335	18.7		
	25	0.44	4.80	18.8	19	355	19.8		
6	22	0.38	6.90	24.3	26	465	25.7		
	23	0.41	6.90	26.1	26	495	27.5		
	24	0.44	6.90	27.9	29	530	29.5		
	25	0.48	6.90	30.2	29	575	31.9		
	26	0.52	6.90	32.5	29	615	34.1		
8	22	0.41	9.05	34.7	37	660	36.8		
	23	0.44	9.05	37.1	37	705	39.2		
	24	0.48	9.05	40.3	43	770	42.7		
	25	0.52	9.05	43.5	43	825	45.9		
	26	0.56	9.05	46.6	43	880	49.0		
	27	0.60	9.05	49.7	43	940	52.1		
10	22	0.44	11.10	46.0	50	880	48.8		
	23	0.48	11.10	50.0	50	950	52.8		
	24	0.52	11.10	53.9	56	1,025	57.0		
	25	0.56	11.10	57.9	56	1,100	61.0		
	26	0.60	11.10	61.8	56	1,170	64.9		
	27	0.65	11.10	66.6	56	1,255	69.7		
12	22	0.48	13.20	59.8	63	1,140	63.3	1,260	63.0
	23	0.52	13.20	64.6	63	1,225	68.1	1,355	67.8
	24	0.56	13.20	69.4	71	1,320	73.3	1,460	73.0
	25	0.60	13.20	74.1	71	1,405	78.0	1,555	77.7
	26	0.65	13.20	80.0	71	1,510	83.9	1,670	83.6
	27	0.70	13.20	85.8	71	1,615	89.7	1,785	89.3
	28	0.76	13.20	92.7	79	1,750	97.1	1,935	96.7

* Pipe of 3-in. size have 12-ft laying length.
[†] 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.
[§] 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.
^{||} Weights shown for push-on joint pipe are also applicable to bell-and-spigot joint pipe.

PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

TABLE 8.4—(contd.)

Standard Dimensions and Weights of Push-On Joint Cast-Iron Pipe||

Size in.	Thickness Class	Thickness	OD†	Weight of Barrel per Foot	Weight of Bell	Weight Based on 18-ft Laying Length		Weight Based on 20-ft Laying Length	
						Per Length‡	Avg. per Foot§	Per Length‡	Avg. per Foot§
						in.		lb	
14	21	0.48	15.30	69.7	79			1,475	73.7
	22	0.51	15.30	73.9	79			1,555	77.8
	23	0.55	15.30	79.5	79			1,670	83.4
	24	0.59	15.30	85.1	88			1,790	89.4
	25	0.64	15.30	92.0	88			1,930	96.4
	26	0.69	15.30	98.8	88			2,065	103.2
	27	0.75	15.30	107.0	88			2,230	111.4
	28	0.81	15.30	115.0	97			2,395	119.8
16	21	0.50	17.40	82.8	96			1,750	87.6
	22	0.54	17.40	89.2	96			1,880	94.0
	23	0.58	17.40	95.6	96			2,010	100.4
	24	0.63	17.40	103.6	108			2,180	108.9
	25	0.68	17.40	111.4	108			2,335	116.7
	26	0.73	17.40	119.3	108			2,495	124.7
	27	0.79	17.40	128.6	108			2,680	134.0
	28	0.85	17.40	137.9	120			2,880	143.9
18	21	0.54	19.50	100.4	115			2,125	106.2
	22	0.58	19.50	107.6	115			2,265	113.3
	23	0.63	19.50	116.5	115			2,445	122.2
	24	0.68	19.50	125.4	128			2,635	131.7
	25	0.73	19.50	134.3	128			2,815	140.7
	26	0.79	19.50	144.9	128			3,025	151.3
	27	0.85	19.50	155.4	128			3,235	161.8
	28	0.92	19.50	167.5	143			3,495	174.7
20	21	0.57	21.60	117.5	135			2,485	124.2
	22	0.62	21.60	127.5	135			2,685	134.2
	23	0.67	21.60	137.5	135			2,885	144.2
	24	0.72	21.60	147.4	149			3,095	154.7
	25	0.78	21.60	159.2	149			3,335	166.7
	26	0.84	21.60	170.9	149			3,565	178.3
	27	0.91	21.60	184.5	149			3,840	191.9
	28	0.98	21.60	198.1	168			4,130	206.5
24	21	0.63	25.80	155.4	171			3,280	164.0
	22	0.68	25.80	167.4	171			3,520	176.0
	23	0.73	25.80	179.4	171			3,760	188.0
	24	0.79	25.80	193.7	191			4,065	203.2
	25	0.85	25.80	207.9	191			4,350	217.5
	26	0.92	25.80	224.4	191			4,680	234.0
	27	0.99	25.80	240.8	218			5,035	251.8
	28	1.07	25.80	259.4	218			5,405	270.2

‡ 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.

† 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.

|| Weights shown for push-on joint pipe are also applicable to bell-and-spigot joint pipe.

TABLE 8.4—(contd.)
Standard Dimensions and Weights of Push-On Joint Cast-Iron Pipe||

Size in.	Thickness Class	Thickness	OD†	Weight of Barrel per Foot	Weight of Bell	Weight Based on 16-ft Laying Length	
						Per Length‡	Avg. per Foot§
		in.		lb			
30	21	0.73	32.00	223.7	245	3,825	239.0
	22	0.79	32.00	241.7	245	4,110	257.0
	23	0.85	32.00	259.5	245	4,395	274.8
	24	0.92	32.00	280.3	271	4,755	297.2
	25	0.99	32.00	300.9	271	5,085	317.8
	26	1.07	32.00	324.4	271	5,460	341.3
	27	1.16	32.00	350.7	318	5,930	370.6
	28	1.25	32.00	376.8	318	6,345	396.7
	29	1.35	32.00	405.6	318	6,810	425.5
36	21	0.81	38.30	297.7	310	5,075	317.1
	22	0.87	38.30	319.2	310	5,415	338.6
	23	0.94	38.30	344.2	310	5,815	363.6
	24	1.02	38.30	372.7	353	6,315	394.8
	25	1.10	38.30	401.1	353	6,770	423.2
	26	1.19	38.30	432.9	353	7,280	455.0
	27	1.29	38.30	468.0	445	7,935	495.8
	28	1.39	38.30	502.9	445	8,490	530.7
	29	1.50	38.30	541.1	445	9,105	568.9
42	21	0.90	44.50	384.6	400	6,555	409.6
	22	0.97	44.50	413.9	400	7,020	438.9
	23	1.05	44.50	447.2	400	7,555	472.2
	24	1.13	44.50	480.4	460	8,145	509.2
	25	1.22	44.50	517.6	460	8,740	546.4
	26	1.32	44.50	558.7	460	9,400	587.4
	27	1.43	44.50	603.7	585	10,245	640.3
	28	1.54	44.50	648.5	585	10,960	685.1
	29	1.66	44.50	697.0	585	11,735	733.6
48	21	0.98	50.80	478.6	450	8,110	506.7
	22	1.06	50.80	516.8	450	8,720	544.9
	23	1.14	50.80	554.9	450	9,330	583.0
	24	1.23	50.80	597.6	573	10,135	633.4
	25	1.33	50.80	644.9	573	10,890	680.7
	26	1.44	50.80	696.7	573	11,720	732.5
	27	1.56	50.80	752.9	735	12,780	798.8
	28	1.68	50.80	808.9	735	13,675	854.8
	29	1.81	50.80	869.1	735	14,640	915.0

‡ 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.
 † 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.
 || Weights shown for push-on joint pipe are also applicable to bell-and-spigot joint pipe.

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PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

TABLE 8.5

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

Size in.	Thickness Class	Thickness	OD†	Weight of Barrel per Foot	Weight of Bell	Weight Based on 18-ft Laying Length*		Weight Based on 20-ft Laying Length	
						Per Length‡	Avg. per Foot§	Per Length‡	Avg. per Foot§
		in.			lb				
3*	22	0.32	3.96	11.4	11	150	12.5		
	23	0.35	3.96	12.4	11	160	13.3		
	24	0.38	3.96	13.3	11	170	14.2		
4	22	0.35	4.80	15.3	16	290	16.2		
	23	0.38	4.80	16.5	16	315	17.4		
	24	0.41	4.80	17.6	16	335	18.5		
	25	0.44	4.80	18.8	16	355	19.7		
6	22	0.38	6.90	24.3	22	460	25.5		
	23	0.41	6.90	26.1	22	490	27.3		
	24	0.44	6.90	27.9	22	525	29.1		
	25	0.48	6.90	30.2	22	565	31.4		
	26	0.52	6.90	32.5	22	605	33.7		
8	22	0.41	9.05	34.7	30	655	36.4		
	23	0.44	9.05	37.1	30	700	38.8		
	24	0.48	9.05	40.3	30	755	42.0		
	25	0.52	9.05	43.5	30	815	45.2		
	26	0.56	9.05	46.6	30	870	48.3		
	27	0.60	9.05	49.7	30	925	51.4		
10	22	0.44	11.10	46.0	40	870	48.2		
	23	0.48	11.10	50.0	40	940	52.2		
	24	0.52	11.10	53.9	40	1,010	56.1		
	25	0.56	11.10	57.9	40	1,080	60.1		
	26	0.60	11.10	61.8	40	1,150	64.0		
	27	0.65	11.10	66.6	40	1,240	68.8		
12	22	0.48	13.20	59.8	50	1,125	62.6	1,245	62.3
	23	0.52	13.20	64.6	50	1,215	67.4	1,340	67.1
	24	0.56	13.20	69.4	50	1,300	72.2	1,440	71.9
	25	0.60	13.20	74.1	50	1,385	76.9	1,530	76.6
	26	0.65	13.20	80.0	50	1,490	82.8	1,650	82.5
	27	0.70	13.20	85.8	50	1,595	88.6	1,765	88.3
	28	0.76	13.20	92.7	50	1,720	95.5	1,905	95.2

* Pipe of 3-in. size have 12-ft laying length.

‡ 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.

† 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.

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TABLE 8.5—(contd.)

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

Size in.	Thickness Class	Thickness	OD†	Weight of Barrel per Foot	Weight of Bell	Weight Based on 18-ft Laying Length		Weight Based on 20-ft Laying Length	
						Per Length‡	Avg. per Foot§	Per Length‡	Avg. per Foot§
		in.		lb					
14	21	0.48	15.30	69.7	78			1,470	73.6
	22	0.51	15.30	73.9	78			1,555	77.8
	23	0.55	15.30	79.5	78			1,670	83.4
	24	0.59	15.30	85.1	78			1,780	89.0
	25	0.64	15.30	92.0	78			1,920	95.9
	26	0.69	15.30	98.8	78			2,055	102.7
	27	0.75	15.30	107.0	78			2,220	110.9
	28	0.81	15.30	115.0	78			2,380	118.9
16	21	0.50	17.40	82.8	95			1,750	87.6
	22	0.54	17.40	89.2	95			1,880	94.0
	23	0.58	17.40	95.6	95			2,005	100.3
	24	0.63	17.40	103.6	95			2,165	108.3
	25	0.68	17.40	111.4	95			2,325	116.2
	26	0.73	17.40	119.3	95			2,480	124.0
	27	0.79	17.40	128.6	95			2,665	133.3
	28	0.85	17.40	137.9	95			2,855	142.7
18	21	0.54	19.50	100.4	113			2,120	106.0
	22	0.58	19.50	107.6	113			2,265	113.2
	23	0.63	19.50	116.5	113			2,445	122.2
	24	0.68	19.50	125.4	113			2,620	131.0
	25	0.73	19.50	134.3	113			2,800	140.0
	26	0.79	19.50	144.9	113			3,010	150.6
	27	0.85	19.50	155.4	113			3,220	161.0
	28	0.92	19.50	167.5	113			3,465	173.2
20	21	0.57	21.60	117.5	134			2,485	124.2
	22	0.62	21.60	127.5	134			2,685	134.2
	23	0.67	21.60	137.5	134			2,885	144.2
	24	0.72	21.60	147.4	134			3,080	154.1
	25	0.78	21.60	159.2	134			3,320	165.9
	26	0.84	21.60	170.9	134			3,550	177.6
	27	0.91	21.60	184.5	134			3,825	191.2
	28	0.98	21.60	198.1	134			4,095	204.8
24	21	0.63	25.80	155.4	177			3,285	164.2
	22	0.68	25.80	167.4	177			3,525	176.2
	23	0.73	25.80	179.4	177			3,765	188.2
	24	0.79	25.80	193.7	177			4,050	202.6
	25	0.85	25.80	207.9	177			4,335	216.8
	26	0.92	25.80	224.4	177			4,665	233.2
	27	0.99	25.80	240.8	177			4,995	249.7
	28	1.07	25.80	259.4	177			5,365	268.2

‡ 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.
 † 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.

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PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

TABLE 8.5—(contd.)

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

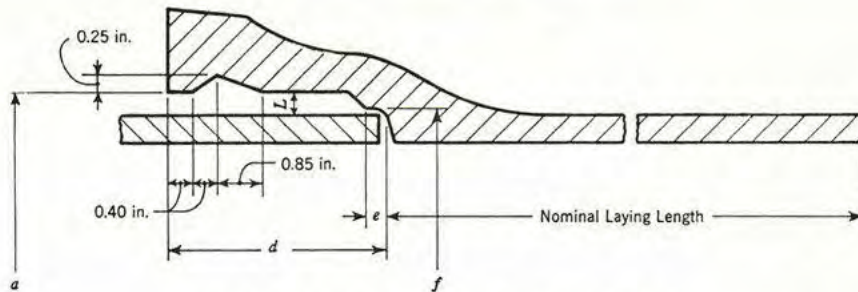
Size in.	Thickness Class	Thickness	OD†	Weight of Barrel per Foot	Weight of Bell	Weight Based on 16-ft Laying Length	
						Per Length‡	Avg. per Foot§
						lb	
in.			lb				
30	21	0.73	32.00	223.7	285	3,865	241.5
	22	0.79	32.00	241.7	285	4,150	259.5
	23	0.85	32.00	259.5	285	4,435	277.3
	24	0.92	32.00	280.3	285	4,770	298.1
	25	0.99	32.00	300.9	285	5,100	318.7
	26	1.07	32.00	324.4	285	5,475	342.2
	27	1.16	32.00	350.7	285	5,895	368.5
	28	1.25	32.00	376.8	285	6,315	394.6
	29	1.35	32.00	405.6	285	6,775	423.4
36	21	0.81	38.30	297.7	395	5,160	322.4
	22	0.87	38.30	319.2	395	5,500	343.9
	23	0.94	38.30	344.2	395	5,900	368.9
	24	1.02	38.30	372.7	395	6,360	397.4
	25	1.10	38.30	401.1	395	6,815	425.8
	26	1.19	38.30	432.9	395	7,320	457.6
	27	1.29	38.30	468.0	395	7,885	492.7
	28	1.39	38.30	502.9	395	8,440	527.6
	29	1.50	38.30	541.1	395	9,055	565.8
42	21	0.90	44.50	384.6	510	6,665	416.5
	22	0.97	44.50	413.9	510	7,130	445.7
	23	1.05	44.50	447.2	510	7,665	479.1
	24	1.13	44.50	480.4	510	8,195	512.3
	25	1.22	44.50	517.6	510	8,790	549.5
	26	1.32	44.50	558.7	510	9,450	590.6
	27	1.43	44.50	603.7	510	10,170	635.6
	28	1.54	44.50	648.5	510	10,885	680.4
	29	1.66	44.50	697.0	510	11,660	728.9
48	21	0.98	50.80	478.6	645	8,305	519.0
	22	1.06	50.80	516.8	645	8,915	557.1
	23	1.14	50.80	554.9	645	9,525	595.2
	24	1.23	50.80	597.6	645	10,205	637.9
	25	1.33	50.80	644.9	645	10,965	685.2
	26	1.44	50.80	696.7	645	11,790	737.0
	27	1.56	50.80	752.9	645	12,690	793.2
	28	1.68	50.80	808.9	645	13,585	849.2
	29	1.81	50.80	869.1	645	14,550	909.4

‡ Including bell. Calculated weight of pipe rounded off to nearest 5 lb.

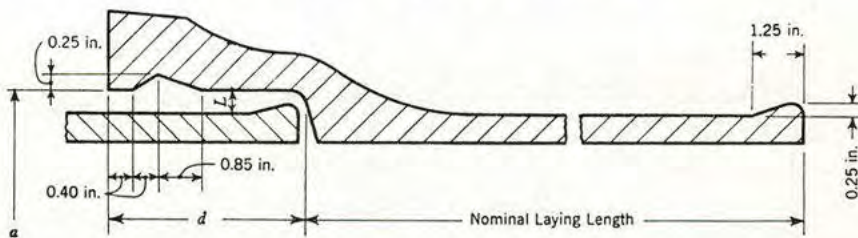
§ Including bell. Average weight per foot based on calculated weight of pipe before rounding.

† 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.

AMERICAN NATIONAL STANDARD



3-24 in. Bell-and-Spigot Pipe With Plain Ends



30-48 in. Bell-and-Spigot Pipe With Beaded Ends

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TABLE 8.6

Standard Bell-and-Spigot Joint Dimensions

For weights of bell-and-spigot joint pipe, see Tables 8.1 and 8.4.

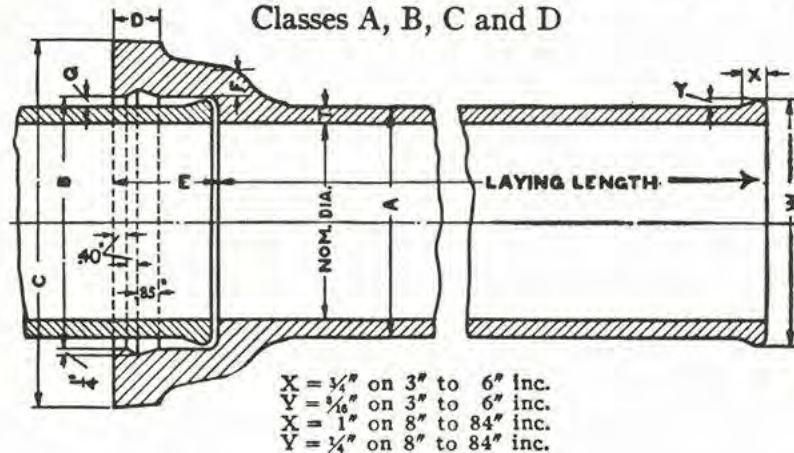
Size	Pipe OD†	Socket Diam. a†	Thickness of Joint L	Socket Depth d	Centering Shoulder	
					Depth e	ID f†
in.						
3	3.96	4.76	0.40	3.30	0.30	4.10
4	4.80	5.60	0.40	3.30	0.30	4.94
6	6.90	7.70	0.40	3.88	0.38	7.06
8	9.05	9.85	0.40	4.38	0.38	9.21
10	11.10	11.90	0.40	4.38	0.38	11.28
12	13.20	14.00	0.40	4.38	0.38	13.38
14	15.30	16.10	0.40	4.50	0.50	15.52
16	17.40	18.40	0.50	4.50	0.50	17.62
18	19.50	20.50	0.50	4.50	0.50	19.72
20	21.60	22.60	0.50	4.50	0.50	21.82
24	25.80	26.80	0.50	4.50	0.50	26.02
30	32.00	33.00	0.50	4.50		
36	38.30	39.30	0.50	4.50		
42	44.50	45.50	0.50	5.00		
48	50.80	51.80	0.50	5.00		

† Tolerances for outside diameter of spigot ends, socket diameter *a*, and centering shoulder inside diameter *f* shall be ±0.06 in. for sizes 3-12 in.; ±0.08 in. for sizes 14-24 in.; ±0.10 in. for sizes 30-36 in.; and ±0.12 in. for sizes 42-48 in.

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



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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.

For weights see pages 70 and 71.

For Classes E, F, G and H see page 72.

Pipe listed in this Table can be furnished with plain ends for use with special couplings. For weights on plain end pipe see pages 145 and 146 under heading "weight per foot without flanges."

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

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Dimensions continued on next page.
See notes on preceding 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)

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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

See notes on page 66.

Dimensions of Pit Cast Pipe only
Not of current manufacture or standard

Bell and Spigot Pipe

Classes E, F, G and H

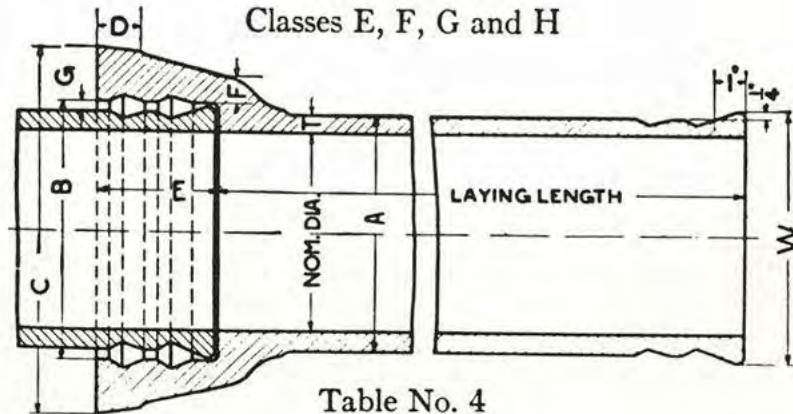


Table No. 4

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

For weights, see page 74.

Can be furnished with single lead groove if desired. For dimensions, see Table No. 1.

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)

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8

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

For weights, see page 74.

Can be furnished with single lead groove if desired. For dimensions, see Table No. 1.

**STANDARD ANSI CLASS THICKNESSES OF
21/45 STRENGTH
GRAY CAST IRON PIPE
American National Standards Institute Standard A21.1
(AWWA C101)**

The tables below are reproduced from ANSI Standard A21.1 (AWWA C101) and are repeated here for convenience. They are computed for metal of 21,000 psi minimum burst tensile strength and 45,000 psi minimum modulus of rupture.

Laying Conditions

A—Flat bottom trench, untamped backfill. F—Bedded in gravel or sand, backfill tamped.
B—Flat bottom trench, tamped backfill.

Nominal Inside Diameter Inches	Working Pressure psi	2½ Feet of Cover			3½ Feet of Cover			5 Feet of Cover			8 Feet of Cover		
		Laying Condition			Laying Condition			Laying Condition			Laying Condition		
		A	B	F	A	B	F	A	B	F	A	B	F
ANSI Class Thickness*													
3	50	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
	150	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
	250	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
350	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
	100	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
	200	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
	300	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	
6	50	21	21	21	21	21	21	21	21	21	21	21	21
	100	21	21	21	21	21	21	21	21	21	21	21	21
	150	21	21	21	21	21	21	21	21	21	21	21	21
	200	21	21	21	21	21	21	21	21	21	21	21	21
	250	21	21	21	21	21	21	21	21	21	21	21	21
	300	21	21	21	21	21	21	21	21	21	21	21	21
350	21	21	21	21	21	21	21	21	21	21	21	21	
8	50	20	20	20	20	20	20	20	20	20	20	20	20
	100	20	20	20	20	20	20	20	20	20	21	20	20
	150	20	20	20	20	20	20	20	20	20	21	20	20
	200	20	20	20	20	20	20	20	20	20	21	21	20
	250	20	20	20	20	20	20	20	20	20	22	21	20
	300	21	20	20	20	20	20	21	21	20	22	22	21
350	21	21	20	21	21	20	21	21	21	23	22	21	
10	50	20	20	20	20	20	20	20	20	20	21	21	20
	100	20	20	20	20	20	20	20	20	20	22	21	20
	150	21	20	20	20	20	20	21	20	20	22	22	21
	200	21	20	20	21	20	20	21	21	20	23	22	21
	250	21	21	20	21	21	20	22	21	21	23	23	22
	300	22	21	21	22	21	21	22	22	21	23	23	22
350	22	22	22	22	22	22	23	23	22	24	23	23	
12	50	21	20	20	20	20	20	21	20	20	22	21	20
	100	21	20	20	21	20	20	21	20	20	22	22	21
	150	21	21	20	21	20	20	21	20	20	23	22	21
	200	22	21	20	21	21	20	22	21	20	23	22	22
	250	22	22	20	22	21	20	22	22	21	24	23	22
	300	22	22	21	22	22	21	23	22	22	24	23	23
350	23	22	22	23	22	22	23	23	22	24	24	23	

* Thickness class includes allowances for foundry practice, corrosion, and either water hammer or truck load, whichever is greater.

STANDARD ANSI CLASS THICKNESSES OF 21/45 STRENGTH GRAY CAST IRON PIPE

American National Standards Institute Manual A21.1 (AWWA H1)

Nominal Inside Diameter Inches	Working Pressure psi	2½ Feet of Cover			3½ Feet of Cover			5 Feet of Cover			8 Feet of Cover		
		Laying Condition			Laying Condition			Laying Condition			Laying Condition		
		A	B	F	A	B	F	A	B	F	A	B	F
ANSI Class Thickness*													
14	50	21	21	21	21	21	21	21	21	21	23	22	21
	100	22	21	21	21	21	21	22	21	21	23	23	21
	150	22	21	21	22	21	21	22	21	21	24	23	22
	200	23	22	21	22	21	21	23	22	21	24	24	23
	250	23	22	21	23	22	21	23	23	22	25	24	23
	300	23	23	22	23	23	22	24	23	23	25	24	24
	350	24	23	23	24	24	23	24	24	24	25	25	24
16	50	22	21	21	21	21	21	22	21	21	23	22	21
	100	22	21	21	22	21	21	22	21	21	24	23	22
	150	22	21	21	22	21	21	23	22	21	24	23	22
	200	23	22	21	23	22	21	23	22	22	24	24	23
	250	23	22	22	23	22	22	23	23	22	25	24	23
	300	24	23	22	23	23	23	24	23	23	25	25	24
	350	24	23	23	24	24	23	25	24	24	26	25	25
18	50	22	21	21	21	21	21	22	21	21	23	22	21
	100	22	21	21	22	21	21	22	21	21	23	22	22
	150	22	21	21	22	21	21	23	22	21	24	23	22
	200	23	22	21	22	22	21	23	22	22	24	23	23
	250	23	22	21	23	22	22	23	23	22	25	24	23
	300	24	23	22	23	23	23	24	24	23	25	25	24
	350	24	23	23	24	24	24	25	24	24	26	25	25
20	50	21	21	21	21	21	21	22	21	21	23	22	21
	100	22	21	21	22	21	21	22	21	21	23	22	21
	150	22	21	21	22	21	21	23	22	21	24	23	22
	200	23	22	21	23	22	21	23	22	21	24	23	22
	250	23	22	21	23	22	22	24	23	22	25	24	23
	300	24	23	22	24	23	23	24	24	23	25	24	24
	350	24	24	23	24	24	24	25	24	24	26	25*	25
24	50	22	21	21	22	21	21	22	21	21	23	22	21
	100	22	21	21	22	21	21	23	21	21	24	23	21
	150	23	21	21	22	21	21	23	22	21	24	23	22
	200	23	22	21	23	22	21	24	22	22	25	24	23
	250	24	23	22	24	22	22	24	23	23	25	24	24
	300	24	23	23	24	23	23	25	24	24	26	25	24
	350	25	24	24	25	24	24	25	25	25	26	26	25

* Thickness class includes allowances for foundry practice, corrosion, and either water hammer or truck load, whichever is greater.

STANDARD THICKNESS CLASS FOR GRAY CAST IRON PIPE

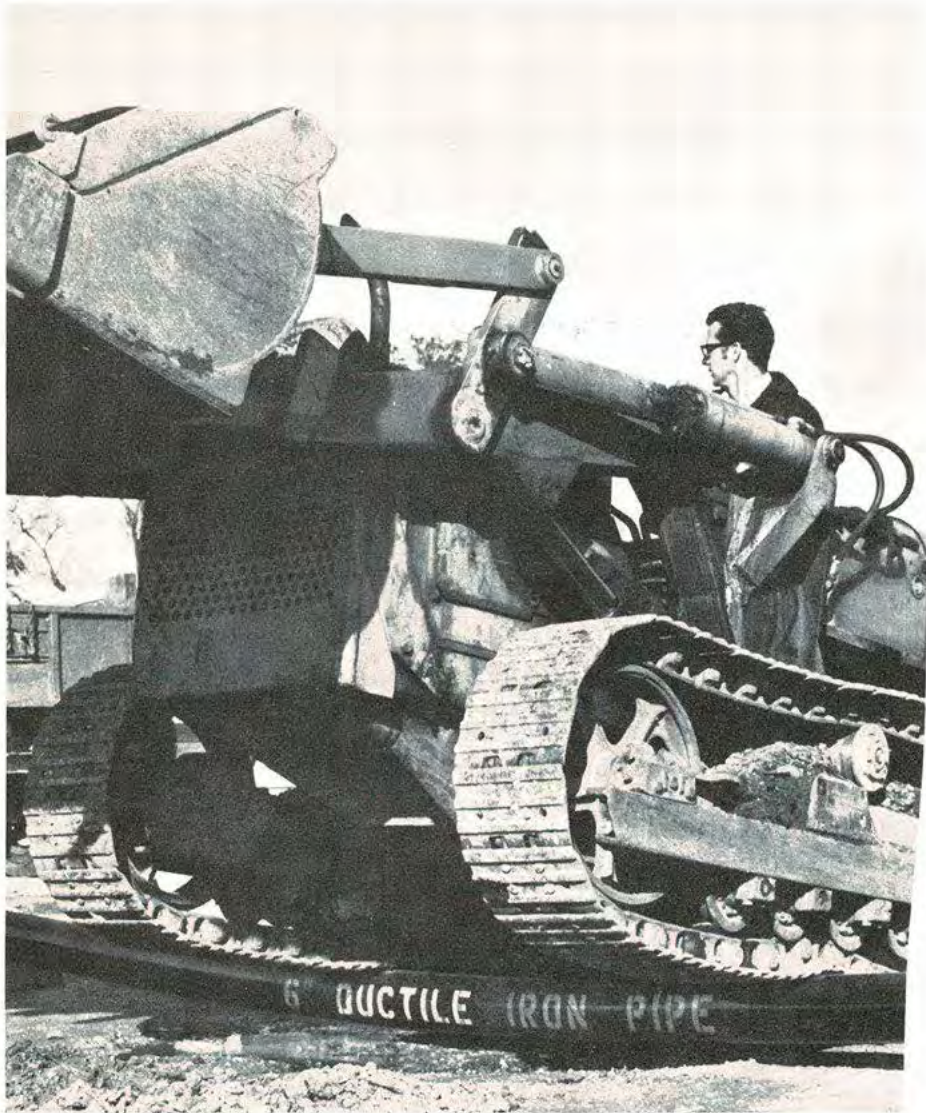
Nominal Diameter Inches	Standard Class Thickness									
	20	21	22	23	24	25	26	27	28	29
3	..	..	.32	.35	.38	.41	.44	.48	.52	.56
4	..	.32	.35	.38	.41	.44	.48	.52	.56	.60
6	..	.35	.38	.41	.44	.48	.52	.56	.60	.65
8	.35	.38	.41	.44	.48	.52	.56	.60	.65	.70
10	.38	.41	.44	.48	.52	.56	.60	.65	.70	.76
12	.41	.44	.48	.52	.56	.60	.65	.70	.76	.82
14	.43	.48	.51	.55	.59	.64	.69	.75	.81	.87
16	.46	.50	.54	.58	.63	.68	.73	.79	.85	.92
18	.50	.54	.58	.63	.68	.73	.79	.85	.92	.99
20	.53	.57	.62	.67	.72	.78	.84	.91	.98	1.06
24	.58	.63	.68	.73	.79	.85	.92	.99	1.07	1.16

Federal Standards for Cast Iron Pipe

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WW-P-421 Federal Specification for Pipe; Water Cast Iron (Bell and Spigot) adopted in July, 1931, contains tables showing pipe wall thicknesses for diameters 4 inches through 24 inches for Class 150 and Class 250 pipe. These thickness classes are now obsolete. Emergency Standard EWW-P-421 was used during World War II. The thickness classes in the original 1931 standard were revised in WW-P-421b (March, 1955) to include thickness classes which corresponded to those in ANSI Standards. At that time, ANSI Standards for cast iron pipe were made a part of the Federal Specification by reference. WW-P-421c (September, 1967) also incorporates ANSI Standards for Gray and Ductile Cast Iron Pipe by reference and shows pipe wall thicknesses which correspond to those standards. WW-P-421c does not list pipe wall thicknesses but rather specifies that the pipe shall be furnished for installation with five feet of cover, Laying Condition B, unless otherwise stated, and that pipe wall thicknesses shown in ANSI Standards A21.6, A21.8 and A21.51 shall be used.

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The high strength and ruggedness
of Ductile Iron Pipe are demonstrated

SECTION III

Ductile Iron Pipe

Introduction

Ductile iron was originally invented by a member company of CIPRA 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 market place.

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, gas 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 VI). As with gray cast iron pipe, protection from severe environmental factors is available (see Section VIII).

Ductile iron pipe provides versatility in design and while it may be designed in accordance with details of ANSI A21.50 (AWWA C150), 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, follow the general procedure of ANSI A21.50.

Ductile iron pipe is manufactured in accordance with ANSI Standards A21.51 (AWWA C 151), A21.52 and Federal Specification WW-P-421c. The outstanding characteristics of ductile iron pipe result from its unique metallurgical properties effected during the manufacturing process.

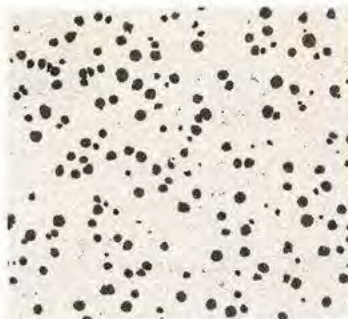
Metallurgy of Ductile Iron Pipe

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.



Comparison of Graphite Particles

The gray cast iron on the left shows flake graphitic particles. The ductile iron on the right has spheroidal graphite.

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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 A21.51 (AWWA C151) and ANSI A21.52 Ductile Iron Pipe Standards 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 generally exceeds that of gray cast iron pipe.

Ductile Iron Pipe Design

The method of thickness design of ductile iron pipe presented in ANSI A21.50 (AWWA C150) 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 the 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 the bending stress developed at the pipe invert. This approach provides a uniform stress level in contrast to a design based on a uniform percentage deflection, which results in wide variations in stress and can result in undesirably high bending stresses. The standard provides a formula for supplementary calculation of deflection, if desired. Numerous calculations have shown, however, that the deflection of 3-in. through 54-in. pipe designed for bending stress according to the procedure in the standard will not exceed 3 percent of the outside diameter of the pipe, a deflection at

which the cement linings will not be damaged. Cement linings are not used for gas pipe.

2. **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.
3. **Trench factors.** The design equation for bending stress 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 are shown in Table 50.2 of the standard.

The design equation for bending stress, which incorporates 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.

4. **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.
5. **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 A21.51 (AWWA C151) include an allowance of 100 psi for surges.
6. **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.

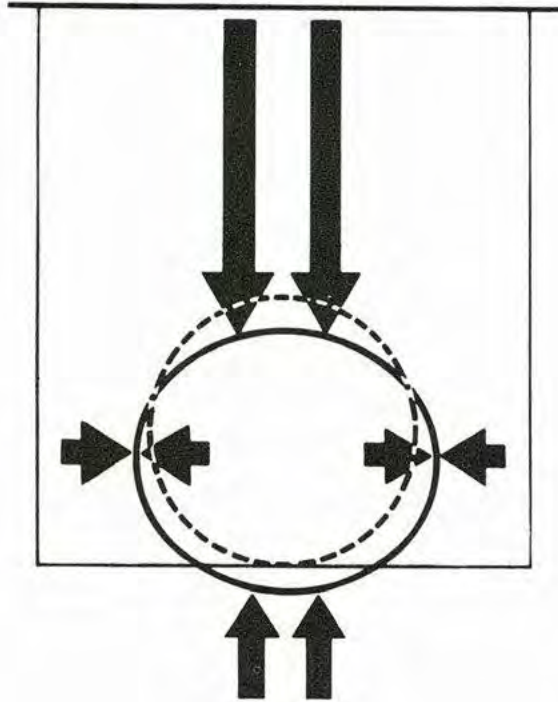
In the calculations for earth loads, the unit weight of 120 lbs. per cubic foot for backfill soil is used. Soil weights generally vary from 110 to 130 lbs. per cubic foot. Experience has shown that 120 lbs. per cubic foot is commonly considered to be a conservative value for most installations.

7. **Allowance for truck superload.** In computing ductile iron pipe thicknesses, truck loads are added to earth loads. The truck superload allowance is a single AASHO 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.
8. **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.
9. **Service allowance.** Comparative corrosion tests of cast iron and ductile iron pipe have proved that the corrosion resistance of ductile iron pipe is greater than that of gray cast iron pipe. ANSI design thickness is increased by 0.08 in. to provide an arbitrary service allowance. CIPRA 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 VIII).
10. **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.
11. **Thickness for tapping.** Some utilities have established minimum numbers of threads for tapped holes in pipe. Consideration should be given to pipe wall thicknesses and tap size to insure serviceable threaded connections. Service conditions should indicate the extent of full-thread engagement necessary and the necessity for use of outside-sealing corporation stops, tapping saddles, or other fixtures. To facilitate checking the number of threads for taps of various sizes in different pipe thicknesses, appropriate tables are provided in the standards for ductile iron pipe, ANSI A21.51 (AWWA C151) and ANSI A21.52.

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.

FLEXIBLE DESIGN THEORY

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Portion of load transferred
to sidefill soil.

Reduced bending stress
in pipe wall due to
sidefill soil support.

**ANSI A21.50-1976
(AWWA C150-76)**

Revision of
A21.50-1971
(AWWA C150-71)

AMERICAN NATIONAL STANDARD
for the
THICKNESS DESIGN OF
DUCTILE-IRON PIPE

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SECRETARIATS

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

Revised edition approved by American National Standards Institute, Inc. Aug. 4, 1976

NOTICE

This Standard has been especially printed by the American Water Works Association for incorporation into this volume. It is current as of December 1, 1975. 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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American National Standard

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WALTER AMORY, *Vice-Chairman*

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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:

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EDWARD C. SEARS, *Vice-Chairman*
JAMES B. RAMSEY, *Secretary*

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Foreword

This foreword is for information only and is not a part of ANSI A21.50 (AWWA C150).

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 co-secretariats have been A.G.A., 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 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 when needed, as well as other matters pertaining to pipe standards.

The first edition of A21.50, the standard for thickness design of ductile-iron pipe, was issued in 1965 and a revision was issued in 1971. Subcommittee 1 reviewed the 1971 edition and submitted a proposed revision to American National Standards Committee A21 in 1975.

Major Revisions

The basic design procedures are unchanged from the 1965 and 1971

editions. Certain design parameters have been changed to the following.

1. Trench load, which includes earth load and truck load, is expressed as vertical pressure in pounds per square inch. Earth loads for all pipe sizes are based on the prism load concept. Truck load is based on a single AASHTO* H-20 truck with 16 000-lb wheel load and 1.5 impact factor. Truck load is included at all depths of cover. In addition to tabulated truck loads, equations are included for complete calculation of truck loads.

2. The design ring bending stress is 48 000 psi, which provides safety factors under trench loading of at least 1.5 based on ring yield strength, and at least 2.0 based on ultimate strength of the material.

3. The design pipe deflection is 3 per cent of the outside diameter. Tests have shown that 3 per cent deflection is permissible without causing any damage to cement linings of ductile-iron pipe.

4. The standard laying conditions have been expanded to include five types. Types 1, 2, and 5 replace A, B, and S, respectively, in A21.50-1971. Types 3 and 4 have been added to provide a wider selection of laying conditions.

5. The design for internal pressure is based on a 2.0 safety factor. The design pressure is obtained by adding 100-psi surge allowance to the working pressure and multiplying the sum by the 2.0 safety factor. (If anticipated surge pressures are greater than 100

* American Association of State Highway and Transportation Officials.

AMERICAN NATIONAL STANDARD

psi, the maximum anticipated pressure must be used.) The resulting design pressure is then applied to the minimum yield strength in tension of 42 000 psi.

6. The standard thickness classes have been renumbered. Class 1 becomes Class 51, Class 2 becomes Class 52, and so on. Class 50 has been added for 6–54-in. pipe and Class 51

has been expanded to include 3–12-in. pipe.

7. The tables have been modified to reflect the preceding changes. Also, a table has been added to show rated working pressure and maximum depth of cover for all the standard laying conditions and standard thickness classes.

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 A21.51 (AWWA, C151), "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 12-14 directly.

Table 12 lists thicknesses for standard laying conditions and depths of cover up to 32 ft.

Table 13 lists thicknesses for 150-350 psi water working pressure.

The greater thickness from Table 12 or 13 for given trench load or internal pressure should be used.

Table 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 1 gives trench load, including earth load, P_e , plus truck load P_t , for 2.5-32 ft cover.

b. Determine the standard laying condition from the descriptions in Table 2 and select the appropriate table for diameter-thickness ratios from Tables 7-11. 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 7-11 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.)

pates additional loads because of frost, the design load should be increased accordingly.

50-4.4 *Truck load, P_t .* The truck loads shown in Table 1 were computed by Eq 5 using the surface load factors in Table 6 and the reduction factors R from Table 4 for a single AASHTO H-20 truck on unpaved road or flexible pavement, 16 000-lb wheel load, and 1.5 impact factor. The surface load factors in Table 6 were calculated by Eq 6 for a single concentrated wheel load centered over an effective pipe length of 3 ft.

50-4.5 *Design for trench load.* Tables 7-11, 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, 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 per cent 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_z are given in Table 2.

Tables similar to Tables 7-11 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, $\frac{D}{t}$ and $\frac{D}{t_1}$, using Eq 2 and 3 with values of E' , K_b , and K_z appropriate to the bedding and backfill conditions.

Design Equations

$$t = \frac{P_t D}{2S} \tag{1}$$

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

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

$$P_s = \frac{wH}{144} = \frac{120H}{144} = \frac{H}{1.2} \tag{4}$$

$$P_t = \frac{C \cdot R \cdot P \cdot F}{12D} \tag{5}$$

$$C = \frac{1}{3} - \frac{2}{3\pi} \arcsin \left[H \sqrt{\frac{A^2 + H^2 + 1.5^2}{(A^2 + H^2)(H^2 + 1.5^2)}} \right] + \frac{AH}{\pi \sqrt{A^2 + H^2 + 1.5^2}} \left[\frac{1}{A^2 + H^2} + \frac{1}{H^2 + 1.5^2} \right] \tag{6}$$

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Explanation of Symbols for Equations

- A = Outside radius of pipe in feet = $\frac{D}{24}$
 C = Surface load factor (Table 6)
 D = Outside diameter in inches (Table 5)
 E = Modulus of elasticity (24×10^6 psi)
 E' = Modulus of soil reaction in pounds per square inch (Table 2)
 F = Impact factor—1.5
 f = Design bending stress—48 000 psi
 H = Depth of cover in feet
 K_b = Bending moment coefficient (Table 2)
 K_z = Deflection coefficient (Table 2)
 P = Wheel load—16 000 lb
 P_e = Earth load in pounds per square inch
 P_i = Design internal pressure in pounds per square inch = 2.0 (working pressure + 100 psi surge allowance)
 P_t = Truck load in pounds per square inch
 P_v = Trench load in pounds per square inch = $P_e + P_t$
 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 receive little or no load from the wheels (Table 4)
 S = Minimum yield strength in tension—42 000 psi
 t = Net thickness in inches
 t_1 = Minimum thickness in inches ($t + 0.08$)
 w = Soil weight—120 pounds per cubic foot
 Δx = Design deflection in inches $\left(\frac{\Delta x}{D} = 0.03\right)$

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

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THICKNESS DESIGN OF DUCTILE-IRON PIPE

TABLE 50.1—(cont.)

Depth of Cover <i>ft</i>	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 <i>ft</i>	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

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TABLE 50.2

Design Values for Standard Laying Conditions

Laying Condition*	Description	E'	Bedding Angle deg	K_b	K_z
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 $\frac{1}{2}$ 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

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* 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

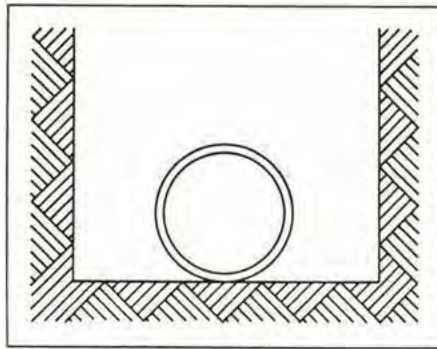
Size in.	Casting Tolerance in.
3-8	0.05
10-12	0.06
14-42	0.07
48	0.08
54	0.09

TABLE 50.4

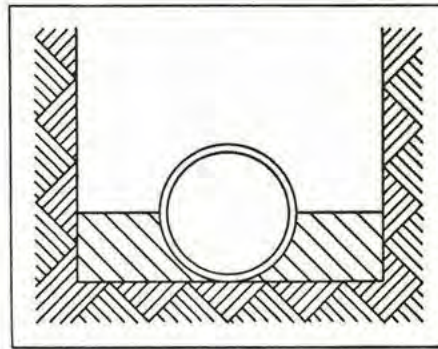
Reduction Factors R for Truck Load Calculations

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

THICKNESS DESIGN OF DUCTILE-IRON PIPE

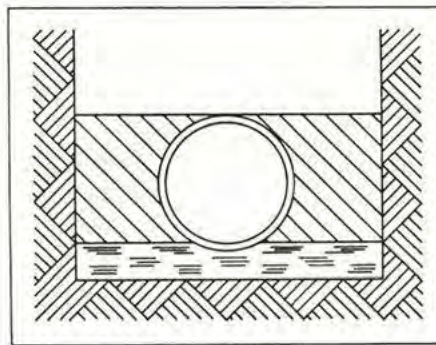


Type 1

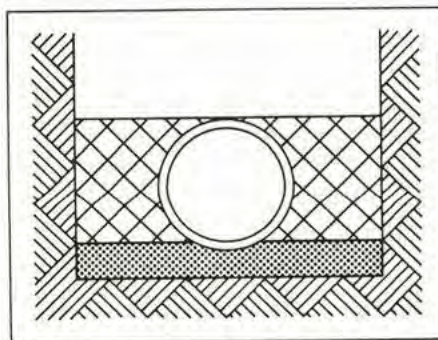


Type 2

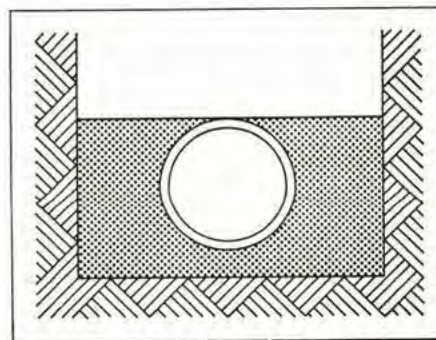
1
8
3



Type 3



Type 4



Type 5

Figure 1. Standard Pipe Laying Conditions

See Table 2

AMERICAN NATIONAL STANDARD

TABLE 50.5

Standard Thickness Classes of Ductile-Iron Pipe

Size <i>in.</i>	Outside Diameter— <i>in.</i>	Thickness Class						
		50	51	52	53	54	55	56
		Thickness— <i>in.</i>						
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

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THICKNESS DESIGN OF DUCTILE-IRON PIPE

TABLE 50.6

Surface Load Factors for Single Truck on Unpaved Road

Depth of Cover <i>ft</i>	Pipe Size— <i>in.</i>							
	3	4	6	8	10	12	14	16
	Surface Load Factor— <i>C</i>							
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 <i>ft</i>	Pipe Size— <i>in.</i>							
	18	20	24	30	36	42	48	54
	Surface Load Factor— <i>C</i>							
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

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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	$\frac{D_t}{t}$ or $\frac{D}{t_1}$	Bending Stress Design	Deflection Design	$\frac{D_t}{t}$ 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			
6.15	4.56	131	10.37	8.85	90
			10.55	9.06	89
6.21	4.61	130	10.74	9.29	88
6.27	4.66	129	10.93	9.53	87
			11.13	9.78	86

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TABLE 50.7—(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 $\frac{D}{t_1}$
11.34	10.04	85	21.91	26.54	58
11.55	10.31	84	22.63	27.85	57
11.78	10.60	83	23.38	29.26	56
12.01	10.90	82			
12.25	11.22	81	24.18	30.77	55
			25.02	32.39	54
12.50	11.56	80	25.92	34.15	53
12.76	11.91	79	26.86	36.05	52
13.03	12.28	78	27.87	38.10	51
13.31	12.67	77			
13.60	13.08	76	28.94	40.32	50
			30.07	42.73	49
13.91	13.51	75	31.28	45.35	48
14.23	13.97	74	32.57	48.20	47
14.56	14.45	73	33.95	51.31	46
14.91	14.96	72			
15.27	15.50	71	35.42	54.72	45
			37.00	58.44	44
15.65	16.07	70	38.69	62.53	43
16.05	16.68	69	40.50	67.03	42
16.46	17.32	68	42.46	71.99	41
16.89	18.00	67			
17.35	18.73	66	44.56	77.47	40
			46.84	83.54	39
17.83	19.50	65	49.30	90.28	38
18.33	20.32	64	51.96	97.80	37
18.85	21.19	63	54.86	106.20	36
19.40	22.12	62			
19.98	23.12	61	58.02	115.62	35
			61.46	126.21	34
20.59	24.18	60	65.23	138.18	33
21.23	25.32	59	69.36	151.73	32
			73.92	167.15	31

* $E' = 150$; $K_1 = 0.235$; $K_2 = 0.108$.

† 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.

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TABLE 50.8

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

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

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THICKNESS DESIGN OF DUCTILE-IRON PIPE

TABLE 50.8—(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 $\frac{D}{t_1}$
14.74	12.94	85	26.95	31.26	57
14.97	13.22	84	27.77	32.71	56
15.21	13.52	83			
15.46	13.83	82	28.64	34.26	55
15.72	14.16	81	29.56	35.93	54
			30.53	37.74	53
15.99	14.50	80	31.57	39.69	52
16.28	14.86	79	32.67	41.80	51
16.57	15.24	78			
16.87	15.64	77	33.84	44.09	50
17.19	16.06	76	35.08	46.56	49
			36.41	49.26	48
17.52	16.51	75	37.83	52.19	47
17.86	16.98	74	39.34	55.40	46
18.22	17.48	73			
18.59	18.00	72	40.96	58.89	45
18.98	18.56	71	42.70	62.73	44
			44.57	66.93	43
19.39	19.14	70	46.57	71.56	42
19.82	19.77	69	48.73	76.66	41
20.27	20.43	68			
20.73	21.13	67	51.06	82.29	40
21.23	21.87	66	53.57	88.54	39
			56.30	95.48	38
21.74	22.67	65	59.25	103.21	37
22.28	23.51	64	62.46	111.85	36
22.85	24.41	63			
23.45	25.37	62	65.96	121.54	35
24.07	26.39	61	69.79	132.44	34
			73.98	144.74	33
24.74	27.49	60	78.57	158.68	32
25.43	28.66	59	83.64	174.54	31
26.17	29.91	58			

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

† 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.

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TABLE 50.9

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

Trench Load (P_v)— <i>psi</i>			Trench Load (P_v)— <i>psi</i>		
Bending Stress Design	Deflection Design	$\frac{D_t^\dagger}{t}$ or $\frac{D}{t_1}$	Bending Stress Design	Deflection Design	$\frac{D_t^\dagger}{t}$ or $\frac{D}{t_1}$
3.25	7.26	310	5.62	7.52	226
3.29	7.27	308	5.70	7.53	224
3.33	7.27	306	5.79	7.54	222
3.37	7.27	304			
3.41	7.28	302	5.87	7.55	220
			5.96	7.56	218
3.45	7.28	300	6.04	7.58	216
3.49	7.28	298	6.13	7.59	214
3.54	7.29	296	6.22	7.60	212
3.58	7.29	294			
3.63	7.30	292	6.32	7.62	210
			6.41	7.63	208
3.67	7.30	290	6.51	7.65	206
3.72	7.30	288	6.60	7.66	204
3.76	7.31	286	6.70	7.68	202
3.81	7.31	284			
3.86	7.32	282	6.80	7.70	200
			6.91	7.72	198
3.91	7.32	280	7.01	7.74	196
3.96	7.33	278	7.12	7.76	194
4.01	7.33	276	7.22	7.78	192
4.06	7.34	274			
4.11	7.34	272	7.33	7.80	190
			7.45	7.82	188
4.17	7.35	270	7.56	7.84	186
4.22	7.35	268	7.68	7.87	184
4.28	7.36	266	7.80	7.89	182
4.33	7.36	264			
4.39	7.37	262	7.92	7.92	180
			8.04	7.95	178
4.45	7.38	260	8.16	7.98	176
4.51	7.38	258	8.29	8.01	174
4.57	7.39	256	8.42	8.04	172
4.63	7.39	254			
4.69	7.40	252	8.55	8.07	170
			8.62	8.09	169
4.76	7.41	250	8.69	8.11	168
4.82	7.42	248	8.75	8.13	167
4.89	7.42	246	8.82	8.14	166
4.96	7.43	244			
5.03	7.44	242	8.89	8.16	165
			8.96	8.18	164
5.10	7.45	240	9.03	8.20	163
5.17	7.46	238	9.10	8.22	162
5.24	7.47	236	9.17	8.24	161
5.31	7.48	234			
5.39	7.48	232	9.25	8.27	160
			9.32	8.29	159
5.47	7.49	230	9.39	8.31	158
5.54	7.51	228	9.47	8.33	157
			9.54	8.36	156

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THICKNESS DESIGN OF DUCTILE-IRON PIPE

TABLE 50.9—(cont.)

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

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TABLE 50.9—(cont.)

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 $\frac{D}{t_1}$
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.

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THICKNESS DESIGN OF DUCTILE-IRON PIPE

TABLE 50.10

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

Trench Load (P_e)— <i>psi</i>			Trench Load (P_e)— <i>psi</i>		
Bending Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$	Bending Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$
5.93	9.70	310	9.95	9.97	226
6.00	9.70	308	10.08	9.98	224
6.07	9.71	306	10.21	9.99	222
6.14	9.71	304			
6.21	9.71	302	10.35	10.01	220
			10.49	10.02	218
6.29	9.72	300	10.62	10.03	216
6.36	9.72	298	10.77	10.05	214
6.43	9.73	296	10.91	10.06	212
6.51	9.73	294			
6.59	9.73	292	11.05	10.08	210
			11.20	10.09	208
6.67	9.74	290	11.35	10.11	206
6.74	9.74	288	11.50	10.13	204
6.83	9.75	286	11.66	10.15	202
6.91	9.75	284			
6.99	9.76	282	11.81	10.17	200
			11.97	10.19	198
7.08	9.76	280	12.13	10.21	196
7.16	9.77	278	12.29	10.23	194
7.25	9.77	276	12.45	10.25	192
7.34	9.78	274			
7.43	9.78	272	12.62	10.27	190
			12.79	10.30	188
7.52	9.79	270	12.96	10.32	186
7.61	9.79	268	13.13	10.35	184
7.71	9.80	266	13.30	10.37	182
7.80	9.81	264			
7.90	9.81	262	13.48	10.40	180
			13.66	10.43	178
8.00	9.82	260	13.84	10.46	176
8.10	9.83	258	14.02	10.50	174
8.20	9.83	256	14.20	10.53	172
8.31	9.84	254			
8.41	9.85	252	14.39	10.57	170
			14.48	10.59	169
8.52	9.86	250	14.57	10.60	168
8.63	9.86	248	14.67	10.62	167
8.74	9.87	246	14.76	10.64	166
8.85	9.88	244			
8.97	9.89	242	14.86	10.66	165
			14.96	10.69	164
9.08	9.90	240	15.05	10.71	163
9.20	9.91	238	15.15	10.73	162
9.32	9.92	236	15.25	10.75	161
9.44	9.93	234			
9.57	9.94	232	15.34	10.78	160
			15.44	10.80	159
9.69	9.95	230	15.54	10.82	158
9.82	9.96	228	15.64	10.85	157
			15.74	10.87	156

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TABLE 50.10—(cont.)

Trench Load (P_v)— <i>psi</i>			Trench Load (P_v)— <i>psi</i>		
Bending Stress Design	Deflection Design	$\frac{Dt}{t}$ or $\frac{D}{t_1}$	Bending Stress Design	Deflection Design	$\frac{Dt}{t}$ or $\frac{D}{t_1}$
15.84	10.90	155	20.69	13.19	112
15.94	10.93	154	20.82	13.29	111
16.04	10.96	153			
16.14	10.98	152	20.96	13.39	110
16.24	11.01	151	21.10	13.50	109
			21.24	13.61	108
16.34	11.04	150	21.39	13.73	107
16.45	11.07	149	21.54	13.85	106
16.55	11.11	148			
16.65	11.14	147	21.69	13.98	105
16.76	11.17	146	21.84	14.11	104
			22.00	14.24	103
16.86	11.21	145	22.16	14.38	102
16.96	11.24	144	22.32	14.53	101
17.07	11.28	143			
17.18	11.31	142	22.49	14.68	100
17.28	11.35	141	22.66	14.84	99
			22.83	15.01	98
17.39	11.39	140	23.01	15.18	97
17.50	11.43	139	23.20	15.36	96
17.60	11.48	138			
17.71	11.52	137	23.38	15.55	95
17.82	11.56	136	23.58	15.75	94
			23.78	15.95	93
17.93	11.61	135	23.99	16.17	92
18.04	11.66	134	24.20	16.39	91
18.15	11.71	133			
18.26	11.76	132	24.42	16.62	90
18.37	11.81	131	24.64	16.87	89
			24.88	17.12	88
18.49	11.86	130	25.12	17.39	87
18.60	11.92	129	25.37	17.67	86
18.72	11.97	128			
18.83	12.03	127	25.63	17.97	85
18.95	12.09	126	25.90	18.28	84
			26.18	18.60	83
19.06	12.15	125	26.47	18.94	82
19.18	12.22	124	26.77	19.30	81
19.30	12.28	123			
19.42	12.35	122	27.09	19.67	80
19.54	12.42	121	27.42	20.07	79
			27.76	20.48	78
19.66	12.50	120	28.11	20.92	77
19.78	12.57	119	28.49	21.38	76
19.91	12.65	118			
20.04	12.73	117	28.87	21.87	75
20.16	12.82	116	29.28	22.38	74
			29.70	22.93	73
20.29	12.91	115	30.15	23.50	72
20.42	13.00	114	30.62	24.11	71
20.55	13.09	113			

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THICKNESS DESIGN OF DUCTILE-IRON PIPE

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

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

† 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.

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TABLE 50.11

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

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

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THICKNESS DESIGN OF DUCTILE-IRON PIPE

TABLE 50.11—(cont.)

Trench Load (P_v)— psi			Trench Load (P_v)— psi		
Bending Stress Design	Deflection Design	$\frac{D_t}{t}$ or $\frac{D}{t_1}$	Bending Stress Design	Deflection Design	$\frac{D_t}{t}$ or $\frac{D}{t_1}$
14.79	15.33	280	24.24	15.86	194
14.96	15.34	278	24.50	15.88	192
15.13	15.34	276			
15.30	15.35	274	24.77	15.91	190
15.48	15.35	272	25.04	15.93	188
			25.31	15.96	186
15.65	15.36	270	25.59	15.99	184
15.83	15.37	268	25.86	16.02	182
16.02	15.37	266			
16.20	15.38	264	26.13	16.06	180
16.39	15.39	262	26.41	16.09	178
			26.68	16.12	176
16.58	15.40	260	26.96	16.16	174
16.77	15.40	258	27.23	16.20	172
16.97	15.41	256			
17.16	15.42	254	27.51	16.24	170
17.36	15.43	252	27.65	16.26	169
			27.78	16.28	168
17.57	15.44	250	27.92	16.31	167
17.77	15.45	248	28.06	16.33	166
17.98	15.45	246			
18.19	15.46	244	28.19	16.35	165
18.40	15.47	242	28.33	16.37	164
			28.47	16.40	163
18.62	15.48	240	28.60	16.42	162
18.84	15.49	238	28.74	16.45	161
19.06	15.51	236			
19.28	15.52	234	28.87	16.48	160
19.51	15.53	232	29.01	16.50	159
			29.15	16.53	158
19.73	15.54	230	29.28	16.56	157
19.97	15.55	228	29.41	16.59	156
20.20	15.57	226			
20.43	15.58	224	29.55	16.62	155
20.67	15.59	222	29.68	16.65	154
			29.82	16.68	153
20.91	15.61	220	29.95	16.71	152
21.16	15.62	218	30.08	16.74	151
21.40	15.64	216			
21.65	15.65	214	30.21	16.78	150
21.90	15.67	212	30.34	16.81	149
			30.48	16.85	148
22.15	15.69	210	30.61	16.89	147
22.40	15.71	208	30.74	16.92	146
22.66	15.73	206			
22.92	15.75	204	30.87	16.96	145
23.18	15.77	202	30.99	17.00	144
			31.12	17.04	143
23.44	15.79	200	31.25	17.09	142
23.70	15.81	198	31.38	17.13	141
23.97	15.83	196			

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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 $\frac{D}{t_1}$
31.50	17.17	140	37.01	21.45	97
31.63	17.22	139	37.17	21.66	96
31.76	17.27	138			
31.88	17.32	137	37.34	21.87	95
32.01	17.37	136	37.52	22.09	94
			37.70	22.32	93
32.13	17.42	135	37.89	22.56	92
32.25	17.47	134	38.08	22.82	91
32.38	17.53	133			
32.50	17.58	132	38.28	23.08	90
32.62	17.64	131	38.49	23.36	89
			38.71	23.65	88
32.75	17.70	130	38.93	23.95	87
32.87	17.76	129	39.17	24.27	86
32.99	17.83	128			
33.11	17.89	127	39.41	24.60	85
33.23	17.96	126	39.67	24.95	84
			39.94	25.31	83
33.35	18.03	125	40.22	25.70	82
33.47	18.11	124	40.51	26.10	81
33.59	18.18	123			
33.71	18.26	122	40.82	26.52	80
33.83	18.34	121	41.14	26.97	79
			41.48	27.44	78
33.95	18.42	120	41.84	27.93	77
34.07	18.51	119	42.21	28.46	76
34.19	18.60	118			
34.31	18.69	117	42.60	29.01	75
34.43	18.78	116	43.02	29.59	74
			43.45	30.20	73
34.55	18.88	115	43.92	30.85	72
34.68	18.98	114	44.40	31.53	71
34.80	19.09	113			
34.92	19.20	112	44.91	32.26	70
35.05	19.31	111	45.46	33.03	69
			46.03	33.85	68
35.17	19.43	110	46.64	34.71	67
35.30	19.55	109	47.28	35.63	66
35.43	19.68	108			
35.56	19.81	107	47.96	36.61	65
35.69	19.95	106	48.68	37.65	64
			49.44	38.77	63
35.83	20.09	105	50.25	39.95	62
35.96	20.24	104	51.11	41.21	61
36.10	20.39	103			
36.25	20.55	102	52.02	42.57	60
36.39	20.72	101	52.99	44.01	59
			54.02	45.56	58
36.54	20.89	100	55.12	47.23	57
36.69	21.07	99	56.28	49.01	56
36.85	21.26	98			

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THICKNESS DESIGN OF DUCTILE-IRON PIPE

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
			99.67	126.56	38
65.14	63.07	50	104.32	136.11	37
67.00	66.13	49	109.40	146.78	36
68.99	69.46	48			
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.

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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.

THICKNESS DESIGN OF DUCTILE-IRON PIPE

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	50
	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	

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

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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
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.

THICKNESS DESIGN OF DUCTILE-IRON PIPE

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
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.

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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.)

Pipe 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
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 conditions other than Type 1.

TABLE 50.13

Thickness for Internal Pressure

Pipe Size in.	Rated Water Working Pressure*—psi									
	150		200		250		300		350	
	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	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.

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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†					
2 0 6	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.

THICKNESS DESIGN OF DUCTILE-IRON PIPE

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.

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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.

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**ANSI A21.51-1976
(AWWA C151-76)**

Revision of
A21.51-1971
(AWWA C151-71)

AMERICAN NATIONAL STANDARD

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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

Revised edition approved by American National Standards Institute, Inc., Aug. 4, 1976

NOTICE

This Standard has been especially printed by the American Water Works Association for incorporation into this volume. It is current as of December 1, 1975. 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

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WALTER AMORY, *Vice-Chairman*

User Members

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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:

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EDWARD C. SEARS, *Vice-Chairman*
JAMES B. RAMSEY, *Secretary*

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American Gas Association
American Society of Civil Engineers
American Society of Mechanical Engineers
American Society for Testing and Materials
American Water Works Association

Cast Iron Pipe Research Association

Individual Producer
Manufacturers' Standardization Society of
the Valve and Fittings Industry
New England Water Works Association
Naval Facilities Engineering Command
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Foreword

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

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 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 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 when needed, as well as other matters pertaining to pipe standards.

The first edition of A21.51, the standard for ductile-iron pipe for water and other liquids, was issued in 1965, and a revision was issued in 1971. Subcommittee 1 reviewed the 1971 edition and submitted a proposed revision to American National Standards Committee A21 in 1975.

Major Revisions

1. An additional minus tolerance of 0.02 in. is permitted along the barrel of the pipe for a distance not to ex-

ceed 12 in. The weight tolerance permitted for any single pipe is 6 per cent for pipe 12 in. or smaller and 5 per cent for pipe larger than 12 in.

2. The tables include data for the five standard laying conditions covered in A21.50–1976. Types 1, 2, and 3 replace A, B, and S, respectively, in A21.51–1971. Types 3 and 4 have been added to provide a wider selection of laying conditions.
3. The pipe thickness selection tables have been revised to reflect the changes in the 1976 edition of A21.50, the standard for thickness design of ductile-iron pipe.
4. The standard thickness classes have been renumbered. Class 1 becomes Class 51; Class 2 becomes Class 52; and so on. Class 50 has been added for 6–54-in. pipe, and Class 51 has been added for 3–12-in. pipe.
5. Pipe weights have been adjusted for 3–24-in. push-on joint pipe to reflect lighter bell weights based on push-on joint bells, which are more compatible with the barrel thicknesses of ductile-iron pipe.
6. A table (Table 3) has been added to show rated working pressure and maximum depth of cover of the standard laying conditions and standard thickness classes.

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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. No requirement for outside coating (Sec. 51-8.1).
b. Cement lining (Sec. 51-8.2). Ex-

perience 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. No requirement for inside coating (Sec. 51-8.3).
- d. Special coatings and linings (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 A21.51-1976
(AWWA C151-76)

Revision of
A21.51-1971
(AWWA C151-71)

American National Standard for

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

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

51-2.2 *Manufacturer.* The party that produces the pipe.

51-2.3 *Inspector.* The representative of the purchaser, authorized to inspect on behalf of the purchaser to determine whether or not the pipe meets this standard.

51-2.4 *Ductile iron.* A cast ferrous material in which a major part of the carbon content occurs as free carbon in nodular or spheroidal form.

51-2.5 *Mechanical joint.* The gasketed and bolted joint as detailed in

ANSI A21.11 (AWWA C111) of latest revision.

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

Sec. 51-3—General Requirements

51-3.1 Pipe with mechanical joints or push-on joints shall conform to the applicable dimensions and weights shown in the tables in this standard and to the applicable requirements of ANSI A21.11 (AWWA C111) of latest revision. Unless otherwise specified, the mechanical-joint glands shall be cast iron in accordance with ANSI 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 The nominal laying length of the pipe shall be as shown in the tables. A maximum of 20 per cent of the total number of pipe of each size specified in an order may be furnished by as much as 24 in. shorter than the

nominal laying length, and an additional 10 per cent may be furnished by as much as 6 in. shorter than nominal laying length.

Sec. 51-4—Inspection and Certification by Manufacturer

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

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51-4.2 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 standard.

51-4.3 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 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 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 gages 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 com-

ply 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 gaged with suitable gages 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 gages. Other socket dimensions shall be gaged as may be appropriate.

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

Size in.	Minus Tolerance in.
3-8	0.05
10-12	0.06
14-42	0.07
48	0.08
54	0.09

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

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

Sec. 51-8—Coatings and Linings

51-8.1 *Outside coating.* The out-

side coating for use under normal conditions shall be a bituminous coating approximately 1 mil 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.

51-8.2 *Cement-mortar linings.* Cement linings shall be in accordance with ANSI A21.4 (AWWA C104) of latest revision. 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 a bituminous material as thick as practicable (at least 1 mil) which conforms to all appropriate requirements for seal coat in ANSI 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. 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 $\frac{1}{2}$ in. in height.

Sec. 51-11—Weighing Pipe

Each pipe shall be weighed before the application of any lining or coating other than the bituminous 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 the midsection of the pipe wall. This specimen shall be machined and tested in accordance with Fig. 1 and ASTM E8-69, "Tension Testing of Metallic Materials." The yield strength shall be determined by the 0.2 per cent offset, half-of-pointer, or extension-under-load method. If check tests are to be made, the 0.2 per cent offset

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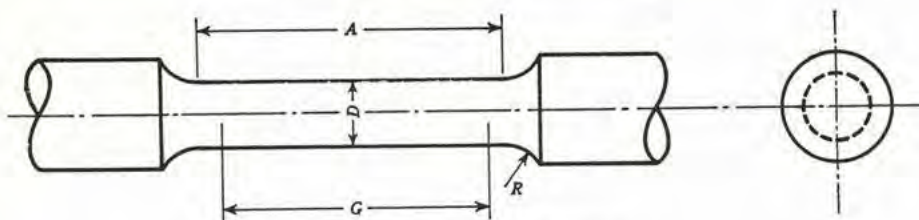


Fig. 1. Tensile-Test Specimen

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

Dimension	Standard Specimen 0.500 in. round	Small-Size Specimens Proportional to Standard			
		0.350 in. round	0.250 in. round	0.175 in. round	0.125 in. round
	Dimensions—in.				
<i>T</i> *	0.71 and greater	0.50–0.70	0.35–0.49	0.25–0.34	0.18–0.24
<i>G</i>	2.000 ± 0.005	1.400 ± 0.005	1.000 ± 0.005	0.700 ± 0.005	0.500 ± 0.005
<i>D</i>	0.500 ± 0.010	0.350 ± 0.007	0.250 ± 0.005	0.175 ± 0.005	0.125 ± 0.005
<i>R</i>	$\frac{3}{8}$ (min.)	$\frac{1}{4}$ (min.)	$\frac{3}{16}$ (min.)	$\frac{3}{32}$ (min.)	$\frac{3}{32}$ (min.)
<i>A</i>	2 $\frac{1}{4}$ (min.)	1 $\frac{3}{4}$ (min.)	1 $\frac{1}{4}$ (min.)	$\frac{3}{4}$ (min.)	$\frac{5}{8}$ (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. larger in diameter than the center on the standard specimen and not more than 0.003 in. 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.

method shall be used. All specimens shall be tested at room temperature [70F ± 10 (21C ± 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.
2. Minimum yield strength: 42 000 psi.
3. Minimum elongation: 10 per cent.

51–12.2 *Impact test.* Tests shall be made in accordance with ASTM E23–72 “Notched Charpy Tests,” ex-

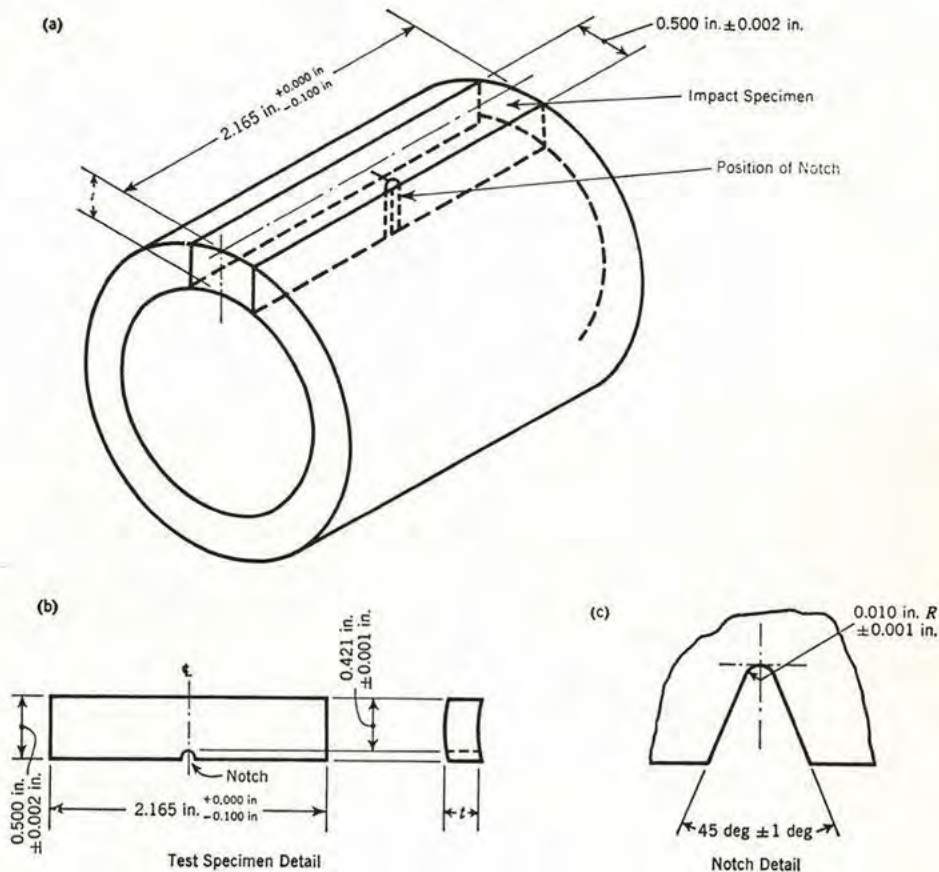
cept that specimens shall be 0.500 in. by full thickness of pipe wall. The notched impact test specimen shall be in accordance with Fig. 2. If the pipe wall thickness exceeds 0.40 in., the impact specimen may be machined to a nominal thickness of 0.40 in. In all tests, impact values are to be corrected to 0.40-in. wall thickness by calculations as follows:

Impact value (corrected)

$$= \frac{0.40}{t} \times \text{impact value (actual)}$$

in which *t* is the thickness of the specimen in inches (wall thickness of pipe).

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Fig. 2. Impact Test Specimen

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

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 for tests conducted at $70\text{ F} \pm 10$ ($21\text{C} \pm 6$).

51-12.3 *Sampling.* At least one tensile and impact sample shall be taken during each casting period of approximately 3 hr. Samples shall be selected

to represent extremes of pipe diameters and thicknesses properly.

Sec. 51-13—Additional Control Tests by Manufacturer

Low-temperature impact tests shall be made from at least one third of the test pipe specified in Sec. 51-12.3 to ensure compliance with a minimum corrected value of 3 ft-lb for tests conducted at -40 F (-40C). Test specimens shall be prepared and tested in accordance with Sec. 51-12.2.

In addition, the manufacturer shall conduct such other control 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.

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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†	
		Thick- ness in.	Thick- ness Class	Thick- ness in.	Thick- ness Class	Thick- ness in.	Thick- ness Class	Thick- ness in.	Thick- ness Class	Thick- ness in.	Thick- ness 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	

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* 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.

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TABLE 51.1—(cont.)

Size <i>in.</i>	Depth of Cover <i>ft.</i>	Laying Condition									
		Type 1†		Type 2†		Type 3†		Type 4†		Type 5†	
		Thick- ness <i>in.</i>	Thick- ness Class	Thick- ness <i>in.</i>	Thick- ness Class	Thick- ness <i>in.</i>	Thick- ness Class	Thick- ness <i>in.</i>	Thick- ness Class	Thick- ness <i>in.</i>	Thick- ness 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.

DUCTILE-IRON PIPE

TABLE 51.1—(cont.)

Size in.	Depth of Cover ft.	Laying Condition									
		Type 1†		Type 2‡		Type 3‡		Type 4‡		Type 5‡	
		Thick- ness in.	Thick- ness Class	Thick- ness in.	Thick- ness Class	Thick- ness in.	Thick- ness Class	Thick- ness in.	Thick- ness Class	Thick- ness in.	Thick- ness 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.

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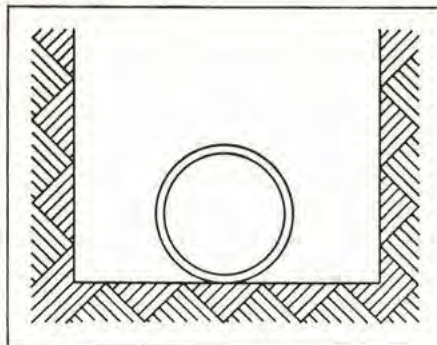
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TABLE 51.1—(cont.)

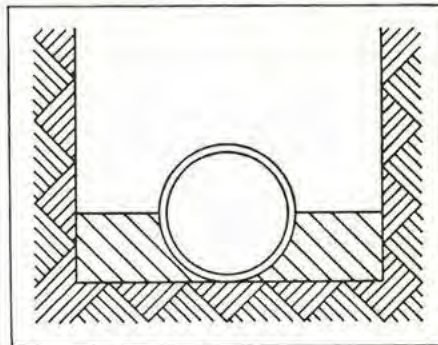
Size in.	Depth of Cover ft.	Laying Condition									
		Type 1†		Type 2†		Type 3†		Type 4†		Type 5†	
		Thick- ness in.	Thick- ness Class	Thick- ness in.	Thick- ness Class	Thick- ness in.	Thick- ness Class	Thick- ness in.	Thick- ness Class	Thick- ness in.	Thick- ness Class
36	2.5	‡	‡	0.43	50	0.43	50	0.43	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			0.57	50	0.57	50	0.57	50	0.57	50
	12			0.65	51	0.57	50	0.57	50	0.57	50
	14			0.65	51	0.57	50	0.57	50	0.57	50
	16			0.73	52	0.65	51	0.57	50	0.57	50
	20			0.81	53	0.73	52	0.65	51	0.57	50
	24			0.89	54	0.81	53	0.73	52	0.57	50
	28			1.05	56	0.89	54	0.81	53	0.65	51
32			—	—	0.97	55	0.89	54	0.73	52	
			—	—	—	—	0.97	55	0.81	53	

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

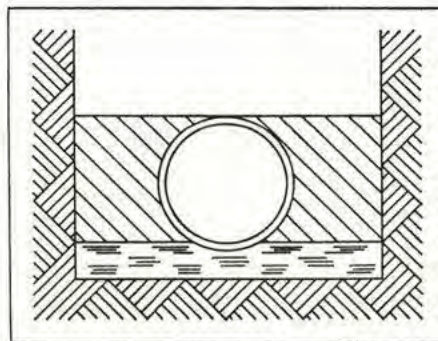
‡ For pipe 30 in. and larger, consideration should be given to the use of laying conditions other than Type 1



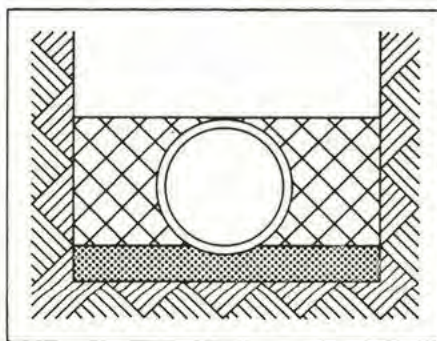
Type 1* Flat-bottom trench.† Loose backfill.



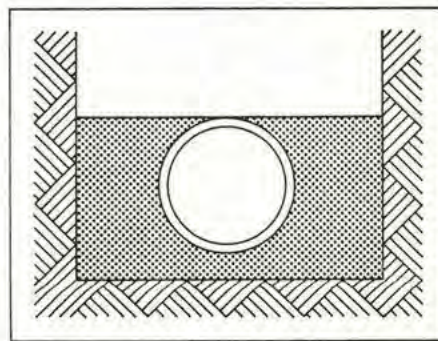
Type 2 Flat-bottom trench.† Backfill lightly consolidated to centerline of pipe.



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



Type 4 Pipe bedded in sand, gravel, or crushed stone to depth of $\frac{1}{3}$ pipe diameter, 4-in. minimum. Backfill compacted to top of pipe. (Approx. 80 per cent Standard Proctor, AASHTO § T-99)



Type 5 Pipe bedded to its centerline in compacted granular material, 4-in. minimum under pipe. Compacted granular or select \ddagger material to top of pipe. (Approx. 90 per cent Standard Proctor, AASHTO § T-99)

Fig. 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, D.C. 20004.

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TABLE 51.2
Standard Thickness for Internal Pressure

Pipe Size in.	Rated Water Working Pressure*—psi									
	150		200		250		300		350	
	Thick- ness in.	Thick- ness Class	Thick- ness in.	Thick- ness Class	Thick- ness in.	Thick- ness Class	Thick- ness in.	Thick- ness Class	Thick- ness in.	Thick- ness 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‡
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‡
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‡
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‡
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
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
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	

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* 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
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
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
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
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
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
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.

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DUCTILE-IRON PIPE

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	9	170	9.4	185	9.4
	52	0.28	3.96	9.9	9	185	10.4	205	10.4
	53	0.31	3.96	10.9	9	205	11.4	225	11.4
	54	0.34	3.96	11.8	9	220	12.3	245	12.2
	55	0.37	3.96	12.8	9	240	13.3	265	13.2
	56	0.40	3.96	13.7	9	255	14.2	285	14.2
4	51	0.26	4.80	11.3	11	215	11.9	235	11.8
	52	0.29	4.80	12.6	11	240	13.2	265	13.2
	53	0.32	4.80	13.8	11	260	14.4	285	14.4
	54	0.35	4.80	15.0	11	280	15.6	310	15.6
	55	0.38	4.80	16.1	11	300	16.7	335	16.6
	56	0.41	4.80	17.3	11	320	17.9	355	17.8
6	50	0.25	6.90	16.0	18	305	17.0	340	16.9
	51	0.28	6.90	17.8	18	340	18.8	375	18.7
	52	0.31	6.90	19.6	18	370	20.6	410	20.5
	53	0.34	6.90	21.4	18	405	22.4	445	22.3
	54	0.37	6.90	23.2	18	435	24.2	480	24.1
	55	0.40	6.90	25.0	18	470	26.0	520	25.9
8	50	0.27	9.05	22.8	26	435	24.2	480	24.1
	51	0.30	9.05	25.2	26	480	26.6	530	26.5
	52	0.33	9.05	27.7	26	525	29.1	580	29.0
	53	0.36	9.05	30.1	26	570	31.5	630	31.4
	54	0.39	9.05	32.5	26	610	33.9	675	33.8
	55	0.42	9.05	34.8	26	650	36.2	720	36.1
10	50	0.29	11.10	30.1	34	575	32.0	635	31.8
	51	0.32	11.10	33.2	34	630	35.1	700	34.9
	52	0.35	11.10	36.2	34	685	38.1	760	37.9
	53	0.38	11.10	39.2	34	740	41.1	820	40.9
	54	0.41	11.10	42.1	34	790	44.0	875	43.8
	55	0.44	11.10	45.1	34	845	47.0	935	46.8
56	0.47	11.10	48.0	34	900	49.9	995	49.7	

* 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.

† 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.

§ Pipe of 3-in. size also available in 12-ft laying length with following weights:

Thickness Class	Thickness in.	Wt. Per Lgth.† lb	Avg. Wt. Per Ft‡ lb
51	0.25	115	9.6
52	0.28	130	10.6
53	0.31	140	11.6
54	0.34	150	12.6
55	0.37	165	13.6
56	0.40	175	14.4

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TABLE 51.4—(cont.)

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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	43	735	40.8	810	40.6
	51	0.34	13.20	42.0	43	800	44.4	885	44.2
	52	0.37	13.20	45.6	43	865	48.0	955	47.8
	53	0.40	13.20	49.2	43	930	51.6	1 025	51.4
	54	0.43	13.20	52.8	43	995	55.2	1 100	55.0
	55	0.46	13.20	56.3	43	1 055	58.7	1 170	58.4
	56	0.49	13.20	59.9	43	1 120	62.3	1 240	62.0
14	50	0.33	15.30	47.5	63	920	51.0	1 015	50.6
	51	0.36	15.30	51.7	63	995	55.2	1 095	54.8
	52	0.39	15.30	55.9	63	1 070	59.4	1 180	59.0
	53	0.42	15.30	60.1	63	1 145	63.6	1 265	63.2
	54	0.45	15.30	64.2	63	1 220	67.7	1 345	67.4
	55	0.48	15.30	68.4	63	1 295	71.9	1 430	71.6
	56	0.51	15.30	72.5	63	1 370	76.0	1 515	75.6
16	50	0.34	17.40	55.8	76	1 080	60.0	1 190	59.6
	51	0.37	17.40	60.6	76	1 165	64.8	1 290	64.4
	52	0.40	17.40	65.4	76	1 255	69.6	1 385	69.2
	53	0.43	17.40	70.1	76	1 340	74.3	1 480	73.9
	54	0.46	17.40	74.9	76	1 425	79.1	1 575	78.7
	55	0.49	17.40	79.7	76	1 510	83.9	1 670	83.5
	56	0.52	17.40	84.4	76	1 595	88.6	1 765	88.2
18	50	0.35	19.50	64.4	87	1 245	69.2	1 375	68.8
	51	0.38	19.50	69.8	87	1 345	74.5	1 485	74.2
	52	0.41	19.50	75.2	87	1 440	80.0	1 590	79.6
	53	0.44	19.50	80.6	87	1 540	85.4	1 700	85.0
	54	0.47	19.50	86.0	87	1 635	90.8	1 805	90.4
	55	0.50	19.50	91.3	87	1 730	95.1	1 915	95.6
	56	0.53	19.50	96.7	87	1 830	101.5	2 020	101.0
20	50	0.36	21.60	73.5	97	1 420	78.9	1 565	78.4
	51	0.39	21.60	79.5	97	1 530	84.9	1 685	84.4
	52	0.42	21.60	85.5	97	1 635	90.9	1 805	90.4
	53	0.45	21.60	91.5	97	1 745	95.9	1 925	96.4
	54	0.48	21.60	97.5	97	1 850	102.9	2 045	102.4
	55	0.51	21.60	103.4	97	1 950	108.8	2 165	108.2
	56	0.54	21.60	109.3	97	2 065	114.7	2 285	114.2

* 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.

† 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.

DUCTILE-IRON PIPE

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	120	1 790	99.6	1 980	98.9
	51	0.41	25.80	100.1	120	1 920	106.8	2 120	106.1
	52	0.44	25.80	107.3	120	2 050	114.0	2 265	113.3
	53	0.47	25.80	114.4	120	2 180	121.1	2 410	120.4
	54	0.50	25.80	121.6	120	2 310	128.3	2 550	127.6
	55	0.53	25.80	128.8	120	2 440	135.5	2 695	134.8
	56	0.56	25.80	135.9	120	2 565	142.6	2 840	141.9
30	50	0.39	32.00	118.5	**	2 350	130.5	2 535	126.6
	51	0.43	32.00	130.5		2 565	142.5	2 775	138.6
	52	0.47	32.00	142.5		2 780	154.5	3 015	150.6
	53	0.51	32.00	154.4		2 995	166.4	3 250	162.6
	54	0.55	32.00	166.3		3 210	178.3	3 490	174.4
	55	0.59	32.00	178.2		3 425	190.2	3 725	186.4
	56	0.63	32.00	190.0		3 635	202.0	3 965	198.2
36	50	0.43	38.30	156.5	††	3 110	172.7	3 345	167.3
	51	0.48	38.30	174.5		3 435	190.7	3 705	185.3
	52	0.53	38.30	192.4		3 755	208.6	4 065	203.2
	53	0.58	38.30	210.3		4 075	226.5	4 420	221.1
	54	0.63	38.30	228.1		4 400	244.3	4 780	238.9
	55	0.68	38.30	245.9		4 720	262.1	5 135	256.7
	56	0.73	38.30	263.7		5 040	279.9	5 490	274.5
42	50	0.47	44.50	198.9	261			4 240	212.0
	51	0.53	44.50	224.0	261			4 740	237.0
	52	0.59	44.50	249.1	261			5 245	262.2
	53	0.65	44.50	274.0	261			5 740	287.0
	54	0.71	44.50	298.9	261			6 240	312.0
	55	0.77	44.50	323.7	261			6 735	336.8
	56	0.83	44.50	348.4	261			7 230	361.4
48	50	0.51	50.80	246.6	316			5 250	262.4
	51	0.58	50.80	280.0	316			5 915	295.8
	52	0.65	50.80	313.4	316			6 585	329.2
	53	0.72	50.80	346.6	316			7 250	362.4
	54	0.79	50.80	379.8	316			7 910	395.6
	55	0.86	50.80	412.9	316			8 575	428.7
	56	0.93	50.80	445.9	316			9 235	461.7
54	50	0.57	57.10	309.8	370			6 565	328.3
	51	0.65	57.10	352.7	370			7 425	371.2
	52	0.73	57.10	395.6	370			8 280	414.1
	53	0.81	57.10	438.3	370			9 135	456.8
	54	0.89	57.10	480.9	370			9 990	499.4
	55	0.97	57.10	523.4	370			10 840	541.9
	56	1.05	57.10	565.8	370			11 685	584.3

* Tolerances 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.

† 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.

** Weight of 30-in. bell is 216 lb for 18-ft pipe and 163 lb for 20-ft pipe.

†† Weight of 36-in. bell is 292 lb for 18-ft pipe and 216 lb for 20-ft pipe.

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AMERICAN NATIONAL STANDARD

TABLE 51.5

Standard Dimensions and Weights of Mechanical-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
3½	51	0.25	3.96	8.9	11	170	9.5	* 190	9.4
	52	0.28	3.96	9.9	11	190	10.5	210	10.4
	53	0.31	3.96	10.9	11	205	11.5	230	11.4
	54	0.34	3.96	11.8	11	225	12.4	245	12.4
	55	0.37	3.96	12.8	11	240	13.4	265	13.4
	56	0.40	3.96	13.7	11	260	14.3	285	14.2
4	51	0.26	4.80	11.3	16	220	12.2	240	12.1
	52	0.29	4.80	12.6	16	245	13.5	270	13.4
	53	0.32	4.80	13.8	16	265	14.7	290	14.6
	54	0.35	4.80	15.0	16	285	15.9	315	15.8
	55	0.38	4.80	16.1	16	305	17.0	340	16.9
	56	0.41	4.80	17.3	16	325	18.2	360	18.1
6	50	0.25	6.90	16.0	22	310	17.2	340	17.1
	51	0.28	6.90	17.8	22	340	19.0	380	18.9
	52	0.31	6.90	19.6	22	375	20.8	415	20.7
	53	0.34	6.90	21.4	22	405	22.6	450	22.5
	54	0.37	6.90	23.2	22	440	24.4	485	24.3
	55	0.40	6.90	25.0	22	470	26.2	520	26.1
8	50	0.27	9.05	22.8	29	440	24.4	485	24.2
	51	0.30	9.05	25.2	29	485	26.8	535	26.6
	52	0.33	9.05	27.7	29	530	29.3	585	29.2
	53	0.36	9.05	30.1	29	570	31.7	630	31.6
	54	0.39	9.05	32.5	29	615	34.1	680	34.0
	55	0.42	9.05	34.8	29	655	36.4	725	36.2
10	50	0.29	11.10	30.1	39	580	32.3	640	32.0
	51	0.32	11.10	33.2	39	635	35.4	705	35.2
	52	0.35	11.10	36.2	39	690	38.4	765	38.2
	53	0.38	11.10	39.2	39	745	41.4	825	41.2
	54	0.41	11.10	42.1	39	795	44.3	880	44.0
	55	0.44	11.10	45.1	39	850	47.3	940	47.0
12	50	0.31	13.20	38.4	49	740	41.1	815	40.8
	51	0.34	13.20	42.0	49	805	44.7	890	44.4
	52	0.37	13.20	45.6	49	870	48.3	960	48.0
	53	0.40	13.20	49.2	49	935	51.9	1 035	51.6
	54	0.43	13.20	52.8	49	1 000	55.5	1 105	55.2
	55	0.46	13.20	56.3	49	1 060	59.0	1 175	58.8
14	50	0.33	15.30	47.5	76	930	51.7	1 025	51.3
	51	0.36	15.30	51.7	76	1 005	55.9	1 110	55.5
	52	0.39	15.30	55.9	76	1 080	60.1	1 195	59.7
	53	0.42	15.30	60.1	76	1 160	64.3	1 280	63.9
	54	0.45	15.30	64.2	76	1 230	68.4	1 360	68.0
	55	0.48	15.30	68.4	76	1 305	72.6	1 445	72.2
	56	0.51	15.30	72.5	76	1 380	76.7	1 525	76.3

* 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.

† 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.

§ Pipe of 3-in. size also available in 12-ft laying length with following weights:

Thickness Class	Thickness in.	Wt. Per Lgth.† lb	Avg. Wt. Per Ft‡ lb
51	0.25	120	9.8
52	0.28	130	10.8
53	0.31	140	11.8
54	0.34	155	12.7
55	0.37	165	13.7
56	0.40	175	14.6

DUCTILE-IRON PIPE

TABLE 51.5—(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
16	50	0.34	17.40	55.8	93	1 095	61.0	1 210	60.4
	51	0.37	17.40	60.6	93	1 185	65.8	1 305	65.2
	52	0.40	17.40	65.4	93	1 270	70.6	1 400	70.0
	53	0.43	17.40	70.1	93	1 355	75.3	1 495	74.8
	54	0.46	17.40	74.9	93	1 440	80.1	1 590	79.6
	55	0.49	17.40	79.7	93	1 530	84.9	1 685	84.4
	56	0.52	17.40	84.4	93	1 610	89.6	1 780	89.0
18	50	0.35	19.50	64.4	111	1 270	70.6	1 400	70.0
	51	0.38	19.50	69.8	111	1 365	76.0	1 505	75.4
	52	0.41	19.50	75.2	111	1 465	81.4	1 615	80.8
	53	0.44	19.50	80.6	111	1 560	86.8	1 725	86.2
	54	0.47	19.50	86.0	111	1 660	92.2	1 830	91.6
	55	0.50	19.50	91.3	111	1 755	97.5	1 935	96.8
	56	0.53	19.50	96.7	111	1 850	102.9	2 045	102.2
20	50	0.36	21.60	73.5	131	1 455	80.8	1 600	80.0
	51	0.39	21.60	79.5	131	1 560	86.8	1 720	86.0
	52	0.42	21.60	85.5	131	1 670	92.8	1 840	92.0
	53	0.45	21.60	91.5	131	1 780	98.8	1 960	98.0
	54	0.48	21.60	97.5	131	1 885	104.8	2 080	104.0
	55	0.51	21.60	103.4	131	1 990	110.7	2 200	110.0
	56	0.54	21.60	109.3	131	2 100	116.6	2 315	115.8
24	50	0.38	25.80	92.9	174	1 845	102.6	2 030	101.6
	51	0.41	25.80	100.1	174	1 975	109.8	2 175	108.8
	52	0.44	25.80	107.3	174	2 105	117.0	2 320	116.0
	53	0.47	25.80	114.4	174	2 235	124.1	2 460	123.1
	54	0.50	25.80	121.6	174	2 365	131.3	2 605	130.3
	55	0.53	25.80	128.8	174	2 490	138.5	2 750	137.5
	56	0.56	25.80	135.9	174	2 620	145.6	2 890	144.6
30	50	0.39	32.00	118.5	216	2 350	130.5	2 585	129.3
	51	0.43	32.00	130.5	216	2 565	142.5	2 825	141.3
	52	0.47	32.00	142.5	216	2 780	154.5	3 065	153.3
	53	0.51	32.00	154.4	216	2 995	166.4	3 305	165.2
	54	0.55	32.00	166.3	216	3 210	178.3	3 540	177.1
	55	0.59	32.00	178.2	216	3 425	190.2	3 780	189.0
	56	0.63	32.00	190.0	216	3 635	202.0	4 015	200.8
36	50	0.43	38.30	156.5	310	3 125	173.7	3 440	172.0
	51	0.48	38.30	174.5	310	3 450	191.7	3 800	190.0
	52	0.53	38.30	192.4	310	3 775	209.6	4 160	207.9
	53	0.58	38.30	210.3	310	4 095	227.5	4 515	225.8
	54	0.63	38.30	228.1	310	4 415	245.3	4 870	243.6
	55	0.68	38.30	245.9	310	4 735	263.1	5 230	261.4
	56	0.73	38.30	263.7	310	5 055	280.9	5 585	279.2
42	50	0.47	44.50	198.9	405			4 385	219.2
	51	0.53	44.50	224.0	405			4 885	244.2
	52	0.59	44.50	249.1	405			5 385	269.4
	53	0.65	44.50	274.0	405			5 885	294.2
	54	0.71	44.50	298.9	405			6 385	319.2
	55	0.77	44.50	323.7	405			6 880	344.0
	56	0.83	44.50	348.4	405			7 375	368.6
48	50	0.51	50.80	246.6	505			5 435	271.8
	51	0.58	50.80	280.0	505			6 105	305.2
	52	0.65	50.80	313.4	505			6 775	338.6
	53	0.72	50.80	346.6	505			7 435	371.8
	54	0.79	50.80	379.8	505			8 100	405.0
	55	0.86	50.80	412.9	505			8 765	438.2
	56	0.93	50.80	445.9	505			9 425	471.2

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* 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 mechanical joint bell for 30-48 in. sizes of ductile-iron pipe have thicknesses different from those shown in ANSI A21.11 (AWWA C111), which are based on gray-iron pipe. These reduced thicknesses provide a lighter weight bell, which is compatible with the wall thicknesses of ductile-iron pipe. The internal socket dimensions, bolt circle and bolt holes of the redesigned bell remain identical to those specified in A21.11 (AWWA C111) to assure interchangeability of the joint.

† 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

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

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.									
		$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	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

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DUCTILE-IRON PIPE

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.						
		$\frac{1}{2}$	$\frac{3}{4}$	1	1 $\frac{1}{4}$	1 $\frac{1}{2}$	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

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

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ANSI A21.52-1976
REVISION OF
A21.52-1971

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AMERICAN NATIONAL STANDARD
for
DUCTILE-IRON PIPE, CENTRIFUGALLY CAST,
IN METAL MOLDS OR SAND-LINED MOLDS,
FOR GAS

SECRETARIATS

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

Revised Edition Approved By
American National Standards Institute June 25, 1976

FOREWORD

This foreword is for information and is not a part of ANSI A21.52.

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. The present scope of Committee A21 activity is: Since 1972 the co-secretariats have been AGA, AWWA and NEWWA. AWWA is the administrative secretariat.

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 carried out 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 or new standards when needed, as well as other matters pertaining to pipe standards.

The first edition of A21.52, the standard for ductile-iron pipe for gas, was issued in 1965 and a revision was issued in 1971. Subcommittee 1 reviewed this standard and submitted a proposed revision to American National Standards Committee A21 in 1975.

Revisions

1. An additional minus tolerance of 0.02 in. is permitted along the barrel of the pipe for a distance not to exceed 12-in. The weight tolerance permitted for any single pipe is 6 percent for 12-in. or smaller pipe and 5 percent for pipe larger than 12-in.
2. The standard laying conditions have been renamed. A becomes Type 1 and B becomes Type 2.
3. The standard thickness classes have been renumbered. Class 1 becomes Class 51, Class 2 becomes Class 52, etc.
4. Some thicknesses have been changed to reflect the effects of the following changes in A21.50: (a) change to AASHO H-20 truck loads; (b) change to prism earth loads for all pipe sizes; (c) change to 45° bedding angle for Laying Condition Type 2. The design stresses and design safety factors are unchanged from the 1971 edition.

Options

This standard includes certain options which, 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 these details and available options, and lists the sections of the standard where they can be found.

1. Size, thickness or class and laying length—Tables
2. a. Special Joints—Sec. 52-3.1
b. Specify ductile-iron gland if required—Sec. 52-3.1
3. Certification by manufacturer—Sec. 52-4.2
4. Inspection by purchaser—Sec. 52-5
5. Coating—Sec. 52-8.1
6. Special Coating—Sec. 52-8.2
7. Special marking on pipe—Sec. 52-11
8. Written transcripts of foundry records—Sec. 52-14
9. Special tests—Sec. 52-15

AMERICAN NATIONAL STANDARD

for

DUCTILE-IRON PIPE CENTRIFUGALLY CAST,
IN METAL MOLDS OR SAND-LINED MOLDS
FOR GAS

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Section 52-1—Scope

This standard covers 3 inch through 24 inch Mechanical Joint ductile-iron pipe, centrifugally cast, in metal molds or sand-lined molds for gas. This standard may be used for pipe with such other types of joints as may be agreed upon at the time of purchase.

Section 52-2—Definitions

Under this standard, the following definitions shall apply:

52-2.1 *Purchaser.* The party entering into a contract or agreement to purchase pipe according to this standard.

52-2.2 *Manufacturer.* The party that produces the pipe.

52-2.3 *Inspector.* The representative of the purchaser, authorized to inspect in behalf of the purchaser, to determine whether or not the pipe meet this standard.

52-2.4 *Ductile Iron.* A cast ferrous material in which a major part of the carbon content occurs as free carbon in nodular or spheroidal form.

52-2.5 *Mechanical-Joint.* The gasketed and bolted joint as detailed in ANSI A21.11 of latest revision.

Section 52-3—General Requirements

52-3.1 Pipe with mechanical joints shall conform to the applicable dimensions and weights shown in the tables in this standard and to the applicable re-

quirements of ANSI A21.11 of latest revision. Unless otherwise specified, the mechanical-joint glands shall be cast iron in accordance with ANSI 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.

52-3.2 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 as much as 24 inches shorter than the nominal laying length and an additional 10 percent may be furnished as much as 6 inches shorter than nominal laying length.

Section 52-4—Inspection and Certification by Manufacturer

52-4.1 The manufacturer shall establish the necessary quality control and inspection practice to assure compliance with this standard.

52-4.2 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 standard.

52-4.3 All pipe shall be clean and sound without defects which 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 standard.

Section 52-5—Inspection by Purchaser

52-5.1 When 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.

52-5.2 The inspector shall have free access to those parts of the manufacturer's plant which are necessary to assure compliance with this standard. 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.

Section 52-6—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.

Section 52-7—Tolerances or Permitted Variations

52-7.1 *Dimensions.* The spigot end, bell and socket of the pipe and the accessories shall be gaged with suitable gages at sufficiently frequent intervals to assure 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 gages. Other socket dimensions shall be gaged as appropriate.

52-7.2 *Thickness.* Minus thickness tolerances of pipe and bell shall not exceed those shown below:

<u>Size, Inch</u>	<u>Minus Tolerance, Inch</u>
3-8	0.05
10-12	0.06
14-24	0.07

An additional minus tolerance of .02 in. shall be permitted along the barrel of the pipe for a distance not to exceed 12 in.

52-7.3 *Weight.* The weight of any single pipe shall not be less than the tabulated weight by more than 6 percent for pipe 12 inches or smaller in diameter, nor by more than 5 percent for pipe larger than 12 inches in diameter.

Section 52-8—Coating

52-8.1 *Outside Coating.* Unless otherwise specified on the purchase order, pipe may be coated on the outside at the manufacturer's option with a bituminous coating approximately one mil thick. 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.

52-8.2 *Special Coating.* For special conditions, other types of coatings may be available. Such special coatings shall be specified in the invitation for bids and on the purchase order.

Section 52-9—Hydrostatic Test

Each pipe shall be subjected to a hydrostatic test of not less than 500 psi. The pipe shall be under the full test pressure for at least 10 seconds. 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.

Section 52-10—Air Test

In addition to the hydrostatic test, each length of pipe and its socket sealing surface shall be subjected to an air test prior to coating. These tests may be

made simultaneously or separately at the manufacturer's option. The air test pressure shall be a minimum of 50 psi. The joint sealing surface test shall be made in such a manner as to assure no leakage when the joint is properly assembled. The pipe shall be under the test pressure a sufficient length of time to permit careful inspection for leakage. While under this air pressure, the pipe shall be immersed in water or covered with a soapy water solution. Any length of pipe that leaks shall be rejected.

Section 52-11—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 8-in. and larger shall be not less than 1/2-in. in height.

Section 52-12—Acceptance Tests

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

52-12.1 *Tensile Test.* A tensile test specimen shall be cut longitudinally from the midsection of the pipe wall. This specimen shall be machined and tested in accordance with Figure 1 and ASTM (American Society for Testing and Materials) designation E8-69 Tension Testing of Metallic Materials. 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 ($70 \pm 10F$).

52-12.1.1 *Acceptance Values.* The acceptance values for test specimens shall be as follows:

Grade of Iron	Tensile Strength, Minimum psi	Yield Strength, Minimum psi	Per cent Elongation, Minimum
60-42-10	60,000	42,000	10

52-12.2 *Impact Test.* Tests shall be made in accordance with ASTM designation E23-66 Notched Charpy Tests, except that specimens shall be 0.500 inch and full thickness of pipe wall. The notched impact test specimen shall be in accordance with Figure 2. In cases when the pipe wall thickness exceeds 0.40 inch, the impact specimen may be machined to a nominal thickness of 0.40 inch.

In all cases, impact values are to be corrected to 0.40 inch wall thickness by calculation as follows:

$$\text{Impact value corrected} = \frac{0.40 \text{ inch}}{t} \times \text{Impact value actual}$$

where t = thickness of the specimen in inches (wall thickness of pipe).

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

52-12.2.1 *Acceptance Value.* The corrected acceptance value for notched impact test specimens shall be a minimum of 7 foot pounds for tests conducted at $70 \pm 10\text{F}$.

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52-12.3 *Sampling.* At least one tensile and impact sample shall be taken during each casting period of approximately three hours. Samples shall be selected to properly represent extremes of pipe diameters and thicknesses.

Section 52-13—Additional Control Tests by Manufacturer

Low temperature impact tests shall be made from at least one-third of the test pipe specified in Section 52-12.3 to assure compliance with a minimum corrected value of 3 foot pounds for tests conducted at -40F . Test specimens shall be prepared and tested in accordance with Section 52-12.2.

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

Section 52-14—Foundry Records

The results of the following tests shall be recorded and retained for one year and shall be available to the purchaser at the foundry. Written transcripts of the results of the following tests shall be furnished when specified on the purchase order:

Acceptance tests, Section 52-12

Low-temperature impact tests, Section 52-13.

Section 52-15—Additional Tests Required by Purchaser

When 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.

Section 52-16—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 which failed. Both of the additional specimens shall meet the prescribed tests to qualify the pipe produced in that period.

Section 52-17—Rejection of Pipe

When any physical acceptance test fails to meet the requirements of Section 52-12 or Section 52-16, the pipe cast in the same period shall be rejected except as subject to the provision of Section 52-18.

Section 52-18—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 specified in Section 52-12.

DIMENSIONS

	Std. Specimen <u>0.500" round</u>	Small Size Specimens Proportional to Standard			
		<u>0.350" round</u>	<u>0.250" round</u>	<u>0.175" round</u>	<u>0.125" round</u>
G—Gage Length	2.000±0.005"	1.400±0.005"	1.000±0.005"	0.700±0.005"	0.500±0.005"
D—Diameter (Note 1)	0.500±0.010"	0.350±0.007"	0.250±0.005"	0.175±0.005"	0.125±0.005"
R—Radius of Fillet	3/8", Min.	1/4", Min.	3/16", Min.	3/32", Min.	3/32", Min.
A—Length of Reduced Section (Note 2)	2 1/4", Min.	1 3/4", Min.	1 1/4", Min.	3/4", Min.	5/8", Min.
Thickness of the section from the wall of the pipe from which the tensile specimen is to be machined.	.71" & Greater	.50" thru .70"	.35" thru .49"	.25" thru .34"	.18" thru .24"

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- NOTE 1. The reduced section may have a gradual taper from the ends toward the center with the ends not more than 0.005 in. larger in diameter than the center on the standard specimen and not more than 0.003 in. 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.
- 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.

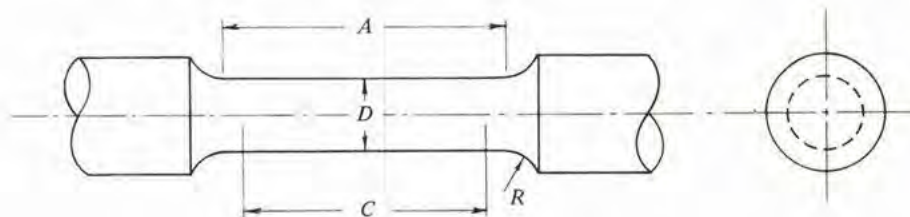


Figure 1. Tensile Test Specimen

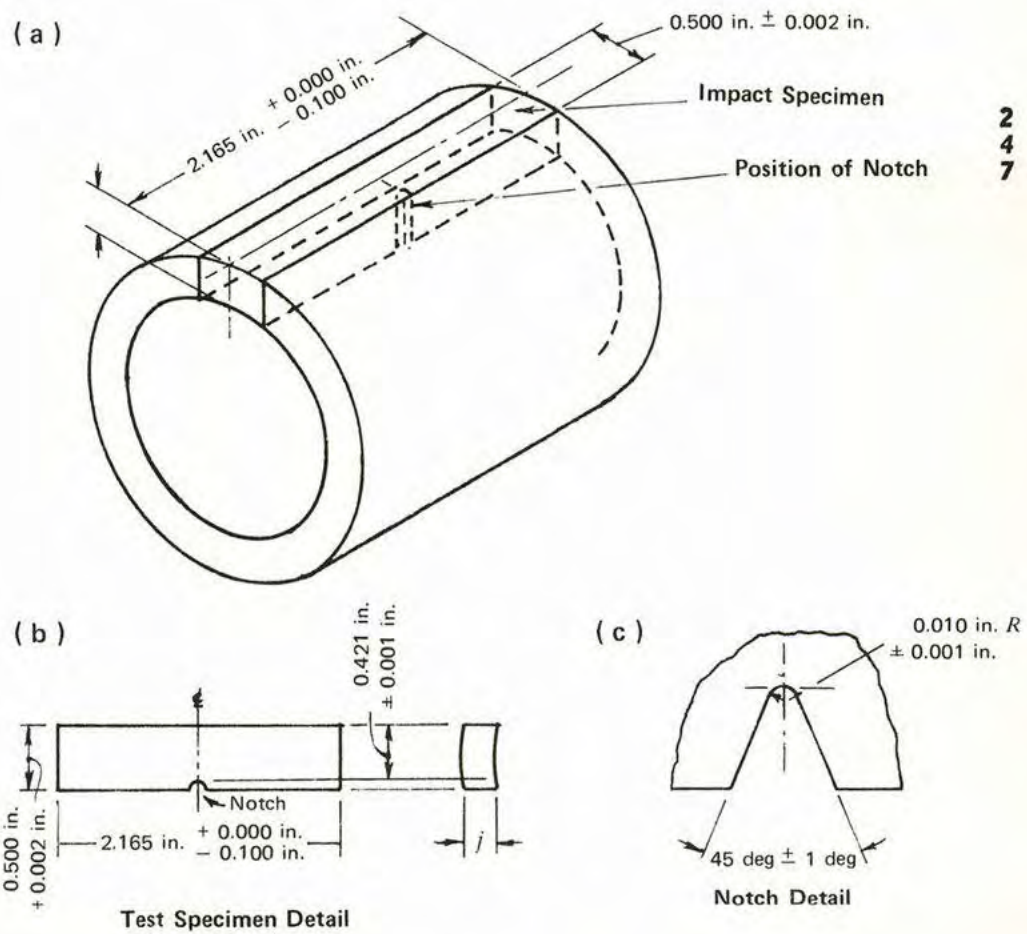


Figure 2. Impact Test Specimen

TABLE 1

Selection Table for Mechanical-Joint Ductile Iron Pipe

The thicknesses in this table are equal to or in excess of those required to withstand 250 psi working pressure.

All pipe in this table for the depths of cover indicated are adequate for trench loads including truck superloads under laying condition Type 2 (flat-bottom trench, backfill lightly consolidated to centerline of pipe).

For other depths of cover and laying condition Type 1 see Table 2. The basis of design is ANSI A21.50 except that for gas pipe the bending stress, f , is 36,000 psi and the safety factor for internal pressure is 2.5. A surge allowance is not required for gas pipe.

Thread engagement in taps for service connections and bag holes may require consideration in selecting pipe thicknesses. See Appendix.

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Size, in.	Thickness Class	Thick- ness in.	OD	Weight Based on 18-ft. Laying Length		Weight Based on 20-ft. Laying Length	
				Per Length†	Avg. Per Foot*	Per Length†	Avg. Per Foot*
5-ft. Cover							
3**	52	0.28	3.96	190	10.5	210	10.4
4	52	0.29	4.80	245	13.5	270	13.4
6	52	0.31	6.90	375	20.8	415	20.7
8	52	0.33	9.05	530	29.3	585	29.2
10	52	0.35	11.10	690	38.4	765	38.2
12	52	0.37	13.20	870	48.3	960	48.0
14	51	0.36	15.30	1005	55.9	1110	55.5
16	51	0.37	17.40	1185	65.8	1305	65.2
18	51	0.38	19.50	1365	76.0	1505	75.4
20	51	0.39	21.60	1560	86.8	1720	86.0
24	51	0.41	25.80	1975	109.8	2175	108.8
8-ft. Cover							
3**	52	0.28	3.96	190	10.5	210	10.4
4	52	0.29	4.80	245	13.5	270	13.4
6	52	0.31	6.90	375	20.8	415	20.7
8	52	0.33	9.05	530	29.3	585	29.2
10	52	0.35	11.10	690	38.4	765	38.2
12	52	0.37	13.20	870	48.3	960	48.0
14	51	0.36	15.30	1005	55.9	1110	55.5
16	51	0.37	17.40	1185	65.8	1305	65.2
18	51	0.38	19.50	1365	76.0	1505	75.4
20	51	0.39	21.60	1560	86.8	1720	86.0
24	51	0.41	25.80	1975	109.8	2175	108.8

† Including bell. Calculated weights of pipe rounded off to nearest 5 lb.

* Including bell. Average weight, per foot, based on calculated weight before rounding.

**Pipe of 3-in. size also available in 12-ft. laying length. Weight, per length† is 130 lb. and average weight, per foot*, is 10.8 lb. for all standard depths of cover.

TABLE 1 (Continued)

Selection Table for Mechanical-Joint Ductile Iron-Pipe

The thicknesses in this table are equal to or in excess of those required to withstand 250 psi working pressure.

All pipe in this table for the depths of cover indicated are adequate for trench loads including truck superloads under laying condition Type 2 (flat-bottom trench, backfill lightly consolidated to centerline of pipe).

For other depths of cover and laying condition Type 1 see Table 2. The basis of design is ANSI A21.50 except that for gas pipe the bending stress, f , is 36,000 psi and the safety factor for internal pressure is 2.5. A surge allowance is not required for gas pipe.

Thread engagement in taps for service connections and bag holes may require consideration in selecting pipe thicknesses. See Appendix.

Size, in.	Thickness Class	Thick- ness in.	OD	Weight Based on 18-ft. Laying Length		Weight Based on 20-ft. Laying Length	
				Per Length†	Avg. Per Foot*	Per Length†	Avg. Per Foot*
12-ft. Cover							
3**	52	0.28	3.96	190	10.5	210	10.4
4	52	0.29	4.80	245	13.5	270	13.4
6	52	0.31	6.90	375	20.8	415	20.7
8	52	0.33	9.05	530	29.3	585	29.2
10	52	0.35	11.10	690	38.4	765	38.2
12	52	0.37	13.20	870	48.3	960	48.0
14	51	0.36	15.30	1005	55.9	1110	55.5
16	51	0.37	17.40	1185	65.8	1305	65.2
18	51	0.38	19.50	1365	76.0	1505	75.4
20	51	0.39	21.60	1560	86.8	1720	86.0
24	52	0.44	25.80	2105	117.0	2320	116.0
16-ft. Cover							
3**	52	0.28	3.96	190	10.5	210	10.4
4	52	0.29	4.80	245	13.5	270	13.4
6	52	0.31	6.90	375	20.8	415	20.7
8	52	0.33	9.05	530	29.3	585	29.2
10	52	0.35	11.10	690	38.4	765	38.2
12	52	0.37	13.20	870	48.3	960	48.0
14	51	0.36	15.30	1005	55.9	1110	55.5
16	52	0.40	17.40	1270	70.6	1400	70.0
18	52	0.41	19.50	1465	81.4	1615	80.8
20	53	0.45	21.60	1780	98.8	1960	98.0
24	54	0.50	25.80	2365	131.3	2605	130.3

† Including bell. Calculated weights of pipe rounded off to nearest 5 lb.

* Including bell. Average weight, per foot, based on calculated weight before rounding.

**Pipe of 3-in. size also available in 12-ft. laying length. Weight, per length† is 130 lb. and average weight, per foot*, is 10.8 lb. for all standard depths of cover.

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TABLE 2

Standard Thickness Selection Table for Ductile-Iron Pipe

Laying Condition Type 1—flat-bottom trench, loose backfill.

Laying Condition Type 2—flat-bottom trench, backfill lightly consolidated to center-line of pipe.

The thicknesses in this table are equal to or in excess of those required to withstand 250 psi working pressure.

All thicknesses shown in this table for the depths of cover indicated are adequate for trench loads including truck superloads.

The basis of design is ANSI A21.50 except that for gas pipe the bending stress, f , is 36,000 psi and the safety factor for internal pressure is 2.5. A surge allowance is not required for gas pipe.

Thread engagement in taps for service connections and bag holes may require consideration in selecting pipe thicknesses. See Appendix.

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Size, in.	Laying Condition	Depth of Cover-ft.							
		2½	3½	5	8	12	16	20	24
3	1	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
	2	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
4	1	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
	2	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
6	1	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
	2	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
8	1	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
	2	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
10	1	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
	2	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
12	1	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.40
	2	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
14	1	0.36	0.36	0.36	0.36	0.36	0.39	0.42	0.45
	2	0.36	0.36	0.36	0.36	0.36	0.36	0.39	0.42
16	1	0.37	0.37	0.37	0.37	0.37	0.43	0.46	0.49
	2	0.37	0.37	0.37	0.37	0.37	0.40	0.43	0.46
18	1	0.41	0.38	0.38	0.38	0.41	0.44	0.50	0.53
	2	0.38	0.38	0.38	0.38	0.38	0.41	0.47	0.50
20	1	0.42	0.39	0.39	0.39	0.45	0.48	0.54	
	2	0.39	0.39	0.39	0.39	0.39	0.45	0.48	0.54
24	1	0.47	0.41	0.41	0.44	0.50	0.56		
	2	0.41	0.41	0.41	0.41	0.44	0.50	0.56	

TABLE 3

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

Size, in.	Thick- ness Class	Thick- ness in.	OD	Weight of Barrel per Foot	Weight of Bell	Weight Based on 18-ft. Laying Length		Weight Based on 20-ft. Laying Length	
						Per Length† lb.	Avg. per Foot*	Per Length†	Avg. per Foot*
3**	52	0.28	3.96	9.9	11	190	10.5	210	10.4
	53	0.31	3.96	10.9	11	205	11.5	230	11.4
	54	0.34	3.96	11.8	11	225	12.4	245	12.4
	55	0.37	3.96	12.8	11	240	13.4	265	13.4
	56	0.40	3.96	13.7	11	260	14.3	285	14.2
4	52	0.29	4.80	12.6	16	245	13.5	270	13.4
	53	0.32	4.80	13.8	16	265	14.7	290	14.6
	54	0.35	4.80	15.0	16	285	15.9	315	15.8
	55	0.38	4.80	16.1	16	305	17.0	340	16.9
	56	0.41	4.80	17.3	16	325	18.2	360	18.1
6	52	0.31	6.90	19.6	22	375	20.8	415	20.7
	53	0.34	6.90	21.4	22	405	22.6	450	22.5
	54	0.37	6.90	23.2	22	440	24.4	485	24.3
	55	0.40	6.90	25.0	22	470	26.2	520	26.1
	56	0.43	6.90	26.7	22	505	27.9	555	27.8
8	52	0.33	9.05	27.7	29	530	29.3	585	29.2
	53	0.36	9.05	30.1	29	570	31.7	630	31.6
	54	0.39	9.05	32.5	29	615	34.1	680	34.0
	55	0.42	9.05	34.8	29	655	36.4	725	36.2
	56	0.45	9.05	37.2	29	700	38.8	775	38.6
10	52	0.35	11.10	36.2	39	690	38.4	765	38.2
	53	0.38	11.10	39.2	39	745	41.4	825	41.2
	54	0.41	11.10	42.1	39	795	44.3	880	44.0
	55	0.44	11.10	45.1	39	850	47.3	940	47.0
	56	0.47	11.10	48.0	39	905	50.2	1000	50.0

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† 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.

**Pipe of 3-in. size also available in 12-ft. laying length with following weights:

Thickness Class	Thickness, in.	Per Length†	Weight (lb.) Avg. per Foot*
52	0.28	130	10.8
53	0.31	140	11.8
54	0.34	155	12.7
55	0.37	165	13.7
56	0.40	175	14.6

TABLE 3 (Continued)

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

Size, in.	Thick- ness Class	Thick- ness in.	OD	Weight of Barrel per Foot	Weight of Bell	Weight Based on 18-ft. Laying Length		Weight Based on 20-ft. Laying Length		
						Per Length† lb.	Avg. per Foot*	Per Length†	Avg. per Foot*	
2 5 2	12	52	0.37	13.20	45.6	49	870	48.3	960	48.0
		53	0.40	13.20	49.2	49	935	51.9	1035	51.6
		54	0.43	13.20	52.8	49	1000	55.5	1105	55.2
		55	0.46	13.20	56.3	49	1060	59.0	1175	58.8
		56	0.49	13.20	59.9	49	1125	62.6	1245	62.3
	14	51	0.36	15.30	51.7	76	1005	55.9	1110	55.5
	52	0.39	15.30	55.9	76	1080	60.1	1195	59.7	
	53	0.42	15.30	60.1	76	1160	64.3	1280	63.9	
	54	0.45	15.30	64.2	76	1230	68.4	1360	68.0	
	55	0.48	15.30	68.4	76	1305	72.6	1445	72.2	
	56	0.51	15.30	72.5	76	1380	76.7	1525	76.3	
16	51	0.37	17.40	60.6	93	1185	65.8	1305	65.2	
	52	0.40	17.40	65.4	93	1270	70.6	1400	70.0	
	53	0.43	17.40	70.1	93	1355	75.3	1495	74.8	
	54	0.46	17.40	74.9	93	1440	80.1	1590	79.6	
	55	0.49	17.40	79.7	93	1530	84.9	1685	84.4	
	56	0.52	17.40	84.4	93	1610	89.6	1780	89.0	
18	51	0.38	19.50	69.8	111	1365	76.0	1505	75.4	
	52	0.41	19.50	75.2	111	1465	81.4	1615	80.8	
	53	0.44	19.50	80.6	111	1560	86.8	1725	86.2	
	54	0.47	19.50	86.0	111	1660	92.2	1830	91.6	
	55	0.50	19.50	91.3	111	1755	97.5	1935	96.8	
	56	0.53	19.50	96.7	111	1850	102.9	2045	102.2	
20	51	0.39	21.60	79.5	131	1560	86.8	1720	86.0	
	52	0.42	21.60	85.5	131	1670	92.8	1840	92.0	
	53	0.45	21.60	91.5	131	1780	98.8	1960	98.0	
	54	0.48	21.60	97.5	131	1885	104.8	2080	104.0	
	55	0.51	21.60	103.4	131	1990	110.7	2200	110.0	
	56	0.54	21.60	109.3	131	2100	116.6	2315	115.8	
24	51	0.41	25.80	100.1	174	1975	109.8	2175	108.8	
	52	0.44	25.80	107.3	174	2105	117.0	2320	116.0	
	53	0.47	25.80	114.4	174	2235	124.1	2460	123.1	
	54	0.50	25.80	121.6	174	2365	131.3	2605	130.3	
	55	0.53	25.80	128.8	174	2490	138.5	2750	137.5	
	56	0.56	25.80	135.9	174	2620	145.6	2890	144.6	

† 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

This appendix is for information and is not a part of A21.52 American National Standard for Ductile-Iron Pipe, Centrifugally Cast, in Metal Molds or Sand-Lined Molds for Gas.

PIPE THICKNESS REQUIRED FOR DIFFERENT TAP SIZES USING AMERICAN NATIONAL STANDARD B2.1 STANDARD TAPER PIPE THREADS WITH 2, 3 AND 4 FULL THREADS.

Pipe Size	No. of Threads	Tap Sizes									
		<u>1/2"</u>	<u>3/4"</u>	<u>1"</u>	<u>1 1/4"</u>	<u>1 1/2"</u>	<u>2"</u>	<u>2 1/2"</u>	<u>3"</u>	<u>3 1/2"</u>	<u>4"</u>
3"	2	.18	.21	.28							
	3	.26	.29	.37							
	4	.33	.36	.46							
4"	2	.17	.19	.26	.31						
	3	.25	.27	.35	.40						
	4	.32	.34	.44	.49						
6"	2	.17	.18	.23	.27	.30					
	3	.25	.26	.32	.36	.39					
	4	.32	.33	.41	.45	.48					
8"	2	.16	.17	.22	.24	.27	.33				
	3	.24	.25	.31	.33	.36	.42				
	4	.31	.32	.40	.42	.45	.51				
10"	2	.15	.17	.21	.23	.25	.30	.44			
	3	.23	.25	.30	.32	.34	.39	.56			
	4	.30	.32	.39	.41	.43	.48	.69			
12"	2	.15	.16	.20	.22	.24	.28	.40	.48		
	3	.23	.24	.29	.31	.33	.37	.52	.60		
	4	.30	.31	.38	.40	.42	.46	.65	.73		
14"	2	.15	.16	.20	.22	.23	.26	.38	.45	.51	.58
	3	.23	.24	.29	.31	.32	.35	.50	.58	.64	.70
	4	.30	.31	.38	.40	.41	.44	.63	.70	.76	.83
16"	2	.15	.16	.20	.21	.22	.25	.37	.43	.48	.54
	3	.23	.24	.29	.30	.31	.34	.50	.56	.60	.66
	4	.30	.31	.38	.39	.40	.43	.62	.68	.73	.79
18"	2	.15	.15	.19	.21	.22	.24	.35	.41	.46	.51
	3	.23	.23	.28	.30	.31	.33	.48	.54	.58	.64
	4	.30	.30	.37	.39	.40	.42	.60	.66	.71	.76

APPENDIX (Continued)

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Pipe Size	No. of Threads	Tap Sizes									
		<u>1/2"</u>	<u>3/4"</u>	<u>1"</u>	<u>1 1/4"</u>	<u>1 1/2"</u>	<u>2"</u>	<u>2 1/2"</u>	<u>3"</u>	<u>3 1/2"</u>	<u>4"</u>
20"	2	.15	.15	.19	.20	.21	.23	.34	.39	.44	.49
	3	.23	.23	.28	.29	.30	.32	.46	.52	.56	.62
	4	.30	.30	.37	.38	.39	.41	.59	.64	.69	.74
24"	2	.14	.15	.19	.20	.21	.22	.32	.37	.40	.45
	3	.22	.23	.28	.29	.30	.31	.44	.50	.52	.58
	4	.29	.30	.37	.38	.39	.40	.57	.62	.65	.70
30"	2	.14	.15	.19	.19	.20	.21	.31	.34	.37	.41
	3	.22	.23	.28	.28	.29	.30	.44	.46	.50	.54
	4	.29	.30	.37	.37	.38	.39	.56	.59	.62	.66
36"	2	.14	.14	.18	.19	.20	.21	.30	.33	.35	.38
	3	.22	.22	.27	.28	.29	.30	.42	.46	.48	.50
	4	.29	.29	.36	.37	.38	.39	.55	.58	.60	.63
42"	2	.14	.14	.18	.19	.19	.20	.29	.32	.34	.36
	3	.22	.22	.27	.28	.28	.29	.42	.44	.46	.48
	4	.29	.29	.36	.37	.37	.38	.54	.57	.59	.61
48"	2	.14	.14	.18	.18	.19	.20	.29	.31	.32	.35
	3	.22	.22	.27	.27	.28	.29	.42	.44	.44	.48
	4	.29	.29	.36	.36	.37	.38	.54	.56	.57	.60

SECTION IV

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 ANSI A21.50, Table 14).

Ductile iron gravity flow pipelines should be designed in accordance with ANSI Standard A21.50 and specified according to ANSI Standard A21.51.



AMERICAN SOCIETY FOR TESTING AND MATERIALS
1916 Race St., Philadelphia, Pa., 19103

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**Standard Specification for
DUCTILE IRON CULVERT PIPE¹**

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.

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1. Scope

1.1 This specification covers 14 to 54-in. (0.356 to 1.372-m) ductile-iron culvert pipe centrifugally cast in metal molds or sand-lined molds.

2. Applicable Documents

2.1 *ASTM Standards*.

A 377, Specification for Cast Iron and Ductile Iron Pressure Pipe²

E 8, Tension Testing of Metallic Material³

E 23, Notch and Bar Impact Testing of Metallic Materials³

2.2 *ANSI Standards*:

A21.50, Thickness Design of Ductile Iron Pipe⁴

A21.51, Ductile-Iron Pipe Centrifugally Cast in Metal Molds or Sand-Lined Molds for Water or Other Liquids⁴

3. General Requirements

3.1 The pipe shall be manufactured of ductile iron that meets the requirements of ANSI A21.51.

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) and may be shorter than nominal in accordance with ANSI A21.51.

4. Inspection and Certification by Manufacturer

4.1 The manufacturer shall establish the necessary quality-control and inspection prac-

tice to assure compliance with this standard specification.

4.2 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 standard specification.

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

5. Inspection by Purchaser

5.1 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.

5.2 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

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

Current edition approved Aug. 29, 1975. Published October 1975.

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

³ *Annual Book of ASTM Standards*, Part 10.

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

with assistance as necessary for handling of pipe.

6. Delivery and Acceptance

6.1 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.

7. Tolerances or Permitted Variations

7.1 *Dimensions*—The spigot end, bell, and socket of the pipe and the accessories shall be gaged with suitable gages at sufficiently frequent intervals to assure that the dimensions comply with the requirements of this standard specification. The smallest inside diameter of the sockets and the outside of the spigot ends shall be tested with circular gages. Other socket dimensions shall be gaged as appropriate.

7.2 *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)

7.3 *Weight*—The weight of any single pipe shall not be less than the tabulated weight by more than 4 %.

8. Coating and Lining

8.1 All pipe shall be coated inside and outside with a bituminous material approximately 1 mil (0.025 mm) thick. 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.

9. Acceptance Tests

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

9.1.1 *Tension Test*—A tension test specimen shall be cut longitudinally from the mid-section of the pipe wall. This specimen shall be machined and tested in accordance with Fig. 1 and Specification E 8. The yield strength shall be determined by the 0.2 % offset, half-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 ($70 \pm 10^\circ\text{F}$ ($21.1 \pm 5.5^\circ\text{C}$)).

9.1.2 *Acceptance Values*—The acceptance values for test specimens shall be as follows:

Grade of Ductile Iron:	60-42-10
Minimum tensile strength, psi (kPa):	60 000 (414)
Minimum yield strength, psi (kPa):	42 000 (290)
Minimum elongation, %:	10

9.1.3 *Impact Test*—Tests shall be made in accordance with Specification E 23, except that specimens shall be 0.50 in. (12.7 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 0.40-in. (10.2-mm) wall thickness by calculations as follows:

$$\text{Impact value (corrected)} = (0.40/t) \times \text{impact value (actual)}$$

where:

t = thickness of the specimen, in. (wall thickness of pipe).

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

9.1.4 *Acceptance Value*—The corrected acceptance value for notched impact test specimens shall be a minimum of 7 lbf-ft (9 J) for tests conducted at $70 \pm 10^\circ\text{F}$ ($21.1 \pm 5.5^\circ\text{C}$).

9.2 *Sampling*—At least one tension and impact sample shall be taken during each casting period of approximately 3 h. Samples shall be selected to represent extremes of pipe diameters and thicknesses properly.

10. Additional Control Tests by Manufacturer

10.1 Low-temperature impact tests shall

be made from at least one third of the test pipe specified in 9.2 to assure compliance with a minimum corrected value of 3 lbf-ft (4 J) for test conducted at -40°F (-40°C). Test specimens shall be prepared and tested in accordance with 9.1.3.

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

11. Foundry Records

11.1 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.

12. Marking Pipe

12.1 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. 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 1/2 in. (12.7 mm) in height.

13. Weighing the Pipe

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

14. Additional Tests Required by Purchaser

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

15. Defective Specimens and Retests

15.1 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.

16. Rejection of Pipe

16.1 If the results of any physical acceptance test fail to meet the requirements of Section 9 or Section 15, the pipe cast in the same period shall be rejected, except as provided in Section 17.

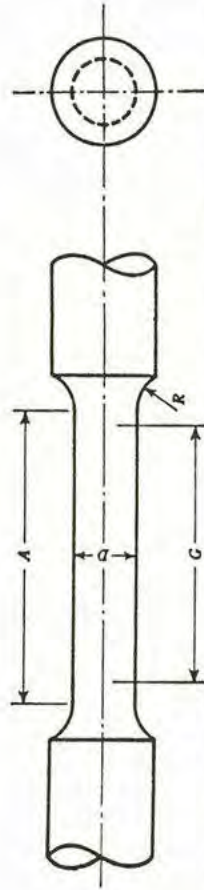
17. Determining Rejection

17.1 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.

TABLE 1 Standard Wall Thickness^a and Weights of Push-On Joint Ductile-Iron Culvert Pipe

Nominal Diameter, in. (mm)	Nominal Thickness for Depths of Cover, 2 to 30 ft, in. (mm)		Thickness Class	18-ft (5.5-m) Laying Length Weight per Length, lb (kg)		20-ft (6 m) Laying Length Weight per Length, lb (kg)	
14 (356)	0.36	(9.1)	1	1005	(456)	1110	(503)
16 (406)	0.37	(9.4)	1	1185	(538)	1305	(592)
18 (457)	0.38	(9.7)	1	1370	(621)	1510	(685)
20 (508)	0.39	(9.9)	1	1560	(708)	1720	(780)
24 (610)	0.41	(10.4)	1	1970	(894)	2170	(984)
30 (762)	0.43	(10.9)	1	2565	(1163)	2775	(1259)
36 (914)	0.48	(12.2)	1	3435	(1558)	3705	(1681)
42 (1067)	0.53	(13.5)	1	—	—	4740	(2150)
48 (1219)	0.58	(12.2)	1	—	—	5915	(2683)
54 (1372)	0.65	(16.5)	1	—	—	7425	(3368)

^a Nominal thickness based on "S" trench condition of ANSI A21.50 with maximum ring deflection of 5% and ring stress of 36 000 psi (248 kPa). Wall thickness of pipe to serve at greater depths of cover may be calculated in accordance with ANSI A21.50.



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.

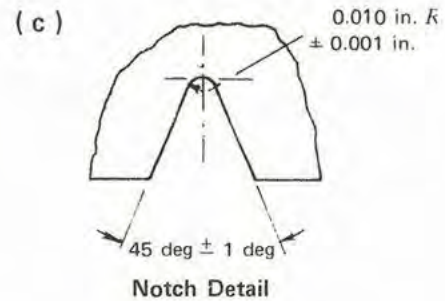
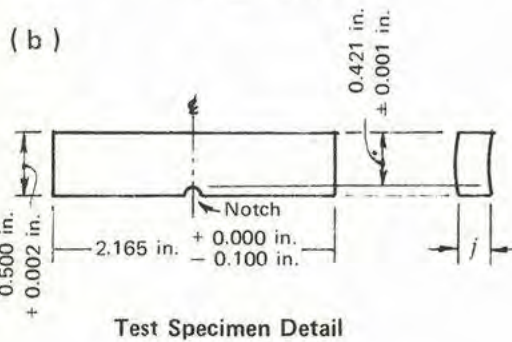
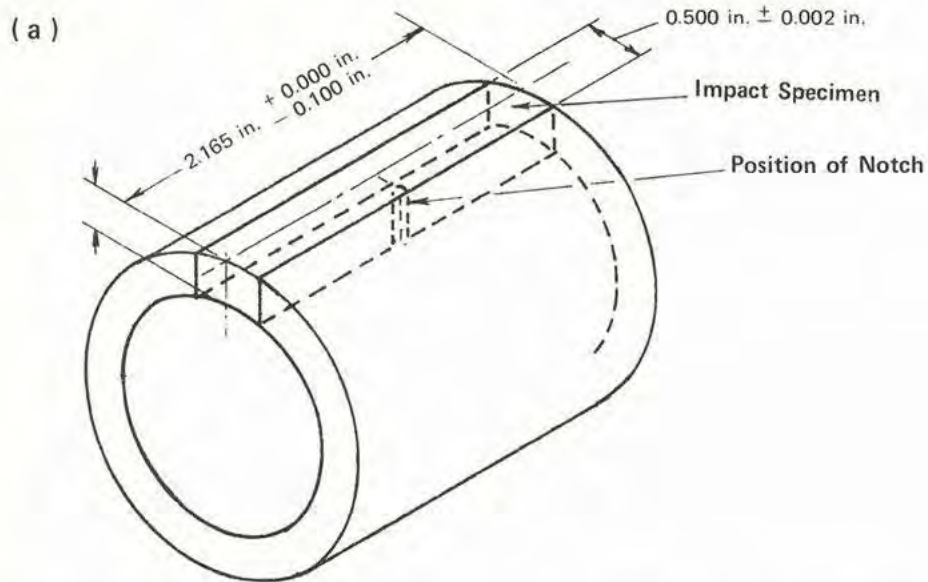
NOTE 2—If desired, on the small size specimens the length of the reduced section may be increased to accommodate an extensometer. However, reference marks for the measurement of elongation should nevertheless be spaced at the indicated gage length (G).

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	Small-Size Specimens Proportional to Standard	Small-Size Specimens Proportional to Standard
	0.50-in. (12.7-mm) Round	0.250-in. (6.35-mm) Round		0.175-in. (4.45-mm) Round
G	2.000 ± 0.005 (50.80 ± 0.13)	1.000 ± 0.005 (25.40 ± 0.13)	0.500 ± 0.005 (12.70 ± 0.13)
D	0.500 ± 0.010 (12.70 ± 0.25)	0.250 ± 0.005 (6.35 ± 0.13)	0.125 ± 0.005 (3.18 ± 0.13)
R, min	3/16 (9.5)	3/16 (4.8)	3/32 (2.4)
A, min	2 1/4 (57.2)	1 1/4 (31.8)	3/4 (19)
T ^a	0.71 and greater	0.35 to 0.49 (8.9 to 12.4)	0.25 to 0.34 (6.4 to 8.6)
		Dimensions, in. (mm)	0.18 to 0.24 (4.6 to 6.1)
			Round

^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

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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**PROPOSED STANDARD
FOR
DUCTILE-IRON GRAVITY SEWER PIPE**

1. Scope

1.1 This standard covers 4-in. through 54-in. ductile iron gravity sewer pipe centrifugally cast in metal molds or sand lined molds with push-on joints. This standard may be used for pipe with such other types of joints as may be agreed upon at the time of purchase.

This standard specifies trench load design procedures for both cement lined pipe and flexible lined pipe. Maximum depth of cover tables are included for both types of linings.

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2. Applicable Documents

2.1 ASTM Standards:

A377, Cast Iron and Ductile Iron Pressure Pipe

E8, Tension Testing of Metallic Material

E23, Notched Charpy Tests

2.2 ANSI Standards:

A21.50, Thickness Design of Ductile-Iron Pipe

A21.4, Cement-Mortar Lining for Cast-Iron and Ductile-Iron Pipe and Fittings for Water

A21.11, Rubber-Gasket Joints for Cast-Iron and Ductile-Iron Pressure Pipe and Fittings

2.3 ASCE Standards:

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

3. General Requirements

3.1 The pipe shall be ductile-iron in accordance with Sec. 12.

3.2 Push-on joints shall comply with all applicable requirements of ANSI 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 standard.

3.3 Unless otherwise specified, pipe shall have nominal length of 18 or 20 ft. A maximum of 20 per cent of the total number of pipe of each size specified in an order may be furnished as much as 24-in. shorter than the nominal laying length, and an additional 10 per cent may be furnished as much as 6-in. shorter than nominal laying length.

4. Inspection and Certification by Manufacturer

4.1 The manufacturer shall establish the necessary quality-control and inspection practice to assure compliance with this standard.

4.2 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 standard.

4.3 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 standard.

5. Inspection by Purchaser

5.1 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.

5.2 The inspector shall have free access to those parts of the manufacturer's plant that are necessary to assure compliance with this standard. 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.

6. Delivery and Acceptance

6.1 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.

7. Tolerances or Permitted Variations

7.1 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 standard.

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

Size In.	Minus Tolerance In.
4-8	0.05
10-12	0.06
14-42	0.07
48	0.08
54	0.09

NOTE: An additional minus tolerance of 0.02-in. shall be permitted along the barrel of the pipe for a distance not to exceed 12-in.

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, nor by more than 5 percent for pipe larger than 12-in. in diameter.

8. Coating and Lining

8.1 *Outside Coating.* The outside coating for use under normal conditions shall be a bituminous coating approximately 1 mil 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.

8.2 *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 A21.4 (AWWA C104) of latest revision.

8.3 *Bituminous Lining.* Unless otherwise specified, the lining for pipe not cement-lined shall be a bituminous material, minimum 1 mil thick, and conforming to all appropriate requirements for seal coat in ANSI A21.4 of latest revision.

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

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

9. Hydrostatic Test

9.1 Each pipe shall be subjected to a hydrostatic test of not less than 500 psi. This test may be made either before or after the outside coating and the bituminous lining 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 sec. 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.

10. Marking Pipe

10.1 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 1/2-in. in height.

11. Weighing Pipe

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

12. Acceptance Tests

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

12.1 *Tensile Test.* A tensile 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 ASTM E8-69-Tension Testing of Metallic Materials. The yield strength shall be determined by the 0.2 percent offset, half-of-pointer, or extension-under-load methods. If check tests are to be made, the 0.2 percent offset method shall be used. All specimens shall be tested at room temperature ($70^{\circ}\text{F} \pm 10$).

12.1.1 *Acceptable Values.* The acceptance values for test specimens shall be as follows:

Grade of iron: 60-42-10

1. Minimum Tensile Strength: 60,000 psi
2. Minimum Yield Strength: 42,000 psi
3. Minimum Elongation: 10 percent

12.2 *Impact Test.* Tests shall be made in accordance with ASTM E23-66-Notched Charpy Test, except that specimens shall be 0.500 in. 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., the impact specimen may be machined to a nominal thickness of 0.40 in. In all tests, impact values are to be corrected to 0.40 in. wall thickness by calculations as follows:

Impact value (corrected) = $\frac{0.40}{t}$ x impact value (actual) in which "t" is the thickness of the specimen in inches (wall thickness of pipe).

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

12.2.1 *Acceptance Value.* The corrected acceptance value for notched impact test specimens shall be a minimum of 7 ft-lb. for tests conducted at $70^{\circ}\text{F} \pm 10$.

12.3 *Sampling.* At least one tensile and impact sample shall be taken during each casting period of approximately 3 hr. Samples shall be selected to represent extremes of pipe diameters and thicknesses properly.

13. Additional Control Tests by Manufacturer

13.1 Low-temperature impact tests shall be made from at least one third of the test pipe specified in 12.3 to assure compliance with a minimum corrected value of 3 ft-lb. for tests conducted at -40°F. Test specimens shall be prepared and tested in accordance with 12.2.

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

14. Foundry Records

14.1 The results of the acceptance tests (12) and low-temperature impact tests (13) shall be recorded and retained for 1 yr. and shall be available to the purchaser at the foundry. Written transcripts shall be furnished, if specified on the purchase order.

15. Additional Tests Required by Purchaser

15.1 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.

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 acceptance test fail to meet the requirements of 12 or 16, the pipe cast in the same period shall be rejected, except as provided in 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 12.

19. Pipe Design

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

19.1 Determining total calculated thickness and standard thickness.

a. Determine trench load P_v . Table 1 gives trench load, including earth load P_e plus truck load P_t , for 2.5 through 32 feet cover.

b. Determine the standard trench class from the descriptions in Table 2 and select the appropriate table of diameter-thickness ratios, Tables 7 through 11. Enter the calculated trench load P_v in 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 net thickness t required by the design for bending stress.

c. 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. 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, design for trench load is not controlled by deflection and this determination need not be completed.)

d. Compare the net thicknesses from steps b and c and select the larger of the two. This will be the net thickness t .

e. Add the service allowance of 0.08 in. to the net thickness t . The resulting thickness is the minimum manufacturing thickness t_1 .

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

g. 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.

19.2 Design Example

Problem: Calculate the thickness for 30 in. cement-lined ductile-iron pipe laid on flat-bottom trench with backfill lightly tamped to centerline of pipe, Laying Condition Type 2, under 10 feet of cover.

- a. 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

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

$$\text{Net thickness } t \text{ for bending stress} = \frac{D}{D/t} = \frac{32.00}{128} = .25$$

c. Re-entering P_v of 9.0 psi in Table 8 the deflection design requires D/t_1 of 108.

$$\begin{aligned} \text{Minimum thickness } t_1 \text{ for deflection design} &= \frac{D}{D/t_1} = \frac{32.00}{108} \\ &= 0.30 \text{ in.} \\ \text{Deduct service allowance} & \quad \quad \quad -0.08 \text{ in.} \\ \text{Net thickness } t \text{ for deflection control} &= \underline{0.22 \text{ in.}} \end{aligned}$$

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

$$\begin{aligned} \text{e. Net thickness} &= 0.25 \text{ in.} \\ \text{Service allowance} &= 0.08 \text{ in.} \\ \text{Minimum thickness} &= \underline{0.33 \text{ in.}} \end{aligned}$$

$$\begin{aligned} \text{f. Casting tolerance} &= 0.07 \text{ in.} \\ \text{Total calculated thickness} &= \underline{0.40 \text{ in.}} \end{aligned}$$

g. 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.

19.3 Design Method

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.

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

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

19.3.1 *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 .

19.3.2 *Earth Load P_e* : Earth load is computed by Equation 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./cu. ft.

19.3.3 *Truck Load P_t* : The truck loads shown in Table 1 were computed by Equation 4 using the surface load factors in Table 6 for a single AASHO H-20 truck on unpaved road or flexible pavement, 16,000 lb. wheel load and 1.5 impact factor. The surface load factors in Table 6 were calculated by Equation 5 for a single concentrated wheel load centered over an effective pipe length of 3 ft.

19.3.4 *Design for Trench Load*: Tables 7 through 11, the tables of diameter-thickness ratios used to design for trench load, were computed by Equations 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 which 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 $\Delta\chi$ is 3 percent of the outside diameter of the pipe for cement-lined pipe and 5 percent for pipe with flexible linings. Design values of the trench parameters, E' , K_b , and K_x are given in Table 2.

Tables similar to Tables 7 through 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 Equations 1 and 2 with values of E' , K_b , and K_x appropriate to the bedding and backfill conditions.

DESIGN EQUATIONS

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

$$P_v = \frac{\Delta\chi/D}{12 K_x} \left[\frac{8E}{\left(\frac{D}{t_1} - 1\right)^3} + 0.732 E' \right] \quad (2)$$

$$P_v = \frac{wH}{144} = \frac{120 H}{144} = \frac{H}{1.2} \quad (3)$$

$$P_t = \frac{CRPF}{12D} \quad (4)$$

$$C = \frac{1}{3} - \frac{2}{3\pi} \arcsin \left[H \sqrt{\frac{A^2 + H^2 + 1.5^2}{(A^2 + H^2)(H^2 + 1.5^2)}} \right] + \frac{AH}{\pi\sqrt{A^2 + H^2 + 1.5^2}} \left[\frac{1}{A^2 + H^2} + \frac{1}{H^2 + 1.5^2} \right] \quad (5)$$

EXPLANATION OF SYMBOLS FOR EQUATIONS

P_v = trench load, psi = $P_e + P_t$

f = design bending stress, 48,000 psi

$\Delta\chi$ = design deflection, in. ($\Delta\chi/D = 0.03$) or ($\Delta x/D = 0.05$ (for flexible linings))

t = net thickness, in.

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

D = outside diameter, in. (Table 5)

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

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

K_b = bending moment coefficient (Table 2)

K_x = deflection coefficient (Table 2)

P_e = earth load, psi

H = depth of cover, ft.

w = soil weight, 120 lb./cu. ft.

P_t = truck load, psi

C = surface load factor (Table 6)

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 receive little or no load from the wheels. (Table 4)

P = wheel load, 16,000 lb.

F = impact factor, 1.5

A = outside radius of pipe, ft. = $D/24$

NOTE: In Eq. 5, angles are in radians.

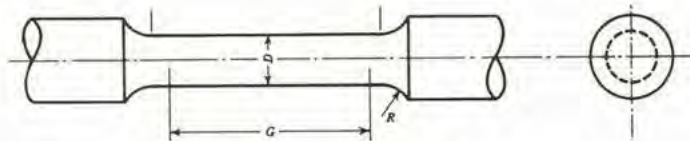


Fig 1. Tensile-Test Specimen

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

Dimension	Standard Specimen 0.300 in. round	Small-Size Specimens Proportional to Standard			
		0.350 in. round	0.250 in. round	0.175 in. round	0.125 in. round
Dimensions—in.					
<i>G</i>	2.000 ± 0.005	1.400 ± 0.005	1.000 ± 0.005	0.700 ± 0.005	0.500 ± 0.005
<i>D</i>	0.500 ± 0.010	0.350 ± 0.007	0.250 ± 0.005	0.175 ± 0.005	0.125 ± 0.005
<i>R</i>	3/8 (min.)	1/4 (min.)	1/8 (min.)	3/16 (min.)	3/32 (min.)
<i>A</i>	2 1/4 (min.)	1 3/4 (min.)	1 1/4 (min.)	3/4 (min.)	5/8 (min.)
<i>T*</i>	0.71 & greater	0.50-0.70	0.35-0.49	0.25-0.34	0.18-0.24

- * 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. larger in diameter than the center on the standard specimen and not more than 0.003 in. 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.

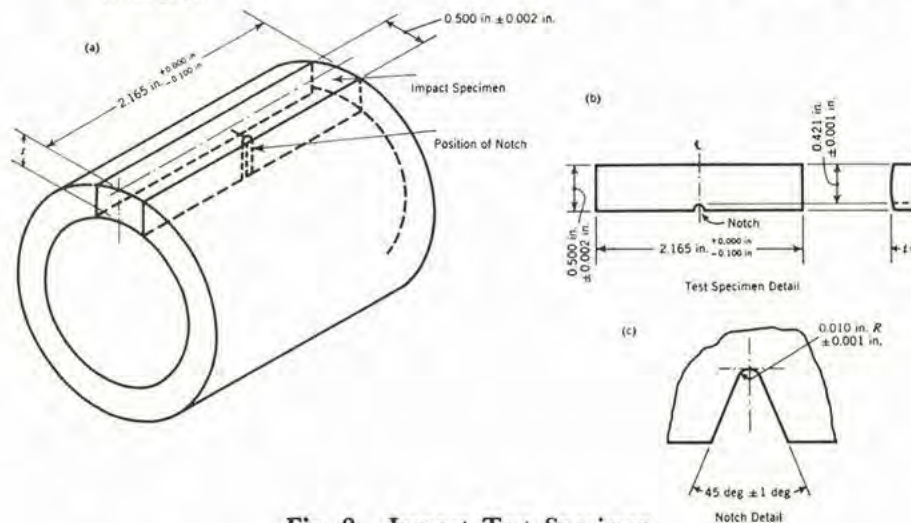


Fig. 2. Impact Test Specimen

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

TABLE 1

Earth Loads (P_e), Truck Loads (P_t), and Trench Loads (P_v), psi

Depth of Cover Ft.	P_e	4-in. Pipe		6-in. Pipe		8-in. Pipe	
		P_t	P_v	P_t	P_v	P_t	P_v
2.5	2.1	9.9	12.0	9.9	12.0	9.8	11.9
3	2.5	7.4	9.9	7.3	9.8	7.3	9.8
4	3.3	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
6	5.0	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
8	6.7	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
10	8.3	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
14	11.7	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
20	16.7	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
28	23.3	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

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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 3**Allowances for Casting Tolerance**

Size In.	Casting Tolerance In.
4-8	0.05
10-12	0.06
14-42	0.07
48	0.08
54	0.09

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4**TABLE 4****Reduction Factors (R) for Truck Load Calculations**

Size In.	<4	Depth of Cover-Ft.		
		4-7 Reduction Factor	8-10	>10
4-12	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

TABLE 5

Standard Thickness Classes of Ductile Iron Pipe

Size In.	Outside Diameter, In.	Thickness in Inches		
		Thickness Class 50	Thickness Class 51	Thickness Class 52
4	4.80	—	0.26	0.29
6	6.90	0.25	0.28	0.31
8	9.05	0.27	0.30	0.33
10	11.10	0.29	0.32	0.35
12	13.20	0.31	0.34	0.37
14	15.30	0.33	0.36	0.39
16	17.40	0.34	0.37	0.40
18	19.50	0.35	0.38	0.41
20	21.60	0.36	0.39	0.42
24	25.80	0.38	0.41	0.44
30	32.00	0.39	0.43	0.47
36	38.30	0.43	0.48	0.53
42	44.50	0.47	0.53	0.59
48	50.80	0.51	0.58	0.65
54	57.10	0.57	0.65	0.73

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TABLE 6

Surface Load Factors for Single Truck on Unpaved Road

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Depth of Cover Ft.	Pipe Size						
	4-in.	6-in.	8-in.	10-in.	12-in.	14-in.	16-in.
	Surface Load Factor, C						
2.5	.0238	.0340	.0443	.0538	.0634	.0726	.0814
3	.0177	.0253	.0330	.0402	.0475	.0546	.0614
4	.0107	.0153	.0201	.0245	.0290	.0335	.0379
5	.0071	.0102	.0134	.0163	.0194	.0224	.0254
6	.0050	.0072	.0095	.0116	.0138	.0159	.0181
7	.0038	.0054	.0071	.0087	.0103	.0119	.0135
8	.0029	.0042	.0055	.0067	.0079	.0092	.0104
9	.0023	.0033	.0043	.0053	.0063	.0073	.0083
10	.0019	.0027	.0035	.0043	.0051	.0060	.0068
12	.0013	.0019	.0025	.0030	.0036	.0042	.0047
14	.0010	.0014	.0018	.0022	.0027	.0031	.0035
16	.0007	.0011	.0014	.0017	.0020	.0024	.0027
20	.0005	.0007	.0009	.0011	.0013	.0015	.0017
24	.0003	.0005	.0006	.0008	.0009	.0011	.0012
28	.0002	.0003	.0005	.0006	.0007	.0008	.0009
32	.0002	.0003	.0004	.0004	.0005	.0006	.0007

Depth of Cover Ft.	Pipe Size							
	18-in.	20-in.	24-in.	30-in.	36-in.	42-in.	48-in.	54-in.
	Surface Load Factor, C							
2.5	.0899	.0980	.1130	.1321	.1479	.1604	.1705	.1784
3	.0681	.0746	.0867	.1028	.1169	.1286	.1384	.1466
4	.0422	.0464	.0545	.0657	.0761	.0853	.0936	.1008
5	.0283	.0312	.0369	.0449	.0525	.0595	.0661	.0720
6	.0202	.0223	.0264	.0323	.0381	.0435	.0486	.0534
7	.0151	.0167	.0198	.0243	.0288	.0329	.0370	.0409
8	.0117	.0129	.0154	.0189	.0224	.0258	.0290	.0322
9	.0093	.0103	.0122	.0151	.0179	.0207	.0233	.0259
10	.0076	.0084	.0100	.0123	.0147	.0169	.0191	.0213
12	.0053	.0059	.0070	.0086	.0103	.0119	.0135	.0151
14	.0039	.0043	.0052	.0064	.0076	.0088	.0100	.0112
16	.0030	.0033	.0040	.0049	.0059	.0068	.0077	.0087
20	.0019	.0021	.0025	.0032	.0038	.0044	.0050	.0056
24	.0013	.0015	.0018	.0022	.0026	.0030	.0035	.0039
28	.0010	.0011	.0013	.0016	.0019	.0022	.0026	.0029
32	.0008	.0008	.0010	.0012	.0015	.0017	.0020	.0022

TABLE 7

Diameter-Thickness Ratios for Laying Condition Type 1

$E' = 150$ $K_b = 0.235$ $K_x = 0.108$

Bending Stress Design	Trench Load P_v , psi			D/t* or D/t _i	Bending Stress Design	Trench Load P_v , psi		D/t* or D/t _i
	Deflection 3%** Max.	Design 5%*** Max.	D/t*			Deflection 3%** Max.	Design 5%*** Max.	
5.17	3.89	6.48	150	6.89	5.18	8.63	120	
5.21	3.91	6.52	149	6.97	5.25	8.74	119	
5.26	3.94	6.57	148	7.05	5.32	8.86	118	
5.30	3.97	6.62	147	7.13	5.39	8.98	117	
5.35	4.00	6.67	146	7.21	5.46	9.11	116	
5.40	4.03	6.72	145	7.29	5.54	9.24	115	
5.45	4.06	6.77	144	7.38	5.62	9.37	114	
5.49	4.09	6.82	143	7.47	5.71	9.51	113	
5.54	4.13	6.88	142	7.56	5.79	9.65	112	
5.59	4.16	6.94	141	7.65	5.88	9.80	111	
5.65	4.20	6.99	140	7.75	5.97	9.96	110	
5.70	4.23	7.05	139	7.85	6.07	10.12	109	
5.75	4.27	7.12	138	7.95	6.17	10.28	108	
5.80	4.31	7.18	137	8.05	6.27	10.46	107	
5.86	4.35	7.25	136	8.16	6.38	10.63	106	
5.91	4.39	7.31	135	8.27	6.49	10.82	105	
5.97	4.43	7.38	134	8.38	6.61	11.01	104	
6.03	4.47	7.46	133	8.49	6.73	11.22	103	
6.09	4.52	7.53	132	8.61	6.86	11.43	102	
6.15	4.56	7.61	131	8.74	6.99	11.64	101	
6.21	4.61	7.69	130	8.86	7.12	11.87	100	
6.27	4.66	7.77	129	8.99	7.26	12.11	99	
6.33	4.71	7.85	128	9.13	7.41	12.35	98	
6.40	4.76	7.94	127	9.27	7.57	12.61	97	
6.46	4.82	8.03	126	9.41	7.73	12.88	96	
6.53	4.87	8.12	125	9.56	7.89	13.15	95	
6.60	4.93	8.22	124	9.71	8.07	13.45	94	
6.67	4.99	8.32	123	9.87	8.25	13.75	93	
6.74	5.05	8.42	122	10.03	8.44	14.07	92	

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* 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.
 ** Maximum 3% deflection is recommended for rigid or semi-rigid linings such as cement mortar and most epoxies.
 *** Maximum 5% deflection is recommended for flexible linings such as bituminous and plastic.

TABLE 7 (Continued)

Diameter-Thickness Ratios for Laying Condition Type 1

$E' = 150$ $K_b = 0.235$ $K_x = 0.108$

Bending Stress Design	Trench Load P_v , psi			D/t* or D/t _i	Bending Stress Design	Trench Load P_v , psi		
	Deflection 3%** Max.	Design 5%*** Max.	D/t*			Deflection 3%** Max.	Design 5%*** Max.	D/t*
6.82	5.11	8.52	121	10.20	8.64	14.40	91	
10.37	8.85	14.74	90	20.59	24.18	40.30	60	
10.55	9.06	15.11	89	21.23	25.32	42.20	59	
10.74	9.29	15.48	88	21.91	26.54	44.23	58	
10.93	9.53	15.88	87	22.63	27.85	46.42	57	
11.13	9.78	16.30	86	23.38	29.26	48.76	56	
11.34	10.04	16.73	85	24.18	30.77	51.28	55	
11.55	10.31	17.19	84	25.02	32.39	53.99	54	
11.78	10.60	17.67	83	25.92	34.15	56.92	53	
12.01	10.90	18.17	82	26.86	36.05	60.08	52	
12.25	11.22	18.70	81	27.87	38.10	63.50	51	
12.50	11.56	19.26	80	28.94	40.32	67.20	50	
12.76	11.91	19.85	79	30.07	42.73	71.22	49	
13.03	12.28	20.46	78	31.28	45.35	75.58	48	
13.31	12.67	21.11	77	32.57	48.20	80.34	47	
13.60	13.08	21.79	76	33.95	51.31	85.52	46	
13.91	13.51	22.52	75	35.42	54.72	91.19	45	
14.23	13.97	23.28	74	37.00	58.44	97.40	44	
14.56	14.45	24.08	73	38.69	62.53	104.22	43	
14.91	14.96	24.93	72	40.50	67.03	111.71	42	
15.27	15.50	25.83	71	42.46	71.99	119.98	41	
15.65	16.07	26.78	70	44.56	77.47	129.11	40	
16.05	16.68	27.79	69	46.84	83.54	139.23	39	
16.46	17.32	28.86	68	49.30	90.28	150.47	38	
16.89	18.00	30.00	67	51.96	97.80	163.00	37	
17.35	18.73	31.21	66	54.86	106.20	177.00	36	
17.83	19.50	32.49	65	58.02	115.62	192.70	35	
18.33	20.32	33.86	64	61.46	126.21	210.36	34	
18.85	21.19	35.32	63	65.23	138.18	230.29	33	
19.40	22.12	36.87	62	69.36	151.73	252.88	32	
19.98	23.12	38.53	61	73.92	167.15	278.58	31	
				78.94	184.77	307.96	30	

* 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.

** Maximum 3% deflection is recommended for rigid or semi-rigid linings such as cement mortar and most epoxies.

*** Maximum 5% deflection is recommended for flexible linings such as bituminous and plastic.

TABLE 8

Diameter-Thickness Ratios for Laying Condition Type 2

$E' = 300 \quad K_b = 0.210 \quad K_x = 0.105$

Bending Stress Design	Trench Load P_v , psi			Bending Stress Design	Trench Load P_v , psi		
	Deflection 3%** Max.	Design 5%*** Max.	D/t* or D/t _i		Deflection 3%** Max.	Design 5%*** Max.	D/t* or D/t _i
7.42	6.61	11.02	150	9.70	7.94	13.24	120
7.48	6.64	11.06	149	9.79	8.01	13.35	119
7.54	6.67	11.11	148	9.89	8.08	13.47	118
7.61	6.70	11.16	147	9.99	8.16	13.60	117
7.67	6.73	11.21	146	10.09	8.23	13.72	116
7.74	6.76	11.27	145	10.19	8.31	13.86	115
7.80	6.79	11.32	144	10.29	8.40	13.99	114
7.87	6.83	11.38	143	10.40	8.48	14.14	113
7.94	6.86	11.43	142	10.51	8.57	14.29	112
8.01	6.89	11.49	141	10.62	8.66	14.44	111
8.08	6.93	11.55	140	10.73	8.76	14.60	110
8.15	6.97	11.61	139	10.84	8.86	14.76	109
8.22	7.01	11.66	138	10.96	8.96	14.93	108
8.29	7.05	11.74	137	11.08	9.07	15.11	107
8.37	7.09	11.81	136	11.21	9.18	15.30	106
8.44	7.13	11.88	135	11.33	9.29	15.49	105
8.52	7.17	11.95	134	11.46	9.41	15.69	104
8.59	7.22	12.03	133	11.59	9.54	15.89	103
8.67	7.26	12.10	132	11.73	9.67	16.11	102
8.75	7.31	12.18	131	11.87	9.80	16.33	101
8.83	7.36	12.26	130	12.01	9.94	16.57	100
8.91	7.41	12.35	129	12.16	10.09	16.81	99
8.99	7.46	12.43	128	12.31	10.24	17.06	98
9.07	7.51	12.52	127	12.46	10.40	17.33	97
9.16	7.57	12.62	126	12.62	10.56	17.60	96
9.25	7.63	12.71	125	12.79	10.73	17.89	95
9.33	7.69	12.81	124	12.96	10.91	18.19	94
9.42	7.75	12.91	123	13.13	11.10	18.50	93
9.51	7.81	13.02	122	13.31	11.29	18.82	92
9.60	7.87	13.12	121	13.49	11.50	19.17	91

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* 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.

** Maximum 3% deflection is recommended for rigid or semi-rigid linings such as cement mortar and most epoxies.

*** Maximum 5% deflection is recommended for flexible linings such as bituminous and plastic.

TABLE 8 (Continued)

Diameter-Thickness Ratios for Laying Condition Type 2

$E' = 300$ $K_b = 0.210$ $K_x = 0.105$

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Bending Stress Design	Trench Load P_v , psi			D/t* or D/t _i	Trench Load P_v , psi			D/t* or D/t _i
	Deflection 3%** Max.	Design 5%*** Max.			Deflection 3%** Max.	Design 5%*** Max.		
13.68	11.71	19.52	90	24.74	27.49	45.81	60	
13.88	11.94	19.89	89	25.43	28.66	47.76	59	
14.08	12.17	20.28	88	26.17	29.91	49.86	58	
14.30	12.42	20.69	87	26.95	31.26	52.10	57	
14.51	12.67	21.12	86	27.77	32.71	54.51	56	
14.74	12.94	21.57	85	28.64	34.26	57.10	55	
14.97	13.22	22.04	84	29.56	35.93	59.89	54	
15.21	13.52	22.53	83	30.53	37.74	62.90	53	
15.46	13.83	23.05	82	31.57	39.69	66.15	52	
15.72	14.16	23.60	81	32.67	41.80	69.67	51	
15.99	14.50	24.17	80	33.84	44.09	73.48	50	
16.28	14.86	24.77	79	35.08	46.56	77.61	49	
16.57	15.24	25.40	78	36.41	49.26	82.10	48	
16.87	15.64	26.07	77	37.83	52.19	86.99	47	
17.19	16.06	26.77	76	39.34	55.40	92.33	46	
17.52	16.51	27.52	75	40.96	58.89	98.16	45	
17.86	16.98	28.30	74	42.70	62.73	104.54	44	
18.22	17.48	29.13	73	44.57	66.93	111.55	43	
18.59	18.00	30.00	72	46.57	71.56	119.26	42	
18.98	18.56	30.93	71	48.73	76.66	127.76	41	
19.39	19.14	31.91	70	51.06	82.29	137.16	40	
19.82	19.77	32.95	69	53.57	88.54	147.57	39	
20.27	20.43	34.05	68	56.30	95.48	159.13	38	
20.73	21.13	35.22	67	59.25	103.21	172.02	37	
21.23	21.87	36.46	66	62.46	111.85	186.42	36	
21.74	22.67	37.78	65	65.96	121.54	202.56	35	
22.28	23.51	39.18	64	69.79	132.44	220.73	34	
22.85	24.41	40.68	63	73.98	144.74	241.23	33	
23.45	25.37	42.28	62	78.57	158.68	264.46	32	
24.07	26.39	43.99	61	83.64	174.54	290.90	31	
				89.23	192.67	321.11	30	

* 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.

** Maximum 3% deflection is recommended for rigid or semi-rigid linings such as cement mortar and most epoxies.

*** Maximum 5% deflection is recommended for flexible linings such as bituminous and plastic.

TABLE 9

Diameter-Thickness Ratios for Laying Condition Type 3

$E' = 400$ $K_b = 0.189$ $K_x = 0.103$

Bending Stress Design	Trench Load P_v , psi			Bending Stress Design	Trench Load P_v , psi		
	Deflection 3%** Max.	Design 5%*** Max.	D/t* or D/t _i		Deflection 3%** Max.	Design 5%*** Max.	D/t* or D/t _i
10.00	8.52	14.19	150	12.78	9.87	16.45	120
10.08	8.54	14.24	149	12.89	9.94	16.57	119
10.16	8.57	14.29	148	13.00	10.02	16.69	118
10.24	8.60	14.34	147	13.11	10.09	16.82	117
10.33	8.64	14.39	146	13.23	10.17	16.95	116
10.41	8.67	14.45	145	13.34	10.25	17.09	115
10.49	8.70	14.50	144	13.46	10.34	17.23	114
10.58	8.73	14.56	143	13.58	10.42	17.37	113
10.66	8.77	14.62	142	13.71	10.51	17.52	112
10.75	8.81	14.68	141	13.83	10.61	17.68	111
10.83	8.84	14.74	140	13.96	10.71	17.84	110
10.92	8.88	14.80	139	14.09	10.81	18.01	109
11.01	8.92	14.87	138	14.22	10.91	18.18	108
11.10	8.96	14.93	137	14.36	11.02	18.37	107
11.19	9.00	15.00	136	14.50	11.13	18.55	106
11.28	9.04	15.07	135	14.64	11.25	18.75	105
11.37	9.09	15.15	134	14.78	11.37	18.95	104
11.46	9.13	15.22	133	14.93	11.50	19.16	103
11.56	9.18	15.30	132	15.08	11.63	19.38	102
11.65	9.23	15.38	131	15.23	11.77	19.61	101
11.75	9.28	15.46	130	15.39	11.91	19.85	100
11.84	9.33	15.55	129	15.55	12.06	20.10	99
11.94	9.38	15.64	128	15.71	12.21	20.35	98
12.04	9.44	15.73	127	15.88	12.37	20.62	97
12.14	9.49	15.82	126	16.06	12.54	20.90	96
12.25	9.55	15.92	125	16.23	12.72	21.20	95
12.35	9.61	16.02	124	16.42	12.90	21.50	94
12.45	9.67	16.12	123	16.61	13.09	21.82	93
12.56	9.74	16.23	122	16.80	13.29	22.15	92
12.67	9.80	16.34	121	17.00	13.50	22.50	91

* 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.

** Maximum 3% deflection is recommended for rigid or semi-rigid linings such as cement mortar and most epoxies.

*** Maximum 5% deflection is recommended for flexible linings such as bituminous and plastic.

TABLE 9 (Continued)

Diameter-Thickness Ratios for Laying Condition Type 3

$E' = 400$ $K_b = 0.189$ $K_x = 0.103$

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Bending Stress Design	Trench Load P_v , psi			Bending Stress Design	Trench Load P_v , psi		
	Deflection 3%** Max.	Design 5%*** Max.	D/t* or D/t _i		Deflection 3%** Max.	Design 5%*** Max.	D/t* or D/t _i
17.21	13.72	22.86	90	29.08	29.80	49.66	60
17.42	13.95	23.24	89	29.83	30.99	51.65	59
17.64	14.18	23.64	88	30.63	32.27	53.78	58
17.86	14.43	24.06	87	31.47	33.64	56.07	57
18.10	14.70	24.49	86	32.36	35.12	58.53	56
18.34	14.97	24.95	85	33.31	36.70	61.17	55
18.59	15.26	25.43	84	34.30	38.41	64.02	54
18.85	15.56	25.93	83	35.37	40.25	67.08	53
19.12	15.88	26.46	82	36.49	42.24	70.40	52
19.40	16.21	27.01	81	37.69	44.39	73.98	51
19.68	16.56	27.60	80	38.97	46.72	77.86	50
19.99	16.93	28.21	79	40.33	49.25	82.08	49
20.30	17.31	28.86	78	41.78	51.99	86.65	48
20.62	17.72	29.54	77	43.33	54.98	91.64	47
20.96	18.15	30.26	76	44.98	58.25	97.08	46
21.31	18.61	31.01	75	46.76	61.81	103.02	45
21.68	19.09	31.81	74	48.66	65.72	109.53	44
22.07	19.59	32.65	73	50.71	70.01	116.68	43
22.47	20.13	33.55	72	52.91	74.72	124.54	42
22.88	20.69	34.49	71	55.28	79.92	133.20	41
23.32	21.29	35.49	70	57.84	85.67	142.78	40
23.78	21.93	36.55	69	60.61	92.04	153.39	39
24.26	22.60	37.67	68	63.61	99.11	165.18	38
24.76	23.32	38.86	67	66.86	106.99	178.32	37
25.29	24.08	40.13	66	70.40	115.80	193.00	36
25.85	24.88	41.47	65	74.27	125.67	209.46	35
26.43	25.74	42.91	64	78.49	136.78	227.97	34
27.04	26.66	44.43	63	83.11	149.32	248.87	33
27.68	27.64	46.06	62	88.19	163.54	272.56	32
28.36	28.68	47.80	61	93.79	179.71	299.51	31
				99.97	198.18	330.31	30

* 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.

** Maximum 3% deflection is recommended for rigid or semi-rigid linings such as cement mortar and most epoxies.

*** Maximum 5% deflection is recommended for flexible linings such as bituminous and plastic.

TABLE 10

Diameter-Thickness Ratios for Laying Condition Type 4

$$E' = 500 \quad K_b = 0.157 \quad K_x = 0.096$$

Bending Stress Design	Trench Load P_v , psi		D/t* or D/t _i	Bending Stress Design	Trench Load P_v , psi		D/t* or D/t _i
	Deflection 3%** Max.	Design 5%*** Max.			Deflection 3%** Max.	Design 5%*** Max.	
16.34	11.04	18.40	150	19.66	12.50	20.83	120
16.45	11.07	18.46	149	19.78	12.57	20.96	119
16.55	11.11	18.51	148	19.91	12.65	21.09	118
16.65	11.14	18.56	147	20.04	12.73	21.22	117
16.76	11.17	18.62	146	20.16	12.82	21.36	116
16.86	11.21	18.68	145	20.29	12.91	21.51	115
16.96	11.24	18.74	144	20.42	13.00	21.66	114
17.07	11.28	18.80	143	20.55	13.09	21.82	113
17.18	11.31	18.86	142	20.69	13.19	21.98	112
17.28	11.35	18.92	141	20.82	13.29	22.15	111
17.39	11.39	18.99	140	20.96	13.39	22.32	110
17.50	11.43	19.06	139	21.10	13.50	22.50	109
17.60	11.48	19.13	138	21.24	13.61	22.69	108
17.71	11.52	19.20	137	21.39	13.73	22.88	107
17.82	11.56	19.27	136	21.54	13.85	23.08	106
17.93	11.61	19.35	135	21.69	13.98	23.29	105
18.04	11.66	19.43	134	21.84	14.11	23.51	104
18.15	11.71	19.51	133	22.00	14.24	23.74	103
18.26	11.76	19.59	132	22.16	14.38	23.97	102
18.37	11.81	19.68	131	22.32	14.53	24.22	101
18.49	11.86	19.77	130	22.49	14.68	24.47	100
18.60	11.92	19.86	129	22.66	14.84	24.74	99
18.72	11.97	19.95	128	22.83	15.01	25.02	98
18.83	12.03	20.05	127	23.01	15.18	25.30	97
18.95	12.09	20.15	126	23.20	15.36	25.61	96
19.06	12.15	20.26	125	23.38	15.55	25.92	95
19.18	12.22	20.36	124	23.58	15.75	26.25	94
19.30	12.28	20.47	123	23.78	15.95	26.59	93
19.42	12.35	20.59	122	23.99	16.17	26.94	92
19.54	12.42	20.71	121	24.20	16.39	27.32	91

* 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.

** Maximum 3% deflection is recommended for rigid or semi-rigid linings such as cement mortar and most epoxies.

*** Maximum 5% deflection is recommended for flexible linings such as bituminous and plastic.

TABLE 10 (Continued)

Diameter-Thickness Ratios for Laying Condition Type 4

$E' = 500$ $K_b = 0.157$ $K_x = 0.096$

2
8
4

Bending Stress Design	Trench Load P_v , psi			Bending Stress Design	Trench Load P_v , psi		
	Deflection 3%** Max.	Design 5%*** Max.	D/t* or D/t _i		Deflection 3%** Max.	Design 5%*** Max.	D/t* or D/t _i
24.42	16.62	27.71	90	37.63	33.88	56.46	60
24.64	16.87	28.11	89	38.50	35.16	58.60	59
24.88	17.12	28.54	88	39.42	36.53	60.88	58
25.12	17.39	28.99	87	40.39	38.00	63.34	57
25.37	17.67	29.45	86	41.42	39.58	65.97	56
25.63	17.97	29.95	85	42.51	41.28	68.81	55
25.90	18.28	30.46	84	43.67	43.12	71.86	54
26.18	18.60	31.00	83	44.91	45.09	75.15	53
26.47	18.94	31.57	82	46.22	47.22	78.71	52
26.77	19.30	32.16	81	47.62	49.53	82.55	51
27.09	19.67	32.79	80	49.11	52.03	86.72	50
27.42	20.07	33.45	79	50.70	54.74	91.24	49
27.76	20.48	34.14	78	52.41	57.69	96.15	48
28.11	20.92	34.87	77	54.23	60.90	101.50	47
28.49	21.38	35.64	76	56.18	64.40	107.33	46
28.87	21.87	36.45	75	58.27	68.23	113.71	45
29.28	22.38	37.31	74	60.52	72.42	120.70	44
29.70	22.93	38.21	73	62.93	77.02	128.36	43
30.15	23.50	39.17	72	65.54	82.08	136.80	42
30.62	24.11	40.18	71	68.35	87.66	146.09	41
31.11	24.75	41.25	70	71.39	93.82	156.37	40
31.62	25.43	42.39	69	74.67	100.65	167.75	39
32.16	26.16	43.59	68	78.24	108.24	180.40	38
32.72	26.92	44.87	67	82.11	116.70	194.50	37
33.32	27.74	46.23	66	86.33	126.15	210.25	36
33.95	28.60	47.67	65	90.93	136.74	227.91	35
34.61	29.53	49.21	64	95.97	148.66	247.77	34
35.30	30.51	50.85	63	101.49	162.12	270.20	33
36.04	31.56	52.60	62	107.56	177.37	295.61	32
36.81	32.68	54.47	61	114.25	194.72	324.53	31
				121.65	214.54	357.57	30

* 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.

** Maximum 3% deflection is recommended for rigid or semi-rigid linings such as cement mortar and most epoxies.

*** Maximum 5% deflection is recommended for flexible linings such as bituminous and plastic.

TABLE 11

Diameter-Thickness Ratios for Laying Condition Type 5

$$E' = 700 \quad K_b = 0.128 \quad K_x = 0.085$$

Bending Stress Design	Trench Load P_v , psi		D/t* or D/t _i	Bending Stress Design	Trench Load P_v , psi		D/t* or D/t _i
	Deflection 3%** Max.	Design 5%*** Max.			Deflection 3%** Max.	Design 5%*** Max.	
30.21	16.78	27.96	150	33.95	18.42	30.70	120
30.34	16.81	28.02	149	34.07	18.51	30.85	119
30.48	16.85	28.08	148	34.19	18.60	30.99	118
30.61	16.89	28.14	147	34.31	18.69	31.15	117
30.74	16.92	28.20	146	34.43	18.78	31.31	116
30.87	16.96	28.27	145	34.55	18.88	31.47	115
30.99	17.00	28.34	144	34.68	18.98	31.64	114
31.12	17.04	28.40	143	34.80	19.09	31.82	113
31.25	17.09	28.48	142	34.92	19.20	32.00	112
31.38	17.13	28.55	141	35.05	19.31	32.19	111
31.50	17.17	28.62	140	35.17	19.43	32.39	110
31.63	17.22	28.70	139	35.30	19.55	32.59	109
31.76	17.27	28.78	138	35.43	19.68	32.80	108
31.88	17.32	28.86	137	35.56	19.81	33.02	107
32.01	17.37	28.94	136	35.69	19.95	33.25	106
32.13	17.42	29.03	135	35.83	20.09	33.48	105
32.25	17.47	29.12	134	35.96	20.24	33.73	104
32.38	17.53	29.21	133	36.10	20.39	33.99	103
32.50	17.58	29.30	132	36.25	20.55	34.25	102
32.62	17.64	29.40	131	36.39	20.72	34.53	101
32.75	17.70	29.50	130	36.54	20.89	34.82	100
32.87	17.76	29.61	129	36.69	21.07	35.12	99
32.99	17.83	29.71	128	36.85	21.26	35.43	98
33.11	17.89	29.82	127	37.01	21.45	35.76	97
33.23	17.96	29.94	126	37.17	21.66	36.10	96
33.35	18.03	30.05	125	37.34	21.87	36.45	95
33.47	18.11	30.18	124	37.52	22.09	36.82	94
33.59	18.18	30.30	123	37.70	22.32	37.20	93
33.71	18.26	30.43	122	37.89	22.56	37.61	92
33.83	18.34	30.56	121	38.08	22.82	38.03	91

* 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.

** Maximum 3% deflection is recommended for rigid or semi-rigid linings such as cement mortar and most epoxies.

*** Maximum 5% deflection is recommended for flexible linings such as bituminous and plastic.

TABLE 11 (Continued)

Diameter-Thickness Ratios for Laying Condition Type 5

$E' = 700$ $K_b = 0.128$ $K_x = 0.085$

Bending Stress Design	Trench Load P_v , psi		D/t* or D/t _i	Bending Stress Design	Trench Load P_v , psi		D/t* or D/t _i
	Deflection 3%** Max.	Design 5%*** Max.			Deflection 3%** Max.	Design 5%*** Max.	
38.28	23.08	38.47	90	52.02	42.57	70.94	60
38.49	23.36	38.93	89	52.99	44.01	73.36	59
38.71	23.65	39.41	88	54.02	45.56	75.94	58
38.93	23.95	39.91	87	55.12	47.23	78.71	57
39.17	24.27	40.44	86	56.28	49.01	81.69	56
39.41	24.60	41.00	85	57.53	50.93	84.89	55
39.67	24.95	41.58	84	58.86	53.00	88.34	54
39.94	25.31	42.19	83	60.28	55.23	92.05	53
40.22	25.70	42.83	82	61.79	57.64	96.07	52
40.51	26.10	43.50	81	63.41	60.25	100.41	51
40.82	26.52	44.21	80	65.14	63.07	105.12	50
41.14	26.97	44.95	79	67.00	66.13	110.22	49
41.48	27.44	45.73	78	68.99	69.46	115.77	48
41.84	27.93	46.56	77	71.12	73.09	121.81	47
42.21	28.46	47.43	76	73.41	77.04	128.40	46
42.60	29.01	48.34	75	75.88	81.36	135.61	45
43.02	29.59	49.31	74	78.54	86.10	143.49	44
43.45	30.20	50.33	73	81.40	91.29	152.15	43
43.92	30.85	51.41	72	84.50	97.01	161.68	42
44.40	31.53	52.56	71	87.85	103.31	172.18	41
44.91	32.26	53.77	70	91.47	110.27	183.78	40
45.46	33.03	55.05	69	95.40	117.98	196.64	39
46.03	33.85	56.41	68	99.67	126.56	210.93	38
46.64	34.71	57.85	67	104.32	136.11	226.84	37
47.28	35.63	59.39	66	109.40	146.78	244.63	36
47.96	36.61	61.02	65	114.94	158.75	264.58	35
48.68	37.65	62.76	64	121.02	172.21	287.01	34
49.44	38.77	64.61	63	127.69	187.41	312.34	33
50.25	39.95	66.58	62	135.03	204.63	341.04	32
51.11	41.21	68.69	61	143.14	224.22	373.70	31
				152.11	246.61	411.02	30

* 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.

** Maximum 3% deflection is recommended for rigid or semi-rigid linings such as cement mortar and most epoxies.

*** Maximum 5% deflection is recommended for flexible linings such as bituminous and plastic.

TABLE 12

Pipe Selection Table. Cement-Lined Pipe.

Pipe Size In.	Thick. Class	Nominal Thick. In.	Type 1	Laying Condition				Type 5
				Type 2	Type 3	Type 4	Type 5	
				Maximum Depth of Cover, Feet†				
4	51	0.26	76	86	96	§	§	
	52	0.29	§	§	§	§	§	
6	50	0.25	32	38	44	56	75	
	51	0.28	49	57	64	80	§	
8	52	0.31	67	77	86	§	§	
	50	0.27	25	30	36	46	64	
10	51	0.30	36	42	49	61	81	
	52	0.33	47	54	62	77	99	
	50	0.29	19	24	29	38	55	
12	51	0.32	27	32	38	49	66	
	52	0.35	35	41	47	59	79	
	50	0.31	17	22	27	36	52	
14	51	0.34	23	28	33	43	60	
	52	0.37	30	35	41	53	71	
	50	0.33	15	19	24	33	49	
16	51	0.36	19	23	28	38	55	
	52	0.39	24	29	34	44	62	
	50	0.34	13	17	21	30	47	
18	51	0.37	16	21	25	34	51	
	52	0.40	20	25	30	40	57	
	50	0.35	11	15	20	29	42	
20	51	0.38	14	19	23	32	49	
	52	0.41	18	22	27	36	53	
	50	0.36	10	14	18	27	38	
24	51	0.39	13	17	21	30	44	
	52	0.42	16	20	25	34	50	
	50	0.38	8	12	17	23	31	
30	51	0.41	10	15	19	27	36	
	52	0.44	13	17	21	30	41	
	50	0.39	**	10	14	18	25	
36	51	0.43		12	16	21	29	
	52	0.47		14	19	24	33	
	50	0.43	**	10	13*	17	25	
	51	0.48		12	16*	20	28	
	52	0.53		15	19	24	32	

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See notes at end of table.

TABLE 12 (Continued)

Pipe Selection Table. Cement-Lined Pipe.

Pipe Size In.	Thick. Class	Nominal Thick. In.	Type 1	Laying Condition				
				Type 2	Type 3	Type 4	Type 5	Maximum Depth of Cover, Feet†
42	50	0.47	**	9	13	16	24	
	51	0.53		12	15	19	27	
	52	0.59		14	18	22	30	
48	50	0.51	**	9	12	15	23	
	51	0.58		12	14	18	26	
	52	0.65		14	18	21	30	
54	50	0.57	**	9	12	15	23	
	51	0.65		12	14	18	25	
	52	0.73		14	17	21	29	

† These pipe are adequate for depths of cover from 2.5 feet up to the maximum shown including an allowance for single H-20 truck with 1.5 impact factor.

** Laying Condition Type 1 is limited to 24" and smaller pipe.

§ Calculated maximum depth of cover exceeds 100 feet.

TABLE 13

Pipe Selection Table. Pipe with Flexible Lining.

Pipe Size In.	Thick. Class	Nominal Thick. In.	Laying Condition				
			Type 1	Type 2	Type 3	Type 4	Type 5
			Maximum Depth of Cover, Feet†				
4	51	0.26	76	86	96	§	§
	52	0.29	§	§	§	§	§
6	50	0.25	32	38	44	56	75
	51	0.28	49	57	64	80	§
8	52	0.31	67	77	86	§	§
	50	0.27	25	30	36	46	64
10	51	0.30	36	42	49	61	81
	52	0.33	47	54	62	77	99
12	50	0.29	19	24	29	38	55
	51	0.32	27	32	38	49	66
14	52	0.35	35	41	47	59	79
	50	0.31	17	22	27	36	52
16	51	0.34	23	28	33	43	60
	52	0.37	30	35	41	53	71
18	50	0.33	15	19	24	33	49
	51	0.36	19	23	28	38	55
20	52	0.39	24	29	34	44	62
	50	0.34	13	17	21	30	47
24	51	0.37	16	21	25	34	51
	52	0.40	20	25	30	40	57
30	50	0.35	11	15	20	29	45
	51	0.38	14	19	23	32	49
36	52	0.41	18	22	27	36	53
	50	0.36	10	14	18	27	44
42	51	0.39	13	17	21	30	47
	52	0.42	16	20	25	34	50
48	50	0.38	8	12	17	25	42
	51	0.41	10	15	19	28	45
54	52	0.44	13	17	21	30	47
	50	0.39	**	10	14	22	39
60	51	0.43		12	16	25	42
	52	0.47		14	19	27	44
66	50	0.43	**	10	14	22	39
	51	0.48		12	16	25	42
72	52	0.53		15	19	27	44

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See notes at end of table.

TABLE 13 (Continued)

Pipe Selection Table. Pipe with Flexible Lining.

Pipe Size In.	Thick. Class	Nominal Thick. In.	Type 1	Laying Condition				Type 5
				Type 2	Type 3	Type 4	Maximum Depth of Cover, Feet†	
42	50	0.47	**	9	13	22	39	
	51	0.53		12	16	25	42	
	52	0.59		14	18	27	44	
48	50	0.51	**	9	13	21	39	
	51	0.58		12	16	24	41	
	52	0.65		14	18	27	44	
54	50	0.57	**	9	13	21	38	
	51	0.65		12	16	24	41	
	52	0.73		14	18	27	44	

† These pipe are adequate for depths of cover from 2.5 feet up to the maximum shown including an allowance for single H-20 truck with 1.5 impact factor.

** Laying Condition Type 1 is limited to 24" and smaller pipe.

§ Calculated maximum depth of cover exceeds 100 feet.

TABLE 14

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.
4	51	0.26	4.80	11.3	11	215	11.9	235	11.8
	52	0.29	4.80	12.6	11	240	13.2	265	13.2
6	50	0.25	6.90	16.0	18	305	17.0	340	16.9
	51	0.28	6.90	17.8	18	340	18.8	375	18.7
	52	0.31	6.90	19.6	18	370	20.6	410	20.5
8	50	0.27	9.05	22.8	26	435	24.2	480	24.1
	51	0.30	9.05	25.2	26	480	26.6	530	26.5
	52	0.33	9.05	27.7	26	525	29.1	580	29.0
10	50	0.29	11.10	30.1	34	575	32.0	635	31.8
	51	0.32	11.10	33.2	34	630	35.1	700	34.9
	52	0.35	11.10	36.2	34	685	38.1	760	37.9
12	50	0.31	13.20	38.4	43	735	40.8	810	40.6
	51	0.34	13.20	42.0	43	800	44.4	885	44.2
	52	0.37	13.20	45.6	43	865	48.0	955	47.8
14	50	0.33	15.30	47.5	63	920	51.0	1015	50.6
	51	0.36	15.30	51.7	63	995	55.2	1095	54.8
	52	0.39	15.30	55.9	63	1070	59.4	1180	59.0
16	50	0.34	17.40	55.8	76	1080	60.0	1190	59.6
	51	0.37	17.40	60.6	76	1165	64.8	1290	64.4
	52	0.40	17.40	65.4	76	1255	69.6	1385	69.2
18	50	0.35	19.50	64.4	87	1245	69.2	1375	68.8
	51	0.38	19.50	69.8	87	1345	74.6	1485	74.2
	52	0.41	19.50	75.2	87	1440	80.0	1590	79.6
20	50	0.36	21.60	73.5	97	1420	78.9	1565	78.4
	51	0.39	21.60	79.5	97	1530	84.9	1685	84.4
	52	0.42	21.60	85.5	97	1635	90.9	1805	90.4
24	50	0.38	25.80	92.9	120	1790	99.6	1980	98.9
	51	0.41	25.80	100.1	120	1920	106.8	2120	106.1
	52	0.44	25.80	107.3	120	2050	114.0	2265	113.3

* Tolerances of OD of spigot end: 4-12 in., ±0.06 in.; 14-24 in., +0.05 in., -0.08 in.; 30-54 in., +0.08 in., -0.06 in.

† 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 14 (Continued)

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.	
2 9 2	30	50	0.39	32.00	118.5	(1)	2350	130.5	2535	126.6
		51	0.43	32.00	130.5		2565	142.5	2775	138.6
		52	0.47	32.00	142.5		2780	154.5	3015	150.6
	36	50	0.43	38.30	156.5	(2)	3110	172.7	3345	167.3
		51	0.48	38.30	174.5		3435	190.7	3705	185.3
		52	0.53	38.30	192.4		3755	208.6	4065	203.2
	42	50	0.47	44.50	198.9	261			4240	212.0
		51	0.53	44.50	224.0	261			4740	237.0
		52	0.59	44.50	249.1	261			5245	262.2
48	50	0.51	50.80	246.6	316			5250	262.4	
	51	0.58	50.80	280.0	316			5915	295.8	
	52	0.65	50.80	313.4	316			6585	329.2	
54	50	0.57	57.10	309.8	370			6565	328.3	
	51	0.65	57.10	352.7	370			7425	371.2	
	52	0.73	57.10	395.6	370			8280	414.1	

* Tolerances of OD of spigot end: 4-12 in., ± 0.06 in.; 14-24 in., $+0.05$ in., -0.08 in.; 30-54 in., $+0.08$ in., -0.06 in.

(1) Weight of 30-in. bell is 216 lb. for 18-ft. pipe and 163 lb. for 20-ft. pipe.

(2) Weight of 36-in. bell is 292 lb. for 18-ft. pipe and 216 lb. for 20-ft. pipe.

† 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.

SECTION V

GRAY AND DUCTILE IRON FITTINGS

Introduction

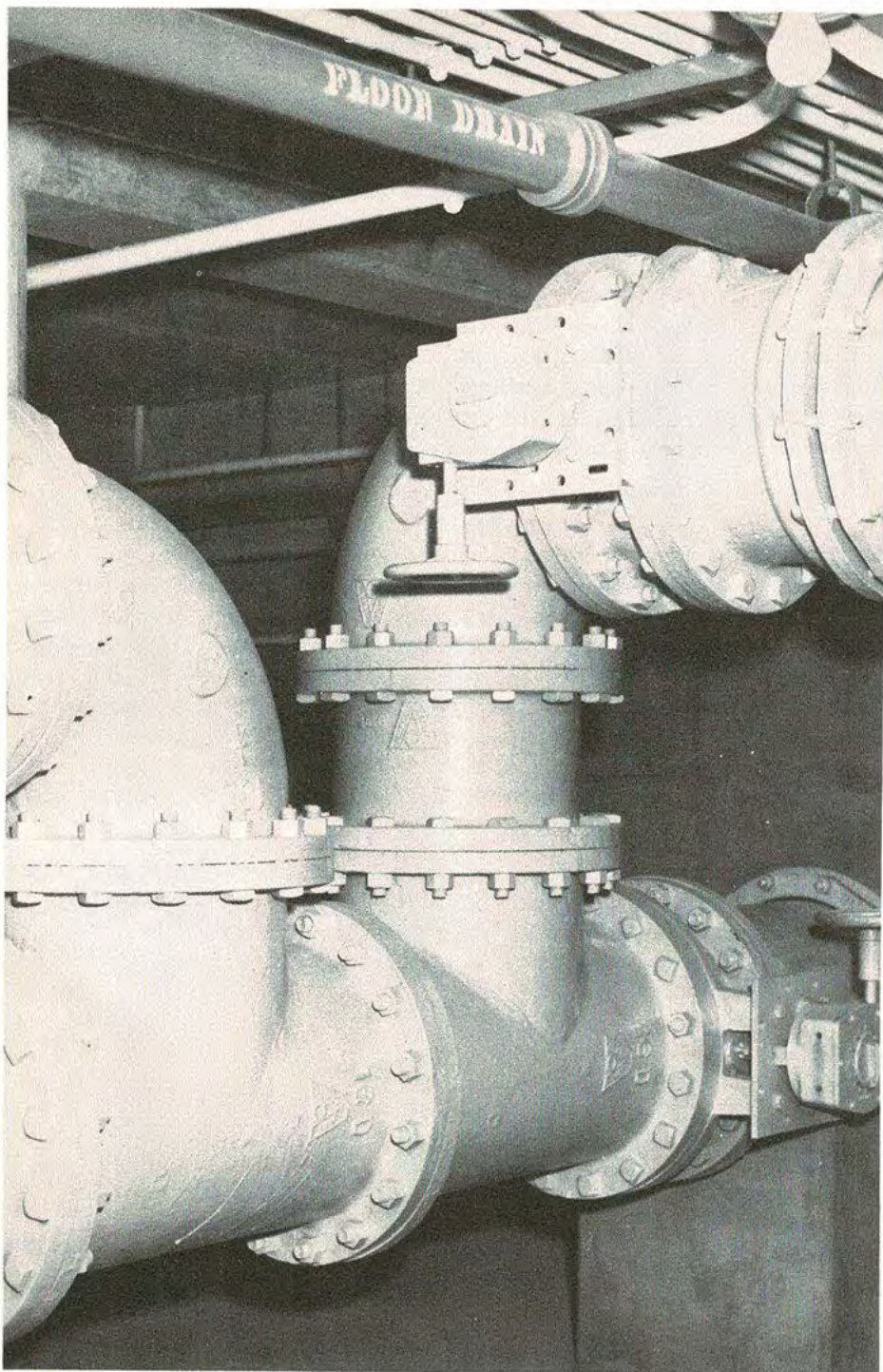
Fittings are produced in accordance with ANSI Standard A21.10 (AWWA C110), ANSI Standard B16.1 as well as manufacturers' standards. Due to their irregular shapes, fittings are statically cast. They are available in either gray or ductile iron and are equipped with mechanical, push-on, caulked lead, flanged 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 A21.10 Standard: bends; tees; crosses; base bends; reducers; sleeves; caps; plugs; offsets; and tapped tees. Included in the fittings manufactured in accordance with ANSI B16.1 are the following: long-radius fittings, reducing elbows, reducing on-the-run tees; side outlet fittings; eccentric reducers and laterals; and true wyes. Manufacturers' standards govern other fittings and in some cases fittings are produced with ANSI B16.1 overall dimensions and ANSI A21.10 thicknesses. All flanged fittings manufactured using ANSI A21.10 have a minimum safety factor of 3.0 times the rated working pressure. Pressure ratings shown in ANSI A21.10 should not be confused with 250-lb. flange ratings covered by ANSI B16.1 which are rated for steam working pressure.

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 an ultimate tensile strength of 70,000 psi, a yield strength of 50,000 psi and a minimum elongation of 5%.

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**ANSI A21.10-1971
(AWWA C110-71)**

Revision of
A21.10-1964
(AWWA C110-64)

AMERICAN NATIONAL STANDARD
for
GRAY-IRON AND DUCTILE-IRON FITTINGS,
2 in. THROUGH 48 in.
FOR WATER AND OTHER LIQUIDS

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PUBLISHED BY AMERICAN WATER WORKS ASSOCIATION, INC.

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NEW ENGLAND WATER WORKS ASSOCIATION

Revised Edition Approved by American National Standards Institute, Inc., July 14, 1971

NOTICE

This Standard has been especially printed by the American Water Works Association for incorporation into this volume. It is current as of December 1, 1975. 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.

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, promotion material, or on tags or labels that the goods are produced in conformity with particular American National Standards.

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<p style="text-align: center;">ANSI Standard</p> <p style="text-align: center;">Approved Dec. 27, 1972</p>	<p style="text-align: center;">Supplement to American National Standard for Gray-Iron and Ductile-Iron Fittings, 2 in. Through 48 in. for Water and Other Liquids</p>	<table style="width: 100%; border: none;"> <tr> <td style="width: 50%; vertical-align: top;"> <p>ANSI A21.10α-1972 Supplement to A21.10-1971</p> </td> <td style="width: 50%; vertical-align: top;"> <p>AWWA C110α-72 Supplement to C110-71</p> </td> </tr> <tr> <td colspan="2" style="text-align: center;"> <p>Administrative Secretariat American Water Works Association</p> </td> </tr> <tr> <td colspan="2" style="text-align: center;"> <p>Co-Secretariats American Gas Association New England Water Works Association</p> </td> </tr> <tr> <td colspan="2"> <p>Copyright © 1973 by the American Water Works Association 6666 West Quincy Avenue, Denver, Colo. 80235. Printed in USA</p> </td> </tr> </table>	<p>ANSI A21.10α-1972 Supplement to A21.10-1971</p>	<p>AWWA C110α-72 Supplement to C110-71</p>	<p>Administrative Secretariat American Water Works Association</p>		<p>Co-Secretariats American Gas Association New England Water Works Association</p>		<p>Copyright © 1973 by the American Water Works Association 6666 West Quincy Avenue, Denver, Colo. 80235. Printed in USA</p>	
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**The following revisions and additions have been made to
ANSI Standard A21.10-1971.**

The statement of scope has been revised to agree with the tables, as follows: In the right column, first line, range has been changed from 3-12 in. to 3-24 in.; in the sixth line, "150-psi or" has been added; in the eighth line, range has been changed from 14-48 in. to 30-48 in.

Sec. 10-1—Scope

This standard covers 2-48-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, bell-and-spigot joints, and flange joints are given in the tables. 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 working pressure, and gray-iron fittings having all types of joints covered by this standard are rated for 150-psi or 250-psi working pressures, as shown in the tables. For the 30-48 in. size range, fittings having 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 psi and 250 psi.

The limit on sulfur has been revised from 0.12 to 0.15 per cent.

**Sec. 10-11—Chemical Analyses of
Gray-Iron Fittings**

Analyses of the iron in gray-iron fittings shall be made at sufficiently frequent intervals to assure compliance with the following limits: phosphorus, 0.90 per cent maximum; and sulfur, 0.15 per cent 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 obtained from either acceptance test specimens or specimens cast for this purpose.

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For Tables 10.3, 10.4, 10.5, 10.6, 10.7, 10.9, and 10.10, the pressure ratings of DI fittings have been revised from 250 to 350 in sizes 14 in. through 24 in.

The same revision has been made for Table 10.13, but the two columns "MJ & Flg." and "Flg. & PE" have been deleted.

Table 10.13A, "Connecting Pieces, One-End Flanged," has been added. In this table the pressure ratings of DI fittings in sizes 3 in. through 12 in. have been revised from 350 to 250.

GRAY-IRON AND DUCTILE-IRON FITTINGS

TABLE 10.3
Mechanical-Joint Bends

Size in.	Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.				Weight—lb†	
			T	A	S	R	MJ & MJ	MJ & PE
90-deg Bends								
2	250	25	0.35	3.25		2.25	14	
2½	250	25	0.35	3.25		2.25	15	
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	I	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	350	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	350	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	350	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	350	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.

* Ductile iron.

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

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TABLE 10.3—Mechanical-Joint Bends (contd.)

Size in.	Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.				Weight—lb†	
			T	A	S	R	MJ & MJ	MJ & PE
45-deg Bends								
2	250	25	0.35	1.8		1.96	13	
2½	250	25	0.35	1.8		1.96	14	
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.

* Ductile iron.

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

GRAY-IRON AND DUCTILE-IRON FITTINGS

TABLE 10.3—Mechanical-Joint Bends (contd.)

Size in.	Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.				Weight—lb†	
			T	A	S	R	MJ & MJ	MJ & PE
22½-deg Bends								
2	250	25	0.35	1.5		2.51	13	
2½	250	25	0.35	1.5		2.51	14	
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.

* Ductile iron.

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

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TABLE 10.3—Mechanical-Joint Bends (contd.)

Size in.	Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.				Weight—lb†	
			T	A	S	R	MJ & MJ	MJ & PE
11½-deg Bends								
2	250	25	0.35	1.5		5.08	13	
2½	250	25	0.35	1.5		5.08	14	
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.

* Ductile iron.

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

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TABLE 10.4—Mechanical-Joint Tees and Crosses (contd.)

Run	Size in. Branch	Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.					Weight—lb†			
				Dimensions—in.					Tee		Cross	
				T	T ₁	H	J	S	All MJ	MJ, PE & MJ	All MJ	MJ, PE, MJ & MJ
6	2	250	25	0.55	0.35	5.2	5.2	13.2	83	78	89	84
6	2	350	DI*	0.55	0.35	5.2	5.2	13.2	83	78	89	84
6	2½	250	25	0.55	0.35	5.2	5.2	13.2	84	79	90	85
6	2½	350	DI	0.55	0.35	5.2	5.2	13.2	84	79	90	85
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.

* Ductile iron.

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

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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 (1,000'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			
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	45	45	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	65	60	10
6	350	DI	7.00	7.00	0.69	0.62	105	100	20
							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

* Ductile iron.

† Dimension "R" is a finished dimension; unfinished bases will be $\frac{1}{8}$ in. longer; for base drilling see Table 10.27.

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

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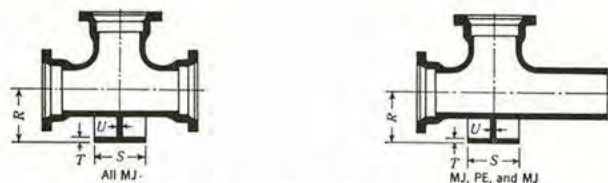


Fig. 10.6. Mechanical-Joint Base Tees (See Table 10.6)

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 (1,000'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

* Ductile iron.

† Dimension "R" is a finished dimension; unfinished bases will be 1/8 in. longer; for base drilling see Table 10.27.

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

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TABLE 10.7—Mechanical-Joint Reducers (contd.)

Size in.		Pressure Rating psi	Iron Strength psi (1,000'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.

* Ductile iron.

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

GRAY-IRON AND DUCTILE-IRON FITTINGS

TABLE 10.7—Mechanical-Joint Reducers (contd.)

Size in.		Pressure Rating psi	Iron Strength psi (1,000'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.

* Ductile iron.

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

TABLE 10.9
Mechanical-Joint Offsets

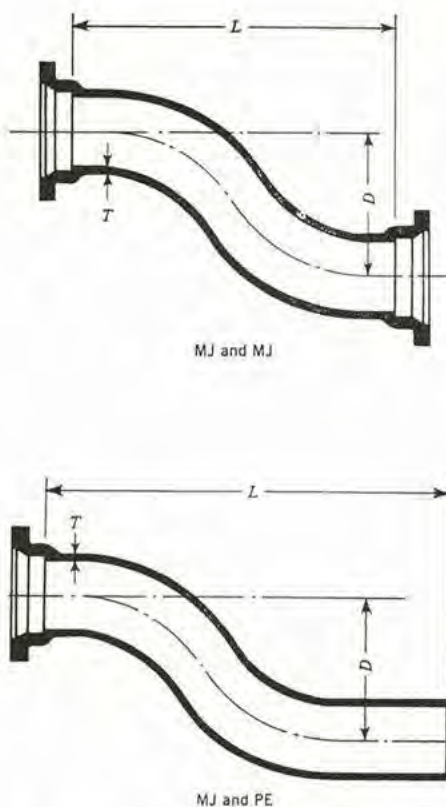


Fig. 10.9. Mechanical-Joint Offsets (See Table 10.9)

Size in.	PR|| psi	Iron Strength psi (1,000's)	D in.	T in.	MJ & MJ		MJ & PE	
					L in.	Wgt.† lb	L in.	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	0.55	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.

* Ductile iron.

|| Pressure rating.

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

GRAY-IRON AND DUCTILE-IRON FITTINGS

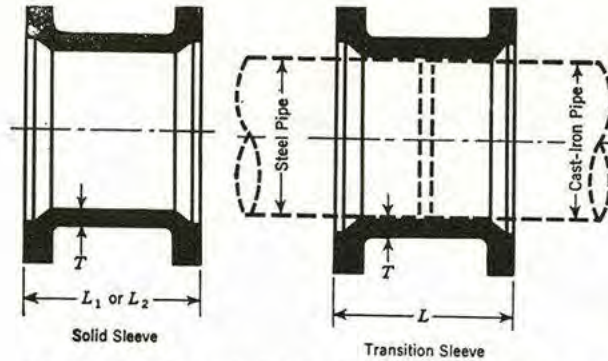


Fig. 10.10. Mechanical-Joint Sleeves (See Table 10.10)

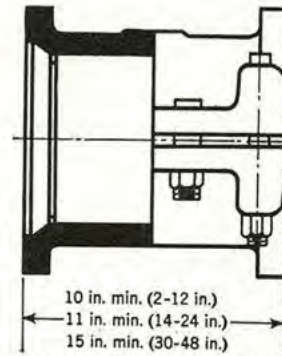


Fig. 10.11. Mechanical-Joint Split Sleeves

Split sleeves are furnished with a pressure rating of 150 psi 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 (1,000'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
2	250	25	0.44	8	12			2.38	8	12
2½	250	25	0.44	8	13			2.75	8	13
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			

* Ductile iron.
 † 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.

AMERICAN NATIONAL STANDARD

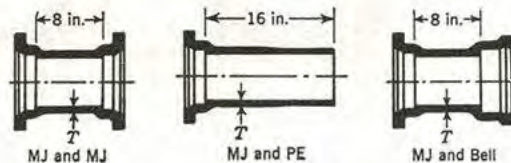


Fig. 10.13. Mechanical-Joint Connecting Pieces (See Table 10.13)

TABLE 10.13
Mechanical-Joint Connecting Pieces

Size in.	Pressure Rating psi	Iron Strength psi (1,000's)	T—in.	Weight—lb†		
				MJ & MJ	MJ & Bell	MJ & PE‡
2	250	25	0.25			
2½	250	25	0.25			
3	250	25	0.48			
3	350	DI*	0.48	35	40	35
4	250	25	0.52	45	55	45
4	350	DI	0.52	45	55	45
6	250	25	0.55	70	80	65
6	350	DI	0.55	70	80	65
8	250	25	0.60	95	115	95
8	350	DI	0.60	95	115	95
10	250	25	0.68	130	150	125
10	350	DI	0.68	130	150	125
12	250	25	0.75	165	190	165
12	350	DI	0.75	165	190	165
14	150	25	0.66	220	230	205
14	250	25	0.82	235	255	220
14	350	DI	0.66	220	230	205
16	150	30	0.70	270	290	250
16	250	30	0.89	290	320	270
16	350	DI	0.70	270	290	250
18	150	30	0.75	325	340	300
18	250	30	0.96	350	385	325
18	350	DI	0.75	325	340	300
20	150	30	0.80	390	405	360
20	250	30	1.03	420	465	385
20	350	DI	0.80	390	405	360
24	150	30	0.89	515	530	475
24	250	30	1.16	555	620	515
24	350	DI	0.89	515	530	475
30	150	30	1.03	840	820	730
30	250	30	1.37	905	1,005	795
30	250	DI	1.03	840	820	730
36	150	30	1.15	1,170	1,170	1,005
36	250	30	1.58	1,270	1,410	1,105
36	250	DI	1.15	1,170	1,170	1,005
42	150	30	1.28	1,500	1,515	1,295
42	250	30	1.78	1,635	1,870	1,430
42	250	DI	1.28	1,500	1,515	1,295
48	150	30	1.42	1,910	1,930	1,640
48	250	30	1.96	2,075	2,395	1,810
48	250	DI	1.42	1,910	1,930	1,640

For dimensional details of mechanical joints, see Table 10.1; plain ends, Table 10.2; bell-and-spigot bells, Table 10.14.

‡ May be furnished from centrifugally cast pipe.

* Ductile iron.

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

GRAY-IRON AND DUCTILE-IRON FITTINGS



Fig. 10.13A. Connecting Pieces, One-End Flanged (See Table 10.13A)

TABLE 10.13A
Connecting Pieces, One-End Flanged

Size in.	Pressure Rating psi	Iron Strength psi (1,000's)	T—in.	Weight—lb†	
				MJ & Flg.‡	Flg. & PE‡
2	250	25	0.25	15	11
2½	250	25	0.25	17	13
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 10.2; flanges, Table 10.26.
‡ May be furnished from centrifugally cast pipe.

* Ductile iron.

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

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Committee Personnel

Subcommittee 3, which developed this standard, had the following personnel at that time:

CARL A. HENRIKSON, *Chairman*
 VANCE C. LISCHER, *Vice-Chairman*

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User Members

WALTER AMORY
 JOHN W. CARROLL
 JOSEPH M. DEVEREAUX
 GEORGE F. KEENAN
 ARNOLD M. TINKEY
 ROBERT D. WILROY

Producer Members

JOHN C. FAY, JR.
 THOMAS D. HOLMES
 THOMAS P. NORWOOD, JR.
 ALBERT H. SMITH, JR.
 CHARLES W. WRIGHT

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

VANCE C. LISCHER, *Chairman*
 CARL A. HENRIKSON, *Vice-Chairman*
 JAMES B. RAMSEY, *Secretary*

Organization Represented

American Gas Association
 American Society of Civil Engineers
 American Society of Mechanical Engineers
 American Society for Testing and Materials
 American Water Works Association
 Cast Iron Pipe Research Association

 Manufacturers' Standardization Society of
 the Valve and Fittings Industry
 New England Water Works Association
 Naval Facilities Engineering Command,
 Department of the Navy
 Independent Producer
 Independent Producer
 Underwriters' Laboratories, Inc.
 Canadian Standards Association

Name of Representative

JOSEPH M. DEVEREAUX
 KENNETH W. HENDERSON
 CHARLES R. VELZY
 SIDNEY VOLOV
 VANCE C. LISCHER
 CARL A. HENRIKSON
 EDWARD C. SEARS
 W. HARRY SMITH

 ABRAHAM FENSTER
 WALTER AMORY

 STANLEY C. BAKER
 WILLIAM T. MAHER
 FRANK CAMEROTA
 MILES SUCHOMEL
 W. F. SEMENCHUK*

* Liaison representative without vote.

Foreword

This foreword is provided for information only and is not a part of ANSI A21.10-1971 (AWWA C110-71)

History

The earliest record of an AWWA standard for cast-iron pipe is contained in the *Proceedings for 1890* and consists of a proposed standard and specifications. Three pipe classifications, A, B, and C, were designated. Class B pipe was used as a standard on the basis of weight as determined from average weight used in a large number of United States cities and towns.

In this standard the subject of fittings was dealt with in a single section in the following words:

All special castings, such as "ells," "tees," "wyes," bends, crosses, etc., shall be made from the same mixture of pig iron as has been approved for pipe; and all such casting shall be submitted to the same care in cleaning and heating, and the bath shall be used under the same conditions as for straight pipe.

A more detailed standard was adopted by NEWWA, Sep. 10, 1902, Sec. 5 of which provided that special castings be made in accordance with a series of tables of dimensions and Sec. 19 that the pipe and other castings (fittings) be in all respects sound and conformable to these specifications.

The next AWWA standard for fittings, C100-08, was approved May 12, 1908. A second edition, C100-52T, was approved by AWWA, Dec. 31, 1952, and by NEWWA, Jan. 22, 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 on Jun.

17, 1955. Standard C100-55 covered fittings in the size range of 4 in. to 60 in., which were all of the so-called long-radius design.

ASA A21.10-1952 (AWWA C110-52)

Under ASA Sectional Committee A21, an American Standard, A21.10, was developed for the so-called "short-body cast-iron fittings." This was for 3-12 in. sizes only and was designed for 250 psi plus water hammer.

In accord with the practices and policy of Committee A21, the radical change in design for the "short-body fittings" was the subject of extensive investigation and research. The strength of the fittings was tested by bursting tests, and hydraulic losses were determined and compared with those found with AWWA "long-body" patterns.

The rated pressure for this standard, based on these bursting tests, provided a factor of safety of 2.5 plus water hammer. By setting a practical value for pressure ratings, rather than using a purely theoretical approach related to pipe design, Committee A21 established a significant precedent.

After approval by the sponsors, a standard was approved by ASA on Sep. 30, 1952, and issued as A21.10-1952.

ASA A21.10-1964 (AWWA C110-64)

It became apparent that the American Standard A21.10-1952 for 3-12 in. fittings of 250-psi working pressure was inadequate in scope and that the extension of the standard to include larger sizes at higher pressure ratings

was essential. AWWA C100-52 included sizes larger than 12 in., but was limited to fittings designed for 173 psi or 400 ft of head.

It was also evident that the design of the larger size of fittings was on a purely empirical basis. Although it is possible to compute the working and bursting pressures of straight pipe with some degree of accuracy, the stress calculations called for in the design of a large cast-iron fitting are so involved and require so many assumptions that, in cooperation with the Cast Iron Pipe Research Association, Committee A21 decided upon a program of bursting tests on various types of fittings in the 14-48-in. size ranges. This program included the test to destruction of a large number of fittings made of various grades of cast iron with various thicknesses and differences in details of construction.

Pressure ratings of the 14-48-in. fittings were determined by burst tests on fittings representative of two major groups of fittings with inherently different relative strengths. The inherently stronger group included bends, reducers, and reducing tees and crosses with second and smaller reducing branches. The inherently weaker group consisted of full-opening and first-reducing branch tees and crosses. Testing was concentrated on the largest and weakest fitting in each type and size, such as 16-, 24-, 36-, and 48-in. full-opening crosses and 24 × 16-, 36 × 24-, and 48 × 36-in. reducing crosses.

In these tests, it was found that wall thickness and iron strength were controlling factors in the bursting strengths of individual fittings of standard design. Therefore, in the revision of A21.10 the wall thickness and iron strength of 14-48-in. fittings were adjusted in combination, as

shown necessary by tests, to obtain the required fitting strength. For example, to obtain the same rating, full-opening and first-reducing branch tees and crosses have greater thickness or higher iron strength, or both, than bends, reducers, and reducing tees and crosses with second and smaller reducing branches.

The minimum grade of cast iron, 25,000-psi iron strength, was retained, and higher grades up to 35,000 psi iron strength were used to secure higher pressure ratings without radically changing the thickness of the castings. A further development was the use of ductile iron with a 60,000-psi yield strength, which permitted thinner walls in the castings.

The minimum safety factor based on bursting tests on representative fittings of the weakest type was three (3.0) times the rated working pressure.

The final draft of the proposed revised standard was developed by Subcommittee 3 and approved by Sectional Committee A21 in December 1963. After approval by the four sponsors, the standard was approved by ASA on Jun. 9, 1964, and issued as A21.10-1964.

Latest Revision of ANSI A21.10

The scope of Subcommittee 3 of ANSI Standards Committee A21 reads: "The scope of the Subcommittee shall include the periodic review of all current A21 standards for fittings and the preparation of revisions or new standards, when needed, for fittings to be used with cast-iron or ductile-iron pressure pipe included in A21 standards."

At the December 1967 meeting of Standards Committee A21, Subcommittee 3 was assigned the task of reviewing and updating A21.10-1964

with revisions, if considered necessary. Accordingly, the subcommittee undertook a study to determine the necessary and desirable revisions.

Data were accumulated to show that a change in grade of ductile iron for fittings from 80-60-03 to 70-50-05 will provide tougher and more impact-resistant fittings. Tests clearly demonstrated that excellent and reliable properties are obtained with unannealed ductile-iron castings of grade 70-50-05. Charpy tests have repeatedly shown that a small decrease in yield strength accompanied by an increase in elongation results in increased toughness. Burst tests on a variety of sizes and types of fittings have assured that all ductile-iron fittings in the standard have a minimum safety factor of 3.0 times the rated working pressure.

Flanged fittings are listed without change from the A21.10-1964 standard. During the subcommittee study, additional burst tests were conducted on large-diameter flanged fittings to obtain further assurance that all flanged fittings have a minimum safety factor of 3.0 times the rated working pressure.

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 in such manner that piping connected to flanges or flanged fittings is properly anchored or restrained to prevent breakage of fittings or flanges.

Subcommittee 3 completed its study and submitted the proposed revision to ANSI Standards Committee A21 in 1970.

Major Revisions

1. *Scope.* Ductile-iron fittings are added to the statement of scope. Ductile-iron mechanical-joint fittings, sizes 3 in. through 12 in., are rated for 350-psi working pressure.

2. *Safety factor and leak test pressures.* A safety factor against bursting of 3.0 times the rated water working pressure and test pressures for leaks or permanent distortions not to exceed 1.5 times the rated water working pressure have been added.

3. *Acceptance tests.* The acceptance values for ductile iron shall be: minimum tensile strength, 70,000 psi; minimum yield strength, 50,000 psi; minimum elongation, 5 per cent.

4. *Tables.* Ductile-iron fittings, sizes 3 in. through 12 in. with mechanical joints, have been added to the tables.

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 summarizes these details and available options and lists the sections of the standard where they can be found:

1. Size, joint type, pressure rating..... Tables
2. Type of iron..... Sec. 10-3.2
3. Certification by manufacturer Sec. 10-4.3
4. Inspection by purchaser..... Sec. 10-5
5. Cement lining..... Sec. 10-8.2
Experience has indicated that bituminous inside coating is not complete protection against loss in pipe capacity due to tuberculation. Cement linings are recommended for most waters.
6. Special coatings and linings.. Sec. 10-8.4
7. Special tests..... Sec. 10-12

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ANSI A21.10-1971
(AWWA C110-71)

Revision of
A21.10-1964
(AWWA C110-64)

American National Standard for

**Gray-Iron and Ductile-Iron Fittings,
2 in. through 48 in.
for Water and Other Liquids**

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Sec. 10-1—Scope

This standard covers 2-48-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, bell-and-spigot joints, and flange joints are given in the tables. 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 3-12-in. size range, ductile-iron mechanical-joint fittings as shown in the tables are rated for 350-psi working pressure, and gray-iron fittings having all types of joints covered by this standard are rated for 250-psi working pressure. For the 14-48-in. size range, fittings having 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 psi and 250 psi.

Sec. 10-2—Definitions

Under this standard the following definitions shall apply:

10-2.1. *Purchaser.* The party entering into a contract or agreement to purchase fittings according to this standard.

10-2.2. *Manufacturer.* The party that produces the fittings.

10-2.3. *Inspector.* The representative of the purchaser, authorized to inspect in behalf of the purchaser to determine whether or not the fittings meet this standard.

10-2.4. *Mechanical joint.* A bolted joint of the stuffing box type as detailed in Table 10.1 and as described in ANSI A21.11 (AWWA C111) of latest revision.

10-2.5. *Push-on joint.* The single rubber gasket joint as described in ANSI A21.11 (AWWA C111) of latest revision.

10-2.6. *Bell-and-spigot joint.* The poured or calked joint as detailed in Table 10.14.

10-2.7. *Flange joint.* The flanged and bolted joint as detailed in Table 10.26.

10-2.8. *Gray iron.* Gray iron is a 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.

10-2.9. *Ductile iron.* Ductile iron is a cast ferrous material in which the free graphite present is in a spheroidal form rather than a flake form.

Sec. 10-3—General Requirements

10-3.1. Fittings with mechanical joints, bell-and-spigot 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 A21.11 (AWWA C111) of latest revision.

10-3.2. 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 3.0 times the rated water working pressure.

10-3.3. Standard fittings shall be furnished with end combinations shown in the tables. When fittings of other designs and 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 kind of fitting.

(Note: All bell fittings, without spigot ends or plain ends, are preferred.)

Sec. 10-4—Inspection and Certification by Manufacturer

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

10-4.2. Repairing of defects by welding or other methods shall not be allowed if such repairs will 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 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, the purchaser shall so specify on the purchase order, stating the conditions (such as time and the extent of the inspection) under which the inspection shall be made.

10-5.2. The inspector shall have free access to those parts of the manufacturer's plant that are necessary to assure compliance with this standard. 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 the handling of fittings.

Sec. 10-6—Delivery and Acceptance

All fittings and accessories shall comply with this standard. Fittings or 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 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 gaged with suitable gages at sufficiently frequent intervals to assure

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 gages. Other socket dimensions shall be gaged as 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 those shown below:

Fitting Size in.	Minus Tolerance in.
<3	0.07
3-6	0.10
8-20	0.12
24-48	0.15

An additional tolerance shall be permitted over areas not exceeding 8 in. in any direction, as follows: for 3-12-in. fittings, 0.02 in.; for 14-48-in. fittings, 0.03 in.

10-7.3. *Weight.* The weight of any fitting shall not be less than the nominal tabulated weight by more than 10 per cent for fittings 12 in. or smaller in diameter and by more than 8 per cent for fittings larger than 12 in. in diameter. The nominal tabulated weights are 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 bituminous coating approximately 1 mil 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 shall be strongly adherent to the fitting.

10-8.2. *Cement-mortar linings.* Cement linings shall be in accordance with ANSI A21.4 (AWWA C104) of

latest revision. If desired, cement linings shall be specified in the invitation for bids and on the purchase order.

10-8.3. *Bituminous inside coating.* Unless otherwise specified, the inside coating for fittings not cement-lined shall be a bituminous material as thick as practicable (at least 1 mil) and conforming to all appropriate requirements for seal coat in ANSI A21.4 (AWWA C104) of 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 manufacturer's identification, nominal diameters of openings, and the number of degrees or fraction of the circle on all bends. The pressure rating shall be distinctly marked on the fitting. 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 those shown below:

Size in.	Height of Letters in.	Relief in.
Less than 8	As large as practical	As large as practical
8-10	$\frac{3}{4}$	$\frac{3}{32}$
12-48	$1\frac{1}{4}$	$\frac{3}{32}$

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

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following:

1. Transverse test conducted in accordance with ASTM A438-62.

2. Tensile test conducted in accordance with ASTM A48-64.

10-10.2 *Choice of tests.* 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. For sampling, at least one sample shall be taken during each period of approximately 3 hr while the melting unit is operated continuously. The acceptance values for tensile and transverse tests shall be as shown in the following table:

Iron Strength psi (1,000's)	Fitting Size in.	Bar Diam. in.	Span* in.	Min.* Break- ing Load lb	Min. Tensile Strength† psi (1,000's)
25	2-14	1.20	18	2,000	25
30	14-24	1.20	18	2,200	30
30	20-48	2.00	24	7,600	30
35	16-24	1.20	18	2,400	35
35	20-36	2.00	24	8,300	35

† ASTM A48-64.
* ASTM A438-62.

For 20- and 24-in. fittings with a body thickness greater than 1 in., a 2-in. test bar shall be used.

10-10.3. *Physical tests—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 A536-70, except the grade shall be 70-50-05. Either the keel block or "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; minimum

yield strength, 50,000 psi; minimum elongation, 5 per cent.

Sec. 10-11—Chemical Analyses of Gray-Iron Fittings

Analyses of the iron in gray-iron fittings shall be made at sufficiently frequent intervals to assure compliance with the following limits: phosphorus, 0.90 per cent maximum; and sulfur, 0.12 per cent 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 obtained from either acceptance test specimens or specimens cast for this purpose.

Sec. 10-12—Additional Tests Required by Purchaser

If other tests 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.

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TABLE 10.1—Standard Mechanical-Joint Dimensions, in Inches

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			Weight—lb	
																		No.	Size	Lgth.	Bell	Gland Bolts Gasket
2	2.50 ±.05	2.50	3.39 ±.05	3.50 ±.05	2.61 ±.05	28	±.06 - 0	4.75 ±.05	6.25 - .10	6.25 - .10	.75 - .05	.62 - .05	.50	.31	.63	.44 - .07	.08	2	1	2½	5.5	3.5
2½	2.75 ±.05	2.50	3.64 ±.05	3.75 ±.05	2.86 ±.05	28	±.06 - 0	5.00 ±.05	6.50 - .10	6.50 - .10	.75 - .05	.62 - .05	.50	.31	.63	.44 - .07	.08	2	1	2½	6	4
3	3.96 ±.06	2.50	4.84 ±.04	4.94 ±.06 - .04	4.06 ±.07 - .03	28	±.06 - 0	6.19 ±.06	7.69 - .12	7.69 - .12	.94 - .06	.62 - .06	.75	.31	.63	.52 - .10	.12	4	1	3	11	7
4	4.80 ±.06	2.50	5.92 ±.04	6.02 ±.06 - .04	4.90 ±.07 - .03	28	±.06 - 0	7.50 ±.06	9.12 - .12	9.12 - .12	1.00 - .06	.75 - .06	.75	.31	.75	.65 - .10	.12	4	1	3½	16	10
6	6.90 ±.06	2.50	8.02 ±.04	8.12 ±.06 - .04	7.00 ±.07 - .03	28	±.06 - 0	9.50 ±.06	11.12 - .12	11.12 - .12	1.06 - .06	.88 - .06	.75	.31	.75	.70 - .10	.12	6	1	3½	23	16
8	9.05 ±.06	2.50	10.17 ±.04	10.27 ±.06 - .04	9.15 ±.07 - .03	28	±.06 - 0	11.75 ±.06	13.37 - .12	13.37 - .12	1.12 - .08	1.00 - .08	.75	.31	.75	.75 - .12	.12	6	1	4	31	25
10	11.10 ±.06	2.50	12.22 ±.06 - .04	12.34 ±.06 - .04	11.20 ±.07 - .03	28	±.06 - 0	14.00 ±.06	15.69 - .12	15.62 - .12	1.19 - .08	1.00 - .08	.75	.31	.75	.80 - .12	.12	8	1	4	41	30
12	13.20 ±.06	2.50	14.32 ±.06 - .04	14.44 ±.06 - .04	13.30 ±.07 - .03	28	±.06 - 0	16.25 ±.06	17.94 - .12	17.88 - .12	1.25 - .08	1.00 - .08	.75	.31	.75	.85 - .12	.12	8	1	4	51	40
14	15.30 ±.05 - .08	3.50	16.40 ±.07 - .05	16.54 ±.07 - .05	15.44 ±.06 - .07	28	±.06 - 0	18.75 ±.06	20.31 - .12	20.25 - .12	1.31 - .12	1.25 - .12	.75	.31	.75	.89 - .12	.12	10	1	4½	79	45
16	17.40 ±.05 - .08	3.50	18.50 ±.07 - .05	18.64 ±.07 - .05	17.54 ±.06 - .07	28	±.06 - 0	21.00 ±.06	22.56 - .12	22.50 - .12	1.38 - .12	1.31 - .12	.75	.31	.75	.97 - .12	.12	12	1	4½	97	55
18	19.50 ±.05 - .08	3.50	20.60 ±.07 - .05	20.74 ±.07 - .05	19.64 ±.06 - .07	28	±.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	1	4½	117	65
20	21.60 ±.05 - .08	3.50	22.70 ±.07 - .05	22.84 ±.07 - .05	21.74 ±.06 - .07	28	±.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	1	4½	140	85
24	25.80 ±.05 - .08	3.50	26.90 ±.07 - .05	27.04 ±.07 - .05	25.94 ±.06 - .07	28	±.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	1	5	185	105
30	32.00 ±.08 - .06	4.00	33.29 ±.08 - .06	33.46 ±.08 - .06	32.17 ±.08 - .06	20	±.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	±.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
44	44.50 ±.08 - .06	4.00	45.79 ±.08 - .06	45.96 ±.08 - .06	44.67 ±.08 - .06	20	±.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	1½	6	570	400
48	50.80 ±.08 - .06	4.00	52.09 ±.08 - .06	52.26 ±.08 - .06	50.97 ±.08 - .06	20	±.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	1½	6	725	475

GRAY-IRON AND DUCTILE-IRON FITTINGS

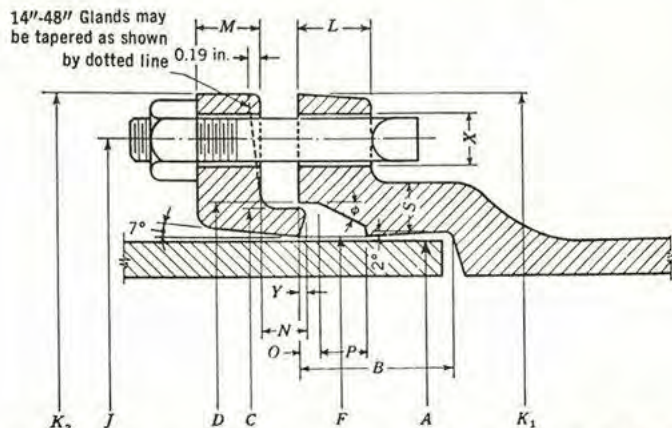


Fig. 10.1. 2-48 in. Standard Mechanical-Joint Dimensions (See Table 10.1)

1. Diameter of cored holes may be tapered an additional 0.06 in.
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. 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 bolt holes. For sizes 2 and $2\frac{1}{2}$ in. both flange and gland may be oval shaped. For sizes 3-48 in., the gland may be polygon shaped.

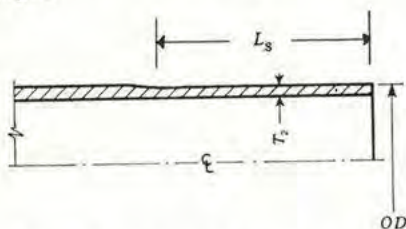


Fig. 10.2. Mechanical-Joint Plain-End Dimensions and Tolerances (See Table 10.2)

1. All sizes of fittings with plain ends have 8 in. of added laying length as compared to the laying length of standard all-ball fittings.

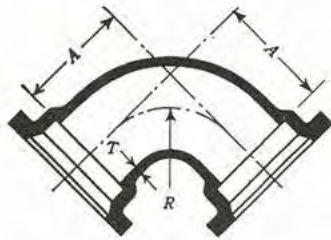
2. On Figure 10.2 above, dimension " L_s " is minimum length of the plain end which must be gaged to assure the outside diameter is within the dimensions and tolerances specified in Table 10.2.

TABLE 10.2

Plain-end Dimensions and Tolerances for Mechanical-Joint Fittings

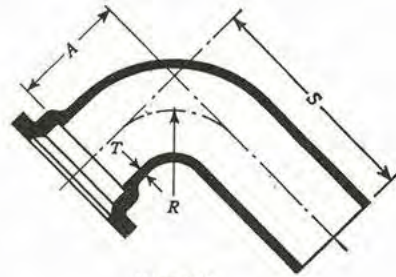
Size in.	OD—in.	T_1 —in.	L_s —in.
3	3.96±0.06	0.48-0.10	5.5
4	4.80±0.06	0.47-0.10	5.5
6	6.90±0.06	0.50-0.10	5.5
8	9.05±0.06	0.54-0.12	5.5
10	11.10±0.06	0.60-0.12	5.5
12	13.20±0.06	0.68-0.12	5.5
14	15.30 ^{+0.05} _{-0.08}	0.66-0.12	8.0
16	17.40 ^{+0.05} _{-0.08}	0.70-0.12	8.0
18	19.50 ^{+0.05} _{-0.08}	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

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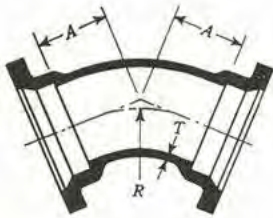


MJ and MJ

90-deg Bends

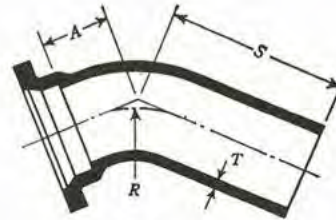


MJ and PE

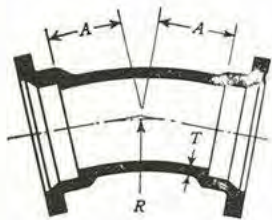


MJ and MJ

45-deg Bends

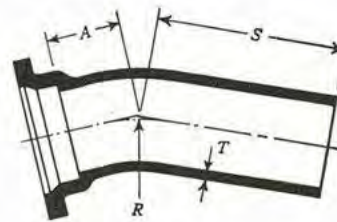


MJ and PE

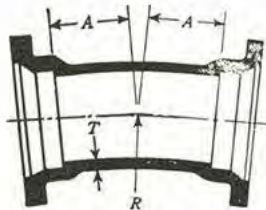


MJ and MJ

22½-deg Bends

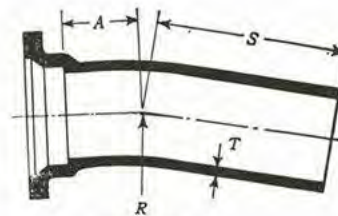


MJ and PE



MJ and MJ

11½-deg Bends



MJ and PE

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

GRAY-IRON AND DUCTILE-IRON FITTINGS

TABLE 10.3
Mechanical-Joint Bends

Size in.	Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.				Weight—lb†	
			T	A	S	R	MJ & MJ	MJ & PE
90-deg Bends								
2	250	25	0.35	3.25		2.25	14	
2½	250	25	0.35	3.25		2.25	15	
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	250	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	250	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	250	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	250	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	250	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

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Dimension details of mechanical-joint bells are shown in Table 10.1; dimension details of plain ends are shown in Table 10.2.

* Ductile iron.

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

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TABLE 10.3—Mechanical-Joint Bends (contd.)

Size in.	Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.				Weight—lb†	
			T	A	S	R	MJ & MJ	MJ & PE
45-deg Bends								
2	250	25	0.35	1.8		1.96	13	
2½	250	25	0.35	1.8		1.96	14	
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	DI	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	250	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	250	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	250	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	250	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	250	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.

* Ductile iron.

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

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GRAY-IRON AND DUCTILE-IRON FITTINGS

TABLE 10.3—Mechanical-Joint Bells (contd.)

Size in.	Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.				Weight—lb†	
			T	A	S	R	MJ & MJ	MJ & PE
22½-deg Bends								
2	250	25	0.35	1.5		2.51	13	
2½	250	25	0.35	1.5		2.51	14	
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	250	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	250	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	250	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	250	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	250	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.

* Ductile iron.

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

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TABLE 10.3—Mechanical-Joint Bends (contd.)

Size in.	Pressure Rating psi†	Iron Strength psi (1,000's)	Dimensions—in.				Weight—lb†	
			T	A	S	R	MJ & MJ	MJ & PE
11¼-deg Bends								
2	250	25	0.35	1.5		5.08	13	
2½	250	25	0.35	1.5		5.08	14	
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	250	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	250	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	250	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	250	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	250	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.

* Ductile iron.

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

GRAY-IRON AND DUCTILE-IRON FITTINGS

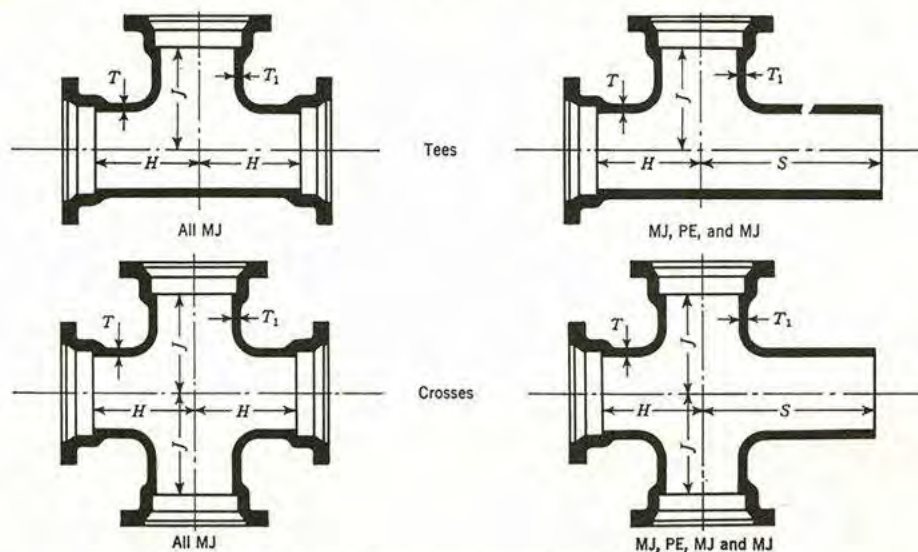


Fig. 10.4. Mechanical-Joint Tees and Crosses (See Table 10.4)

 TABLE 10.4
 Mechanical-Joint Tees and Crosses

Size in.		Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.					Weight—lb†			
Run	Branch			T	T ₁	H	J	S	Tee		Cross	
									All MJ	MJ, PE & MJ	All MJ	MJ, PE, MJ & MJ
2	2	250	25	0.35	0.35	3.25	3.25		22		28	
2½	2	250	25	0.35	0.35	3.25	3.25		23		30	
2½	2½	250	25	0.35	0.35	3.25	3.25		24		31	
3	2	250	25	0.48	0.35	4.0	4.0	12.0	39	39	46	46
3	2	350	DI*	0.48	0.35	4.0	4.0	12.0	39	39	46	46
3	2½	250	25	0.48	0.35	4.0	4.0	12.0	40	40	47	47
3	2½	350	DI	0.48	0.35	4.0	4.0	12.0	40	40	47	47
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	2	250	25	0.52	0.35	4.8	4.8	12.8	57	52	63	58
4	2	350	DI	0.52	0.35	4.8	4.8	12.8	57	52	63	58
4	2½	250	25	0.52	0.35	4.8	4.8	12.8	58	53	64	59
4	2½	350	DI	0.52	0.35	4.8	4.8	12.8	58	53	64	59
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.

* Ductile iron.

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

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TABLE 10.4—Mechanical-Joint Tees and Crosses (contd.)

Size in.		Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.					Weight—lb†			
Run	Branch			T	T ₁	H	J	S	Tee		Cross	
									All MJ	MJ, PE & MJ	All MJ	MJ, PE, MJ & MJ
6	2	250	25	0.55	0.35	5.2	5.2	13.2	83	78	89	84
6	2	350	DI*	0.55	0.35	5.2	5.2	13.2	83	78	89	84
6	2½	250	25	0.55	0.35	5.2	5.2	13.2	84	79	90	85
6	2½	350	DI	0.55	0.35	5.2	5.2	13.2	84	79	90	85
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	250	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	250	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	250	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	250	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.

* Ductile iron.

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

GRAY-IRON AND DUCTILE-IRON FITTINGS

TABLE 10.4—Mechanical-Joint Tees and Crosses (contd.)

Size in.		Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.					Weight—lb†			
Run	Branch			T	T ₁	H	J	S	Tee		Cross	
								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	250	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	250	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	250	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	250	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	250	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	250	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	250	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	250	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	250	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	250	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	250	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	250	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	250	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	250	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	250	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	250	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.

* Ductile iron.

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

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TABLE 10.4—Mechanical-Joint Tees and Crosses (contd.)

Size in.		Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.					Weight—lb†			
Run	Branch			T	T ₁	H	J	S	Tee		Cross	
								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	250	D1*	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	250	D1	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	250	D1	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	250	D1	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	250	D1	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	250	D1	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	250	D1	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	250	D1	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	250	D1	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	250	D1	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	250	D1	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	250	D1	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	250	D1	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	250	D1	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	250	D1	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	D1	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	D1	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.

* Ductile iron.

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

GRAY-IRON AND DUCTILE-IRON FITTINGS

TABLE 10.4—Mechanical-Joint Tees and Crosses (contd.)

Size in.		Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.					Weight—lb†			
Run	Branch			T	T ₁	H	J	S	Tee		Cross	
									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.

* Ductile iron.

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

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TABLE 10.4—Mechanical-Joint Tees and Crosses (contd.)

Size in.		Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.					Weight—lb†			
Run	Branch			T	T ₁	H	J	S	Tee		Cross	
									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.

* Ductile iron.

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

GRAY-IRON AND DUCTILE-IRON FITTINGS



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 (1,000'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	250	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	250	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	250	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	250	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	250	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

* Ductile iron.

† Dimension "R" is a finished dimension; unfinished bases will be 1/8 in. longer; for base drilling see Table 10.27.

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

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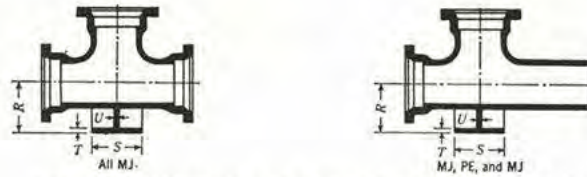


Fig. 10.6. Mechanical-Joint Base Tees (See Table 10.6)

For other dimensions of base tees, see Table 10.4.

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TABLE 10.6
Mechanical-Joint Base Tees

Size in.	Pressure Rating psi	Iron Strength psi (1,000'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	250	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	250	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	250	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	250	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	250	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

* Ductile iron.

† Dimension "R" is a finished dimension; unfinished bases will be $\frac{1}{2}$ in. longer; for base drilling see Table 10.27.

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

GRAY-IRON AND DUCTILE-IRON FITTINGS

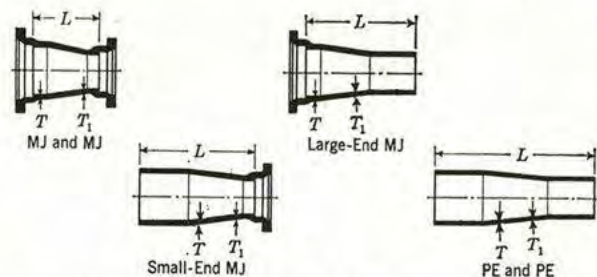


Fig. 10.7. Mechanical-Joint Reducers (See Table 10.7)

TABLE 10.7
Mechanical-Joint Reducers

Size in.		Pressure Rating psi	Iron Strength psi (1,000'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
3	2	250	25	0.48	0.35	6	23	8½	17				
3	2	350	DI*	0.48	0.35	6	23	8½	17				
3	2¼	250	25	0.48	0.35	6	23	8½	17				
3	2¼	350	DI	0.48	0.35	6	23	8½	17				
4	2	250	25	0.52	0.35	7	31	9½	20				
4	2	350	DI	0.52	0.35	7	31	9½	20				
4	2¼	250	25	0.52	0.35	7	32	9½	21				
4	2¼	350	DI	0.52	0.35	7	32	9½	21				
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	2	250	25	0.55	0.35	9	44	9½	28				
6	2	350	DI	0.55	0.35	9	44	9½	28				
6	2¼	250	25	0.55	0.35	9	45	9½	29				
6	2¼	350	DI	0.55	0.35	9	45	9½	29				
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.

* Ductile iron.

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

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TABLE 10.7—Mechanical-Joint Reducers (contd.)

Size in.		Pressure Rating psi	Iron Strength psi (1,000'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	250	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	250	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	250	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	250	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	250	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	250	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	250	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	250	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	250	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	250	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	250	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	250	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	250	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	250	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	250	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.

* Ductile iron.

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

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GRAY-IRON AND DUCTILE-IRON FITTINGS

TABLE 10.7—Mechanical-Joint Reducers (contd.)

Size in.		Pressure Rating psi	Iron Strength psi (1,000'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	250	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	250	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	250	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	250	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	250	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	250	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	250	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	250	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	250	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.

* Ductile iron.

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

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TABLE 10.7—Mechanical-Joint Reducers (contd.)

Size in.		Pressure Rating psi	Iron Strength psi (1,000'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.

* Ductile iron.

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

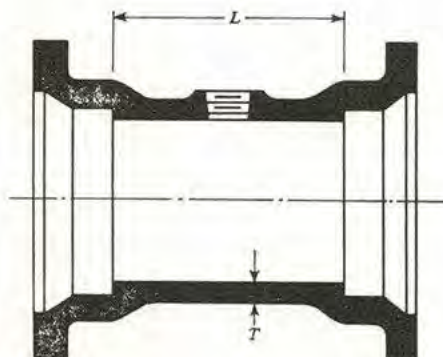


Fig. 10.8. Mechanical-Joint Tapped Tees
(See Table 10.8)

TABLE 10.8
Mechanical-Joint Tapped Tees

Size in.	Pressure Rating psi	Iron Strength psi (1,000'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

* Ductile iron.

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

GRAY-IRON AND DUCTILE-IRON FITTINGS

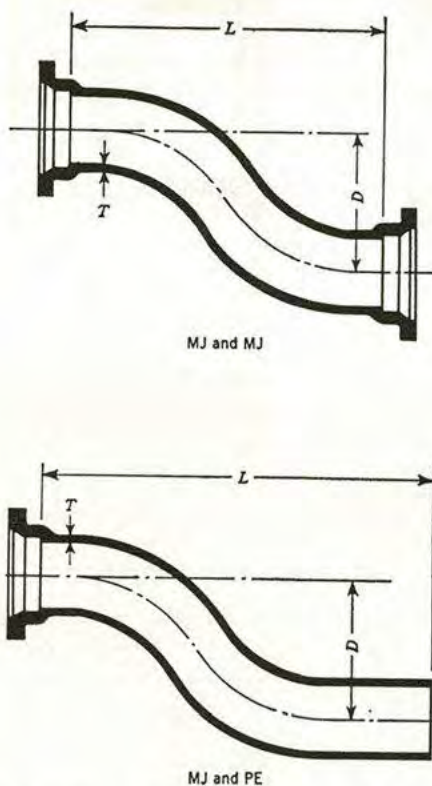


Fig. 10.9. Mechanical-Joint Offsets (See Table 10.9)

TABLE 10.9
Mechanical-Joint Offsets

Size in.	PR|| psi	Iron Strength psi (1,000's)	D in.	T in.	MJ & MJ		MJ & PE	
					L in.	Wgt.† lb	L in.	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	0.55	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	250	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	250	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	250	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	250	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	250	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	250	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.

* Ductile iron.

|| Pressure rating.

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

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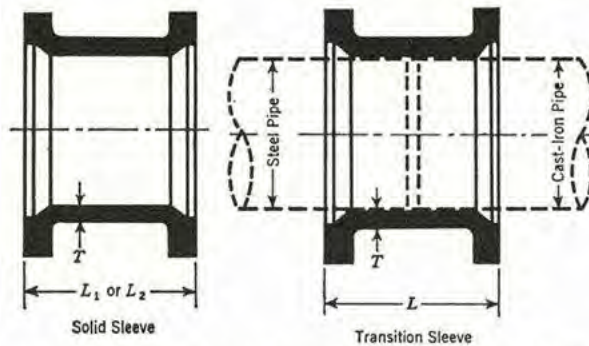


Fig. 10.10. Mechanical-Joint Sleeves (See Table 10.10)

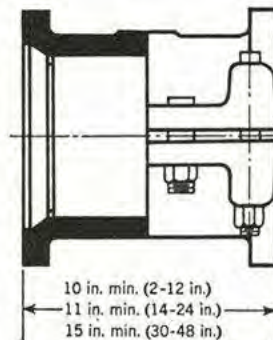


Fig. 10.11. Mechanical-Joint Split Sleeves

Split sleeves are furnished with a pressure rating of 150 psi 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 (1,000'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
2	250	25	0.44	8	12			2.38	8	12
2½	250	25	0.44	8	13			2.75	8	13
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	250	DI	0.82	9.5	165	15	225			
16	250	30	0.89	9.5	200	15	275			
16	250	DI	0.89	9.5	200	15	275			
18	250	30	0.96	9.5	240	15	330			
18	250	DI	0.96	9.5	240	15	330			
20	250	30	1.03	9.5	275	15	380			
20	250	DI	1.03	9.5	275	15	380			
24	250	30	1.16	9.5	360	15	505			
24	250	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			

* Ductile iron.
 † 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.

GRAY-IRON AND DUCTILE-IRON FITTINGS

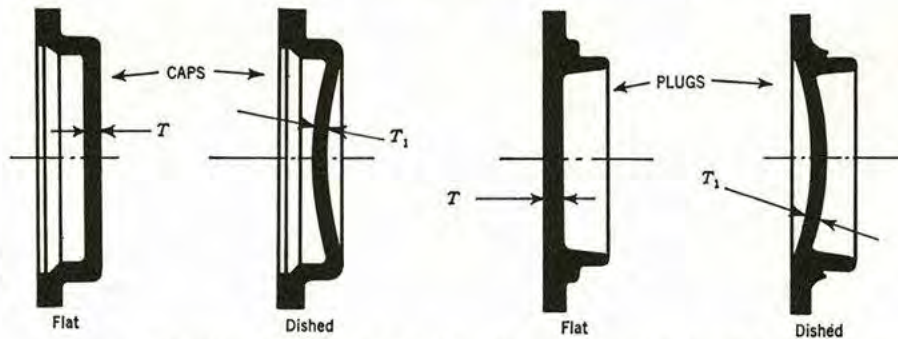


Fig. 10.12. Mechanical-Joint Caps and Plugs (See Table 10.12)

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TABLE 10.12
Mechanical-Joint Caps and Plugs

Size in.	Pressure Rating psi	Iron Strength psi (1,000's)	Caps				Plugs			
			Dimensions—in.		Weight—lb		Dimensions—in.		Weight—lb	
			T	T ₁	Flat	Dished	T	T ₁	Flat	Dished
2	250	25	0.50		6		0.50		5	
2½	250	25	0.50		6		0.50		5	
3	250	25	0.50	0.48	12	12	0.50	0.48	10	10
3	350	D1	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	D1	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	D1	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	D1	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	D1	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	D1	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	D1	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	D1	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	D1	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	D1	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	D1	1.16	0.89	345	300	1.16	0.89	335	290
30	150	30		1.37		680		1.37		660
30	250	D1		1.03		590		1.03		575
36	150	30		1.58		1,005		1.58		975
36	250	D1		1.15		850		1.15		815
42	150	30		1.78		1,535		1.78		1,355
42	250	D1		1.28		1,180		1.28		1,110
48	150	30		1.96		1,950		1.96		1,810
48	250	D1		1.42		1,595		1.42		1,455

* Ductile iron.

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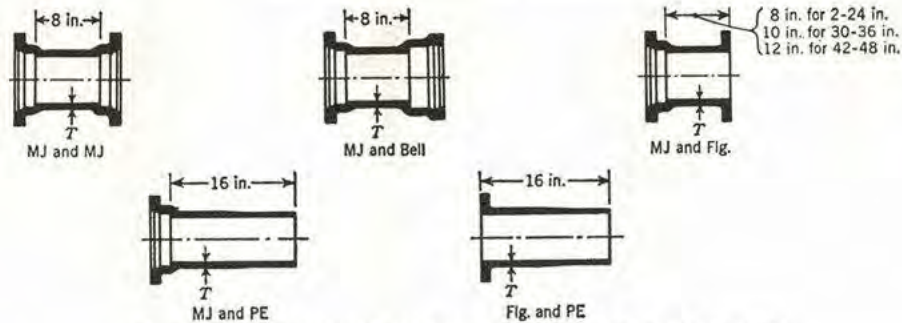


Fig. 10.13. Mechanical-Joint Connecting Pieces (See Table 10.13)

TABLE 10.13
Mechanical-Joint Connecting Pieces

Size in.	Pressure Rating psi	Iron Strength psi (1,000's)	T—in.	Weight—lb†				
				MJ & MJ	MJ & Bell	MJ & Fig.‡	MJ & PE‡	Fig. & PE‡
2	250	25	0.25			15		11
2½	250	25	0.25			17		13
3	250	25	0.48	35	40	30	35	30
3	350	DI*	0.48	35	40	30	35	30
4	250	25	0.52	45	55	40	45	40
4	350	DI	0.52	45	55	40	45	40
6	250	25	0.55	70	80	60	65	55
6	350	DI	0.55	70	80	60	65	55
8	250	25	0.60	95	115	85	95	85
8	350	DI	0.60	95	115	85	95	85
10	250	25	0.68	130	150	115	125	115
10	350	DI	0.68	130	150	115	125	115
12	250	25	0.75	165	190	155	165	155
12	350	DI	0.75	165	190	155	165	155
14	150	25	0.66	220	230	195	205	180
14	250	25	0.82	235	255	210	220	195
14	250	DI	0.66	220	230	195	205	180
16	150	30	0.70	270	290	240	250	220
16	250	30	0.89	290	320	260	270	240
16	250	DI	0.70	270	290	240	250	220
18	150	30	0.75	325	340	280	300	255
18	250	30	0.96	350	385	305	325	280
18	250	DI	0.75	325	340	280	300	255
20	150	30	0.80	390	405	340	360	305
20	250	30	1.03	420	465	365	385	335
20	250	DI	0.80	390	405	340	360	305
24	150	30	0.89	515	530	455	475	415
24	250	30	1.16	555	620	495	515	455
24	250	DI	0.89	515	530	455	475	415
30	150	30	1.03	840	820	760	730	600
30	250	30	1.37	905	1,005	840	795	665
30	250	DI	1.03	840	820	760	730	600
36	150	30	1.15	1,170	1,170	1,070	1,005	830
36	250	30	1.58	1,270	1,410	1,195	1,105	930
36	250	DI	1.15	1,170	1,170	1,070	1,005	830
42	150	30	1.28	1,500	1,515	1,505	1,295	1,115
42	250	30	1.78	1,635	1,870	1,685	1,430	1,250
42	250	DI	1.28	1,500	1,515	1,505	1,295	1,115
48	150	30	1.42	1,910	1,930	1,885	1,640	1,390
48	250	30	1.96	2,075	2,395	2,140	1,810	1,560
48	250	DI	1.42	1,910	1,930	1,885	1,640	1,390

For dimensional details of mechanical joints, see Table 10.1; plain ends, Table 10.2; bell-and-spigot bells, Table 10.14; flanges, Table 10.26.
 † May be furnished from centrifugally cast pipe.
 ‡ Ductile iron.
 † Weight does not include accessory weights. See Table 10.1 for accessory weights.

GRAY-IRON AND DUCTILE-IRON FITTINGS

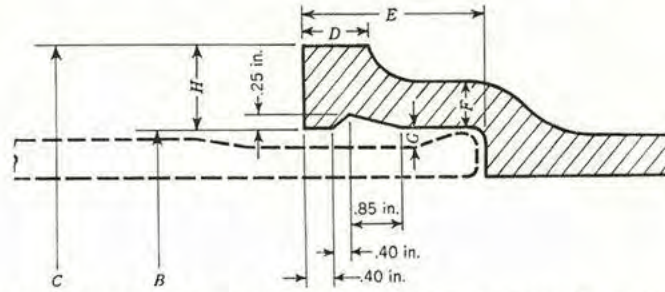


Fig. 10.14. Bell-and-Spigot Bell Dimensions and Tolerances (See Table 10.14)

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TABLE 10.14
Bell-and-Spigot Bell Dimensions and Tolerances

Size in.	Bell Design	Dimensions—in.							Wgt. of Bell lb
		B*	C	D	E	F	G	H	
3		4.66±0.12	7.26	1.25	3.50	0.65	0.35	1.30	20
4		5.70±0.12	8.30	1.50	4.00	0.65	0.40	1.30	25
6		7.80±0.12	10.60	1.50	4.00	0.70	0.40	1.40	35
8		10.00±0.12	13.00	1.50	4.00	0.75	0.41	1.50	49
10		12.10±0.12	15.30	1.50	4.00	0.80	0.42	1.60	62
12		14.20±0.12	17.60	1.50	4.00	0.85	0.42	1.70	76
14	I	16.10±0.12	19.50	1.50	4.00	0.85	0.40	1.70	88
14	II†	16.10±0.12	19.70	1.50	4.00	0.90	0.40	1.80	94
16	I	18.40±0.12	22.00	1.75	4.00	0.90	0.50	1.80	114
16	II	18.40±0.12	22.20	1.75	4.00	1.00	0.50	1.90	125
18	I	20.50±0.15	24.30	1.75	4.00	0.95	0.50	1.90	133
18	II	20.50±0.15	24.70	1.75	4.00	1.05	0.50	2.10	151
20	I	22.60±0.15	26.60	1.75	4.00	1.00	0.50	2.00	156
20	II	22.60±0.15	27.20	1.75	4.00	1.15	0.50	2.30	185
24	I	26.80±0.15	31.00	2.00	4.00	1.05	0.50	2.10	199
24	II	26.80±0.15	31.80	2.00	4.00	1.25	0.50	2.50	245
30	I	33.00±0.20	37.60	2.00	4.50	1.15	0.50	2.30	298
30	II	33.00±0.20	39.00	2.00	4.50	1.50	0.50	3.00	407
36	I	39.30±0.20	44.90	2.00	4.50	1.40	0.50	2.80	446
36	II	39.30±0.20	46.10	2.00	4.50	1.80	0.50	3.40	574
42	I	45.50±0.20	51.50	2.00	5.00	1.50	0.50	3.00	586
42	II	45.50±0.20	53.10	2.00	5.00	1.95	0.50	3.80	786
48	I	51.80±0.24	58.40	2.00	5.00	1.65	0.50	3.30	745
48	II	51.80±0.24	60.20	2.00	5.00	2.20	0.50	4.20	1,023

* This table shows only one socket diameter, Dimension B, as standard for each size bell. This socket is for use with pipe in accordance with ANSI A21.6 (AWWA C106) and A21.8 (AWWA C108). For pipe 14 in. and larger with special OD sizes, the socket diameters for the fittings should be specified.

† Bell Design II shows a thicker bell section, as required with a thicker body section of fittings; the changes in dimensions C, F, and H should be noted.

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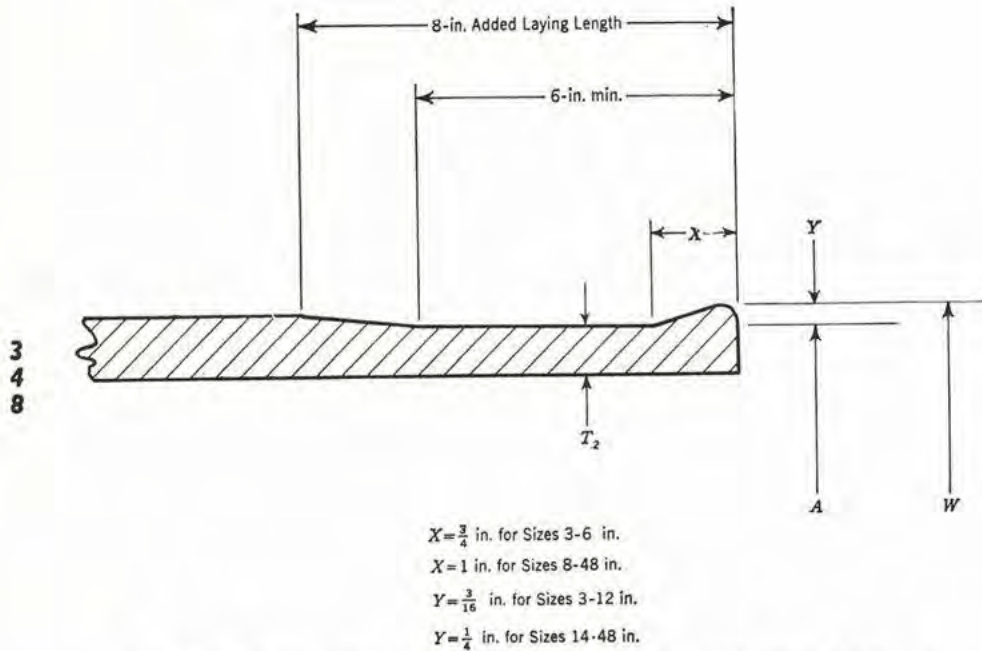


Fig. 10.15. Bell-and-Spigot End Dimensions and Tolerances (See Table 10.15)

TABLE 10.15
Bell-and-Spigot End Dimensions and Tolerances

Size in	Dimensions—in.			Wgt. of Spigot End lb
	A [†]	T ₂	W	
3	3.96	0.48 - 0.10	4.34 ± 0.12	11
4	4.90	0.47 - 0.10	5.28 ± 0.12	14
6	7.00	0.50 - 0.10	7.38 ± 0.12	22
8	9.18	0.54 - 0.12	9.56 ± 0.12	32
10	11.25	0.60 - 0.12	11.63 ± 0.12	43
12	13.35	0.68 - 0.12	13.73 ± 0.12	58
14	15.30	0.66 - 0.12	15.80 ± 0.12	65
16	17.40	0.70 - 0.12	17.90 ± 0.12	78
18	19.50	0.75 - 0.12	20.00 ± 0.15	94
20	21.60	0.80 - 0.12	22.10 ± 0.15	112
24	25.80	0.89 - 0.15	26.30 ± 0.15	148
30	32.00	1.03 - 0.15	32.50 ± 0.20	212
36	38.30	1.15 - 0.15	38.80 ± 0.20	284
42	44.50	1.28 - 0.15	45.00 ± 0.20	366
48	50.80	1.42 - 0.15	51.30 ± 0.24	464

[†] This table shows only one spigot outside diameter, Dimension A, for each size. This spigot is for use with pipe made in accordance with ANSI A21.6 (AWWA C106) and A21.8 (AWWA C108). For pipe 14 in. and larger with special OD sizes, the spigot OD's should be specified to match those of the pipe.

GRAY-IRON AND DUCTILE-IRON FITTINGS

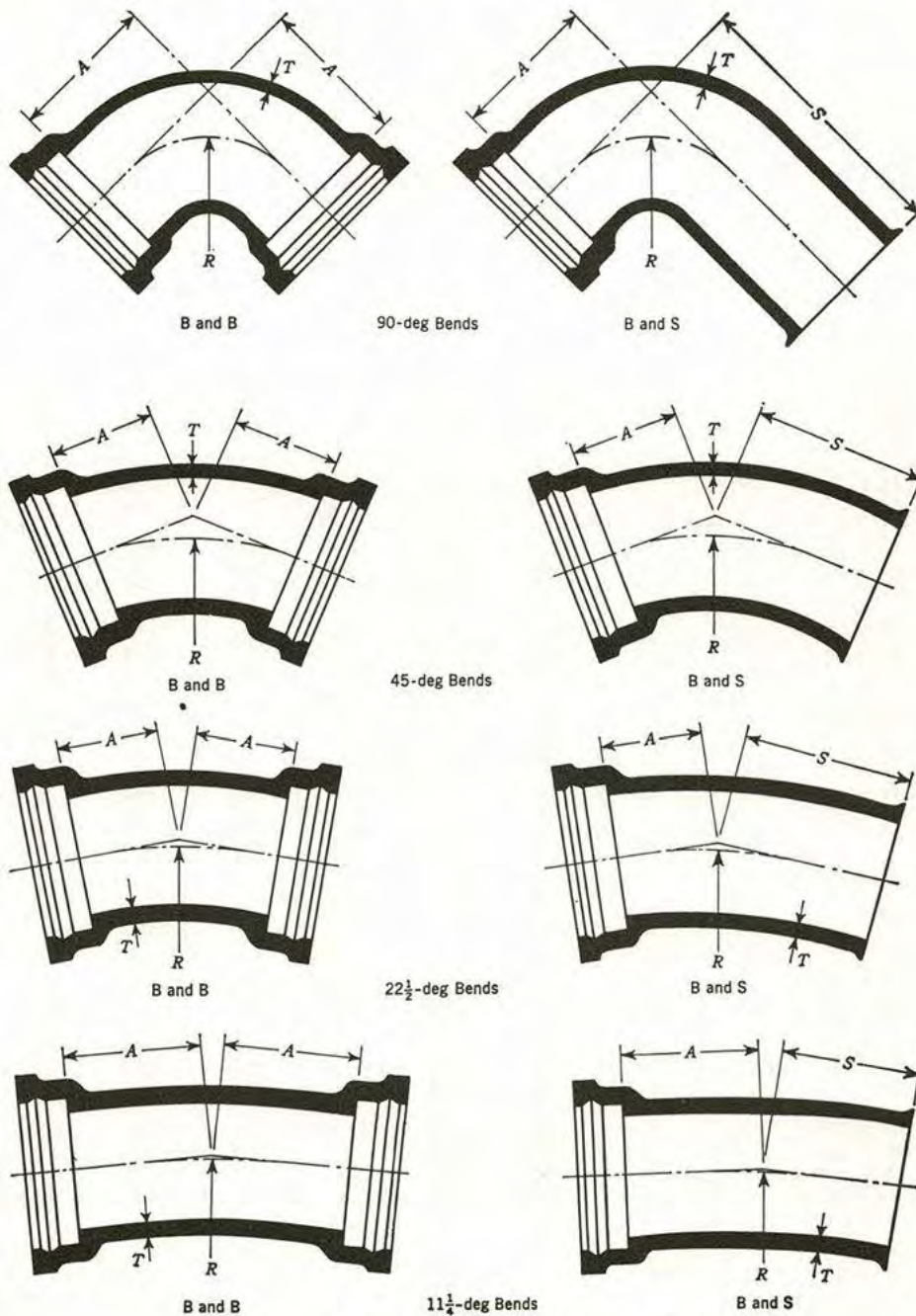


Fig. 10.16. Bell-and-Spigot Bends (See Table 10.16)

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TABLE 10.16
Bell-and-Spigot Bends

Size in.	Bell Design	Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.				Weight—lb	
				T	A	S	R	B & B	B & S
90-deg Bends									
3		250	25	0.48	5.5	13.5	4.0	55	45
4		250	25	0.52	6.5	14.5	4.5	70	60
6		250	25	0.55	8.0	16.0	6.0	110	95
8		250	25	0.60	9.0	17.0	7.0	165	150
10		250	25	0.68	11.0	19.0	9.0	230	210
12		250	25	0.75	12.0	20.0	10.0	305	285
14	I	150	25	0.66	14.0	22.0	11.5	360	335
14	II	250	25	0.82	14.0	22.0	11.5	410	385
14	I	250	DI*	0.66	14.0	22.0	11.5	360	335
16	I	150	30	0.70	15.0	23.0	12.5	465	430
16	II	250	30	0.89	15.0	23.0	12.5	545	500
16	I	250	DI	0.70	15.0	23.0	12.5	465	430
18	I	150	30	0.75	16.5	24.5	14.0	575	540
18	II	250	30	0.96	16.5	24.5	14.0	695	635
18	I	250	DI	0.75	16.5	24.5	14.0	575	540
20	I	150	30	0.80	18.0	26.0	15.5	710	670
20	II	250	30	1.03	18.0	26.0	15.5	880	805
20	I	250	DI	0.80	18.0	26.0	15.5	710	670
24	I	150	30	0.89	22.0	30.0	18.5	1,055	1,000
24	II	250	30	1.16	22.0	30.0	18.5	1,335	1,235
24	I	250	DI	0.89	22.0	30.0	18.5	1,055	1,000
30	I	150	30	1.03	25.0	33.0	21.5	1,660	1,575
30	II	250	30	1.37	25.0	33.0	21.5	2,210	2,020
30	I	250	DI	1.03	25.0	33.0	21.5	1,660	1,575
36	I	150	30	1.15	28.0	36.0	24.5	2,480	2,315
36	II	250	30	1.58	28.0	36.0	24.5	3,305	3,015
36	I	250	DI	1.15	28.0	36.0	24.5	2,480	2,315
42	I	150	30	1.28	31.0	39.0	27.5	3,440	3,220
42	II	250	30	1.78	31.0	39.0	27.5	4,690	4,270
42	I	250	DI	1.28	31.0	39.0	27.5	3,440	3,220
48	I	150	30	1.42	34.0	42.0	30.5	4,635	4,355
48	II	250	30	1.96	34.0	42.0	30.5	6,340	5,780
48	I	250	DI	1.42	34.0	42.0	30.5	4,635	4,355

Dimension details of bells are shown in Table 10.14; those of spigots, Table 10.15.
* Ductile iron.

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GRAY-IRON AND DUCTILE-IRON FITTINGS

 TABLE 10.16—*Bell-and-Spigot Bends (contd.)*

Size in.	Bell Design	Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.				Weight—lb	
				T	A	S	R	B & B	B & S
45-deg Bends									
3		250	25	0.48	3.0	11.0	3.62	50	40
4		250	25	0.52	4.0	12.0	4.81	65	55
6		250	25	0.55	5.0	13.0	7.25	100	85
8		250	25	0.60	5.5	13.5	8.44	145	130
10		250	25	0.68	6.5	14.5	10.88	200	180
12		250	25	0.75	7.5	15.5	13.25	270	250
14	I	150	25	0.66	7.5	15.5	12.06	290	265
14	II	250	25	0.82	7.5	15.5	12.06	330	300
14	I	250	DI*	0.66	7.5	15.5	12.06	290	265
16	I	150	30	0.70	8.0	16.0	13.25	375	340
16	II	250	30	0.89	8.0	16.0	13.25	435	390
16	I	250	DI	0.70	8.0	16.0	13.25	375	340
18	I	150	30	0.75	8.5	16.5	14.50	450	415
18	II	250	30	0.96	8.5	16.5	14.50	540	485
18	I	250	DI	0.75	8.5	16.5	14.50	450	415
20	I	150	30	0.80	9.5	17.5	16.88	560	520
20	II	250	30	1.03	9.5	17.5	16.88	685	615
20	I	250	DI	0.80	9.5	17.5	16.88	560	520
24	I	150	30	0.89	11.0	19.0	18.12	785	730
24	II	250	30	1.16	11.0	19.0	18.12	985	890
24	I	250	DI	0.89	11.0	19.0	18.12	785	730
30	I	150	30	1.03	15.0	23.0	27.75	1,345	1,260
30	II	250	30	1.37	15.0	23.0	27.75	1,800	1,605
30	I	250	DI	1.03	15.0	23.0	27.75	1,345	1,260
36	I	150	30	1.15	18.0	26.0	35.00	2,095	1,935
36	II	250	30	1.58	18.0	26.0	35.00	2,785	2,495
36	I	250	DI	1.15	18.0	26.0	35.00	2,095	1,935
42	I	150	30	1.28	21.0	29.0	42.25	2,995	2,770
42	II	250	30	1.78	21.0	29.0	42.25	4,065	3,645
42	I	250	DI	1.28	21.0	29.0	42.25	2,995	2,770
48	I	150	30	1.42	24.0	32.0	49.50	4,120	3,840
48	II	250	30	1.96	24.0	32.0	49.50	5,635	5,075
48	I	250	DI	1.42	24.0	32.0	49.50	4,120	3,840

Dimension details of bells are shown in Table 10.14; those of spigots, Table 10.15.
* Ductile iron.

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TABLE 10.16—Bell-and-Spigot Bends (contd.)

Size in.	Bell Design	Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.				Weight—lb	
				T	A	S	R	B & B	B & S
22½-deg Bends									
3		250	25	0.48	3.0	11.0	7.56	50	40
4		250	25	0.52	4.0	12.0	10.06	65	55
6		250	25	0.55	5.0	13.0	15.06	100	85
8		250	25	0.60	5.5	13.5	17.62	145	130
10		250	25	0.68	6.5	14.5	22.62	200	180
12		250	25	0.75	7.5	15.5	27.62	270	250
14	I	150	25	0.66	7.5	15.5	25.12	295	270
14	II	250	25	0.82	7.5	15.5	25.12	330	305
14	I	250	DI*	0.66	7.5	15.5	25.12	295	270
16	I	150	30	0.70	8.0	16.0	27.62	380	345
16	II	250	30	0.89	8.0	16.0	27.62	440	395
16	I	250	DI	0.70	8.0	16.0	27.62	380	345
18	I	150	30	0.75	8.5	16.5	30.19	460	425
18	II	250	30	0.96	8.5	16.5	30.19	545	490
18	I	250	DI	0.75	8.5	16.5	30.19	460	425
20	I	150	30	0.80	9.5	17.5	35.19	565	525
20	II	250	30	1.03	9.5	17.5	35.19	695	620
20	I	250	DI	0.80	9.5	17.5	35.19	565	525
24	I	150	30	0.89	11.0	19.0	37.69	795	740
24	II	250	30	1.16	11.0	19.0	37.69	1,000	905
24	I	250	DI	0.89	11.0	19.0	37.69	795	740
30	I	150	30	1.03	15.0	23.0	57.81	1,365	1,280
30	II	250	30	1.37	15.0	23.0	57.81	1,835	1,640
30	I	250	DI	1.03	15.0	23.0	57.81	1,365	1,280
36	I	150	30	1.15	18.0	26.0	72.88	2,135	1,975
36	II	250	30	1.58	18.0	26.0	72.88	2,835	2,545
36	I	250	DI	1.15	18.0	26.0	72.88	2,135	1,975
42	I	150	30	1.28	21.0	29.0	88.00	3,050	2,835
42	II	250	30	1.78	21.0	29.0	88.00	4,155	3,735
42	I	250	DI	1.28	21.0	29.0	88.00	3,050	2,835
48	I	150	30	1.42	24.0	32.0	103.06	4,210	3,930
48	II	250	30	1.96	24.0	32.0	103.06	5,760	5,200
48	I	250	DI	1.42	24.0	32.0	103.06	4,210	3,930

Dimension details of bells are shown in Table 10.14; those of spigots, Table 10.15.
* Ductile iron.

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GRAY-IRON AND DUCTILE-IRON FITTINGS

TABLE 10.16—Bell-and-Spigot Bends (contd.)

Size in.	Bell Design	Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.				Weight—lb	
				T	A	S	R	B & B	B & S
11½-deg Bends									
3		250	25	0.48	3.0	11.0	15.25	50	40
4		250	25	0.52	4.0	12.0	20.31	65	55
6		250	25	0.55	5.0	13.0	30.50	100	85
8		250	25	0.60	5.5	13.5	35.50	145	130
10		250	25	0.68	6.5	14.5	45.69	200	180
12		250	25	0.75	7.5	15.5	55.81	270	250
14	I	150	25	0.66	7.5	15.5	50.75	295	270
14	II	250	25	0.82	7.5	15.5	50.75	335	305
14	I	250	DI*	0.66	7.5	15.5	50.75	295	270
16	I	150	30	0.70	8.0	16.0	55.81	380	345
16	II	250	30	0.89	8.0	16.0	55.81	440	395
16	I	250	DI	0.70	8.0	16.0	55.81	380	345
18	I	150	30	0.75	8.5	16.5	60.94	460	425
18	II	250	30	0.96	8.5	16.5	60.94	550	490
18	I	250	DI	0.75	8.5	16.5	60.94	460	425
20	I	150	30	0.80	9.5	17.5	71.06	570	530
20	II	250	30	1.03	9.5	17.5	71.06	700	625
20	I	250	DI	0.80	9.5	17.5	71.06	570	530
24	I	150	30	0.89	11.0	19.0	76.12	800	745
24	II	250	30	1.16	11.0	19.0	76.12	1,005	905
24	I	250	DI	0.89	11.0	19.0	76.12	800	745
30	I	150	30	1.03	15.0	23.0	116.75	1,375	1,290
30	II	250	30	1.37	15.0	23.0	116.75	1,840	1,645
30	I	250	DI	1.03	15.0	23.0	116.75	1,375	1,290
36	I	150	30	1.15	18.0	26.0	147.25	2,145	1,985
36	II	250	30	1.58	18.0	26.0	147.25	2,850	2,560
36	I	250	DI	1.15	18.0	26.0	147.25	2,145	1,985
42	I	150	30	1.28	21.0	29.0	177.69	3,065	2,850
42	II	250	30	1.78	21.0	29.0	177.69	4,175	3,755
42	I	250	DI	1.28	21.0	29.0	177.69	3,065	2,850
48	I	150	30	1.42	24.0	32.0	208.12	4,230	3,950
48	II	250	30	1.96	24.0	32.0	208.12	5,790	5,230
48	I	250	DI	1.42	24.0	32.0	208.12	4,230	3,950

Dimension details of bells are shown in Table 10.14; those of spigots, Table 10.15.
* Ductile iron.

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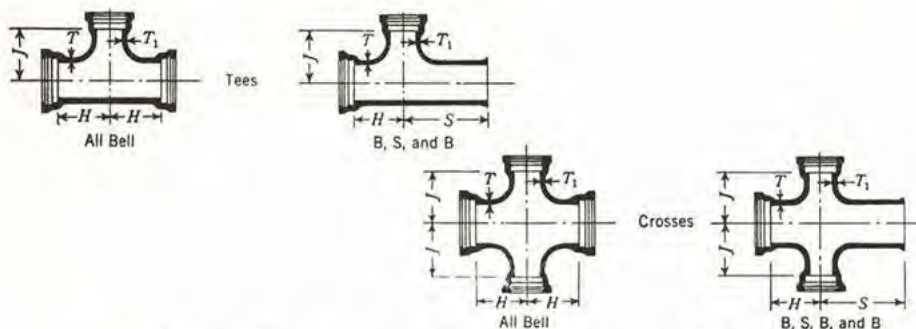


Fig. 10.17. Bell-and-Spigot Tees and Crosses (See Table 10.17)

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TABLE 10.17
Bell-and-Spigot Tees and Crosses

Size in.		Bell Design	Pres- sure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.					Weight—lb			
Run	Br.†				T	T ₁	H	J	S	Tee		Cross	
										All Bell	B, S & B	All Bell	B, S, B & B
3	3		250	25	0.48	0.48	5.50	5.50	13.50	80	70	105	95
4	3		250	25	0.52	0.48	6.50	6.50	14.50	100	90	125	115
4	4		250	25	0.52	0.52	6.50	6.50	14.50	105	95	140	130
6	3		250	25	0.55	0.48	8.00	8.00	16.00	140	125	165	150
6	4		250	25	0.55	0.52	8.00	8.00	16.00	150	135	180	165
6	6		250	25	0.55	0.55	8.00	8.00	16.00	160	145	210	195
8	4		250	25	0.60	0.52	9.00	9.00	17.00	210	195	240	225
8	6		250	25	0.60	0.55	9.00	9.00	17.00	220	205	265	250
8	8		250	25	0.60	0.60	9.00	9.00	17.00	240	225	305	290
10	4		250	25	0.68	0.52	11.00	11.00	19.00	290	270	320	300
10	6		250	25	0.68	0.55	11.00	11.00	19.00	300	280	350	330
10	8		250	25	0.68	0.60	11.00	11.00	19.00	320	300	390	370
10	10		250	25	0.80	0.80	11.00	11.00	19.00	370	350	465	445
12	4		250	25	0.75	0.52	12.00	12.00	20.00	375	355	405	385
12	6		250	25	0.75	0.55	12.00	12.00	20.00	385	365	435	415
12	8		250	25	0.75	0.60	12.00	12.00	20.00	405	385	475	455
12	10		250	25	0.87	0.80	12.00	12.00	20.00	460	440	555	535
12	12		250	25	0.87	0.87	12.00	12.00	20.00	485	465	600	580
14	6	I	150	25	0.66	0.55	14.00	14.00	22.00	465	440	520	495
14	6	II	250	25	0.82	0.55	14.00	14.00	22.00	530	500	580	550
14	6	I	250	DI*	0.66	0.55	14.00	14.00	22.00	465	440	520	495
14	8	I	150	25	0.66	0.60	14.00	14.00	22.00	485	465	555	530

Dimension details of bells are shown in Table 10.14; those of spigots, Table 10.15.

†Branch.

* Ductile iron.

GRAY-IRON AND DUCTILE-IRON FITTINGS

TABLE 10.17—Bell-and-Spigot Tees and Crosses (contd.)

Run	Size in.	Bell Design	Pres- sure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.					Weight—lb			
					T	T ₁	H	J	S	Tee		Cross	
										All Bell	B, S & B	All Bell	B, S, B & B
14	8	II	250	25	0.82	0.60	14.00	14.00	22.00	550	520	620	590
14	8	I	250	DI*	0.66	0.60	14.00	14.00	22.00	485	465	555	530
14	10	I	150	25	0.66	0.68	14.00	14.00	22.00	505	480	600	580
14	10	II	250	25	0.82	0.68	14.00	14.00	22.00	570	540	660	630
14	10	I	250	DI	0.66	0.68	14.00	14.00	22.00	505	480	600	580
14	12	II	150	25	0.82	0.75	14.00	14.00	22.00	600	570	710	680
14	12	II	250	30	0.82	0.75	14.00	14.00	22.00	600	570	710	680
14	12	I	250	DI	0.66	0.75	14.00	14.00	22.00	530	505	650	625
14	14	II	150	25	0.82	0.82	14.00	14.00	22.00	630	600	775	745
14	14	II	250	30	0.82	0.82	14.00	14.00	22.00	630	600	775	745
14	14	I	250	DI	0.66	0.66	14.00	14.00	22.00	545	520	675	650
16	6	I	150	30	0.70	0.55	15.00	15.00	23.00	590	550	635	600
16	6	II	250	30	0.89	0.55	15.00	15.00	23.00	685	635	735	685
16	6	I	250	DI	0.70	0.55	15.00	15.00	23.00	590	550	635	600
16	8	I	150	30	0.70	0.60	15.00	15.00	23.00	605	570	680	640
16	8	II	250	30	0.89	0.60	15.00	15.00	23.00	705	655	770	725
16	8	I	250	DI	0.70	0.60	15.00	15.00	23.00	605	570	680	640
16	10	I	150	30	0.70	0.68	15.00	15.00	23.00	625	590	725	690
16	10	II	250	30	0.89	0.68	15.00	15.00	23.00	725	675	815	765
16	10	I	250	DI	0.70	0.68	15.00	15.00	23.00	625	590	725	690
16	12	I	150	30	0.70	0.75	15.00	15.00	23.00	650	615	770	735
16	12	II	250	30	0.89	0.75	15.00	15.00	23.00	745	695	855	805
16	12	I	250	DI	0.70	0.75	15.00	15.00	23.00	650	615	770	735
16	14	II	150	30	0.89	0.82	15.00	15.00	23.00	780	735	920	870
16	14	II	250	35	0.89	0.82	15.00	15.00	23.00	780	735	920	870
16	14	I	250	DI	0.70	0.66	15.00	15.00	23.00	665	625	785	750
16	16	II	150	30	0.89	0.89	15.00	15.00	23.00	830	780	1,010	965
16	16	II	250	35	0.89	0.89	15.00	15.00	23.00	830	780	1,010	965
16	16	I	250	DI	0.70	0.70	15.00	15.00	23.00	695	660	860	820
18	6	I	150	30	0.75	0.55	13.00	15.50	21.00	655	595	685	640
18	6	II	250	30	0.96	0.55	13.00	15.50	21.00	755	695	800	745
18	6	I	250	DI	0.75	0.55	13.00	15.50	21.00	635	595	685	640
18	8	I	150	30	0.75	0.60	13.00	15.50	21.00	655	615	725	685
18	8	II	250	30	0.96	0.60	13.00	15.50	21.00	770	715	835	780
18	8	I	250	DI	0.75	0.60	13.00	15.50	21.00	655	615	725	685
18	10	I	150	30	0.75	0.68	13.00	15.50	21.00	675	635	760	720
18	10	II	250	30	0.96	0.68	13.00	15.50	21.00	790	730	875	815
18	10	I	250	DI	0.75	0.68	13.00	15.50	21.00	675	635	760	720
18	12	I	150	30	0.75	0.75	13.00	15.50	21.00	700	650	810	770
18	12	II	250	30	0.96	0.75	13.00	15.50	21.00	810	750	915	855
18	12	I	250	DI	0.75	0.75	13.00	15.50	21.00	700	650	810	770
18	14	I	150	30	0.75	0.66	16.50	16.50	24.50	800	755	920	880
18	14	II	250	30	0.96	0.82	16.50	16.50	24.50	950	895	1,090	1,035
18	14	I	250	DI	0.75	0.66	16.50	16.50	24.50	800	755	920	880
18	16	II	150	30	0.96	0.89	16.50	16.50	24.50	1,005	945	1,190	1,130
18	16	II	250	35	0.96	0.89	16.50	16.50	24.50	1,005	945	1,190	1,130
18	16	I	250	DI	0.75	0.70	16.50	16.50	24.50	830	790	995	950
18	18	II	150	30	0.96	0.96	16.50	16.50	24.50	1,050	990	1,275	1,215
18	18	II	250	35	0.96	0.96	16.50	16.50	24.50	1,050	990	1,275	1,215
18	18	I	250	DI	0.75	0.75	16.50	16.50	24.50	865	825	1,055	1,015

Dimension details of bells are shown in Table 10.14; those of spigots, Table 10.15.

† Branch.

* Ductile iron.

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TABLE 10.17—Bell-and-Spigot Tees and Crosses (contd.)

Run	Size in.	Bell Design	Pres- sure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.					Weight—lb			
					T	T ₁	H	J	S	Tee		Cross	
										All Bell	B, S & B	All Bell	B, S, B & B
20	6	I	150	30	0.80	0.55	14.00	17.00	22.00	770	725	820	770
20	6	II	250	30	1.03	0.55	14.00	17.00	22.00	935	860	985	910
20	6	I	250	D1*	0.80	0.55	14.00	17.00	22.00	770	725	820	770
20	8	I	150	30	0.80	0.60	14.00	17.00	22.00	785	740	860	815
20	8	II	250	30	1.03	0.60	14.00	17.00	22.00	955	880	1,020	945
20	8	I	250	D1	0.80	0.60	14.00	17.00	22.00	785	740	860	815
20	10	I	150	30	0.80	0.68	14.00	17.00	22.00	810	765	895	850
20	10	II	250	30	1.03	0.68	14.00	17.00	22.00	975	895	1,060	980
20	10	I	250	D1	0.80	0.68	14.00	17.00	22.00	810	765	895	850
20	12	I	150	30	0.80	0.75	14.00	17.00	22.00	835	790	945	900
20	12	II	250	30	1.03	0.75	14.00	17.00	22.00	995	920	1,100	1,020
20	12	I	250	D1	0.80	0.75	14.00	17.00	22.00	835	790	945	900
20	14	I	150	30	0.80	0.66	14.00	17.00	22.00	840	790	955	910
20	14	II	250	35	1.03	0.82	14.00	17.00	22.00	1,020	940	1,150	1,070
20	14	I	250	D1	0.80	0.66	14.00	17.00	22.00	840	790	955	910
20	16	I	150	30	0.80	0.70	18.00	18.00	26.00	995	950	1,155	1,110
20	16	II	250	35	1.03	0.89	18.00	18.00	26.00	1,215	1,140	1,400	1,320
20	16	I	250	D1	0.80	0.70	18.00	18.00	26.00	995	950	1,155	1,110
20	18	II	150	35	1.03	0.96	18.00	18.00	26.00	1,270	1,195	1,495	1,415
20	18	I	250	D1	0.80	0.75	18.00	18.00	26.00	1,025	980	1,215	1,170
20	20	II	150	35	1.03	1.03	18.00	18.00	26.00	1,325	1,250	1,600	1,525
20	20	I	250	D1	0.80	0.80	18.00	18.00	26.00	1,065	1,015	1,290	1,245
24	6	I	150	30	0.89	0.55	15.00	19.00	23.00	1,025	975	1,080	1,025
24	6	II	250	30	1.16	0.55	15.00	19.00	23.00	1,285	1,185	1,330	1,230
24	6	I	250	D1	0.89	0.55	15.00	19.00	23.00	1,025	975	1,080	1,025
24	8	I	150	30	0.89	0.60	15.00	19.00	23.00	1,050	995	1,110	1,060
24	8	II	250	30	1.16	0.60	15.00	19.00	23.00	1,300	1,200	1,365	1,265
24	8	I	250	D1	0.89	0.60	15.00	19.00	23.00	1,050	995	1,110	1,060
24	10	I	150	30	0.89	0.68	15.00	19.00	23.00	1,070	1,020	1,160	1,105
24	10	II	250	30	1.16	0.68	15.00	19.00	23.00	1,320	1,220	1,400	1,300
24	10	I	250	D1	0.89	0.68	15.00	19.00	23.00	1,070	1,020	1,160	1,105
24	12	I	150	30	0.89	0.75	15.00	19.00	23.00	1,085	1,030	1,190	1,140
24	12	II	250	30	1.16	0.75	15.00	19.00	23.00	1,335	1,235	1,435	1,335
24	12	I	250	D1	0.89	0.75	15.00	19.00	23.00	1,085	1,030	1,190	1,140
24	14	I	150	30	0.89	0.66	15.00	19.00	23.00	1,095	1,040	1,205	1,150
24	14	II	250	30	1.16	0.82	15.00	19.00	23.00	1,360	1,260	1,485	1,380
24	14	I	250	D1	0.89	0.66	15.00	19.00	23.00	1,095	1,040	1,205	1,150
24	16	I	150	30	0.89	0.70	15.00	19.00	23.00	1,120	1,070	1,265	1,210
24	16	II	250	35	1.16	0.89	15.00	19.00	23.00	1,400	1,295	1,555	1,455
24	16	I	250	D1	0.89	0.70	15.00	19.00	23.00	1,120	1,070	1,265	1,210
24	18	I	150	30	0.89	0.75	22.00	22.00	30.00	1,445	1,395	1,650	1,600
24	18	II	250	35	1.16	0.96	22.00	22.00	30.00	1,820	1,715	2,060	1,960
24	18	I	250	D1	0.89	0.75	22.00	22.00	30.00	1,445	1,395	1,650	1,600
24	20	II	150	35	1.16	1.03	22.00	22.00	30.00	1,890	1,790	2,185	2,080
24	20	I	250	D1	0.89	0.80	22.00	22.00	30.00	1,485	1,430	1,725	1,675
24	24	II	150	35	1.16	1.16	22.00	22.00	30.00	2,005	1,900	2,405	2,305
24	24	I	250	D1	0.89	0.89	22.00	22.00	30.00	1,565	1,510	1,890	1,835
30	6	I	150	30	1.03	0.55	18.00	23.00	26.00	1,710	1,615	1,760	1,670
30	6	II	250	30	1.37	0.55	18.00	23.00	26.00	2,260	2,050	2,310	2,100
30	6	I	250	D1	1.03	0.55	18.00	23.00	26.00	1,710	1,615	1,760	1,670
30	8	I	150	30	1.03	0.60	18.00	23.00	26.00	1,730	1,640	1,800	1,705

Dimension details of bells are shown in Table 10.14; those of spigots, Table 10.15.

† Branch.

* Ductile iron.

GRAY-IRON AND DUCTILE-IRON FITTINGS

TABLE 10.17—Bell-and-Spigot Tees and Crosses (contd.)

Size in.		Bell Design	Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.					Weight—lb			
Run	Br.†									Tee		Cross	
					T	T ₁	H	J	S	All Bell	B, S & B	All Bell	B, S, B & B
30	8	II	250	30	1.37	0.60	18.00	23.00	26.00	2,280	2,070	2,345	2,135
30	8	I	250	D1*	1.03	0.60	18.00	23.00	26.00	1,730	1,640	1,800	1,705
30	10	I	150	30	1.03	0.68	18.00	23.00	26.00	1,750	1,655	1,840	1,750
30	10	II	250	30	1.37	0.68	18.00	23.00	26.00	2,295	2,085	2,380	2,170
30	10	I	250	D1	1.03	0.68	18.00	23.00	26.00	1,750	1,655	1,840	1,750
30	12	I	150	30	1.03	0.75	18.00	23.00	26.00	1,770	1,680	1,885	1,790
30	12	II	250	30	1.37	0.75	18.00	23.00	26.00	2,315	2,105	2,415	2,205
30	12	I	250	D1	1.03	0.75	18.00	23.00	26.00	1,770	1,680	1,885	1,790
30	14	I	150	30	1.03	0.66	18.00	23.00	26.00	1,775	1,685	1,890	1,800
30	14	II	250	30	1.37	0.82	18.00	23.00	26.00	2,335	2,125	2,460	2,250
30	14	I	250	D1	1.03	0.66	18.00	23.00	26.00	1,775	1,685	1,890	1,800
30	16	I	150	30	1.03	0.70	18.00	23.00	26.00	1,805	1,710	1,950	1,860
30	16	II	250	30	1.37	0.89	18.00	23.00	26.00	2,375	2,165	2,540	2,325
30	16	I	250	D1	1.03	0.70	18.00	23.00	26.00	1,805	1,710	1,950	1,860
30	18	I	150	30	1.03	0.75	18.00	23.00	26.00	1,825	1,735	2,000	1,910
30	18	II	250	35	1.37	0.96	18.00	23.00	26.00	2,410	2,200	2,605	2,395
30	18	I	250	D1	1.03	0.75	18.00	23.00	26.00	1,825	1,735	2,000	1,910
30	20	I	150	30	1.03	0.80	18.00	23.00	26.00	1,855	1,765	2,060	1,970
30	20	II	250	35	1.37	1.03	18.00	23.00	26.00	2,450	2,240	2,690	2,480
30	20	I	250	D1	1.03	0.80	18.00	23.00	26.00	1,855	1,765	2,060	1,970
30	24	II	150	35	1.37	1.16	25.00	25.00	33.00	2,860	2,765	3,175	3,085
30	24	I	250	D1	1.03	0.89	25.00	25.00	33.00	2,350	2,260	2,655	2,560
30	30	II	150	35	1.37	1.37	25.00	25.00	33.00	3,050	2,960	3,565	3,470
30	30	I	250	D1	1.03	1.03	25.00	25.00	33.00	2,520	2,430	2,990	2,900
36	8	I	150	30	1.15	0.60	20.00	26.00	28.00	2,540	2,365	2,605	2,430
36	8	II	250	30	1.58	0.60	20.00	26.00	28.00	3,350	3,035	3,410	3,100
36	8	I	250	D1	1.15	0.60	20.00	26.00	28.00	2,540	2,365	2,605	2,430
36	10	I	150	30	1.15	0.68	20.00	26.00	28.00	2,560	2,385	2,650	2,475
36	10	II	250	30	1.58	0.68	20.00	26.00	28.00	3,365	3,050	3,445	3,130
36	10	I	250	D1	1.15	0.68	20.00	26.00	28.00	2,560	2,385	2,650	2,475
36	12	I	150	30	1.15	0.75	20.00	26.00	28.00	2,580	2,405	2,685	2,510
36	12	II	250	30	1.58	0.75	20.00	26.00	28.00	3,380	3,065	3,475	3,160
36	12	I	250	D1	1.15	0.75	20.00	26.00	28.00	2,580	2,405	2,685	2,510
36	14	I	150	30	1.15	0.66	20.00	26.00	28.00	2,580	2,410	2,685	2,510
36	14	II	250	30	1.58	0.82	20.00	26.00	28.00	3,400	3,090	3,515	3,205
36	14	I	250	D1	1.15	0.66	20.00	26.00	28.00	2,580	2,410	2,685	2,510
36	16	I	150	30	1.15	0.70	20.00	26.00	28.00	2,605	2,430	2,745	2,570
36	16	II	250	30	1.58	0.89	20.00	26.00	28.00	3,435	3,120	3,585	3,270
36	16	I	250	D1	1.15	0.70	20.00	26.00	28.00	2,605	2,430	2,745	2,570
36	18	I	150	30	1.15	0.75	20.00	26.00	28.00	2,630	2,455	2,785	2,610
36	18	II	250	30	1.58	0.96	20.00	26.00	28.00	3,465	3,150	3,640	3,330
36	18	I	250	D1	1.15	0.75	20.00	26.00	28.00	2,630	2,455	2,785	2,610
36	20	I	150	30	1.15	0.80	20.00	26.00	28.00	2,655	2,480	2,840	2,665
36	20	II	250	35	1.58	1.03	20.00	26.00	28.00	3,505	3,190	3,720	2,405
36	20	I	250	D1	1.15	0.80	20.00	26.00	28.00	2,655	2,480	2,840	2,665
36	24	I	150	30	1.15	0.89	20.00	26.00	28.00	2,710	2,535	2,945	2,770
36	24	II	250	35	1.58	1.16	20.00	26.00	28.00	3,575	3,220	3,860	3,505
36	24	I	250	D1	1.15	.89	20.00	26.00	28.00	2,710	2,535	2,945	2,770
36	30	II	150	35	1.58	1.37	28.00	28.00	36.00	4,330	4,155	4,765	4,590
36	30	I	250	D1	1.15	1.03	28.00	28.00	36.00	3,495	3,320	3,915	3,745
36	36	II	150	35	1.58	1.58	28.00	28.00	36.00	4,595	4,415	5,285	4,630
36	36	I	250	D1	1.15	1.15	28.00	28.00	36.00	3,720	3,545	4,365	4,190

Dimension details of bells are shown in Table 10.14; those of spigots, Table 10.15.

† Branch.

* Ductile iron.

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TABLE 10.17—Bell-and-Spigot Tees and Crosses (contd.)

Size in.		Bell Design	Pres- sure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.					Weight—lb			
Run	Br.†				T	T ₁	H	J	S	Tee		Cross	
										All Bell	B, S & B	All Bell	B, S, B & B
42	12	I	150	30	1.28	0.75	23.00	30.00	31.00	3,620	3,380	3,730	3,495
42	12	II	250	30	1.78	0.75	23.00	30.00	31.00	4,880	4,425	4,970	4,520
42	12	I	250	D1*	1.28	0.75	23.00	30.00	31.00	3,620	3,380	3,730	3,495
42	14	I	150	30	1.28	0.66	23.00	30.00	31.00	3,620	3,385	3,730	3,495
42	14	II	250	30	1.78	0.82	23.00	30.00	31.00	4,900	4,445	5,010	4,560
42	14	I	250	D1	1.28	0.66	23.00	30.00	31.00	3,620	3,385	3,730	3,495
42	16	I	150	30	1.28	0.70	23.00	30.00	31.00	3,650	3,415	3,790	3,550
42	16	II	250	30	1.78	0.89	23.00	30.00	31.00	4,930	4,480	5,080	4,615
42	16	I	250	D1	1.28	0.70	23.00	30.00	31.00	3,650	3,415	3,790	3,550
42	18	I	150	30	1.28	0.75	23.00	30.00	31.00	3,670	3,435	3,825	3,590
42	18	II	250	30	1.78	0.96	23.00	30.00	31.00	4,960	4,505	5,135	4,680
42	18	I	250	D1	1.28	0.75	23.00	30.00	31.00	3,670	3,435	3,825	3,590
42	20	I	150	30	1.28	0.80	23.00	30.00	31.00	3,695	3,460	3,880	3,645
42	20	II	250	30	1.78	1.03	23.00	30.00	31.00	4,995	4,545	5,210	4,755
42	20	I	250	D1	1.28	0.80	23.00	30.00	31.00	3,695	3,460	3,880	3,645
42	24	II	150	30	1.78	1.16	23.00	30.00	31.00	5,065	4,610	5,345	4,890
42	30	I	250	D1	1.28	1.37	31.00	31.00	39.00	6,365	5,910	6,875	6,420
42	30	II	150	30	1.78	1.37	31.00	31.00	39.00	4,665	4,430	5,035	4,800
42	30	I	250	D1	1.28	1.03	31.00	31.00	39.00	4,865	4,630	5,440	5,205
42	36	I	150	D1	1.28	1.15	31.00	31.00	39.00	6,115	5,875	6,695	6,460
42	36	II	250	D1	1.78	1.58	31.00	31.00	39.00	5,095	4,860	5,895	5,660
42	42	I	150	D1	1.28	1.28	31.00	31.00	39.00	6,375	6,140	7,220	6,985
42	42	II	250	D1	1.78	1.78	31.00	31.00	39.00	4,940	4,635	5,050	4,750
48	12	I	150	30	1.42	0.75	26.00	34.00	34.00	6,695	6,090	6,790	6,185
48	12	II	250	30	1.96	0.75	26.00	34.00	34.00	4,940	4,635	5,050	4,750
48	12	I	250	D1	1.42	0.75	26.00	34.00	34.00	4,935	4,635	5,045	4,745
48	14	I	150	30	1.42	0.66	26.00	34.00	34.00	6,715	6,115	6,830	6,230
48	14	II	250	30	1.96	0.82	26.00	34.00	34.00	4,935	4,635	5,045	4,745
48	14	I	250	D1	1.42	0.66	26.00	34.00	34.00	4,965	4,665	5,105	4,800
48	16	I	150	30	1.42	0.70	26.00	34.00	34.00	6,750	6,145	6,895	6,295
48	16	II	250	30	1.96	0.89	26.00	34.00	34.00	4,965	4,665	5,105	4,800
48	16	I	250	D1	1.42	0.70	26.00	34.00	34.00	4,985	4,680	5,140	4,840
48	18	I	150	30	1.42	0.75	26.00	34.00	34.00	6,775	6,170	6,950	6,350
48	18	II	250	30	1.96	0.96	26.00	34.00	34.00	4,985	4,680	5,140	4,840
48	18	I	250	D1	1.42	0.75	26.00	34.00	34.00	5,010	4,705	5,190	4,890
48	20	I	150	30	1.42	0.80	26.00	34.00	34.00	6,810	6,210	7,025	6,420
48	20	II	250	30	1.96	1.03	26.00	34.00	34.00	5,010	4,705	5,190	4,890
48	20	I	250	D1	1.42	0.80	26.00	34.00	34.00	5,060	4,750	5,280	4,980
48	24	I	150	30	1.42	0.89	26.00	34.00	34.00	6,875	6,270	7,150	6,545
48	24	II	250	30	1.96	1.16	26.00	34.00	34.00	5,060	4,750	5,280	4,980
48	24	I	250	D1	1.42	0.89	26.00	34.00	34.00	7,055	6,455	7,515	6,910
48	30	II	150	30	1.96	1.37	26.00	34.00	34.00	5,165	4,860	5,500	5,200
48	30	I	250	D1	1.42	1.03	26.00	34.00	34.00	8,615	8,015	9,285	8,060
48	36	II	150	30	1.96	1.58	34.00	34.00	42.00	6,325	6,025	6,835	6,530
48	36	I	250	D1	1.42	1.15	34.00	34.00	42.00	6,515	6,215	7,215	6,915
48	42	I	150	D1	1.42	1.28	34.00	34.00	42.00	8,195	7,955	8,900	8,600
48	42	II	250	D1	1.96	1.78	34.00	34.00	42.00	6,475	6,275	7,440	7,140
48	48	I	150	D1	1.42	1.42	34.00	34.00	42.00	8,480	8,175	9,470	9,165
48	48	II	250	D1	1.96	1.96	34.00	34.00	42.00	6,475	6,275	7,440	7,140

Dimension details of bells are shown in Table 10.14; those of spigots, Table 10.15.

† Branch.

* Ductile iron.

GRAY-IRON AND DUCTILE-IRON FITTINGS

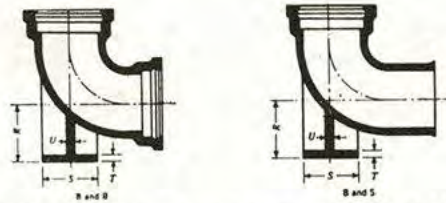


Fig. 10.18. Bell-and-Spigot Base Bends (See Table 10.18)

For other dimensions of base bends, see Table 10.16.

TABLE 10.18
Bell-and-Spigot Base Bends

Size in.	Bell Design	Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.				Weight—lb		Weight (Base Only) lb
				R†	S Diam	T	U	B & B	B & S	
3		250	25	4.88	5.00	0.56	0.50	65	55	10
4		250	25	5.50	6.00	0.62	0.50	80	70	10
6		250	25	7.00	7.00	0.69	0.62	130	115	20
8		250	25	8.38	9.00	0.94	0.88	205	190	40
10		250	25	9.75	9.00	0.94	0.88	275	255	45
12		250	25	11.25	11.00	1.00	1.00	370	350	65
14	I	150	25	12.50	11.00	1.00	1.00	430	405	70
14	II	250	25	12.50	11.00	1.00	1.00	480	455	70
14	I	250	DI*	12.50	11.00	1.00	1.00	430	405	70
16	I	150	30	13.75	11.00	1.00	1.00	540	505	75
16	II	250	30	13.75	11.00	1.00	1.00	620	575	75
16	I	250	DI	13.75	11.00	1.00	1.00	540	505	75
18	I	150	30	15.00	13.50	1.12	1.12	690	655	115
18	II	250	30	15.00	13.50	1.12	1.12	810	750	115
18	I	250	DI	15.00	13.50	1.12	1.12	690	655	115
20	I	150	30	16.00	13.50	1.12	1.12	830	790	120
20	II	250	30	16.00	13.50	1.12	1.12	1,000	925	120
20	I	250	DI	16.00	13.50	1.12	1.12	830	790	120
24	I	150	30	18.50	13.50	1.12	1.12	1,185	1,130	130
24	II	250	30	18.50	13.50	1.12	1.12	1,465	1,365	130
24	I	250	DI	18.50	13.50	1.12	1.12	1,185	1,130	130
30	I	150	30	23.00	16.00	1.19	1.15	1,850	1,765	190
30	II	250	30	23.00	16.00	1.19	1.15	2,400	2,210	190
30	I	250	DI	23.00	16.00	1.19	1.15	1,850	1,765	190
36	I	150	30	26.00	19.00	1.25	1.15	2,730	2,565	250
36	II	250	30	26.00	19.00	1.25	1.15	3,555	3,265	250
36	I	250	DI	26.00	19.00	1.25	1.15	2,730	2,565	250
42	I	150	30	30.00	23.50	1.44	1.28	3,850	3,630	410
42	II	250	30	30.00	23.50	1.44	1.28	5,100	4,680	410
42	I	250	DI	30.00	23.50	1.44	1.28	3,850	3,630	410
48	I	150	30	34.00	25.00	1.56	1.42	5,150	4,870	515
48	II	250	30	34.00	25.00	1.56	1.42	6,855	6,295	515
48	I	250	DI	34.00	25.00	1.56	1.42	5,150	4,870	515

† Dimension "R" is a finished dimension; unfinished bases will be $\frac{1}{8}$ in. longer. Base drilling is shown in Table 10.27.

* Ductile iron.

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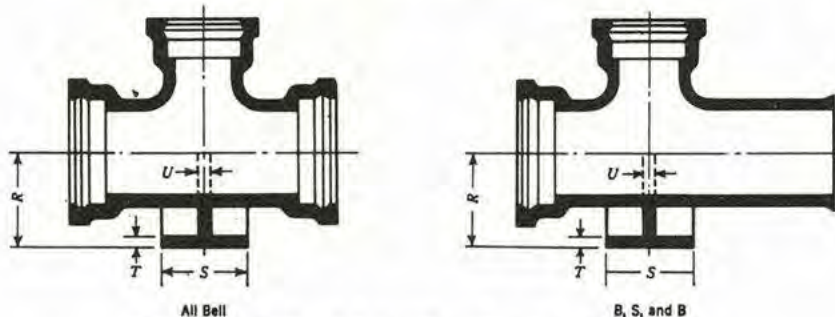


Fig. 10.19. Bell-and-Spigot Base Tees (See Table 10.19)

For other dimensions of base tees, see Table 10.17.

TABLE 10.19
Bell-and-Spigot Base Tees

Size in.	Bell Design	Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.				Weight—lb		Weight (Base Only) lb
				R†	S Diam.	T	U	B & B	B & S	
3		250	25	4.88	5.00	0.56	0.50	85	75	5
4		250	25	5.50	6.00	0.62	0.50	115	105	10
6		250	25	7.00	7.00	0.69	0.62	175	160	15
8		250	25	8.38	9.00	0.94	0.88	270	255	30
10		250	25	9.75	9.00	0.94	0.88	400	380	30
12		250	25	11.25	11.00	1.00	1.00	530	510	45
14	I	150	25	12.50	11.00	1.00	1.00	680	650	50
14	II	250	30	12.50	11.00	1.00	1.00	680	650	50
14	I	250	D1*	12.50	11.00	1.00	1.00	595	570	50
16	I	150	30	13.75	11.00	1.00	1.00	880	830	50
16	II	250	35	13.75	11.00	1.00	1.00	880	830	50
16	I	250	D1	13.75	11.00	1.00	1.00	745	710	50
18	II	150	30	15.00	13.50	1.12	1.12	1,125	1,065	75
18	II	250	35	15.00	13.50	1.12	1.12	1,125	1,065	75
18	I	250	D1	15.00	13.50	1.12	1.12	940	900	75
20	II	150	35	16.00	13.50	1.12	1.12	1,400	1,355	75
20	I	250	D1	16.00	13.50	1.12	1.12	1,140	1,090	75
24	II	150	35	18.50	13.50	1.12	1.12	2,085	1,980	80
24	I	250	D1	18.50	13.50	1.12	1.12	1,645	1,590	80
30	II	150	35	23.00	16.00	1.19	1.15	3,170	3,080	120
30	I	250	D1	23.00	16.00	1.19	1.15	2,640	2,550	120
36	II	150	35	26.00	19.00	1.25	1.15	4,755	4,575	160
36	I	250	D1	26.00	19.00	1.25	1.15	3,880	3,705	160
42	I	150	D1	30.00	23.50	1.44	1.28	5,365	5,130	270
42	II	250	D1	30.00	23.50	1.44	1.28	6,645	6,410	270
48	I	150	D1	34.00	25.00	1.56	1.42	7,115	6,810	335
48	II	250	D1	34.00	25.00	1.56	1.42	8,815	8,510	335

† Dimension "R" is a finished dimension; unfinished bases will be $\frac{1}{8}$ in. longer. Base drilling is shown in Table

*Ductile iron.

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GRAY-IRON AND DUCTILE-IRON FITTINGS

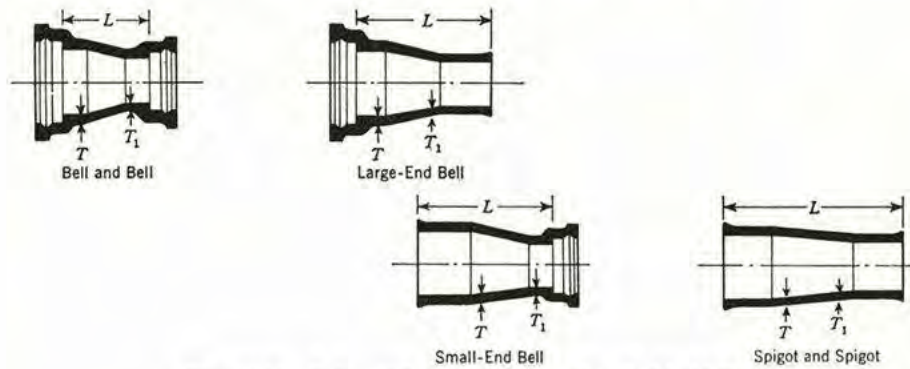


Fig. 10.20. Bell-and-Spigot Reducers (See Table 10.20)

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TABLE 10.20
Bell-and-Spigot Reducers

End Size in.		Bell Design	Pressure Rating psi	Iron Strength psi (1,000's)	Thickness in.		Bell & Bell		Small-End Bell		Large-End Bell		Spigot & Spigot	
Lg.	Sm.				T Large End	T ₁ Small End	L in.	Wgt. lb	L in.	Wgt. lb	L in.	Wgt. lb	L in.	Wgt. lb
4	3		250	25	0.52	0.48	7	55	15	45	15	45	23	35
6	3		250	25	0.55	0.48	9	75	17	60	17	65	25	55
6	4		250	25	0.55	0.52	9	80	17	65	17	70	25	55
8	4		250	25	0.60	0.52	11	110	19	95	19	100	27	80
8	6		250	25	0.60	0.55	11	125	19	110	19	110	27	95
10	4		250	25	0.68	0.52	12	135	20	115	20	125	28	105
10	6		250	25	0.68	0.55	12	150	20	130	20	135	28	120
10	8		250	25	0.68	0.60	12	170	20	150	20	155	28	135
12	4		250	25	0.75	0.52	14	165	22	145	22	155	30	135
12	6		250	25	0.75	0.55	14	185	22	165	22	170	30	155
12	8		250	25	0.75	0.60	14	210	22	190	22	195	30	175
12	10		250	25	0.75	0.68	14	235	22	215	22	215	30	200
14	6	I	150	25	0.66	0.55	16	210	24	190	24	200	32	175
14	6	II	250	25	0.82	0.55	16	230	24	200	24	215	32	185
14	6	I	250	DI*	0.66	0.55	16	210	24	190	24	200	32	175
14	8	I	150	25	0.66	0.60	16	235	24	205	24	220	32	195
14	8	II	250	25	0.82	0.60	16	255	24	225	24	235	32	210
14	8	I	250	DI	0.66	0.60	16	235	24	205	24	220	32	195
14	10	I	150	25	0.66	0.68	16	260	24	235	24	240	32	220
14	10	II	250	25	0.82	0.68	16	280	24	250	24	260	32	235
14	10	I	250	DI	0.66	0.68	16	260	24	235	24	240	32	220
14	12	I	150	25	0.66	0.75	16	290	24	265	24	270	32	250
14	12	II	250	25	0.82	0.75	16	310	24	280	24	290	32	265
14	12	I	250	DI	0.66	0.75	16	290	24	265	24	270	32	250

Eccentric reducers with the same dimensions and weights given for concentric reducers are available from most manufacturers if specified on purchase order. Dimension details for bells are shown in Table 10.14; for spigots, in Table 10.15.

* Ductile iron.

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TABLE 10.20—Bell-and-Spigot Reducers (contd.)

End Size in.		Bell Design	Pressure Rating psi	Iron Strength psi (1,000's)	Thickness in.		Bell & Bell		Small-End Bell		Large-End Bell		Spigot & Spigot	
Lg.	Sm.				T Large End	T ₁ Small End	L in.	Wgt. lb	L in.	Wgt. lb	L in.	Wgt. lb	L in.	Wgt. lb
16	6	I	150	30	0.70	0.55	18	260	26	225	26	245	34	210
16	6	II	250	30	0.89	0.55	18	290	26	245	26	280	34	230
16	6	I	250	DI*	0.70	0.55	18	260	26	225	26	245	34	210
16	8	I	150	30	0.70	0.60	18	285	26	250	26	270	34	235
16	8	II	250	30	0.89	0.60	18	320	26	270	26	300	34	255
16	8	I	250	DI	0.70	0.60	18	285	26	250	26	270	34	235
16	10	I	150	30	0.70	0.68	18	320	26	285	26	300	34	265
16	10	II	250	30	0.89	0.68	18	350	26	300	26	330	34	280
16	10	I	250	DI	0.70	0.68	18	320	26	285	26	300	34	265
16	12	I	150	30	0.70	0.75	18	345	26	315	26	330	34	295
16	12	II	250	30	0.89	0.75	18	380	26	330	26	360	34	315
16	12	I	250	DI	0.70	0.75	18	345	26	315	26	330	34	295
16	14	I	150	30	0.70	0.66	18	360	26	325	26	340	34	305
16	14	II	250	30	0.89	0.82	18	415	26	365	26	385	34	340
16	14	I	250	DI	0.70	0.66	18	360	26	325	26	340	34	305
18	8	I	150	30	0.75	0.60	19	330	27	290	27	310	35	275
18	8	II	250	30	0.96	0.60	19	375	27	315	27	355	35	300
18	8	I	250	DI	0.75	0.60	19	330	27	290	27	310	35	275
18	10	I	150	30	0.75	0.68	19	360	27	325	27	345	35	305
18	10	II	250	30	0.96	0.68	19	405	27	350	27	385	35	330
18	10	I	250	DI	0.75	0.68	19	360	27	325	27	345	35	305
18	12	I	150	30	0.75	0.75	19	390	27	350	27	375	35	335
18	12	II	250	30	0.96	0.75	19	440	27	380	27	420	35	365
18	12	I	250	DI	0.75	0.75	19	390	27	350	27	375	35	335
18	14	I	150	30	0.75	0.66	19	405	27	365	27	380	35	345
18	14	II	250	30	0.96	0.82	19	475	27	415	27	445	35	390
18	14	I	250	DI	0.75	0.66	19	405	27	365	27	380	35	345
18	16	I	150	30	0.75	0.70	19	450	27	410	27	415	35	375
18	16	II	250	30	0.96	0.89	19	530	27	470	27	480	35	425
18	16	I	250	DI	0.75	0.70	19	450	27	410	27	415	35	375
20	10	I	150	30	0.80	0.68	20	410	28	370	28	395	36	350
20	10	II	250	30	1.03	0.68	20	475	28	400	28	455	36	385
20	10	I	250	DI	0.80	0.68	20	410	28	370	28	395	36	350
20	12	I	150	30	0.80	0.75	20	445	28	400	28	430	36	385
20	12	II	250	30	1.03	0.75	20	510	28	435	28	490	36	420
20	12	I	250	DI	0.80	0.75	20	445	28	400	28	430	36	385
20	14	I	150	30	0.80	0.66	20	455	28	410	28	430	36	390
20	14	II	250	30	1.03	0.82	20	545	28	475	28	515	36	445
20	14	I	250	DI	0.80	0.66	20	455	28	410	28	430	36	390
20	16	I	150	30	0.80	0.70	20	505	28	460	28	470	36	425
20	16	II	250	30	1.03	0.89	20	600	28	530	28	555	36	480
20	16	I	250	DI	0.80	0.70	20	505	28	460	28	470	36	425
20	18	I	150	30	0.80	0.75	20	540	28	500	28	505	36	460
20	18	II	250	30	1.03	0.96	20	655	28	580	28	595	36	525
20	18	I	250	DI	0.80	0.75	20	540	28	500	28	505	36	460
24	12	I	150	30	0.89	0.75	24	590	32	540	32	570	40	520
24	12	II	250	30	1.16	0.75	24	695	32	595	32	675	40	580
24	12	I	250	DI	0.89	0.75	24	590	32	540	32	570	40	520
24	14	I	150	30	0.89	0.66	24	600	32	545	32	575	40	525
24	14	II	250	30	1.16	0.82	24	735	32	635	32	705	40	610
24	14	I	250	DI	0.89	0.66	24	600	32	545	32	575	40	525
24	16	I	150	30	0.89	0.70	24	645	32	595	32	610	40	560
24	16	II	250	30	1.16	0.89	24	795	32	700	32	750	40	650

Eccentric reducers with the same dimensions and weights given for concentric reducers are available from most manufacturers if specified on purchase order. Dimension details for bells are shown in Table 10.14; for spigots, in Table 10.15.

* Ductile iron.

GRAY-IRON AND DUCTILE-IRON FITTINGS

TABLE 10.20—Bell-and-Spigot Reducers (contd.)

End Size in.		Bell Design	Pressure Rating psi	Iron Strength psi (1,000's)	Thickness in.		Bell & Bell		Small-End Bell		Large-End Bell		Spigot & Spigot	
Lg.	Sm.				T Large End	T ₁ Small End	L in.	Wgt. lb	L in.	Wgt. lb	L in.	Wgt. lb	L in.	Wgt. lb
24	16	I	250	DI*	0.89	0.70	24	645	32	595	32	610	40	560
24	18	I	150	30	0.89	0.75	24	690	32	640	32	650	40	600
24	18	II	250	30	1.16	0.96	24	850	32	755	32	795	40	700
24	18	I	250	DI	0.89	0.75	24	690	32	640	32	650	40	600
24	20	I	150	30	0.89	0.80	24	735	32	685	32	690	40	640
24	20	II	250	30	1.16	1.03	24	920	32	825	32	845	40	750
24	20	I	250	DI	0.89	0.80	24	735	32	685	32	690	40	640
30	18	I	150	30	1.03	0.75	30	990	38	905	38	950	46	865
30	18	II	250	30	1.37	0.96	30	1,285	38	1,090	38	1,225	46	1,030
30	18	I	250	DI	1.03	0.75	30	990	38	905	38	950	46	865
30	20	I	150	30	1.03	0.80	30	1,050	38	965	38	1,005	46	920
30	20	II	250	30	1.37	1.03	30	1,365	38	1,170	38	1,290	46	1,095
30	20	I	250	DI	1.03	0.80	30	1,050	38	965	38	1,005	46	920
30	24	I	150	30	1.03	0.89	30	1,160	38	1,075	38	1,110	46	1,025
30	24	II	250	30	1.37	1.16	30	1,515	38	1,320	38	1,415	46	1,220
30	24	I	250	DI	1.03	0.89	30	1,160	38	1,075	38	1,110	46	1,025
36	20	I	150	30	1.15	0.80	36	1,465	44	1,305	44	1,425	52	1,260
36	20	II	250	30	1.58	1.03	36	1,900	44	1,610	44	1,830	52	1,540
36	20	I	250	DI	1.15	0.80	36	1,465	44	1,305	44	1,425	52	1,260
36	24	I	150	30	1.15	0.89	36	1,595	44	1,435	44	1,545	52	1,380
36	24	II	250	30	1.58	1.16	36	2,075	44	1,785	44	1,975	52	1,685
36	24	I	250	DI	1.15	0.89	36	1,595	44	1,435	44	1,545	52	1,380
36	30	I	150	30	1.15	1.03	36	1,840	44	1,675	44	1,755	52	1,590
36	30	II	250	30	1.58	1.37	36	2,445	44	2,155	44	2,250	52	1,960
36	30	I	250	DI	1.15	1.03	36	1,840	44	1,675	44	1,755	52	1,590
42	20	I	150	30	1.28	0.80	42	1,940	50	1,720	50	1,895	58	1,675
42	20	II	250	30	1.78	1.03	42	2,580	50	2,160	50	2,505	58	2,085
42	20	I	250	DI	1.28	0.80	42	1,940	50	1,720	50	1,895	58	1,675
42	24	I	150	30	1.28	0.89	42	2,090	50	1,870	50	2,040	58	1,820
42	24	II	250	30	1.78	1.16	42	2,770	50	2,350	50	2,675	58	2,255
42	24	I	250	DI	1.28	0.89	42	2,090	50	1,870	50	2,040	58	1,820
42	30	I	150	30	1.28	1.03	42	2,370	50	2,150	50	2,285	58	2,065
42	30	II	250	30	1.78	1.37	42	3,195	50	2,775	50	3,000	58	2,580
42	30	I	250	DI	1.28	1.03	42	2,370	50	2,150	50	2,285	58	2,065
42	36	I	150	30	1.28	1.15	42	2,710	50	2,495	50	2,550	58	2,330
42	36	II	250	30	1.78	1.58	42	3,655	50	3,235	50	3,365	58	2,945
42	36	I	250	DI	1.28	1.15	42	2,710	50	2,495	50	2,550	58	2,330
48	30	I	150	30	1.42	1.03	48	3,010	56	2,730	56	2,925	64	2,645
48	30	II	250	30	1.96	1.37	48	4,070	56	3,510	56	3,875	64	3,315
48	30	I	250	DI	1.42	1.03	48	3,010	56	2,730	56	2,925	64	2,645
48	36	I	150	30	1.42	1.15	48	3,390	56	3,110	56	3,230	64	2,950
48	36	II	250	30	1.96	1.58	48	4,585	56	4,025	56	4,295	64	3,735
48	36	I	250	DI	1.42	1.15	48	3,390	56	3,110	56	3,230	64	2,950
48	42	I	150	30	1.42	1.28	48	3,785	56	3,505	56	3,565	64	3,295
48	42	II	250	30	1.96	1.78	48	5,170	56	4,610	56	4,750	64	4,190
48	42	I	250	DI	1.42	1.28	48	3,785	56	3,505	56	3,565	64	3,295

Eccentric reducers with the same dimensions and weights given for concentric reducers are available from most manufacturers if specified on purchase order. Dimension details for bells are shown in Table 10.14; for spigots, in Table 10.15.

* Ductile iron.

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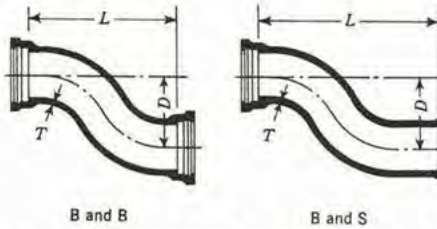


Fig. 10.21. Bell-and-Spigot Offsets (See Table 10.21)

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TABLE 10.21
Bell-and-Spigot Offsets

Size in.	BD†	PR‡ psi	IS§ psi (1,000's)	D in.	T in.	B&B		B&S		Size in.	BD†	PR‡ psi	IS§ psi (1,000's)	D in.	T in.	B&B		B&S	
						L in.	Wgt. lb	L in.	Wgt. lb							L in.	Wgt. lb	L in.	Wgt. lb
3		250	25	6	0.48	19	70	27	60	14	I	150	25	6	0.66	27	400	35	375
3		250	25	12	0.48	22	80	30	70	14	II	250	25	6	0.82	27	465	35	435
3		250	25	18	0.48	30	90	38	80	14	I	250	DI*	6	0.66	27	400	35	375
4		250	25	6	0.52	19	90	27	80	14	I	150	25	12	0.66	38	500	46	475
4		250	25	12	0.52	22	100	30	90	14	II	250	25	12	0.82	38	590	46	560
4		250	25	18	0.52	30	120	38	110	14	I	250	DI	12	0.66	38	500	46	475
6		250	25	6	0.55	20	135	28	120	14	I	150	25	18	0.66	49	805	57	580
6		250	25	12	0.55	26	160	34	145	14	II	250	25	18	0.82	49	710	57	680
6		250	25	18	0.55	33	190	41	175	14	I	250	DI	18	0.66	49	605	57	580
8		250	25	6	0.60	21	195	29	180	16	I	150	30	6	0.70	27	495	35	460
8		250	25	12	0.60	28	235	36	220	16	II	250	30	6	0.89	27	595	35	545
8		250	25	18	0.60	35	275	43	260	16	I	250	DI	6	0.70	27	495	35	460
10		250	25	6	0.68	22	265	30	245	16	I	150	30	12	0.70	40	635	48	600
10		250	25	12	0.68	30	325	38	305	16	II	250	30	12	0.89	40	770	48	720
10		250	25	18	0.68	38	385	46	365	16	I	250	DI	12	0.70	40	635	48	600
12		250	25	6	0.75	26	370	34	350	16	I	150	30	18	0.70	50	745	58	710
12		250	25	12	0.75	37	470	45	450	16	II	250	30	18	0.89	50	910	58	860
12		250	25	18	0.75	48	570	56	550	16	I	250	DI	18	0.70	50	745	58	710

Dimension details of bells are given in Table 10.14; those of spigots, Table 10.15.
† Bell design.

‡ Pressure rating.
§ Iron strength.
* Ductile iron.

TABLE 10.22

Bell-and-Spigot Tapped Tees

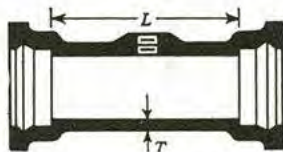


Fig. 10.22. Bell-and-Spigot Tapped Tees
(See Table 10.22)

Size in.	Pressure Rating psi	T in.	L in.	Max. Tap in Boss in.	Wgt. lb
3	250	0.48	8	2½	55
4	250	0.52	8	2½	65
6	250	0.55	8	2½	95
8	250	0.60	8	2½	130
10	250	0.68	8	2½	170
12	250	0.75	8	2½	215

Two bosses can be used to make a tapped cross. Dimension details of bells are given in Table 10.14.

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TABLE 10.23

Bell-and-Spigot Sleeves
Solid Sleeves—250 psi Pressure Rating
Split Sleeves—150 psi Pressure Rating

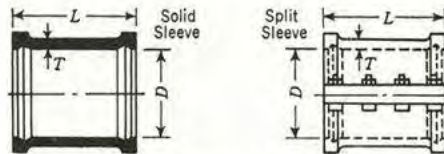


Fig. 10.23. Bell-and-Spigot Sleeves
(See Table 10.23)

Size in.	IS† psi (1,000's)	D in.	T in.	L in.		Sleeve Wgt.—lb			
						Solid		Split#	
				S§	L||	S§	L||	S§	L||
3	25	4.76	0.65	10	15	35	50	55	80
4	25	5.80	0.65	10	15	45	65	65	100
6	25	7.90	0.70	10	15	65	90	90	130
8	25	10.10	0.75	12	15	100	120	135	165
10	25	12.20	0.80	12	18	130	180	165	245
12	25	14.30	0.85	14	18	185	225	230	295
14	25	16.20	0.85	15	18	215	255	275	310
14	DI*	16.20	0.85	15	18	215	255		
16	30	18.50	0.90	15	24	270	400	330	510
16	DI	18.50	0.90	15	24	270	400		
18	30	20.60	0.95	15	24	320	470	380	585
18	DI	20.60	0.95	15	24	320	470		
20	30	22.70	1.03	15	24	380	555		
20	DI	22.70	1.03	15	24	380	555		
24	30	26.90	1.16	15	24	510	750		
24	DI	26.90	1.16	15	24	510	750		
30	30	33.10	1.37	15	24	725	1,075		
30	DI	33.10	1.37	15	24	725	1,075		
36	30	39.40	1.58	15	24	1,015	1,490		
36	DI	39.40	1.58	15	24	1,015	1,490		
42	30	45.60	1.78	15	24	1,310	1,870		
42	DI	45.60	1.78	15	24	1,310	1,870		
48	30	51.90	1.96	15	24	1,645	2,415		
48	DI	51.90	1.96	15	24	1,645	2,415		

* Ductile iron.
† Iron strength.
§ Short.
|| Long.

Split sleeves are furnished in Class 150 only and can be furnished with boss and tap for service connection. Manufacturers should be consulted for details.

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Fig. 10.24. Bell-and-Spigot Caps and Plugs (See Table 10.24)

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TABLE 10.24
Bell-and-Spigot Caps and Plugs

Size in.	Pressure Rating psi	Iron Strength psi (1,000's)	Caps					Plugs				
			Dimension in.			Wgt. lb		Dimensions in.			Wgt. lb	
			T	T ₁	D	Flat	Dished	T	T ₁	H	Flat	Dished
3	250	25	0.50		3.50	20		0.50		5.50	6	
4	250	25	0.60		4.00	25		0.60		5.50	10	
6	250	25	0.65		4.00	40		0.65		5.50	15	
8	250	25	0.70		4.00	55		0.70		5.50	25	
10	250	25	0.75		4.00	75		0.75		6.00	40	
12	250	25	0.75		4.00	100		0.75		6.00	50	
14	250	30	1.00	0.82	4.00	140	135	1.00	0.82	6.00	75	75
14	250	DI*	0.82	0.66	4.00	125	115	0.82	0.66	6.00	65	65
16	250	30	1.11	0.89	4.00	185	175	1.11	0.89	6.50	105	115
16	250	DI	0.89	0.70	4.00	165	150	0.89	0.70	6.50	90	90
18	250	30	1.25	0.96	4.00	240	220	1.25	0.96	6.50	140	135
18	250	DI	0.96	0.75	4.00	200	180	0.96	0.75	6.50	115	110
20	250	30	1.40	1.03	4.00	310	280	1.40	1.03	6.50	180	175
20	250	DI	1.03	0.80	4.00	245	220	1.03	0.80	6.50	145	140
24	250	30	1.50	1.16	4.00	440	400	1.50	1.16	8.00	375	415
24	250	DI	1.16	0.89	4.00	345	310	1.16	0.89	8.00	290	315
30	150	30		1.37	4.50		715		1.37	8.00		595
30	250	DI		1.03	4.50		515		1.03	8.00		440
36	150	30		1.58	4.50		1,100		1.58	8.00		900
36	250	DI		1.15	4.50		790		1.15	8.00		670
42	150	30		1.78	5.00		1,610		1.78	9.00		1,375
42	250	DI		1.28	5.00		1,110		1.28	9.00		965
48	150	30		1.96	5.00		2,215		1.96	9.00		1,875
48	250	DI		1.42	5.00		1,520		1.42	9.00		1,310

* Ductile Iron.

GRAY-IRON AND DUCTILE-IRON FITTINGS

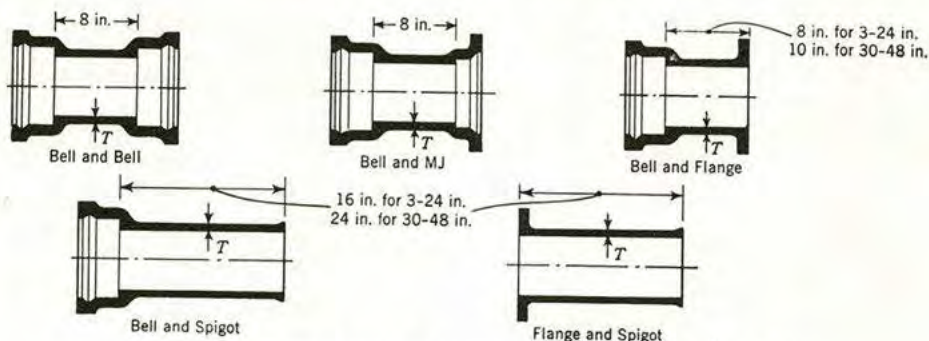


Fig. 10.25. Bell-and-Spigot Connecting Pieces (See Table 10.25)

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TABLE 10.25
Bell-and-Spigot Connecting Pieces

Size in.	Pressure Rating psi	Iron Strength psi (1,000's)	T in.	Weight—lb				
				Bell & Bell	Bell & Spigot	Bell & MJ	Bell & Flange	Flange & Spigot
3	250	25	0.48	50	40	40	35	30
4	250	25	0.52	65	55	55	50	40
6	250	25	0.55	95	80	80	70	60
8	250	25	0.60	130	115	115	105	85
10	250	25	0.68	170	155	150	140	120
12	250	25	0.75	215	195	190	180	165
14	150	25	0.66	240	215	230	205	180
14	250	25	0.82	270	240	255	230	195
14	250	DI*	0.66	240	215	230	205	180
16	150	30	0.70	305	270	290	255	220
16	250	30	0.89	345	300	320	290	240
16	250	DI	0.70	305	270	290	255	220
18	150	30	0.75	360	320	340	295	255
18	250	30	0.96	420	385	385	335	305
18	250	DI	0.75	360	320	340	295	255
20	150	30	0.80	420	375	405	355	310
20	250	30	1.03	510	435	465	410	340
20	250	DI	0.80	420	375	405	355	310
24	150	30	0.89	545	490	530	465	415
24	250	30	1.16	675	580	620	555	460
24	250	DI	0.89	545	490	530	465	415
30	150	30	1.03	805	925	820	740	815
30	250	30	1.37	1,090	1,165	1,005	935	945
30	250	DI	1.03	805	925	820	740	815
36	150	30	1.15	1,170	1,290	1,170	1,070	1,115
36	250	30	1.58	1,525	1,615	1,410	1,320	1,315
36	250	DI	1.15	1,170	1,290	1,170	1,070	1,115
42	150	30	1.28	1,535	1,675	1,515	1,430	1,480
42	250	30	1.78	2,070	2,145	1,870	1,800	1,755
42	250	DI	1.28	1,535	1,675	1,515	1,430	1,480
48	150	30	1.42	1,950	2,125	1,930	1,790	1,855
48	250	30	1.96	2,670	2,740	2,395	2,280	2,190
48	250	DI	1.42	1,950	2,125	1,930	1,790	1,855

Dimension details for mechanical-joint bells are given in Table 10.1; calking bells, Table 10.14; spigots, Table 10.15; flanges, Table 10.26. Bell and spigot, flange and spigot, and bell and flange connecting pieces may be furnished from centrifugally cast pipe with plain ends, if applicable.

* Ductile iron.

TABLE 10.26
Flange Details

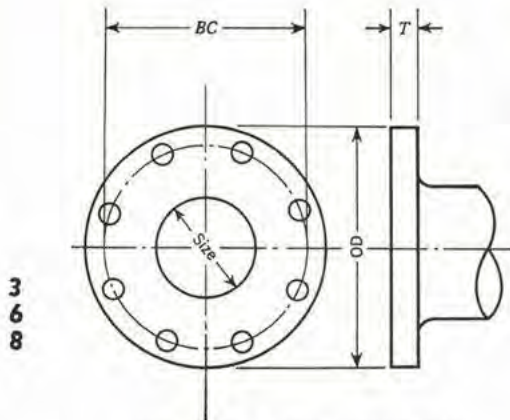


Fig. 10.26. Flange Details (See Table 10.26)

Size in.	Dimensions—in.					No. of Bolts
	OD	BC	T	Bolt Hole Dia.	Bolt Diam. & Length	
2	6.00	4.75	0.62 ±.12	$\frac{3}{8}$	$\frac{3}{8} \times 2\frac{1}{2}$	4
3	7.50	6.00	0.75 ±.12	$\frac{3}{8}$	$\frac{3}{8} \times 2\frac{1}{2}$	4
4	9.00	7.50	0.94 ±.12	$\frac{3}{8}$	$\frac{3}{8} \times 3$	8
6	11.00	9.50	1.00 ±.12	$\frac{3}{8}$	$\frac{3}{8} \times 3\frac{1}{2}$	8
8	13.50	11.75	1.12 ±.12	$\frac{3}{8}$	$\frac{3}{8} \times 3\frac{1}{2}$	8
10	16.00	14.25	1.19 ±.12	1	$\frac{3}{8} \times 3\frac{1}{2}$	12
12	19.00	17.00	1.25 ±.12	1	$\frac{3}{8} \times 3\frac{1}{2}$	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	$1\frac{1}{8}$	$1\frac{1}{8} \times 4\frac{1}{2}$	16
20	27.50	25.00	1.69 ±.19	$1\frac{1}{8}$	$1\frac{1}{8} \times 5$	20
24	32.00	29.50	1.88 ±.19	$1\frac{1}{8}$	$1\frac{1}{8} \times 5\frac{1}{2}$	20
30	38.75	36.00	2.12 ±.25	$1\frac{1}{8}$	$1\frac{1}{8} \times 6\frac{1}{2}$	28
36	46.00	42.75	2.38 ±.25	$1\frac{1}{8}$	$1\frac{1}{8} \times 7$	32
42	53.00	49.50	2.62 ±.25	$1\frac{1}{8}$	$1\frac{1}{8} \times 7\frac{1}{2}$	36
48	59.50	56.00	2.75 ±.25	$1\frac{1}{8}$	$1\frac{1}{8} \times 7\frac{1}{2}$	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.

LAYING LENGTH DIMENSIONS: Face-to-face dimensions shall conform to a tolerance of ± 0.06 in. for sizes 2-10 in. and ± 0.12 in. 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.

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 125 lb flanges shown in ANSI B16.1-1967 and can be joined with 125 lb B16.1 flanges. The flanges do not match the 250 lb flanges shown in ANSI B16.1-1967 and cannot be joined with 250 lb B16.1 flanged fittings and valves. If flanges are required to be joined with 250 lb B16.1-1967 flanges, this shall be specified on the purchase order since special manufacture is required.

TABLE 10.27
Base Drilling Details

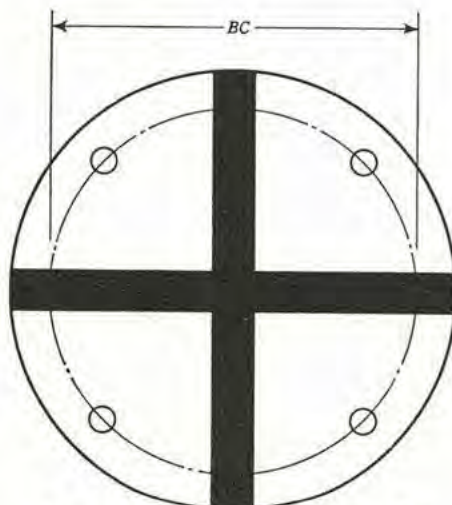


Fig. 10.27. Base Drilling Details (See Table 10.27)

Nom. Diam. in.	Dimensions—in.			Approx. Wgt. of Base—lb	
	BC	Bolt Hole Diam.	No. of Bolts	Bends	Tees
2	3.50	$\frac{3}{8}$	4	5	5
3	3.88	$\frac{3}{8}$	4	10	5
4	4.75	$\frac{3}{8}$	4	10	10
6	5.50	$\frac{3}{8}$	4	20	15
8	7.50	$\frac{3}{8}$	4	40	30
10	7.50	$\frac{3}{8}$	4	45	30
12	9.50	$\frac{3}{8}$	4	65	45
14	9.50	$\frac{3}{8}$	4	70	50
16	9.50	$\frac{3}{8}$	4	75	50
18	11.75	$\frac{3}{8}$	4	115	75
20	11.75	$\frac{3}{8}$	4	120	75
24	11.75	$\frac{3}{8}$	4	130	80
30	14.25	1	4	190	120
36	17.00	1	4	250	160
42	21.25	$1\frac{1}{8}$	4	410	270
48	22.75	$1\frac{1}{8}$	4	515	335

Bases are not faced or drilled unless so specified in the purchase order.

GRAY-IRON AND DUCTILE-IRON FITTINGS

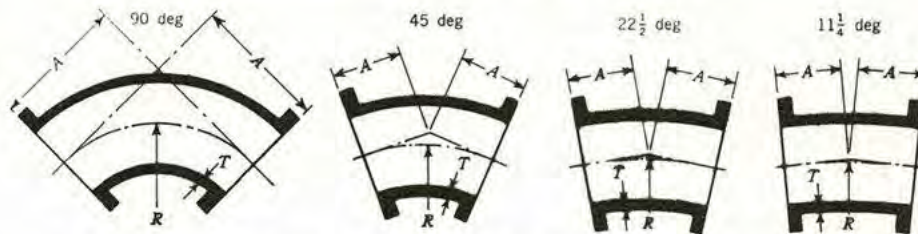


Fig. 10.28. Flanged Bends (See Table 10.28)

TABLE 10.28
Flanged Bends

Size in.	PR† psi	Iron Strength psi (1,000's)	T	90 deg		45 deg		22½ deg		11½ deg		90 deg	45 deg	22½ deg	11½ deg
				A	R	A	R	A	R	A	R				
Dimensions—in.												Weight—lb			
2	250	25	0.35	4.5	3.0	2.5	2.44	2.5	5.03	2.5	10.15	14	12	11	11
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	500	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	72.08	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	72.08	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	72.08	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	3,830	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 10.26.
† Pressure rating.
* Ductile iron.

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Fig. 10.29. Flanged Tees and Crosses (See Table 10.29)

TABLE 10.29
Flanged Tees and Crosses

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Size—in.		Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.				Weight—lb	
Run	Branch			T	T ₁	H	J	Tee	Cross
2	2	250	25	0.35	0.35	4.5	4.5	20	25
3	2	250	25	0.48	0.35	5.5	5.5	35	40
3	3	250	25	0.48	0.48	5.5	5.5	40	50
4	2	250	25	0.52	0.35	6.5	6.5	50	60
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	2	250	25	0.55	0.35	8.0	8.0	80	85
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	D1*	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	D1	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	D1	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	D1	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	D1	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	D1	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 10.26.

* Ductile iron.

GRAY-IRON AND DUCTILE-IRON FITTINGS

TABLE 10.29—Flanged Tees and Crosses (contd.)

Size—in.		Pressure Rating psi	Iron Strength psi (1,000'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 10.26.

* Ductile iron.

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TABLE 10.29—Flanged Tees and Crosses (contd.)

Size—in.		Pressure Rating psi	Iron Strength psi (1,000'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	D1	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	D1	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	D1	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	D1	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	D1	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	D1	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	D1	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	D1	0.89	0.89	22.0	22.0	1,330	1,570
30	12	150	30	1.33	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	D1	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	D1	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	D1	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	D1	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	D1	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	D1	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	D1	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	D1	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	D1	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	D1	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	D1	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 10.26.

* Ductile iron.

GRAY-IRON AND DUCTILE-IRON FITTINGS

TABLE 10.29—Flanged Tees and Crosses (contd.)

Size—in.		Pressure Rating psi	Iron Strength psi (1,000'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

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Dimension details of flanges are in Table 10.26.

* Ductile iron.

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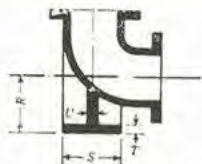


Fig. 10.30. Flanged Base Bends (See Table 10.30)

For other dimensions of base bends, see Table 10.28.

TABLE 10.30
Flanged Base Bends

Size in.	Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.				Weight—lb	
			R†	S Diam.	T	U	Base Fitting	Base Only
2	250	25	4.12	4.62	0.50	0.50	19	5
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	D1*	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	D1	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	D1	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	D1	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	D1	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	D1	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	D1	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	D1	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	D1	34.00	25.00	1.56	1.42	4,610	515

† Dimension "R" is a finished dimension; unfinished bases will be $\frac{1}{8}$ in. longer; details for base drilling are given in Table 10.27.

* Ductile iron.

GRAY-IRON AND DUCTILE-IRON FITTINGS

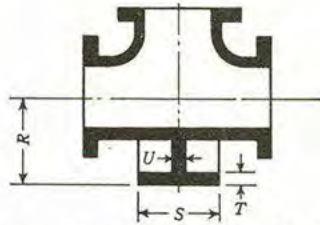


Fig. 10.31. Flanged Base Tees (See Table 10.31)

For other dimensions of base tees, see Table 10.29.

TABLE 10.31
Flanged Base Tees

Size in.	Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.				Weight—lb	
			R†	S Diam.	T	U	Base Fitting	Base Only
2	250	25	4.12	4.62	0.50	0.50	25	5
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	D1	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	D1	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	D1	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	D1	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	D1	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	D1	26.00	19.00	1.25	1.15	3,320	160
42	150	D1	30.00	23.50	1.44	1.28	4,740	270
42	250	D1	30.00	23.50	1.44	1.28	5,850	270
48	150	D1	34.00	25.00	1.56	1.42	6,235	335
48	250	D1	34.00	25.00	1.56	1.42	7,720	335

† Dimension "R" is a finished dimension; unfinished bases will be $\frac{1}{8}$ in. longer; details for base drilling are given in Table 10.27.

* Ductile iron.

AMERICAN NATIONAL STANDARD

TABLE 10.32
Flanged Reducers

Size—in.		Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.			Wgt. lb
Large	Small			T Large End	T ₁ Small End	L	
3	2	250	25	0.48	0.35	6	16
4	2	250	25	0.52	0.35	7	25
4	3	250	25	0.52	0.48	7	30
6	2	250	25	0.55	0.35	9	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	8	250	35	0.82	0.55	16	165
14	8	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	0.65	16	190
14	10	250	25	0.82	0.68	16	205
14	12	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	1.08	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	1.08	0.75	20	375
20	12	250	DI	0.80	0.75	20	345
20	14	150	30	0.80	0.66	20	365
20	14	250	30	1.08	0.82	20	405
20	14	250	DI	0.80	0.66	20	365
20	16	150	30	0.80	0.70	20	390
20	16	250	30	1.08	0.89	20	445
20	16	250	DI	0.80	0.70	20	390

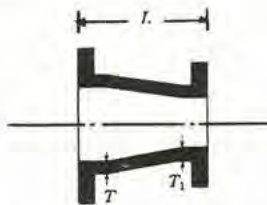


Fig. 10.32. Flanged Reducers
(See Table 10.32)

Size		Pressure Rating psi	Iron Strength psi (1,000's)	Dimensions—in.			Wgt. lb
Large	Small			T Large End	T ₁ Small End	L	
20	18	150	30	0.80	0.75	20	410
20	18	250	30	1.03	0.95	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	555
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	0.95	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	1.68	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 10.26. Eccentric reducers with the same dimensions and weights given for concentric reducers are available from most manufacturers if specified on the purchase order.

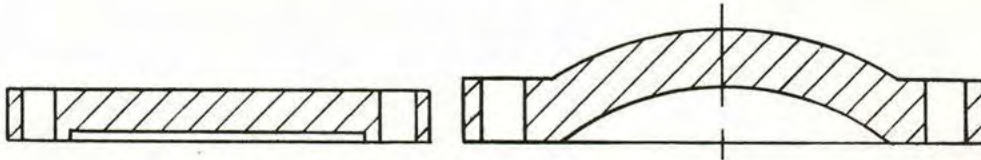
* Ductile iron.

SPECIAL FITTINGS

This appendix is for information only and is not a part of ANSI A21.10 (AWWA C110).

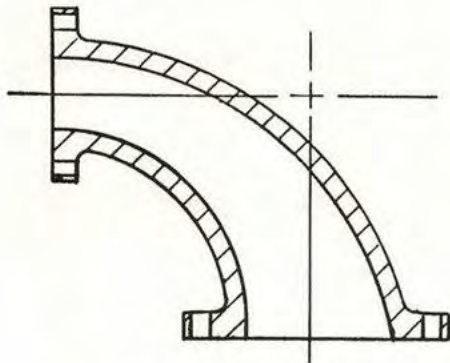
These special fittings are not a part of the standard but are available. For dimensions and pressure ratings, consult your supplier.

BLIND FLANGES

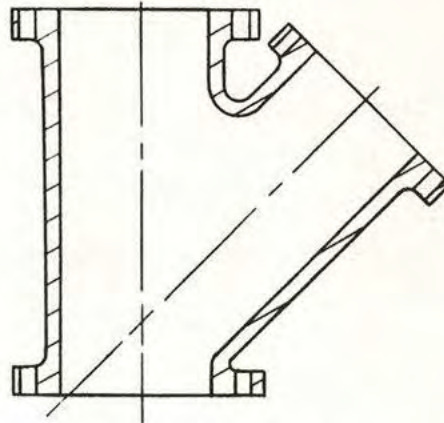


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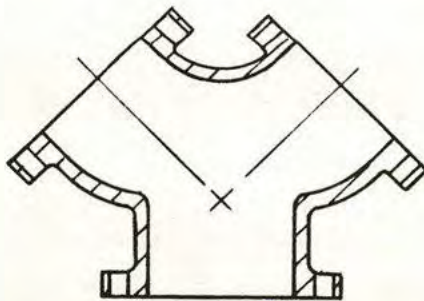
FLANGED 90° REDUCING BENDS



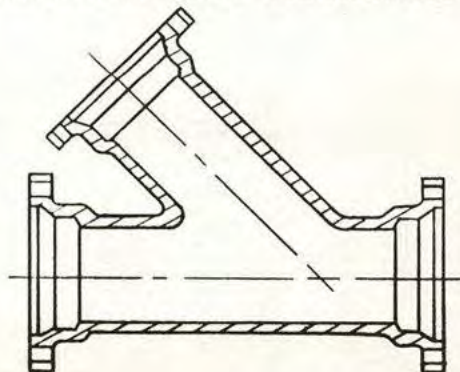
FLANGE WYE BRANCHES



FLANGED TRUE WYES



MECHANICAL JOINT WYE BRANCHES



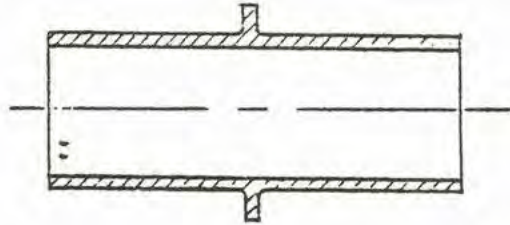
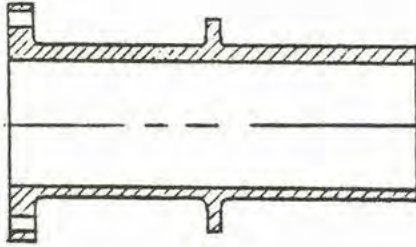
SPECIAL FITTINGS

WALL SLEEVES

FLANGE AND PLAIN END

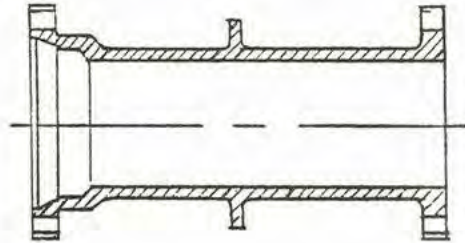
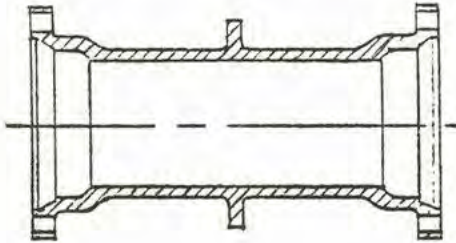
PLAIN END AND PLAIN END

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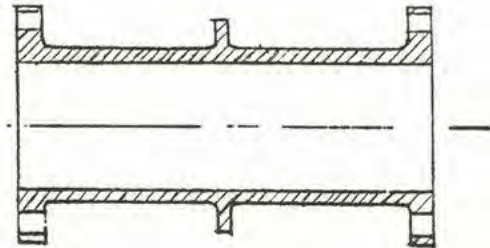
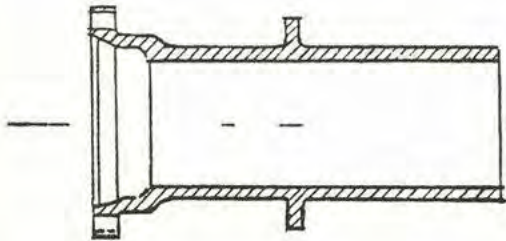
MJ AND MJ

MJ AND FLANGE



MJ AND PLAIN END

FLANGE AND FLANGE

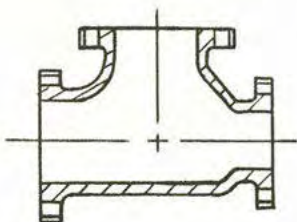


MJ AND PLAIN END

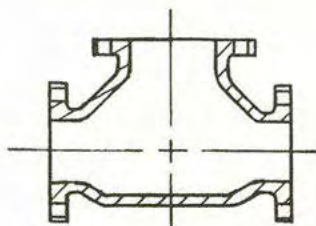
FLANGE AND FLANGE

SPECIAL FITTINGS

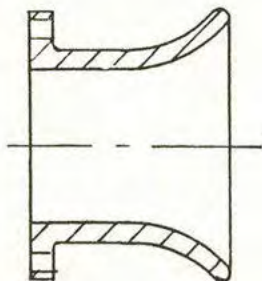
FLANGED REDUCING TEES



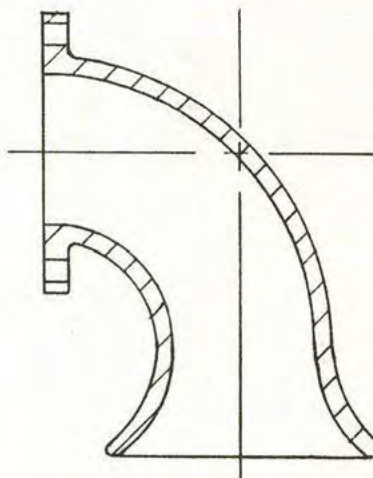
BULL HEAD TEE



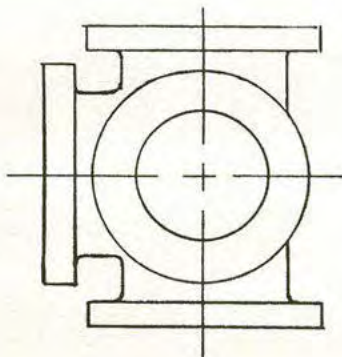
FLANGE AND FLARE



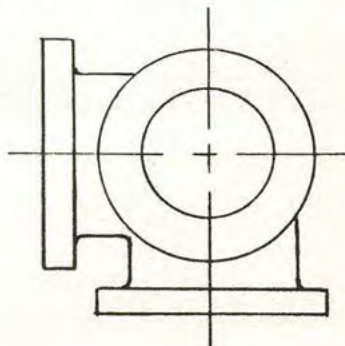
FLANGE AND FLARE 90° BENDS



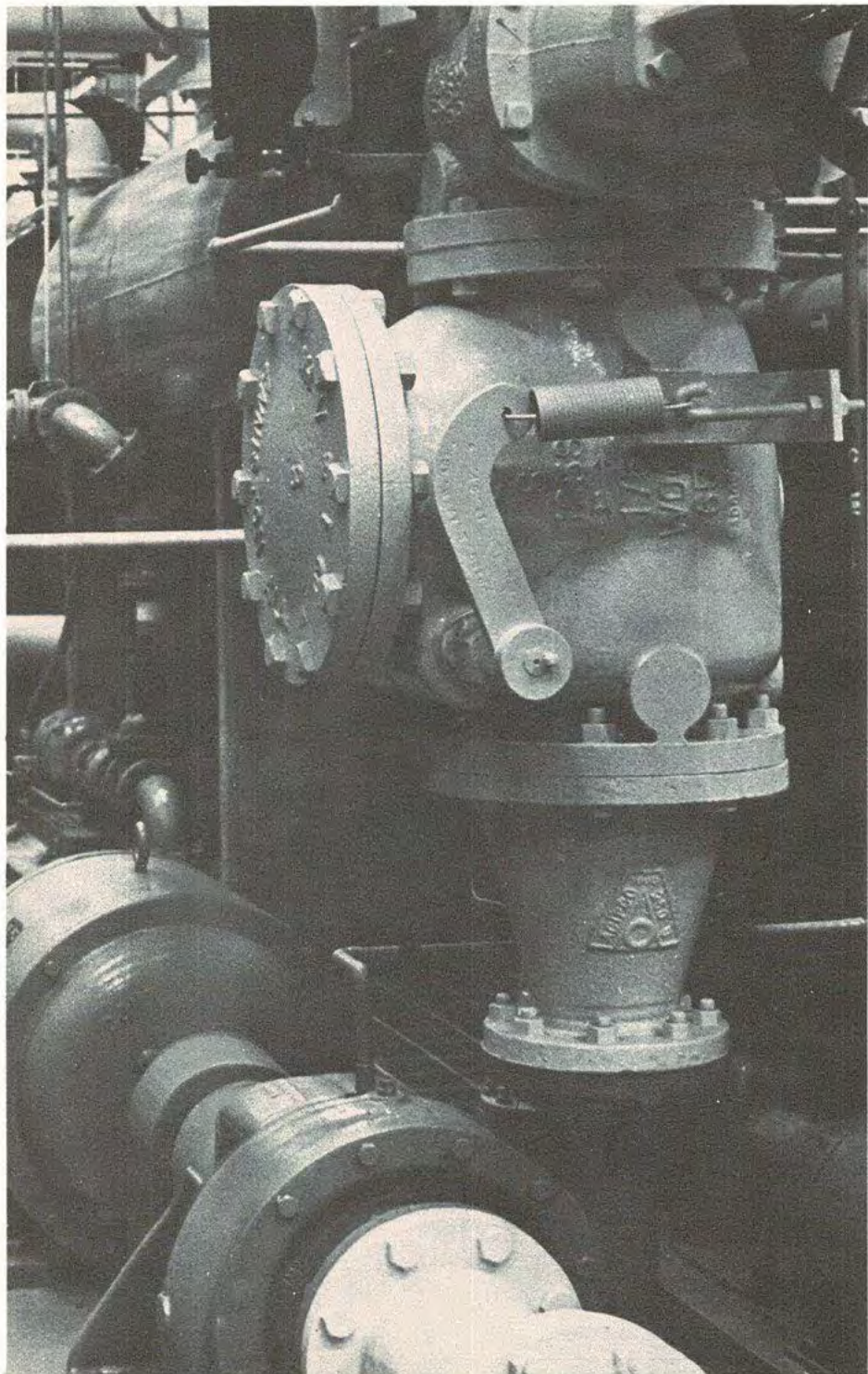
SIDE OUTLET TEES



SIDE OUTLET 90° ELBOWS



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SECTION VI

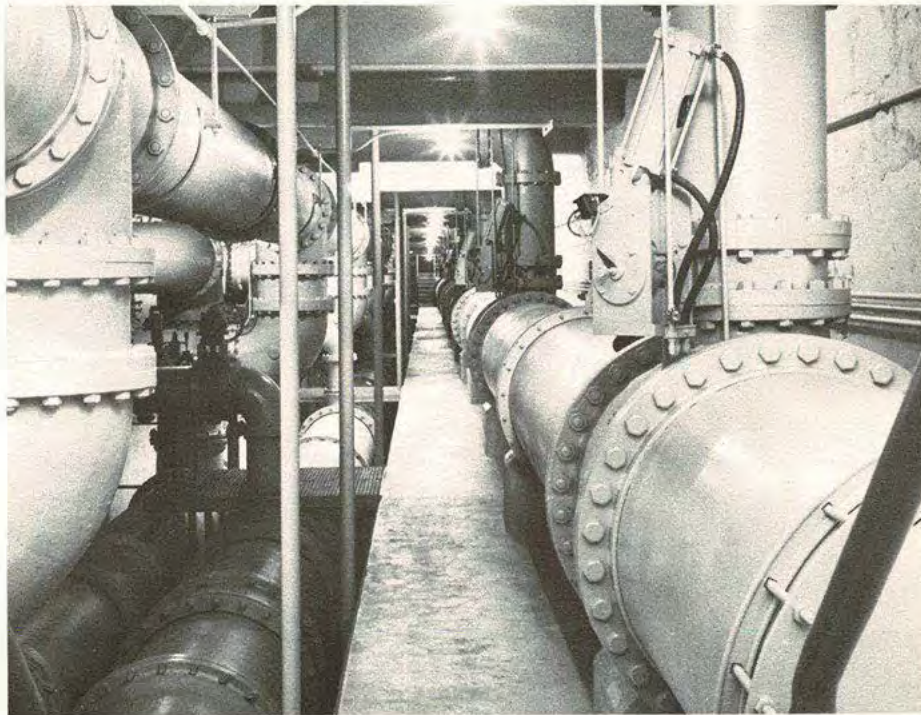
Joints for Gray & Ductile Iron Pipe

Introduction

Mechanical and push-on joints covered by ANSI Standard A21.11 (AWWA C111) comply with Federal Specification WW-P-421c.

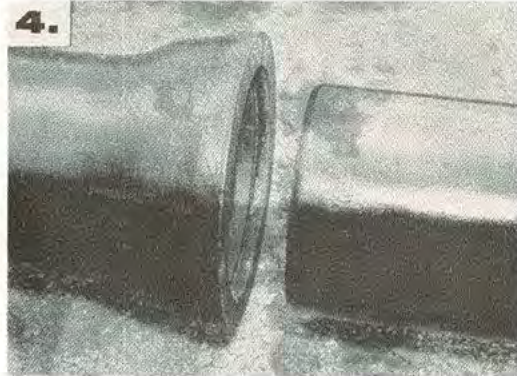
The American National Standard for Flanged Pipe with Threaded Flanges, ANSI A21.15, (AWWA C115) was adopted in 1975.

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 A21.11-1972
(AWWA C111-72)**

Revision of
ANSI A21.11-1964
(AWWA C111-64)

AMERICAN NATIONAL STANDARD
for
**RUBBER-GASKET JOINTS FOR CAST-IRON
AND DUCTILE-IRON
PRESSURE PIPE AND FITTINGS**

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PUBLISHED BY AMERICAN WATER WORKS ASSOCIATION, INC.

SPONSORS

AMERICAN GAS ASSOCIATION
AMERICAN SOCIETY FOR TESTING AND MATERIALS
AMERICAN WATER WORKS ASSOCIATION
NEW ENGLAND WATER WORKS ASSOCIATION

Revised Edition Approved by the American National Standards Institute, Inc., Mar. 2, 1972

NOTICE

This Standard has been especially printed by the American Water Works Association for incorporation into this volume. It is current as of December 1, 1975. 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.

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

Foreword

This foreword is provided for information only and is not a part of ANSI A21.11-1972 (AWWA C111-72).

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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. The present scope of Committee A21 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 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 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 pipe and fittings.

Subcommittee 2 reviewed the 1964 edition of A21.11 and submitted a proposed revision to American National Standards Committee in 1971.

Major Revisions

Scope. The name of the standard has been changed to "Rubber-Gasket Joints for Cast-Iron and Ductile-Iron

Pressure Pipe and Fittings." The standard now also includes 54-in.-diameter push-on joints.

Mechanical joint glands. Physical acceptance test standards for ductile-iron mechanical joint glands are now included in the standard. However, because of their excellent service record and because neither additional strength nor ductility is required for the service intended, cast-iron glands will be furnished with ductile-iron pipe and fittings unless ductile-iron glands are specified.

Gaskets. Requirements for maximum compression set and resistance to ozone cracking of gasket rubber for mechanical and push-on joints have been added to the standard. ASTM methods of testing for these requirements are also listed in the standard.

Performance requirements of the push-on joint. Because the push-on joints covered by this standard are not standardized, but are furnished in accordance with the manufacturer's standard design dimensions and tolerances, performance requirements are considered appropriate for inclusion in this standard. These performance requirements include the adoption of minimum working-pressure ratings for each joint size. The long and excellent service record of the mechanical joint with standardized dimensions has proved its performance ability; therefore, performance criteria are not necessary.

Mechanical joint dimensions. The manufacturer has been provided with an option to furnish ductile-iron pipe, 30 in. and larger in diameter, with bell

thicknesses compatible with the wall thickness of the pipe. The bolt length for 14-in. mechanical joints has been changed from $\frac{3}{4}$ in. by 4 in. to $\frac{3}{4}$ in. by $4\frac{1}{2}$ in. to assure full nut engagement.

Note: Push-on joints for cast-iron pipe are so designed 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.

Options

This standard includes certain options that, if desired, must be specified

in the invitation for bids and on the purchase order. These options are found in the following sections of the standard:

1. Inspection, subsection 11-4.2
2. Certification and Test Records, subsection 11-5.1
3. Special Requirements for the Mechanical Joint, subsections 11-6.1 and 11-6.3

Note: Subsection 11-6.3 provides for tapped holes in the bells of mechanical joints for stud bolts. This option is intended for use where headed bolts or slotted holes will not suffice, as, for example, where the bell is to be embedded in a concrete wall.

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Committee Personnel

Subcommittee 2, which developed this standard, had the following personnel at that time:

FRANK J. CAMEROTA, *Chairman* MILES R. SUCHOMEL, *Vice-Chairman*

Consumer or General Interest Members

STANLEY C. BAKER CHARLES E. SMITH
KENNETH J. CARL MAURICE C. STOUT
JOHN W. CARROLL

Producer Members

BRUCE I. DEDMAN RICHARD C. WETZEL
EDWARD C. SEARS CHARLES W. WRIGHT
ALBERT H. SMITH, JR.

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

WALTER AMORY, *Chairman*
CARL A. HENRIKSON, *Vice-Chairman*
JAMES B. RAMSEY, *Secretary*
CHARLES R. VELZY, *Treasurer*

Organization Represented

American Gas Association
American Society of Civil Engineers
American Society of Mechanical Engineers
American Society for Testing and Materials
American Water Works Association
Cast Iron Pipe Research Association

Individual Producers

Manufacturers' Standardization Society of the
Valve and Fittings Industry
Naval Facilities Engineering Command
New England Water Works Association
Underwriters' Laboratories, Inc.
Canadian Standards Association

Name of Representative

LEONARD ORLANDO, JR.
KENNETH W. HENDERSON
CHARLES R. VELZY
(Vacant)
VANCE C. LISCHER
CARL A. HENRIKSON
EDWARD C. SEARS
W. HARRY SMITH
FRANK J. CAMEROTA
WILLIAM T. MAHER

ABRAHAM FENSTER
STANLEY C. BAKER
WALTER AMORY
MILES R. SUCHOMEL
W. F. SEMENCHUK*

* Liaison representative without vote.

American National Standard for

RUBBER-GASKET JOINTS FOR CAST-IRON AND DUCTILE-IRON PRESSURE PIPE AND FITTINGS

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11-1—Scope

This standard covers rubber-gasket joints of the following types for cast-iron and ductile-iron pressure pipe and fittings.

11-1.1 *Mechanical joint.* The mechanical joint is designed for pipe and fittings in sizes 2-48 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 2-54 in. for conveying water or other liquids.

11-2—Definitions

11-2.1 *Joints and accessories.* For the purpose of this standard the word "joint" includes accessories.

11-2.2 *Mechanical joint.* The 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, 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.* The 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 so designed and shaped 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 in behalf of the purchaser to determine whether the requirements of this standard have been met.

11-3—General Requirements

11-3.1. Joints made in conformance with the provisions of this standard are intended for use on cast-iron and ductile-iron pipe and fittings manufactured in accordance with the following standards, where applicable:

ANSI A21.6-1970 (AWWA C106-70)—Cast-Iron Pipe Centrifugally

Cast in Metal Molds, for Water or Other Liquids

ANSI A21.7-1970—Cast-Iron Pipe Centrifugally Cast in Metal Molds, for Gas

ANSI A21.8-1970 (AWWA C108-70)—Cast-Iron Pipe Centrifugally Cast in Sand-Lined Molds, for Water or Other Liquids

ANSI A21.9-1970—Cast-Iron Pipe Centrifugally Cast in Sand-lined Molds, for Gas

Federal Specification WW-P-421c—Pipe, Cast Gray and Ductile Iron, Pressure (for Water and Other Liquids)

Federal Specification WW-P-360b—Pipe, Cast Iron, Pressure (for Gas, Water, or other Liquids)

ANSI A21.10-1971 (AWWA C110-71)—Gray-Iron and Ductile-Iron Fittings, 2-48 in., for Water and Other Liquids

ANSI A21.12-1971 (AWWA C112-71)—2-in. and 2½-in. Cast-Iron Pipe, Centrifugally Cast, for Water or Other Liquids

ANSI A21.14-1968—Gray-Iron and Ductile-Iron Fittings, 3-24 in., for Gas

ANSI A21.51-1971 (AWWA C151-71)—Ductile-Iron Pipe, Centrifugally Cast in Metal Molds or Sand-Lined Molds, for Water or Other Liquids

ANSI A21.52-1971—Ductile-Iron Pipe, Centrifugally Cast, in Metal Molds or Sand-Lined Molds for Gas

11-3.2. The joints shall have the same pressure rating as the pipe or fitting of which they are a part.

11-3.3. A recommended method of joint assembly shall be furnished by the manufacturer on request of the purchaser.

11-3.4. 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.

11-4—Inspection

11-4.1. Inspection shall be made in accordance with the provisions of the standard under which the pipe or fittings are purchased.

11-4.2. If the purchaser wishes to inspect the manufacture of glands, bolts, or gaskets that may be made by subcontractors, special arrangements therefor must be made at the time the order is placed.

11-5—Certification and Test Records

11-5.1. 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. A record of the specified tests of glands, bolts, and gaskets shall be retained for 1 yr and shall be available to the purchaser at the foundry.

11-6—Special Requirements for the Mechanical Joint

11-6.1. *Glands.* Unless otherwise specified, cast-iron glands shall be furnished with ductile-iron pipe and fittings. Glands shall have a bituminous coating unless otherwise specified and shall have cast or stamped upon them the manufacturer's identification, the nominal size, and the letters "DI" or word "ductile" if made of ductile iron.

11-6.1.1. *Cast-iron glands.* The acceptability of the cast iron used in the glands shall be determined by

RUBBER-GASKET JOINTS

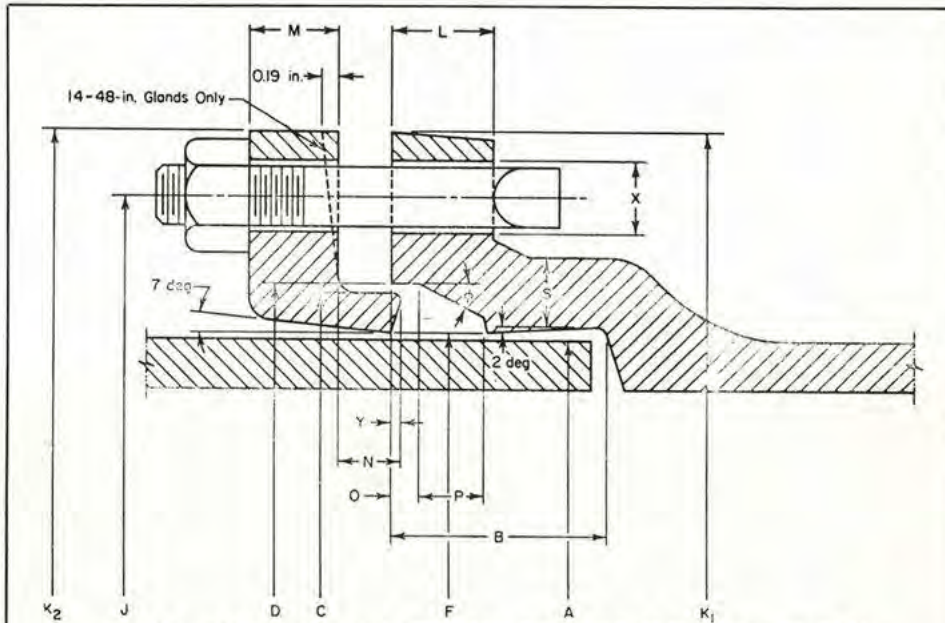


Fig. 11.1. Mechanical-Joint Dimensions for Sizes 2-48 in. (See Table 11.1)

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 bolt holes. For sizes 2 and $2\frac{1}{2}$ in., both flange and gland may be oval in shape. For sizes 3-48 in., the gland may be polygon in shape.

5. Gland thickness "M" for sizes 14-48 in. may be tapered as shown at the option of the manufacturer.

6. The "L" dimension shown in Table 11.1 for 2-in. and $2\frac{1}{2}$ -in. sizes applies to mechanical-joint pipe. The "L" dimension for 2-in. and $2\frac{1}{2}$ -in. fittings is 0.75 in. (-0.05 in.).

7. At the manufacturer's option, ductile-iron pipe in sizes 30-in. and larger may be furnished with the bell-flange thicknesses shown in Table 11.1 (dimension L), or with reduced bell-flange thicknesses that are compatible with the wall thickness 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	J	K ₁		K ₂	L*	M	N	O	P	S		Bolts	
									Centrifugal Pipe Fittings	Pit Cast Pipe and Fittings							Centrifugal Pipe Fittings	Pit Cast Pipe and Fittings	Y	No.	Size	Length
2 ±0.05	2.50	±0.05	3.39	±0.05	3.50	28°	+0.06-0.0	±0.05 4.75	-0.05 6.25	-0.10 6.25	-0.05 0.56	-0.05 0.62	0.50 0.31	0.63	0.37	-0.07 0.44	0.08	2	½	2½
2½ ±0.05	2.75	±0.05	3.64	±0.05	3.75	28°	+0.06-0.0	±0.05 5.00	-0.05 6.50	-0.10 6.50	-0.05 0.56	-0.05 0.62	0.50 0.31	0.63	0.37	-0.07 0.44	0.08	2	½	2½
3 ±0.06	3.96	±0.04	4.84	+0.06-0.04	4.94	28°	+0.06-0.0	±0.06 6.19	-0.12 7.69	-0.12 7.69	-0.06 0.94	-0.06 0.62	0.75 0.31	0.63	0.47	-0.10 0.52	0.12	4	¾	3
4 ±0.06	4.80	±0.04	5.92	+0.06-0.04	6.02	28°	+0.06-0.0	±0.06 7.50	-0.12 9.06	-0.12 9.12	-0.06 1.00	-0.06 0.75	0.75 0.31	0.75	0.55	-0.10 0.65	0.12	4	¾	3½
5 ±0.06	6.90	±0.04	8.02	+0.06-0.04	8.12	28°	+0.06-0.0	±0.06 9.50	-0.12 11.06	-0.12 11.12	-0.06 1.06	-0.06 0.88	0.75 0.31	0.75	0.60	-0.10 0.70	0.12	6	¾	3½
8 ±0.06	9.05	±0.04	10.17	+0.06-0.04	10.27	28°	+0.06-0.0	±0.06 11.75	-0.12 13.31	-0.12 13.37	-0.08 1.12	-0.08 1.00	0.75 0.31	0.75	0.66	-0.12 0.75	0.12	6	¾	4
10 ±0.06	11.10	±0.06-0.04	12.22	+0.06-0.04	12.34	28°	+0.06-0.0	±0.06 14.00	-0.12 15.62	-0.12 15.62	-0.08 1.19	-0.08 1.00	0.75 0.31	0.75	0.72	-0.12 0.80	0.12	8	¾	4
12 ±0.06	13.20	±0.06-0.04	14.32	+0.06-0.04	14.44	28°	+0.06-0.0	±0.06 16.25	-0.12 17.88	-0.12 17.94	-0.08 1.25	-0.08 1.00	0.75 0.31	0.75	0.79	-0.12 0.85	0.12	8	¾	4
14 ±0.05-0.08	15.30	±0.07-0.05	16.40	+0.07-0.05	16.54	28°	+0.06-0.0	±0.06 18.75	-0.12 20.25	-0.12 20.31	-0.12 20.25	-0.12 1.31	-0.12 1.25	0.75 0.31	0.75	0.85	-0.12 0.89	10	¾	4½
16 ±0.05-0.08	17.40	±0.07-0.05	18.50	+0.07-0.05	18.64	28°	+0.06-0.0	±0.06 21.00	-0.12 22.50	-0.12 22.50	-0.12 22.50	-0.12 1.38	-0.12 1.31	0.75 0.31	0.75	0.91	-0.12 0.97	12	¾	4½
18 ±0.05-0.08	19.50	±0.07-0.05	20.60	+0.07-0.05	20.74	28°	+0.06-0.0	±0.06 23.25	-0.12 24.75	-0.12 24.83	-0.12 24.75	-0.12 1.44	-0.12 1.38	0.75 0.31	0.75	0.97	-0.15 1.05	12	¾	4½
20 ±0.05-0.08	21.60	±0.07-0.05	22.70	+0.07-0.05	22.84	28°	+0.06-0.0	±0.06 25.50	-0.12 27.00	-0.12 27.08	-0.12 27.00	-0.12 1.50	-0.12 1.44	0.75 0.31	0.75	1.03	-0.15 1.12	14	¾	4½
24 ±0.05-0.08	25.80	±0.07-0.05	26.90	+0.07-0.05	27.04	28°	+0.06-0.0	±0.06 30.00	-0.12 31.50	-0.12 31.58	-0.12 31.50	-0.12 1.62	-0.12 1.56	0.75 0.31	0.75	1.08	-0.15 1.22	16	¾	5
30 ±0.08-0.06	32.00	±0.08-0.06	33.20	+0.08-0.06	33.46	20°	+0.06-0.0	±0.06 36.88	-0.12 38.12	-0.12 38.12	-0.12 39.12	-0.12 1.81	-0.12 2.00	0.75 0.38	1.00	1.20	-0.15 1.50	20	1	6
36 ±0.08-0.06	38.30	±0.08-0.06	39.50	+0.08-0.06	39.76	20°	+0.06-0.0	±0.06 43.75	-0.12 46.00	-0.12 46.00	-0.12 46.00	-0.12 2.00	-0.12 2.00	0.75 0.38	1.00	1.35	-0.15 1.80	24	1	6
42 ±0.08-0.06	44.50	±0.08-0.06	45.70	+0.08-0.06	45.96	20°	+0.06-0.0	±0.06 53.12	-0.12 55.12	-0.12 55.12	-0.12 55.12	-0.12 2.00	-0.12 2.00	0.75 0.38	1.00	1.48	-0.15 1.95	28	1½	6
48 ±0.08-0.06	50.80	±0.08-0.06	52.00	+0.08-0.06	52.26	20°	+0.06-0.0	±0.06 57.50	-0.12 60.00	-0.12 60.00	-0.12 60.00	-0.12 2.00	-0.12 2.00	0.75 0.38	1.00	1.61	-0.15 2.20	32	1½	6

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 A48-64 for tensile strength or A438-68 for transverse breaking load. At the option of the manufacturer, either the tensile test or the transverse test may be used as the acceptance test. The required properties are given in the following table:

Class of Iron	Bar Diam. in.	Span in.	Min. Breaking Load—lb (1,000's)	Min. Tensile psi (1,000's)
25	1.2	18	2	25
25	2	24	6.8	25

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 A536-67. The ductile iron from which the glands are cast shall have a minimum elongation of 3 per cent.

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 gauged at sufficiently frequent intervals to assure 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" (or "SM"), and the year of manufacture shall be molded in the rubber as shown in Fig. 11.2.

Rubber gaskets shall be vulcanized natural or vulcanized synthetic rubber, free of porous areas, foreign materials, and visible defects. No reclaimed rubber shall be used.

Quality-control procedures shall be utilized to assure that gaskets meet the requirements of this standard. The manufacturer shall retain monthly reports of representative quality-control tests results for gaskets manufactured that month.

The required properties of the gasket rubber and the required methods of test are given in the following table:

Property	ASTM Test Method	Required Value
Hardness		
Durometer "A"	D2240-68	75 ± 5
Min. ultimate tensile—psi	D412-68	1,500
Min. ultimate elongation—per cent*	D412-68	150
Min. aging—per cent†	D572-67‡	60
Max. compression set—per cent	D395-67 method B	20
Resistance to ozone cracking	D-1149-64§	No cracking

* Of original length.

† Of original values for tensile and ultimate elongation.

‡ Oxygen pressure method, after 96 hr at 70C ± 1 deg at 300 psi ± 10.

§ After a minimum of 25 hr exposure in 50-pphm ozone concentration at 104F on a loop-mounted gasket with approximately 20 per cent 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. At the manufacturer's option, they shall be made of either

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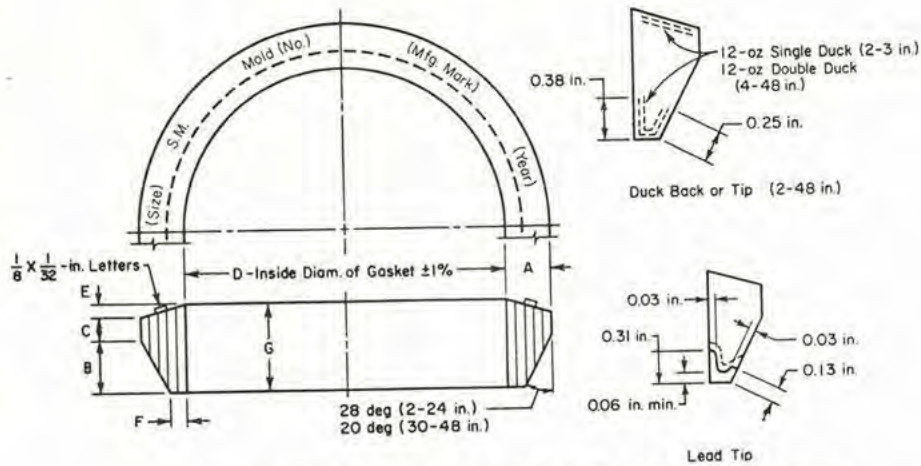


Fig. 11.2. Mechanical-Joint Gasket, 2-48 in. (See Table 11.2 and Notes)

Notes

1. Tipped or backed 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 and backs shall be frictioned before molding.

TABLE 11.2
2-48-in. Mechanical-Joint Gasket Dimensions—in.

Pipe Size	Pipe OD	Dimensions of Plain Rubber Gaskets						
		A ±0.01 in.	B	C	D +1 per cent -1 per cent	E	F ±0.01 in.	G ±0.02 in.
2	2.50	0.48	0.62	0.31	2.48	0.12	0.15	1.05
2½	2.75	0.48	0.62	0.31	2.72	0.12	0.15	1.05
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

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high-strength cast iron containing a minimum of 0.50 per cent copper, or high-strength, low-alloy steel. The steel shall have the following characteristics:

Characteristic	Value
Min. yield strength—psi	45,000
Min. elongation in 2 in.—per cent	20
Max. content—per cent	
Carbon	0.20
Manganese	1.25
Sulfur	0.05
Min. content—per cent	
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 B1.1-1960—Unified Screw Threads, and to B1.2-1966—Screw Thread Gages and Gaging. Thread form shall conform to the standards and to the dimensions of the coarse-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 deg to insure 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 insure 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 in./in. 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 stress at the root of the thread:

Bolt Diameter in.	Load lb
$\frac{5}{8}$	9,000
$\frac{3}{4}$	13,500
1	24,500
$1\frac{1}{4}$	40,000

11-6.5.3. *Workmanship.* Bolt shanks shall be straight within $\frac{1}{16}$ in./6 in. of length. 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.

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.

11-7—Special Requirements for the 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 di-

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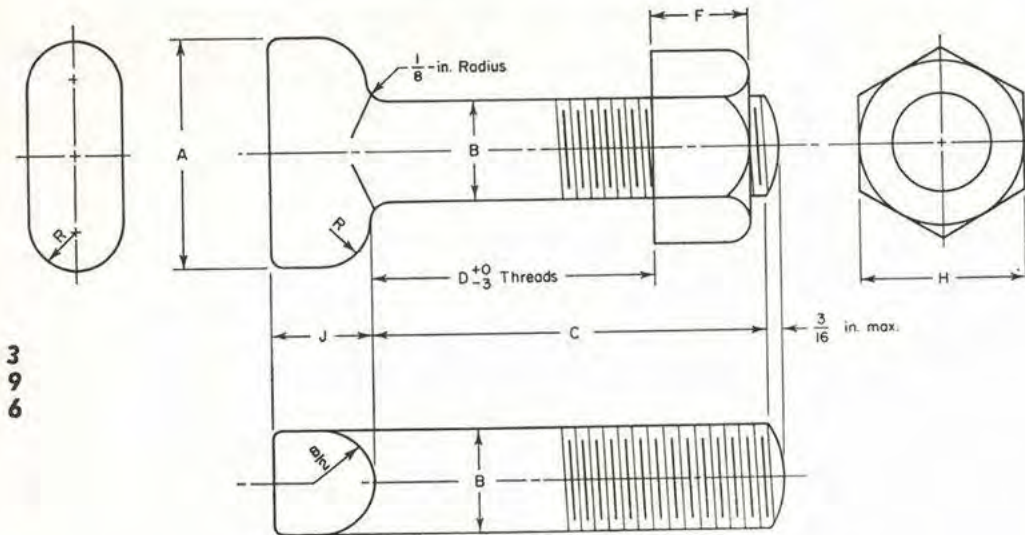


Fig. 11.3. Mechanical-Joint Bolts and Nuts

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 $\frac{3}{16}$ in. above the top of the bolt head.

TABLE 11.3

Mechanical-Joint Bolt and Nut Dimensions—in.

Nom. Size	A ± 0.05	B ± 0.03	C $+0.25$ -0.06	D	E^*	F	H	J $+0.15$ -0.03	R Max.
$\frac{3}{8} \times 2\frac{1}{2}$	1.50	0.625	2.5	1.25	11	0.625 ± 0.04	$1.062 + 0.00$ -0.04	0.625	0.312
$\frac{3}{8} \times 3$	1.50	0.625	3.0	1.75	11	0.625 ± 0.04	$1.062 + 0.00$ -0.04	0.625	0.312
$\frac{3}{4} \times 3\frac{1}{2}$	1.75	0.750	3.5	1.75	10	0.750 ± 0.06	$1.250 + 0.00$ -0.06	0.750	0.375
$\frac{3}{4} \times 4$	1.75	0.750	4.0	2.25	10	0.750 ± 0.06	$1.250 + 0.00$ -0.06	0.750	0.375
$\frac{3}{4} \times 4\frac{1}{2}$	1.75	0.750	4.5	2.75	10	0.750 ± 0.06	$1.250 + 0.00$ -0.06	0.750	0.375
$\frac{3}{4} \times 5$	1.75	0.750	5.0	3.25	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
$1\frac{1}{2} \times 6$	2.50	1.250	6.0	3.75	7	1.250 ± 0.08	$2.000 + 0.00$ -0.08	1.250	0.625

* 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)].

mensions shall be gaged at sufficiently frequent intervals to assure 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 as to provide an adequate compressive force against the spigot and socket after assembly to effect a positive seal under all combinations of joint and gasket tolerances. The trade name or trademark, size, mold number, gasket manufacturer's mark, and year of manufacture shall be molded on the gaskets. Markings shall not be located on the sealing surfaces.

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.

The required properties of the gasket rubber and the required method of test are given in the following table:

Property	ASTM Test Method	Main Body of Gasket	Harder Portion (if Used)
Nominal hardness Durometer "A"	D2240-68	50-65	80-85
Tolerance on nominal hardness		±5	±5
Min. ultimate tensile— <i>psi</i>	D412-68	2,000	1,200
Min. ultimate elongation— <i>per cent</i> *	D412-68	300	125
Min. aging— <i>per cent</i> †	D572-67‡	60	—
Max. compression set— <i>per cent</i>	D395-67 method B	20	—
Resistance to ozone cracking	D-1149-64§	No cracking	—

* Of original length.

† Of original values of tensile and ultimate elongation.

‡ Oxygen pressure method: after 96 hr at 70 C ± 1° at 300 psi ± 10.

§ After a minimum of 25 hr exposure in 50-pphm ozone concentration at 104 F on a loop-mounted gasket with approximately 20 per cent elongation at outer surface.

Quality-control procedures shall be utilized to assure that the gaskets will meet the requirements of this stand-

ard. The manufacturer shall retain monthly reports of representative quality-control test results for gaskets manufactured in 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 C601-68—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.

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 have records to show the results of these tests.

11-8.1. *Working-pressure ratings.* The working-pressure rating of the push-on joint is established by sub-

jecting 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 in the table at the end of 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:

Joint Size— <i>in.</i>	Minimum Working- Pressure Rating— <i>psi</i>
16 and smaller	350
18	300
20-24	250
30-54	200

11-8.2. *Assembly.* Assembly of representative sizes shall be possible with the joints having minimum clearances 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.

Appendix A

Notes on Installation of Mechanical Joints

These notes are not part of the standard, but are given for information.

The successful operation of the mechanical joint specified requires that the spigot be centrally located in the bell and that adequate anchorage shall be provided where abrupt changes in direction and dead ends occur.

The rubber gasket seals most 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 to remove all loose rust or foreign material. Lubrication and additional cleaning are provided by brushing both the gasket and the spigot (as with soapy water for example) just prior to slipping the

gasket onto the spigot 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.

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 done by partially tightening the bottom bolt first, then the top bolt, next the bolts at either side, and finally the remaining bolts. This cycle should be repeated until all bolts are within the range of torques shown in the table. If effective sealing is not attained at the maximum torque indicated, the joint should be disassembled, thoroughly cleaned, and reassembled. Overstressing of bolts to compensate for poor installation practice is to be avoided.

Pipe Size— <i>in.</i>	Bolt Size— <i>in.</i>	Range of Torque— <i>ft-lb</i>	Length of Wrench— <i>in.*</i>
2-3	$\frac{5}{8}$	45-60	8
4-24	$\frac{3}{4}$	75-90	10
30-36	1	85-100	12
42-48	$1\frac{1}{4}$	105-120	14

* 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.

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ANSI A21.15-1975
(AWWA C115-75)

First Edition

AMERICAN NATIONAL STANDARD

for

**FLANGED CAST-IRON AND DUCTILE-IRON
PIPE WITH THREADED FLANGES**

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ADMINISTRATIVE SECRETARIAT
AMERICAN WATER WORKS ASSOCIATION

CO-SECRETARIATS
AMERICAN GAS ASSOCIATION
NEW ENGLAND WATER WORKS ASSOCIATION

Approved by American National Standards Institute, Inc. May 28, 1975.

NOTICE

This Standard has been especially printed by the American Water Works Association for incorporation into this volume. It is current as of December 1, 1975. 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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Committee Personnel

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

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WALTER AMORY, *Vice-Chairman*

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American Society of Civil Engineers
American Society of Mechanical Engineers
American Society for Testing and Materials
American Water Works Association

Cast Iron Pipe Research Association

Individual Producer

Manufacturers' Standardization Society of
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Foreword

This foreword is provided for information only and is not a part of ANSI A21.15 (AWWA C115).

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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-A21.10 (AWWA C110). 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 has

been indicated. Consequently, Subcommittee 1 submitted a proposed standard for flanged pipe to Committee A21 in 1974.

II—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 these details and available options and lists the sections of the standard where they can be found:

1. Size, whether cast-iron or ductile-iron, thickness or class, and finished length
2. Certification by manufacturer—Sec. 15-3.2
3. Inspection by purchaser—Sec. 15-4.1
4. Flanges for ductile-iron pipe—Sec. 15-7.3
5. Bolt-hole alignment—Sec. 15-8.4
6. Cement lining—Sec. 15-9.2. Experience has indicated that bituminous inside coating is not complete protection against loss in pipe capacity because of tuberculation. Cement linings are recommended for most waters.
7. Special coatings and linings—Sec. 15-9.5.

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American National Standard for
**Flanged Cast-Iron and Ductile-Iron
Pipe With Threaded Flanges**

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Sec. 15-1—Scope

This standard pertains to 3-48 in. gray-iron and 3-54 in. ductile-iron flanged pipe with threaded flanges for water or other liquids. The flanged pipe are rated for a maximum working pressure of either 150 or 250 psi as specified in the tables. All flanges are rated for a maximum working pressure of 250 psi.

Sec. 15-2—Definitions

Under this standard the following definitions shall apply:

15-2.1. *Purchaser.* The party entering into a contract or agreement to purchase flanged pipe according to this standard.

15-2.2. *Manufacturer.* The party that produces the flanged pipe.

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 meet this standard.

15-2.4. *Gray iron.* Gray iron is a cast ferrous material in which a major part of the carbon content occurs as graphite in the form of flakes interspersed throughout the metal.

15-2.5. *Ductile iron.* Ductile iron is a cast ferrous material in which the graphite present is in a spheroidal form rather than in flake form.

**Sec. 15-3—Inspection and
Certification by Manufacturer**

15-3.1. The manufacturer shall establish the necessary quality control and inspection practice to ensure compliance with this standard.

15-3.2. The manufacturer shall, if required on the purchase order, furnish a sworn statement that the flanged pipe comply with the requirements of this standard.

15-3.3. All flanged pipe shall be clean and sound without defects that will 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. 15-4—Inspection by Purchaser

15-4.1. 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.

15-4.2. 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 gages as are necessary for inspection. The manufacturer shall provide the inspector with assistance as necessary for the handling of flanged pipe.

Sec. 15-5—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. 15-6—Pipe Barrel

15-6.1. Gray-iron pipe barrels shall conform to the requirements of ANSI A21.6 (AWWA C106) or ANSI A21.8 (AWWA C108) of latest revision, and ductile-iron pipe barrels shall conform to the requirements of ANSI A21.51 (AWWA C151) of latest revision.

15-6.2. The nominal thicknesses of gray-iron and ductile-iron flanged pipe shall not be less than those shown in Tables 15.1 and 15.2.

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TABLE 15.1
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	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
30	23	150	0.85	32.00	240	259.5
30	25	250	0.99	32.00	240	300.9
36	23	150	0.94	38.30	350	344.2
36	25	250	1.10	38.30	350	401.1
42	23	150	1.05	44.50	500	447.2
42	25	250	1.22	44.50	500	517.6
48	23	150	1.14	50.80	625	554.9
48	25	250	1.33	50.80	625	644.9

* ANSI-A21.6 (AWWA C106) and A21.8 (AWWA C108).

NOTE: The nominal thicknesses of gray-iron flanged pipe shall not be less than those shown in this table

THREADED FLANGED PIPE

15-6.3. The minus thickness tolerances of pipe shall not exceed the following:

Pipe Size in.	Gray-Iron Pipe (A21.6, A21.8) in.	Ductile-Iron Pipe (A21.51) in.
3-8	0.05	0.05
10-12	0.06	0.06
14-24	0.08	0.07
30-42	0.10	0.07
48	0.10	0.08
54	—	0.09

15-6.4. Threads on the pipe barrel shall be taper pipe threads (NPT) in accordance with ANSI B2.1 adapted to the gray-iron and ductile-iron pipe outside diameters shown in Tables 15.1 and 15.2.

Sec. 15-7—Flanges

15-7.1. Flanges shall conform to the dimensions shown in Table 15.3.

15-7.2. All flanges shall have a taper pipe thread (NPT) in accordance with ANSI B2.1 adapted to the

gray-iron and ductile-iron pipe outside diameters shown in Tables 15.1 and 15.2.

15-7.3. 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. Flanges shall conform to the respective chemical and physical properties specified for gray-iron and ductile-iron fittings in ANSI A21.10 (AWWA C110).

Sec. 15-8—Fabrication

15-8.1. *Bolt holes.* Bolt holes shall be in accordance with the dimensions shown in Table 15.3. The bolt holes shall be equally spaced.

15-8.2. *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

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TABLE 15.2

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	Pipe Barrel per ft
3	3	250	0.31	3.96	7	10.9
4	3	250	0.32	4.80	13	13.8
6	3	250	0.34	6.90	17	21.4
8	3	250	0.36	9.05	27	30.1
10	3	250	0.38	11.10	38	39.2
12	3	250	0.40	13.20	58	49.2
14	3	250	0.42	15.30	72	60.1
16	3	250	0.43	17.40	90	70.1
18	3	250	0.44	19.50	90	80.6
20	3	250	0.45	21.60	115	91.5
24	3	250	0.47	25.80	160	114.4
30	3	250	0.51	32.00	240	154.4
36	3	250	0.58	38.30	350	210.3
42	3	250	0.65	44.50	500	274.0
48	3	250	0.72	50.80	625	346.6
54	3	250	0.81	57.10	760	438.3

* ANSI A21.51 (AWWA C151).

NOTE: The nominal thicknesses of ductile-iron flanged pipe shall not be less than those shown in this table.

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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.

15-8.3. *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 deg.

15-8.4. *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. The machined flange faces shall be perpendicular to the pipe axis.

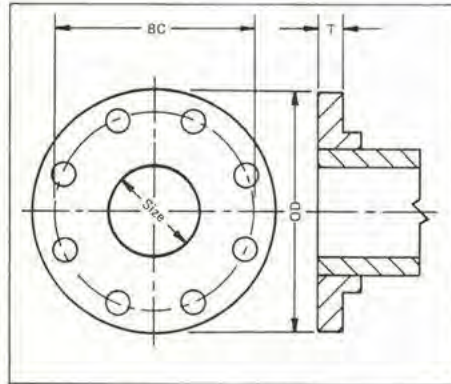


Fig. 15.1 Flange Details
See Table 15.3

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	$\frac{3}{4}$	$\frac{5}{8} \times 2\frac{1}{2}$	4
4	9.00	7.50	0.94 ± 0.12	$\frac{3}{4}$	$\frac{5}{8} \times 3$	8
6	11.00	9.50	1.00 ± 0.12	$\frac{7}{8}$	$\frac{3}{4} \times 3\frac{1}{2}$	8
8	13.50	11.75	1.12 ± 0.12	$\frac{7}{8}$	$\frac{3}{4} \times 3\frac{1}{2}$	8
10	16.00	14.25	1.19 ± 0.12	1	$\frac{7}{8} \times 4$	12
12	19.00	17.00	1.25 ± 0.12	1	$\frac{7}{8} \times 4$	12
14	21.00	18.75	1.38 ± 0.19	$1\frac{1}{8}$	1 × 4 $\frac{1}{2}$	12
16	23.50	21.25	1.44 ± 0.19	$1\frac{1}{8}$	1 × 4 $\frac{1}{2}$	16
18	25.00	22.75	1.56 ± 0.19	$1\frac{1}{4}$	$1\frac{1}{8} \times 5$	16
20	27.50	25.00	1.69 ± 0.19	$1\frac{1}{4}$	$1\frac{1}{8} \times 5$	20
24	32.00	29.50	1.88 ± 0.19	$1\frac{3}{8}$	$1\frac{1}{4} \times 5\frac{1}{2}$	20
30	38.75	36.00	2.12 ± 0.25	$1\frac{3}{8}$	$1\frac{1}{2} \times 6\frac{1}{2}$	28
36	46.00	42.75	2.38 ± 0.25	$1\frac{5}{8}$	$1\frac{1}{2} \times 7$	32
42	53.00	49.50	2.62 ± 0.25	$1\frac{5}{8}$	$1\frac{1}{2} \times 7\frac{1}{2}$	36
48	59.50	56.00	2.75 ± 0.25	$1\frac{5}{8}$	$1\frac{1}{2} \times 8$	44
54	66.25	62.75	3.00 ± 0.25	2	$1\frac{3}{4} \times 8\frac{1}{2}$	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.

ular to the pipe center line and shall be parallel such that any two face-to-face dimensions 180 deg apart at the flange OD shall not differ by more than 0.06 in.

15-8.5. *Finished pipe length.* Flanged pipe shall be furnished to the lengths specified on the order. When pipe is furnished with two flanges, the face-to-face dimensions shall conform to a tolerance of ± 0.12 in. The overall length of flange and plain-end pipe shall conform to a tolerance of ± 0.25 in.

15-8.6. *Finished pipe weight.* The weight of any single pipe shall not be less than the calculated weight by more than 10 per cent.

Sec. 15-9—Coatings and Linings

15-9.1. *Outside coating.* Unless otherwise specified, the outside coating shall be a bituminous coating approximately 1 mil 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.

15-9.2. *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

A21.4 (AWWA C104) of latest revision.

15-9.3. *Inside coating.* Unless otherwise specified, the inside coating for pipe that is not cement-lined shall be a bituminous material as thick as practicable (at least 1 mil) and conforming to all appropriate requirements for seal coat in ANSI A21.4 (AWWA C104) of latest revision.

15-9.4. *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. 15-9.1.).

15-9.5. *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. 15-10—Marking

The length and the weight shall be shown on each pipe. The manufacturer's mark and the letters *DI*, if ductile iron, shall be cast or stamped on the flanges.

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Appendix

This appendix is provided for information only and is not a part of ANSI A21.15 (AWWA C115).

A1—Bolts, Gaskets, and Installation

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 and nuts conform to ANSI B18.2.2. Bolts smaller than $\frac{3}{4}$ in. have either standard square or heavy hex heads

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and heavy hex nuts. Bolts $\frac{3}{4}$ in. and larger have either square or hex heads and either hex or heavy hex nuts. Bolts and nuts are threaded in accordance with American National Standard B1.1 for Screw Threads—Coarse Thread Series, Class 2A, external, and Class 2B, internal. Bolts and nuts of low-carbon steel conforming to the chemical and mechanical requirements of ASTM A307, 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 cast-iron flange is used with a flat ring gasket.

Gaskets. Gaskets are rubber, either ring or full face, and are $\frac{1}{8}$ in. thick, unless otherwise specified by the owner or consulting engineer, conforming to the dimensions shown in Table A1 of this appendix.

Installation. The design, assembly, and installation of the flanged piping system are the responsibility of the purchaser. The following suggestions are for general guidance:

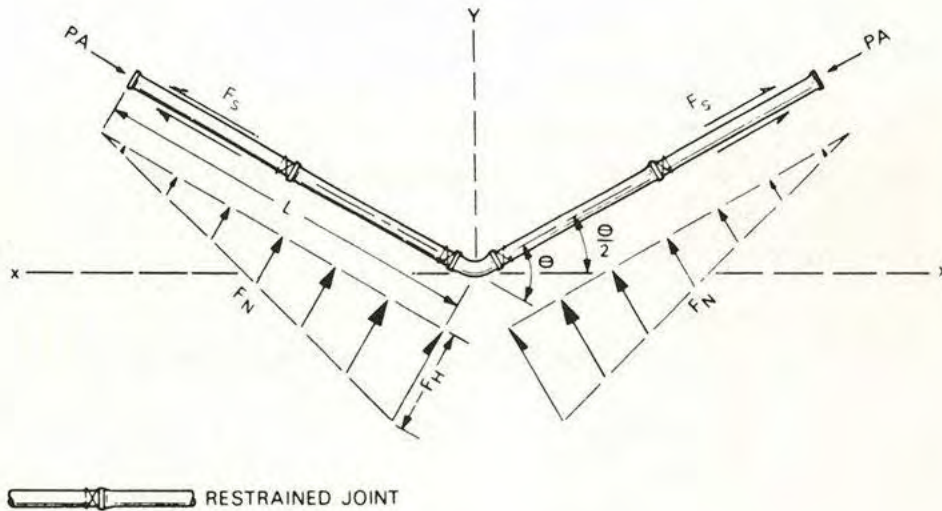
- (a) The underground use of the flanged joint is generally not desirable because of the rigidity of the joint.
- (b) Flanged joints should be fitted so that the contact faces bear uniformly on the gasket and then are made up with relatively uniform bolt stress.

TABLE A1
Flange Gasket Details

Nominal Pipe Size in.	Dimensions—in.						
	Ring		Full Face				
	Nominal ID	OD	Nominal ID	OD	BC	Bolt Hole Diameter	Number of Holes
3	3	5 $\frac{3}{8}$	3	7 $\frac{1}{2}$	6	$\frac{3}{4}$	4
4	4	6 $\frac{7}{8}$	4	9	7 $\frac{1}{2}$	$\frac{3}{4}$	8
6	6	8 $\frac{3}{4}$	6	11	9 $\frac{1}{2}$	$\frac{7}{8}$	8
8	8	11	8	13 $\frac{1}{2}$	11 $\frac{3}{4}$	$\frac{7}{8}$	8
10	10	13 $\frac{3}{8}$	10	16	14 $\frac{1}{2}$	1	12
12	12	16 $\frac{1}{2}$	12	19	17	1	12
14	14	17 $\frac{3}{4}$	14	21	18 $\frac{3}{4}$	1 $\frac{1}{8}$	12
16	16	20 $\frac{1}{2}$	16	23 $\frac{1}{2}$	21 $\frac{1}{4}$	1 $\frac{1}{8}$	16
18	18	21 $\frac{3}{8}$	18	25	22 $\frac{3}{4}$	1 $\frac{1}{4}$	16
20	20	23 $\frac{5}{8}$	20	27 $\frac{1}{2}$	25	1 $\frac{1}{2}$	20
24	24	28 $\frac{1}{2}$	24	32	29 $\frac{1}{2}$	1 $\frac{3}{8}$	20
30	30	34 $\frac{3}{4}$	30	38 $\frac{3}{4}$	36	1 $\frac{3}{8}$	28
36	36	41 $\frac{1}{4}$	36	46	42 $\frac{3}{4}$	1 $\frac{5}{8}$	32
42	42	48	42	53	49 $\frac{1}{2}$	1 $\frac{3}{4}$	36
48	48	54 $\frac{1}{2}$	48	59 $\frac{1}{2}$	56	1 $\frac{5}{8}$	44
54	54	61	54	66 $\frac{1}{2}$	62 $\frac{3}{4}$	2	44

END OF STANDARD

Thrust restraint: A new design concept.



The why of thrust restraint.

It's a fundamental design principle of fluid mechanics that dynamic and static pressures, acting at change in size or direction of a pipe, produce unbalanced thrust forces at bends, tees, wyes, dead-ends, reducers, offsets, etc. Existing design procedures for restraint of such forces do not result in the desired accuracy.

A new design concept from CIPRA.

Cast Iron Pipe Research Association (CIPRA) has developed a new procedure for restrained joint systems for gray and ductile iron pipe. This procedure includes consideration of lateral soil pressure and pipe soil friction, variables which can be reliably determined using present-day soils engineering knowledge.

Reducing the problem to a formula.

Space does not permit showing the complete derivation of the following formula (derivation is given in the technical paper mentioned in the last paragraph). The theory behind the formula, however, is as follows: In the force diagram shown here for a typical installation, lateral soil resistance (F_N) is a function of the length to be restrained (L) and the horizontal force (F_H) due to the passive soil pressure (P_p). Solving for (L) results in this formula:

$$(1) L = \frac{S_f \text{ KPA}}{KF_s + DP_p}$$

where

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$$(2) K = 4 \tan \Theta/2 \text{ (Calculation Coefficient)}$$

S_f = safety factor P = design pressure (psi)

Θ = pipe bend (degrees) D = O.D. of pipe (ft)

$$(3) F_s = A_p C + W \tan \delta \text{ frictional resistance (lb/lf)}$$

$$(4) P_p = w H_c N_\phi + 2 C_s \sqrt{N_o}$$

$$(5) N_\phi = \tan^2 \left(45 + \frac{\phi}{2} \right) \text{ ratio}$$

$$(6) W = R w \pi H D$$

$$A = \frac{\pi d^2}{4} \quad d = \text{O.D. pipe (in)} \quad \Theta = \text{pipe bend (degrees)}$$

A_p = area of pipe surface ft^2/lf

$$(7) C = f_c C_s \text{ (psf)}$$

$$(8) \delta = f_\phi \phi \text{ (degrees)}$$

w = soil wt. (lb) H_c = soil depth pipe (ft)

C_s = soil cohesion (lb/ft²) ϕ = internal soil friction angle (degrees)

H = depth of cover (ft) R = reduction factor

f_c = ratio (pipe cohesion/soil cohesion)

f_ϕ = ratio (pipe friction angle/soil friction angle)

Now, with the following two tables, we can proceed with a design example that shows the efficacy of this new formula.

Table I

Existing Condition	Reduction Factor, R
1. General construction-Backfill soils compacted to critical void ratio	2/3
2. Well-compacted backfill and select backfill	3/4
3. Shallow cover-depth of cover less than 1/2 of the outside diameter	1/2

Table II Soil Friction and Cohesion Factors

Soil Description	Friction Angle ϕ (Degrees)	Cohesion C_s (psf)	f_ϕ	f_c
Well graded sand (dry)	44.5	0	0.76	0
(sat.)	39	0	0.80	0
Silt (passing 200 sieve) (dry)	40	0	0.95	0
(sat.)	32	0	0.75	0
Cohesive granular soil (wet to moist)	13-22	385- 920	0.65	0.35
Clay (wet to moist) (at max. comp.)	11.5-16.5	460-1,175	0.50	0.50
			0.50	0.80

4
1
5

Design example.

Calculate:

Restrained length (L) for a 12-inch ductile iron pipeline using restrained joints for horizontal bend of 45°.

Project Data

$D = 13.2 \text{ inch} = 1.10 \text{ feet}$

$A = \frac{\pi D^2}{4} = 136.85 \text{ inch}^2$

$P = 250 \text{ psi (operating plus surge pressure)}$

$PA = 250 (136.85) = 34,212 \text{ lbs.}$

$H = 5 \text{ feet and } H_o = 5 + 1.10/2 = 5.55 \text{ feet}$

$\theta = 45^\circ$, use $S_r = 1.25$ $C_s = 500 \text{ psf}$

$W = 120 \text{ pcf, laying condition "B", nominal length} = 18 \text{ feet}$

Cohesive-moist granular soil $\phi = 17^\circ$

From Table II $f_c = 0.35$ $f_\phi = 0.65$

From Table I $R = 2/3$

Computations

$\theta = 45^\circ$ (2) $K = 1.657$ (5) $N_\phi = 1.826$

(3) $F_s = \pi (1.10) [(.35 \times 500) + 120(2/3)5 \tan(.65 \times 17)] = 874.7 \text{ plf}$

(4) $P_p = (120 (5.55) (1.826) + (2) 500 \sqrt{1.826}) = 2567.4 \text{ psf}$

(1) $L = \frac{1.25(1.657) 34,212}{1.657(874.7) + 1.10(2567.4)} = 16.58 \text{ feet}$

Therefore restrain one joint (18 feet) on each side of bend.

Write for comprehensive technical paper.

The preceding calculations determine the location(s) for restraining. The technical paper supporting this concept gives theory, calculations, and examples of various restraint methods. Included are thrust blocks (gravity and bearing), restrained joints, tie rods, and combinations of these.

TABLE B (Horizontal Bends)
Length To Be Restrained (Feet) at 100 psi for Clay

θ = Bend angle in degrees
 H = Depth of cover (ft.)
 D = Nominal diameter (in.)
 R = $2/3$ (except as noted)

Soil Properties:

$\phi = 14^\circ$
 $C_u = 0.0$
 $f_c = 0.5$
 $f = 0.5$

Notes:

- 1) Values left of heavy line $D > H$ and $R = 0.5$.
- 2) To determine values at pressures other than 100 psi, multiply by the ratio of the pressure to 100.

D	θ/H	Soil Properties									
		1	1 1/2	2	2 1/2	3	4	5	6	8	10
6	90	4.3	4.3	4.2	4.1	4.0	3.9	3.7	3.6	3.4	3.1
	45	2.9	2.9	2.9	2.8	2.7	2.6	2.5	2.4	2.2	2.0
	22 1/2	1.9	1.9	1.8	1.8	1.7	1.6	1.5	1.5	1.3	1.2
8	90	5.7	5.6	5.5	5.4	5.3	5.1	4.9	4.7	4.4	4.1
	45	4.0	3.9	3.8	3.7	3.6	3.4	3.2	3.1	2.9	2.6
	22 1/2	2.5	2.5	2.4	2.3	2.2	2.1	2.0	1.9	1.7	1.6
10	90	7.0	6.8	6.7	6.6	6.4	6.2	6.0	5.8	5.4	5.0
	45	4.8	4.7	4.6	4.5	4.4	4.2	4.0	3.8	3.5	3.2
	22 1/2	3.1	3.0	2.9	2.8	2.7	2.6	2.4	2.3	2.1	1.9
12	90	8.3	8.1	7.9	7.8	7.6	7.3	7.1	6.8	6.4	6.0
	45	5.7	5.6	5.4	5.3	5.2	4.9	4.7	4.5	4.1	3.8
	22 1/2	3.7	3.5	3.4	3.3	3.2	3.1	2.9	2.8	2.5	2.3
14	90	9.6	9.4	9.2	9.0	8.8	8.5	8.2	7.9	7.4	6.9
	45	6.6	6.4	6.3	6.1	6.0	5.7	5.4	5.2	4.8	4.4
	22 1/2	4.2	4.1	4.0	3.8	3.7	3.5	3.3	3.2	2.9	2.7
16	90	10.9	10.6	10.4	10.2	10.0	9.6	9.3	9.0	8.4	7.9
	45	7.5	7.3	7.1	6.9	6.8	6.4	6.2	5.9	5.4	5.0
	22 1/2	4.8	4.6	4.5	4.4	4.2	4.0	3.8	3.6	3.3	3.0
18	90	12.2	11.9	11.7	11.4	11.2	10.8	10.4	10.0	9.4	8.8
	45	8.4	8.2	7.9	7.7	7.6	7.2	6.9	6.6	6.1	5.6
	22 1/2	5.3	5.2	5.0	4.9	4.7	4.5	4.2	4.0	3.7	3.4
20	90	13.4	13.2	12.9	12.6	12.4	11.9	11.5	11.1	10.4	9.7
	45	9.3	9.0	8.8	8.6	8.3	8.0	7.6	7.3	6.7	6.2
	22 1/2	5.9	5.7	5.5	5.4	5.2	4.9	4.7	4.4	4.0	3.7
24	90	16.0	15.7	15.3	15.0	14.7	14.2	13.7	13.2	12.4	11.6
	45	11.0	10.7	10.4	10.1	9.9	9.4	9.0	8.6	8.0	7.4
	22 1/2	7.0	6.7	6.5	6.3	6.2	5.8	5.5	5.3	4.8	4.4
30	90	19.8	19.3	18.9	18.5	18.2	17.5	16.9	16.3	15.2	14.3
	45	13.5	13.1	12.8	12.5	12.2	11.6	11.1	10.6	9.8	9.1
	22 1/2	8.5	8.2	8.0	7.8	7.5	7.1	6.8	6.5	5.9	5.4
36	90	23.5	23.1	22.5	22.0	21.6	20.8	20.1	19.4	18.1	17.0
	45	16.0	15.6	15.1	14.8	14.4	13.8	13.2	12.6	11.6	10.8
	22 1/2	10.0	9.7	9.4	9.2	8.9	8.5	8.0	7.7	7.0	6.4
42	90	27.1	26.6	26.0	25.4	25.0	24.0	23.2	22.4	21.0	19.7
	45	18.4	17.9	17.4	17.0	16.6	15.8	15.1	14.5	13.4	12.5
	22 1/2	11.5	11.2	10.8	10.5	10.2	9.7	9.2	8.8	8.0	7.4
48	90	30.8	30.2	29.7	28.9	28.3	27.3	26.3	25.4	23.8	22.4
	45	20.7	20.2	19.8	19.2	18.7	17.9	17.1	16.4	15.2	14.1
	22 1/2	12.9	12.6	12.2	11.8	11.5	10.9	10.4	9.9	9.1	8.4
54	90	34.4	33.7	33.1	32.2	31.6	30.5	29.4	28.4	26.6	25.0
	45	23.1	22.5	22.0	21.4	20.9	19.9	19.1	18.3	16.9	15.7
	22 1/2	14.3	14.0	13.6	13.2	12.8	12.2	11.6	11.0	10.1	9.3

TABLE C (Horizontal Bends)
Length To Be Restrained (Feet) at 100 psi for Sand

		Soil Properties:										Notes:											
		$\theta = 39^\circ$										1) Values left of heavy line $D > H$ and $R = 0.5$.											
		$f_c = 0.0$										2) To determine values at pressures other than 100 psi, multiply by the ratio of the pressure to 100.											
		$C = 800$																					
		$f = 0.8$																					
		$R = 2/3$ (except as noted)																					
		$\theta =$ Bend angle in degrees $H =$ Depth of cover (ft.) $D =$ Nominal diameter (in.) $R =$ Bend radius (ft.)																					
D	θ/H	1	1 1/2	2	2 1/2	3	4	5	6	8	10	D	θ/H	1	1 1/2	2	2 1/2	3	4	5	6	8	10
6	90	25.2	17.5	13.4	10.9	9.1	6.9	5.6	4.7	3.5	2.8	20	90	63.2	46.7	37.0	30.7	26.2	20.3	16.5	14.0	10.6	8.6
	45	14.5	10.2	7.9	6.4	5.4	4.1	3.3	2.8	2.1	1.7	45	45	33.6	25.6	20.7	17.4	15.0	11.7	9.6	8.2	6.3	5.1
	22 1/2	8.1	5.7	4.5	3.7	3.1	2.4	1.9	1.6	1.2	1.0	22 1/2	22 1/2	18.0	14.0	11.4	9.7	8.4	6.6	5.4	4.6	3.6	2.9
	11 1/4	4.3	3.1	2.4	2.0	1.7	1.3	1.0	0.9	0.7	0.5	11 1/4	11 1/4	9.4	7.4	6.1	5.2	4.5	3.5	2.9	2.5	1.9	1.6
8	90	31.9	22.4	17.3	14.0	11.8	9.0	7.2	6.1	4.6	3.7	24	90	78.4	53.5	42.8	35.7	30.6	23.8	19.5	16.5	12.6	10.2
	45	18.0	12.9	10.0	8.2	7.0	5.3	4.3	3.6	2.7	2.2	45	45	39.2	29.0	23.7	20.0	17.3	13.7	11.3	9.6	7.4	6.0
	22 1/2	10.0	7.2	5.7	4.7	4.0	3.0	2.5	2.1	1.6	1.3	22 1/2	22 1/2	20.4	15.7	13.0	11.0	9.6	7.6	6.3	5.4	4.2	3.4
	11 1/4	5.3	3.9	3.1	2.5	2.1	1.6	1.3	1.1	0.9	0.7	11 1/4	11 1/4	10.5	8.3	6.9	5.9	5.1	4.1	3.4	2.9	2.3	1.9
10	90	37.9	26.8	20.8	17.0	14.3	10.9	8.8	7.4	5.6	4.5	30	90	89.4	62.6	50.7	42.5	36.7	28.7	23.6	20.0	15.4	12.5
	45	21.2	15.3	12.0	9.9	8.4	6.4	5.2	4.4	3.3	2.7	45	45	44.0	33.3	27.6	23.5	20.5	16.3	13.6	11.6	9.0	7.3
	22 1/2	11.7	8.5	6.7	5.6	4.7	3.7	3.0	2.5	1.9	1.5	22 1/2	22 1/2	22.7	17.9	15.0	12.9	11.3	9.1	7.6	6.5	5.1	4.2
	11 1/4	6.2	4.6	3.6	3.0	2.6	2.0	1.6	1.4	1.0	0.8	11 1/4	11 1/4	11.6	9.4	7.9	6.8	6.0	4.9	4.1	3.5	2.7	2.3
12	90	43.6	31.2	24.3	19.9	16.8	12.9	10.4	8.7	6.6	5.3	36	90	98.8	77.9	58.0	49.0	42.5	33.5	27.7	23.6	18.2	14.8
	45	24.1	17.6	13.9	11.5	9.8	7.6	6.1	5.2	3.9	3.2	45	45	48.0	39.0	31.1	26.8	23.5	18.9	15.8	13.5	10.6	8.6
	22 1/2	13.2	9.8	7.8	6.5	5.5	4.3	3.5	3.0	2.3	1.8	22 1/2	22 1/2	24.6	20.3	16.8	14.6	12.9	10.4	8.8	7.6	5.9	4.9
	11 1/4	7.0	5.2	4.2	3.5	3.0	2.3	1.9	1.6	1.2	1.0	11 1/4	11 1/4	12.6	10.4	8.8	7.7	6.8	5.6	4.7	4.1	3.2	2.6
14	90	49.0	35.3	27.6	22.7	19.2	14.8	12.0	10.1	7.6	6.2	42	90	106.9	85.4	64.5	54.9	47.8	38.0	31.5	26.9	20.8	17.0
	45	26.8	19.8	15.8	13.1	11.2	8.6	7.0	6.0	4.5	3.7	45	45	51.3	42.3	34.2	29.7	26.2	21.2	17.8	15.4	12.0	9.9
	22 1/2	14.6	11.0	8.8	7.3	6.3	4.9	4.0	3.4	2.6	2.1	22 1/2	22 1/2	26.1	21.9	18.3	16.0	14.3	11.7	9.9	8.6	6.8	5.6
	11 1/4	7.7	5.8	4.7	3.9	3.4	2.6	2.2	1.8	1.4	1.1	11 1/4	11 1/4	13.3	11.2	9.6	8.4	7.5	6.2	5.3	4.6	3.6	3.0
16	90	54.0	39.3	30.9	25.4	21.6	16.6	13.5	11.4	8.7	7.0	48	90	114.0	92.3	77.6	60.5	52.9	42.3	35.2	30.2	23.4	19.2
	45	29.2	21.9	17.5	14.6	12.5	9.7	7.9	6.7	5.1	4.1	45	45	54.1	45.2	38.9	32.3	28.7	23.4	19.8	17.1	13.5	11.1
	22 1/2	15.8	12.0	9.7	8.1	7.0	5.5	4.5	3.8	2.9	2.4	22 1/2	22 1/2	27.4	23.3	20.2	17.4	15.5	12.8	10.9	9.5	7.5	6.3
	11 1/4	8.3	6.4	5.2	4.4	3.8	3.0	2.4	2.1	1.6	1.3	11 1/4	11 1/4	14.0	11.9	10.4	9.1	8.2	6.8	5.8	5.1	4.0	3.4
18	90	58.7	43.1	34.0	28.1	23.9	18.5	15.0	12.7	9.6	7.8	54	90	120.2	98.5	83.5	65.7	57.7	46.4	38.8	33.3	26.0	21.3
	45	31.5	23.8	19.1	16.0	13.7	10.7	8.8	7.4	5.7	4.6	45	45	56.5	47.8	41.5	34.8	31.0	25.5	21.6	18.8	14.9	12.3
	22 1/2	17.0	13.0	10.6	8.9	7.7	6.0	5.0	4.2	3.2	2.6	22 1/2	22 1/2	28.6	24.5	21.5	18.6	16.7	13.9	11.9	10.4	8.3	6.9
	11 1/4	8.9	6.9	5.6	4.8	4.1	3.3	2.7	2.3	1.8	1.4	11 1/4	11 1/4	14.5	12.5	11.0	9.7	8.8	7.3	6.3	5.5	4.4	3.7

TABLE D (Horizontal Bends)
Length To Be Restrained (Feet) at 100 psi for Silt

		Soil Properties:										Notes:											
		= 32° $f_c = 0.0$										1) Values left of heavy line D > H and R = 0.5.											
		C _v = 0.0 f = 0.75										2) To determine values at pressures other than 100 psi, multiply by the ratio of the pressure to 100.											
θ	Bend angle in degrees																						
H	Depth of cover (ft.)																						
D	Nominal diameter (in.)																						
R	= 2/3 (except as noted)																						
D	θ/H	1	1 1/2	2	2 1/2	3	4	5	6	8	10	D	θ/H	1	1 1/2	2	2 1/2	3	4	5	6	8	10
6	90	34.2	23.7	18.2	14.7	12.4	9.4	7.6	6.3	4.8	3.8	20	90	85.6	63.3	50.2	41.6	35.5	27.5	22.4	18.9	14.4	11.7
	45	19.6	13.8	10.6	8.7	7.3	5.6	4.5	3.8	2.8	2.3		45	45.5	34.7	28.0	23.5	20.3	15.9	13.0	11.1	8.5	6.9
	22 1/2	10.9	7.8	6.0	4.9	4.2	3.2	2.6	2.2	1.6	1.3		22 1/2	24.4	18.9	15.4	13.1	11.3	8.9	7.4	6.3	4.8	3.9
	11 1/4	5.9	4.2	3.3	2.7	2.3	1.7	1.4	1.2	0.9	0.7		11 1/4	12.7	10.0	8.2	7.0	6.1	4.8	4.0	3.4	2.6	2.1
8	90	43.3	30.4	23.4	19.0	16.0	12.2	9.8	8.2	6.2	5.0	24	90	106.1	72.5	58.0	48.3	41.4	32.2	26.4	22.3	17.1	13.8
	45	24.4	17.5	13.6	11.1	9.4	7.2	5.8	4.9	3.7	3.0		45	53.0	39.2	32.0	27.1	23.4	18.5	15.3	13.0	10.0	8.1
	22 1/2	13.5	9.8	7.7	6.3	5.3	4.1	3.3	2.8	2.1	1.7		22 1/2	27.6	21.2	17.5	14.9	13.0	10.3	8.6	7.3	5.7	4.6
	11 1/4	7.2	5.3	4.1	3.4	2.9	2.2	1.8	1.5	1.2	0.9		11 1/4	14.2	11.2	9.3	7.9	6.9	5.5	4.6	4.0	3.1	2.5
10	90	51.3	36.4	28.2	23.0	19.4	14.8	12.0	10.0	7.6	6.1	30	90	120.9	84.8	68.6	57.6	49.7	38.9	32.0	27.2	20.0	16.9
	45	28.6	20.7	16.3	13.4	11.3	8.7	7.1	6.0	4.5	3.6		45	59.5	45.1	37.3	31.9	27.8	22.1	18.4	15.7	12.2	9.9
	22 1/2	15.8	11.6	9.1	7.5	6.4	5.0	4.0	3.4	2.6	2.1		22 1/2	30.7	24.2	20.3	17.4	15.3	12.3	10.3	8.8	6.9	5.6
	11 1/4	8.4	6.2	4.9	4.1	3.5	2.7	2.2	1.8	1.4	1.1		11 1/4	15.7	12.7	10.7	9.2	8.1	6.6	5.5	4.7	3.7	3.0
12	90	59.1	42.3	32.9	26.9	22.8	17.4	14.1	11.9	9.0	7.2	36	90	133.7	105.4	78.5	66.4	57.5	45.4	37.5	31.9	24.6	20.0
	45	32.6	23.9	18.9	15.6	13.3	10.2	8.3	7.0	5.3	4.3		45	64.8	52.7	42.1	36.2	31.8	25.5	21.3	18.3	14.3	11.7
	22 1/2	17.8	13.2	10.5	8.7	7.5	5.8	4.7	4.0	3.0	2.5		22 1/2	33.2	27.4	22.7	19.7	17.4	14.1	11.9	10.3	8.0	6.6
	11 1/4	9.4	7.1	5.6	4.7	4.0	3.1	2.6	2.2	1.7	1.3		11 1/4	17.0	14.1	11.9	10.4	9.2	7.5	6.4	5.5	4.3	3.6
14	90	66.3	47.9	37.4	30.8	26.1	20.0	16.2	13.7	10.4	8.3	42	90	144.6	115.6	87.4	74.4	64.7	51.4	42.7	36.4	28.2	23.0
	45	36.2	26.8	21.3	17.7	15.1	11.7	9.5	8.1	6.1	5.0		45	69.3	57.2	46.3	40.1	35.4	28.7	24.1	20.8	16.3	13.4
	22 1/2	19.7	14.8	11.9	9.9	8.5	6.6	5.4	4.6	3.5	2.8		22 1/2	35.3	29.6	24.8	21.7	19.3	15.8	13.4	11.6	9.1	7.6
	11 1/4	10.4	7.9	6.3	5.3	4.6	3.6	2.9	2.5	1.9	1.5		11 1/4	18.0	15.2	13.0	11.4	10.2	8.4	7.1	6.2	4.9	4.1
16	90	73.1	53.2	41.8	34.5	29.3	22.5	18.3	15.4	11.7	9.5	48	90	154.2	124.9	105.0	81.9	71.6	57.3	47.7	40.9	31.8	26.0
	45	39.5	29.6	23.7	19.7	16.9	13.1	10.7	9.1	6.9	5.6		45	73.1	61.2	52.6	46.3	38.8	31.7	26.7	23.2	18.2	15.1
	22 1/2	21.4	16.3	13.1	11.0	9.5	7.4	6.1	5.2	4.0	3.2		22 1/2	37.1	31.5	27.3	23.5	21.0	17.4	14.8	12.9	10.2	8.5
	11 1/4	11.2	8.6	7.0	5.9	5.1	4.0	3.3	2.8	2.1	1.7		11 1/4	18.9	16.1	14.1	12.3	11.1	9.2	7.9	6.9	5.5	4.6
18	90	79.5	58.4	46.1	38.1	32.4	25.0	20.4	17.2	13.1	10.6	54	90	162.5	133.3	113.0	89.0	78.1	62.8	52.6	45.2	35.2	28.9
	45	42.6	32.2	25.9	21.7	18.8	14.5	11.9	10.1	7.7	6.3		45	76.4	64.7	56.0	47.0	41.9	34.5	29.3	25.4	20.1	16.7
	22 1/2	22.9	17.6	14.3	12.0	10.4	8.2	6.7	5.7	4.4	3.6		22 1/2	38.6	33.1	29.0	25.1	22.6	18.8	16.1	14.1	11.2	9.3
	11 1/4	12.0	9.3	7.6	6.4	5.6	4.4	3.6	3.1	2.4	1.9		11 1/4	19.6	16.9	14.9	13.1	11.9	9.9	8.5	7.5	6.0	5.0

SECTION VII

BASIC PROCEDURES FOR THE INSTALLATION OF DUCTILE AND CAST IRON PIPE

Basic Procedures for the Installation of Ductile and Cast Iron Pipe

For the purposes of this section, the word "pipe" includes ductile and cast iron pipe; where a procedure refers to one of these materials only, it is so specified. It should be noted 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.

Introduction

Proper installation procedures will enhance the long and useful life of both ductile and cast iron pipe. The information presented in this paper may be useful as general guidelines for the installation of these materials. More specific data is available in The Guides for the Installation of Ductile Iron Pipe and Gray Cast Iron Water Mains which are available from CIPRA.

Receiving, Handling and Storage

It is important that all pipe be carefully inspected for damage that may have occurred in transit. Unloading may be accomplished using slings, hooks, pipe tongs or skids. Under no circumstances should pipe be dropped on old automobile tires or other cushions and when handled on skidways, it should not be skidded or rolled against pipe already on the ground. Care should be exercised to avoid injury to the coating or lining; if damage occurs, repairs must be made.

Manufacturers who employ special methods of packaging pipe for shipment will gladly send instructions for unloading.

Proper storage procedures are important and warrant special consideration:

—Suggested maximum allowable stacking heights are available and should be observed; each pipe size should be stacked separately.

—Lubricant for rubber joints should be kept in a sanitary condition as an aid in disinfection of the main.

—Rubber gaskets should be used on a first-in, first-out basis and should be stored in a cool, dark location to avoid deterioration.

The Trench

Trench location is of prime importance in urban areas where water mains are installed to a line and grade established by the engineer to avoid damage to other subsurface utilities. In these areas no excavation should be attempted before obtaining clearance from other utilities.

If a gas service pipe is broken, the gas utility should be notified immediately and an experienced gas service man should supervise repairs.

House sewers must be returned to good condition after installation of the water main. Any installation in the proximity of underground telephone or power conduits should proceed only after notification of the appropriate utility.

Trees, shrubs, lawns, fences, etc. must be protected during construction; where removal is necessary, permission must be obtained and replacement made. Pavement, sidewalks and curbs must be replaced according to local standards.

The required earth cover over pipe varies depending on pipe size and geographical location. Generally a minimum cover of 4 to 5 feet is required for large diameter mains; for small diameter mains, cover varies from 2½ to 4 feet in the southern states to as much as 7 or 8 feet in the northern states because of the depth of frost penetration.

One of the most important requirements of a good trench is the preparation of the trench bottom; it should be true and even in order to insure soil support for the full length of the pipe barrel. In this phase of the excavation, the following should be observed:

—A trench for cast iron pipe passing over a sewer or previous excavation requires compaction to provide support equal to native soil.

—If a sling is used to lower the pipe, an indentation not exceeding 18 inches in length should be made at the middle of the trench bed to facilitate the removal of the sling.

—Soft subgrade requires the addition of crushed stone; in extreme cases, piling may be necessary for proper support.

—Large bell holes are not required for push-on or mechanical joint pipe; however, a small depression is necessary to permit the pipe barrel to lie flat and to allow space for joint assembly.

The following suggested trench widths are sufficient to permit proper pipe installation with room for joint assembly and backfill tamping around the pipe:

TABLE 1
SUGGESTED TRENCH WIDTH

Nominal Pipe Size (Inches)	Trench Width (Inches)	Nominal Pipe Size (Inches)	Trench Width (Inches)
4	28	20	44
6	30	24	48
8	32	30	54
10	34	36	60
12	36	42	66
14	38	48	72
16	40	54	78
18	42		

The trench should never be wider than the width used as design criteria.

When rock excavation is necessary, certain precautions must be taken. Any rock encountered must be removed so that it will not be closer than 6 inches to the bottom and sides of pipe in sizes up to 24 inches in diameter and no closer than 9 inches for pipe in sizes 30 inches or larger in diameter. Following rock excavation, a bed of approved material should be placed on the bottom of the trench to the above-mentioned distances, leveled and tamped. A straight-edge may be used for checking the trench bottom to detect high points of rock that may protrude through the cushion.

City, state, or Federal regulations usually govern requirements for blasting; barricade placement and other warning devices for public safety; shoring; storage of excavated material; and protection of underground and surface structures.

If it is determined that soils are corrosive or expansive (some dense clays expand when saturated and have been known to exert as much as 17,500 lbs. of pressure per square foot), special care should be exercised. Economical protection against corrosive soils is available through the use of 8-mil thick, loose polyethylene encasement as outlined in American National Standards Institute (ANSI) Standard A21.5. Because of its high strength, ductile iron pipe is recommended for expansive soil areas.

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Installing The Pipe

Laying Conditions

Ductile and cast iron pipe, like any other pipe, are installed with respect to the trench bottom using specific laying or bedding conditions. The following conditions are recommended for cast iron pipe:

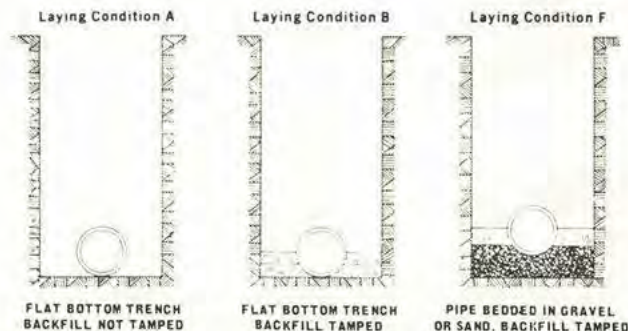


Figure 1

Each laying condition has its merits as well as its relationship to the ability of the pipe to carry loads placed upon it, with Laying Condition B being the most common.

For ductile iron pipe, laying condition types 1, 2, 3, 4 or 5 are recommended. For details see ANSI Standard A21.50 (Section III).

Pipe Placement

Proper equipment and procedures are necessary for safe and efficient pipe placement. Some of the more important considerations are:

—Bell and plain ends must be cleaned to prevent leaking joints and to assure proper seating of the gaskets.

—Before placement in the trench, pipe should be inspected for damage and the inside should be swabbed to remove loose dirt and foreign objects.

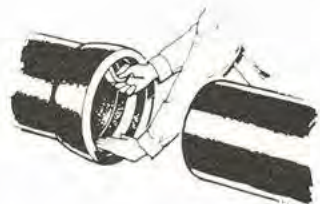
—Bells usually face the direction in which the work is progressing. When the main is being laid downhill, the pipes are frequently laid with the bells facing uphill for ease of installation.

—When laying push-on joint pipe, the correct gasket must be used for the type of joint being installed and the gasket must face the proper direction. Sand or grit must be removed from the gasket groove to assure watertightness.

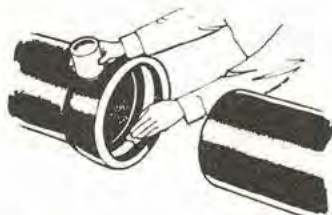
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Following are the steps in push-on joint assembly:

Figure 2



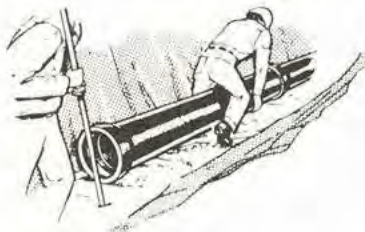
- (1) Clean and lubricate the groove and bell socket and insert the gasket, making sure that it faces the proper direction and is correctly seated.



- (2) Apply lubricant to the gasket and the plain end of the pipe. 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 the gasket and may cause a leak. Push the plain end into the bell of the pipe. Keep the joint straight while pushing. Make deflection after the joint is made.



- (4) Small pipe can be pushed home with a long bar. Large pipe require additional power, such as a jack, lever puller or backhoe. The supplier will 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.

Joins and Fittings

Mechanical or push-on joint fittings can be used with push-on joint pipe. The plain end of the pipe usually is provided with 1 or 2 painted gauge lines which show whether it has been properly positioned in the bell socket after assembly. The pipe manufacturer's instructions as to the location of these lines should be followed.

Pit cast pipe was manufactured in 4 classifications (A, B, C and D), each having a different outside diameter than modern ductile or cast iron pipe. Before making extensions, existing pipe in a system should be measured to determine if transition fittings are required.

When laying mechanical joint pipe, the socket and plain ends should be clean. The assembly of the joint is simple and requires the use of an ordinary ratchet wrench. A torque wrench should be used for the first day or two of construction to accustom the workmen to the proper amount of pressure to apply to the wrench.

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TABLE 2

SUGGESTED TORQUE

<u>Bolt Size</u>	<u>Ft. Lbs.</u>
5/8 inch	45-60
3/4 inch	75-90
1 inch	85-100
1 1/4 inch	105-120

Flanged joints are seldom used in underground water mains except for valves and fittings for large meter settings, valve vaults and similar installations. Joint deflection is available in both push-on and mechanical joint pipe. Pipe should be assembled in a straight line both horizontally and vertically before deflection is made. For mechanical joint pipe, the bolts should be partially tightened before the length of pipe is deflected.

Maximum allowable deflections are listed in the following table and should not be exceeded. For design purposes, deflection should be limited to 80% of the values shown in Table 3.

MAXIMUM DEFLECTION FULL LENGTH PIPE

Push-On Type Joint

Pipe Dia.	Deflec. Angle	Maximum Deflection Pipe Lengths of				Approximate Radius of Curve Produced by Succession of Joints, Pipe Lengths of			
		12'	16'	18'	20'	12'	16'	18'	20'
2"	5°	12"	17"	19"	21"	140'	185'	205'	230'
2 1/4"	5°	12"	17"	19"	21"	140'	185'	205'	230'
3"	5°	12"	17"	19"	21"	140'	185'	205'	230'
4"	5°	--	17"	19"	21"	--	185'	205'	230'
6"	5°	--	17"	19"	21"	--	185'	205'	230'
8"	5°	--	17"	19"	21"	--	185'	205'	230'
10"	5°	--	17"	19"	21"	--	185'	205'	230'
12"	5°	--	17"	19"	21"	--	185'	205'	230'
14"	3°	--	10"	11"	12"	--	300'	340'	380'
16"	3°	--	10"	11"	12"	--	300'	340'	380'
18"	3°	--	10"	11"	12"	--	300'	340'	380'
20"	3°	--	10"	11"	12"	--	300'	340'	380'
24"	3°	--	10"	11"	12"	--	300'	340'	380'
30"	3°	--	6"	11"	12"	--	450'	340'	380'
36"	3°	--	6"	11"	12"	--	450'	340'	380'
42"	2°	--	6"	7 1/2"	8"	--	450'	510'	570'
48"	2°	--	6"	7 1/2"	8"	--	450'	510'	570'
54"	1° -30'	--	5"	5 1/2"	6"	--	510'	680'	760'

TABLE 3

Frozen house services are often thawed by heat from high level electrical current. Current may be conducted across ductile or cast iron pipe joints by the use of special gaskets with metal tips or embedded metal conductors; wedges inserted at the joints; or conductive cables and metal strips.

It is important to use an adequate safety factor with regard to electrical current needs.

Cutting Pipe

Cast iron pipe may be cut with a hydraulic squeeze cutter (for pipe up to 20 inches in diameter); a rotary wheel hand cutter; an abrasive wheel cutter; a milling wheel; or a power driven hacksaw. Cast iron pipe should not be cut with an oxyacetylene torch.

Because of the nature of ductile iron, all cutters cannot be used, particularly the hydraulic squeeze cutter. Ductile iron pipe may be cut with an abrasive wheel cutter; a rotary wheel hand cutter (with carbide cutters); a guillotine pipe saw; a milling wheel; or an oxyacetylene torch. (If an oxyacetylene torch is used on ductile iron sewer or gas pipe, the presence of combustible gases could cause an explosion.)

Cut ends of ductile and cast iron pipe should be beveled and filed to prevent gasket damage in joint assembly.

Railroad and Highway Crossings

Regulations relative to the installation of water mains under highways and railroad crossings are specific and complete and often require a casing pipe. Mechanical or push-on joints should be used under railroads because of their ability to withstand vibration.

State, local and area regulations should be checked and the needed permits obtained well in advance of the actual work.

Valve and Hydrant Installation

To assure that the pipe will not be required to carry their weight, heavy valves and fittings should be supported by treated timbers, crushed stone, concrete pads or specially tamped trench bottoms.

When valves are placed in masonry vaults, special precautions must be taken to protect the pipeline. Cast iron valve boxes, when used, should rest above the valve body so that no weight is transferred to the valve itself.

New valves may be installed in existing mains by the use of cutting-in valves and sleeves or by use of a solid sleeve.

Blow-offs and drains should discharge above ground and should be installed so that there is no possibility of sewage or other contamination entering the main. Air release and/or vacuum vents should be provided at high points in the line and in areas of negative pressure.

Fire hydrants should be placed to provide maximum accessibility and minimum possibility of damage from vehicles or injury to pedestrians. In areas of the country where an undrained hydrant barrel would freeze, a drainage pit 2 feet in diameter and 3 feet deep should be excavated below the hydrant opening and filled with coarse sand to a depth of 6 inches above the hydrant opening but providing sufficient aggregate void space to more than equal the volume of the barrel. The drainage pit should neither be near, nor connected to, a sewer. Hydrants may be anchored by any one of several methods, such as thrust blocks, tie rods, or special restrained fittings (see Thrust Restraint), and special procedures are necessary for each method.

To prevent water hammer, valve and hydrants should be closed very slowly, especially for the last few turns near full closure.

Thrust Restraint

Thrust forces are created in a pipeline at changes in direction, tees, deadends or where changes in pipe size occur at reducers. Available restraint methods include concrete thrust blocks, restrained joints and tie rods. Forces to be restrained are given in Table 4.

RESULTANT THRUST AT FITTINGS AT 100 PSI WATER PRESSURE

Total Pounds					
Nom. Pipe Dia. In.	Dead End	90° Bend	45° Bend	22 1/2° Bend	11 1/4° Bend
4	1,810	2,559	1,385	706	355
6	3,739	5,288	2,862	1,459	733
8	6,433	9,097	4,923	2,510	1,261
10	9,677	13,685	7,406	3,776	1,897
12	13,685	19,353	10,474	5,340	2,683
14	18,385	26,001	14,072	7,174	3,604
16	23,779	33,628	18,199	9,278	4,661
18	29,865	42,235	22,858	11,653	5,855
20	36,644	51,822	28,046	14,298	7,183
24	52,279	73,934	40,013	20,398	10,249
30	80,425	113,738	61,554	31,380	15,766
36	115,209	162,931	88,177	44,952	22,585
42	155,528	219,950	119,036	60,684	30,489
48	202,683	286,637	155,127	79,083	39,733
54	256,072	362,140	195,989	99,914	50,199

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NOTE:

To determine thrust at pressures other than 100 psi, multiply the thrust obtained in the table by the ratio of the pressure to 100.

For example, the thrust on a 12 inch, 90° bend at 125 psi is $19,353 \times \frac{125}{100} = 24,191$ pounds.

Table 4

To determine the size of a concrete thrust block, divide the total force by the bearing value of the soil. The quotient will be the size of the bearing area of the thrust block in square feet. Approximate values for various types of soil are listed in Table 5.

SOIL	BEARING LOAD (lb/sq. ft.)
Muck	0
Soft Clay	1,000
Silt	1,500
Sandy Silt	3,000
Sand	4,000
Sandy Clay	6,000
Hard Clay	9,000

* No responsibility can be assumed for the accuracy of the data in this table due to the wide variation of bearing load capabilities for each soil type.

TABLE 5

- The following precautions must be observed when constructing thrust blocks:
- Blocks must be poured against undisturbed soil.
 - The pipe joint and bolts must be accessible.
 - Concrete should be cured for at least 5 days and should have a compression strength of 2,000 lbs. at 28 days.
 - Blocks must be positioned to counteract the direction of the resultant thrust force.

Restrained push-on and mechanical joints are available for all pipe sizes and present no installation problems. They are used for resisting thrust forces where there is a shortage of space or where the soil behind a fitting will not provide adequate support. This restraining method involves placement of these special joints at appropriate fittings and for a predetermined number of pipe lengths on each side. See Section VI for the design of thrust restraint systems utilizing restrained joints.

Tie rods may be used by themselves or in combination with other restraint devices. When tie rods are used with steel bands around the pipe barrel, only 1 rod should be attached to each band and the band should be cocked to prevent slippage along the pipe barrel. A band placed behind a bell may be used for 2 rods. For mechanical joint pipe, tie rods may be threaded through the bolt holes in the flange and secured by nuts. All rods and bands should be made of corrosion-resistant material or coated to prevent rust or deterioration.

Restraint may be necessary for more than 1 length of pipe on each side of any change in direction, or at any deadend or tee.

Backfilling

The purpose of backfilling is to fill the trench and to protect the pipe by providing support along and under it. It is one of the most important phases of water main construction and proper procedures are imperative.

Backfill material should be of good quality and should be free of cinders, frozen material, ashes, refuse, boulders, rocks or organic material. Soil containing stones up to 8 inches in their greatest dimension may be used from 1 foot above the top of the pipe to the ground surface.

Local authorities control requirements for backfilling under paved streets and the soil is usually compacted in 6-inch lifts, using air or gasoline-powered compactors. Many cities require that the entire trench be filled with compacted earth or select material, such as sand, gravel or limestone screenings. Compaction below and to the top of the pipe is intended to provide support for the water main and all tamping above the pipe is to support the new pavement.

Water jetting or trench flooding are sometimes used to obtain the necessary consolidation of the soil.

After backfilling operations have been completed, the work area must be restored to its original condition.

Testing

If possible, all new pipelines should be hydrostatically tested before backfilling is completed. Sufficient earth should be placed on the pipe between

FLUSHING AND DISINFECTING

TABLE 6

CIPRA RECOMMENDED ALLOWABLE LEAKAGE PER 1000-FT. OF PIPELINE*
(GALLONS PER HOUR)

Avg. Test Pressure PSI	NOMINAL PIPE DIAMETER - INCHES																
	2	3	4	6	8	10	12	14	16	18	20	24	30	36	42	48	54
450	0.32	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	0.30	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	0.28	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	0.26	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	0.25	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	0.24	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	0.23	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	0.21	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	0.20	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	0.19	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	0.17	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	0.15	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

*For Mechanical or push-on joint pipe with 18-ft. nominal lengths. To obtain the recommended allowable leakage for pipe with 20-ft. nominal lengths, multiply the leakage calculated from the above table by 0.9.

If the pipeline under test contains sections of various diameters, the allowable leakage will be the sum of the computed leakage for each size.

joints to prevent movement under test pressure. In city streets, heavy traffic demands may require backfilling after a few lengths of pipe have been laid. The pipeline should be filled slowly and care should be exercised to vent all high points and expel all air. All fittings and hydrants should be properly anchored and all valves completely closed before applying test pressure.

In performing the test, pressure is applied by means of an adequate pump connected to the pipe, bringing the main up to the test pressure, which is recommended as 1.5 times the working pressure at the point of testing. This test pressure should be held for 2 hours. Make-up water should be measured with a meter or by pumping water from a vessel of known volume.

FLUSHING AND DISINFECTING

All new water systems or extensions to existing systems should be thoroughly flushed and disinfected before being placed in service. Public health authorities require disinfection and bacteriological examination to assure freedom from contamination. (Refer to AWWA Standard C601 for Disinfecting Water Mains.)

The flushing velocity should be at least 2.5 fps for small mains. For mains larger than 18 inches in diameter, a lower rate may be used. Table 7 lists required openings to obtain the required velocity of 2.5 fps for flushing and is excerpted from AWWA Standard C601.

REQUIRED OPENINGS—ETC.

(40-psi Residual Pressure)

Pipe Size in.	Flow Required to Produce 2.5-fps Velocity gpm	Orifice Size in.	Hydrant Outlet Nozzles	
			Number	Size in.
4	100	15/16	1	2 1/2
6	220	1 3/8	1	2 1/2
8	390	1 7/8	1	2 1/2
10	610	2 5/16	1	2 1/2
12	880	2 13/16	1	2 1/2
14	1,200	3 1/4	2	2 1/2
16	1,565	3 5/8	2	2 1/2
18	1,980	4 3/16	2	2 1/2

^aWith 40 psi residual pressure, a 2 1/2 in. hydrant outlet nozzle will discharge approximately 1,000 gpm and a 4 1/2 in. hydrant nozzle will discharge approximately 2,500 gpm.

TABLE 7

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Disinfection of mains can be accomplished by the addition of chlorine as a liquid, a hypochlorite solution or hypochlorite tablets. Liquid chlorine is injected into the main under pressure with a portable chlorinator to provide at least 50 ppm available chlorine. To insure that the required concentration is maintained, chlorine residuals should be checked. The chlorinated water solution should remain in the pipe for at least 24 hours, at the end of which period the chlorine concentration should be at least 25 ppm. Final flushing may then be accomplished.

The slug method of chlorination, which is used for large diameter water mains of long length, consists of moving a column of highly concentrated chlorine solution (at least 300 ppm) along the interior of the pipe with at least 3 hours contact with the pipe wall.

The tablet method is generally used for short extensions (no longer than 2,500 feet) of 12-inch and smaller diameter mains. The required number of tablets are placed in the crown of each pipe length and held in place by an approved mastic. The main is then filled with water at a velocity of less than 1 fps and the water is left in the main for 24 hours before flushing. Table 8, excerpted from AWWA Standard C601, indicates the number of tablets required for each size of pipe up to 12 inches in diameter.

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**NUMBER OF HYPOCHLORITE TABLETS OF 5-G
REQUIRED FOR DOSE OF 50 Mg/1***

Length of Section Ft.	Diameter of Pipe in.					
	2	4	6	8	10	12
13 or less	1	1	2	2	3	5
18	1	1	2	3	5	6
20	1	1	2	3	5	7
30	1	2	3	5	7	10
40	1	2	4	6	9	14

*Based on 3¾ g available chlorine per tablet.

TABLE 8

Repairing Main Breaks

Many devices and materials are available to repair pipe breaks, including mechanical joint split sleeves, bolted repair clamps, bell repair clamps, solid sleeves, mechanical joint bell split sleeves, and repair clamps.

Following the repair of main breaks, proper disinfection procedures are necessary to provide protection from contamination and caution must be exercised to insure that a strong concentration of chlorine does not enter the customer's service lines.

Section VIII

ENVIRONMENTAL FACTORS RELATED TO THE DESIGN AND USE OF GRAY AND 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.

Tuberculation. In certain parts of the United States, uncoated or unlined cast iron water mains may develop a growth on the interior surface of the pipe. These growths are called tubercles and their accumulation has a two-fold effect upon flow capacity: (1) it reduces the actual inside diameter of the main; and, (2) the rough surface of the pipe creates a turbulence in the flow and causes additional frictional head loss. These growths can only occur where the water comes in contact with the metal of the pipe and the remedy for this situation is to use cement-mortar linings wherever aggressive waters are to be transported.

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Cement-Mortar Lined Gray and Ductile Cast 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 cement-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 50 years of service, friction flow tests show that this original cement-lined cast iron pipe has retained a Hazen-Williams coefficient (C Factor) of 131.

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. Almost all gray and ductile cast iron pipe installed in water systems today are cement lined.

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 Standard A21.4, "Cement-Mortar Lining for Cast Iron and Ductile 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.

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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-inch 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.

Financial Advantages. As a demonstration of the financial advantages accruing from the use of cement linings, consider a typical instance based on a 24" pipe, 30,000 feet long carrying 8 mgd.

Tests made on numerous cement-lined pipe installations have established a "C" value of 140.

Tests made on bituminous lined pipe have established a "C" value of 130 when new, and a "C" value of approximately 100 after 30 years' service. Assuming no increase in demand and a pumping cost of \$0.05 per million gallons to lift water one foot in elevation, the annual cost of pumping water against friction head only, if bituminous lined pipe were used (actual inside diameter 24.44

inches), would range from \$8,322.00 per year when the pipe was new $C=130$ to \$13,797.00 per year when the pipe was 30 years old $C=100$.

In the case of the 24-inch cement-lined pipe actual inside diameter=24.25", the pumping cost for the first year with a "C" value of 140, would be \$7,533.60 and would remain at that figure throughout the 30-year period. The actual saving for this period, resulting from the use of cement-lined pipe, would be \$105,780.00.

In the case of smaller diameter pipe used in distribution systems, sizes are usually determined by fire protection requirements. The additional volume of water available when cement linings are used may stop a fire in its early stages that would otherwise become a conflagration.

Where tuberculating waters are carried, the loss in capacity of smaller bituminous lined mains occurs at a faster rate than is the case with larger mains. This can mean that in a relatively short time the capacity of bituminous lined pipe is so reduced that cleaning or replacement becomes advisable. Cement lining is a minor part of the total cost of a pipeline project, and assures high carrying capacity for the life of the pipe.

Some old existing non-cement-mortar-lined pipelines have become tuberculated when exposed to very aggressive water. An effective correction of this condition is cleaning and cement-lining in place or cleaning followed by appropriate water treatment. No lasting value will result from cleaning a tuberculated pipeline unless it is followed by appropriate water treatment or installation of a lining. The advisability of pipeline rehabilitation will be dictated by an evaluation of the structural condition of the pipe and the adequacy of the pipe size following rehabilitation.

The nomograph (pg. 422) 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 known factor. Arrows (∇) on the inside diameter line represent actual inside diameter of cement-mortar-lined ductile iron pipe Class 52, three inches through 12 inches, and Class 51, 14 inches and larger.

Almost all gray and ductile iron pipe for water transmission and distribution are cement-mortar-lined in accordance with ANSI Standard A21.4 (AWWA C104) or Federal specifications.

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

H = head loss in feet per 1,000 feet

NOMOGRAPH FOR PIPE SIZE, HEAD LOSS AND DISCHARGE

Based on Hazen-Williams Formula: $Q = 0.006756 CD^{2.63} H^{.54}$

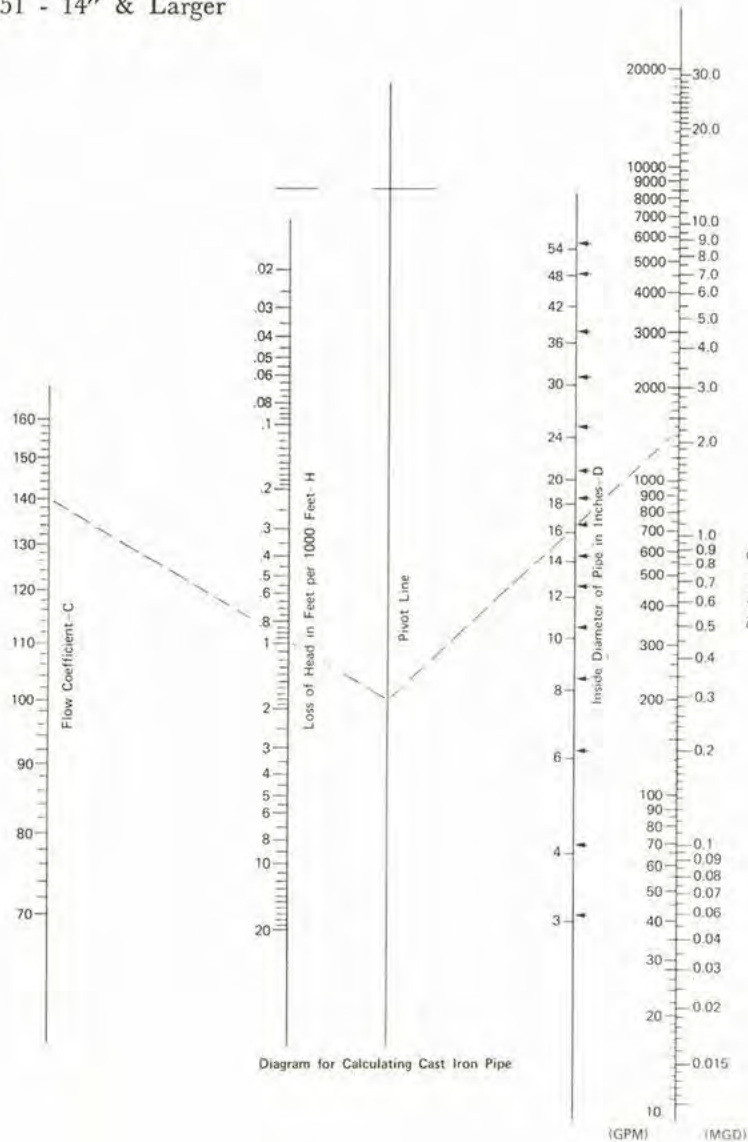
For Cement Mortar Lined Cast Iron Pipe $C = 140$.

(←) Shown are actual Inside Diameters of Cement
Mortar Lined Ductile Iron Pipe

Class 52 - 3"-12" &

Class 51 - 14" & Larger

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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 gray or ductile iron pipe has a C factor of 140. Unlined pipe exposed to aggressive waters will suffer loss in C factor due to tuberculation.

Both gray and ductile iron pipe have flow advantages resulting from their greater than nominal internal diameters. For example, Class 52, 12-inch ductile iron pipe has an inside diameter of 12.46 inches. Cement-lined pipe of this same class has an inside diameter of 12.34 inches.

Example 1 — Maximum Delivery

To find the maximum delivery of an 8-inch, Class 52, 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 52 ductile iron pipe.

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.

Water Hammer or Surge

Water hammer is a real force and has caused failure of many pipelines. It is the result of a sudden decrease in the pipeline fluid velocity. This rapid deceleration of the liquid mass sets up pressure waves which are transmitted through the pipeline system. It is estimated that in water transmission and distribution systems, a change in velocity of 1 fps in critical time can increase the pipeline pressure by approximately 50 psi. Water hammer can be caused by quick acting valves, check valves, rapid closure of fire hydrants, earthquakes, the sudden loss of power at pumping plants, and other situations. While there are surge suppression devices available, experience has shown that these devices, due to inactivity, rusting, silting, loss of power, overloading, etc., do not always properly arrest surge forces.

Therefore, water hammer must be considered in pipe thickness calculations. Procedures for the analysis of surge pressure in simple pipelines are presented in many reference works. The analysis of water hammer in a network of piping, such as that of a conventional water distribution system, is extremely complex. For this reason, standard water hammer allowances based on experience and good judgment are used in the Design Standards for Gray Cast Iron Pipe (ANSI A21.1) and for Ductile Iron Pipe (ANSI A21.50) as follows:

ALLOWANCES FOR SURGE PRESSURE

Pipe Size (in.)	Surge Pressure (psi) Gray Iron Pipe	Surge Pressure (psi) Ductile Iron Pipe
3-10	120	100
12-14	110	100
16-18	100	100
20	90	100
24	85	100
30	80	100
36	75	100
42-48	70	100

Each pipeline project is unique and the designer is cautioned to review possible causes of water hammer and to increase the allowance if circumstances dictate.

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- A Column Separation Accompanying Liquid Transients in Pipes by R. A. Faltzer. Transactions (ASME), December, 1967.

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**ANSI A21.4-1974
(AWWA C104-74)**

Revision of
A21.4-1971
(AWWA C104-71)

AMERICAN NATIONAL STANDARD
for
**CEMENT-MORTAR LINING FOR
CAST-IRON AND DUCTILE-IRON PIPE
AND FITTINGS FOR WATER**

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ADMINISTRATIVE SECRETARIAT
AMERICAN WATER WORKS ASSOCIATION

Co-SECRETARIATS
AMERICAN GAS ASSOCIATION
NEW ENGLAND WATER WORKS ASSOCIATION

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American National Standard

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American Society of Civil Engineers
American Society of Mechanical Engineers
American Society for Testing and Materials
American Water Works Association
Cast Iron Pipe Research Association

Individual Producers

Manufacturers' Standardization Society of
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Foreword

This foreword is for information and is not a part of ANSI A21.4-1974 (AWWA C104-74).

I—History of Standard

The first recorded installation of cement-mortar linings in cast-iron pipe was in 1922 at Charleston, S.C., under the supervision of J. E. Gibson.

From 1922 to 1929, many installations were made under various manufacturers' specifications. In 1929, ASA (now ANSI) Sectional Committee A21 issued a tentative standard for cement-mortar linings. This was published as a tentative standard by AWWA in 1932. After many revisions and refinements, it 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, much 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 bituminous 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." This 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. This reduction was based on more than 20 years of Cast Iron Pipe Research Association (CIPRA) studies of experimental test lines having cement-mortar linings varying from $\frac{1}{2}$ 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. This qualification 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.

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Under this test, the sand shall not produce a color darker than required in the standard. The sand shall be acceptable, 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 colorimetric tests of sand from an established source of supply shall be made once each 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 C117-69, "Standard Method of Test for Materials Finer Than No. 200 (75- μ m) Sieve in Mineral Aggregates by Washing."

At the option of the manufacturer, the clay content and sand grain fineness may be determined by using the American Foundrymen's Society 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 Designation C119-71, is equal to the AFS percentage of clay plus the percentage passing through the No. 200 sieve.

No more than 2 per cent shall be lost in the decantation test.

The decantation tests of sand from an established source of supply shall be made once each 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 1 year.

Sec. 4-4—Water

The water used for tempering the mortar shall meet the requirements of

the United States Public Health Service Drinking Water Standards 1962.

Sec. 4-5—Mortar

Mortar for the lining shall be composed of cement, sand, and water. The mortar shall be well mixed and of proper consistency to produce a dense, homogeneous lining that will adhere firmly to the pipe or fitting surface. 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—Preparation of Pipe and Fittings for Lining

The surface to be lined shall be free from foreign material, which would adversely affect the lining adhesion or cause inclusions, blisters, or voids in the lining. The surface shall be free from projections of iron 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 the centrifugal process. Fittings shall be lined by a process that will produce linings meeting the requirements of this standard.

4-7.2. *Mortar.* The waterway surfaces of pipe and fittings shall be completely covered with the specified mortar. The mortar shall be entirely free from holidays or visible bubbles of air and shall be thoroughly compacted throughout. The consistency of the mortar and the time and speed of spinning of the pipe shall be so adjusted as to minimize the segregation of the sand from the cement and to deliver the finished lining substantially free of laitance.

4-7.3. *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. 4-12.

Sec. 4-8—Socket

The socket shall be free of mortar.

Sec. 4-9—Protection of Work

The lined pipe and fittings shall be protected from extreme heat due to direct rays of the sun, from impact of rainfall, and from freezing temperatures until the linings have cured sufficiently to withstand these conditions.

Sec. 4-10—Thickness of Lining

4-10.1. *Standard thickness.* The thickness of linings for pipe and fittings, as determined in Sec. 4-11, shall be not less than $\frac{1}{8}$ in. for 3-12 in. pipe, $\frac{3}{8}$ in. for 14-24 in. pipe, and $\frac{1}{2}$ in. for 30-54 in. pipe.

4-10.2. *Double thickness.* Linings with thicknesses twice those specified in Sec. 4-10.1 shall be furnished if specified by the purchaser.

4-10.3. *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.

4-10.4. *Permitted tolerances.* A thickness tolerance of $+\frac{1}{8}$ in. shall be permitted on pipe and $+\frac{1}{4}$ in. on fittings.

Sec. 4-11—Determination of Thickness

Lining thickness shall be determined at intervals frequent enough to assure compliance. Thickness of lining may be determined by means of spear measurement, with a hardened-steel point not larger than $\frac{1}{8}$ in. in diameter. The inspector shall pierce the lining immediately after it is placed in the pipe or fitting and before the mortar has set. The lining shall be pierced at four equidistant points on two cross sections of the barrel at each end of the pipe or fitting. The first set shall be not more than 4 in. from the respective ends of the pipe or fitting. The second set shall be made as far into the interior of the pipe or fitting as can be readily reached without injuring the lining.

Sec. 4-12—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. 4-13. The cure may be effected by the application of a seal coat to the still-moist lining.

Sec. 4-13—Lining Quality

The lining shall be free from voids, ridges, or corrugations that reduce the thickness of lining to less than the specified thickness.

Unbonded areas of cement lining in a pipe or fitting are acceptable if the dimension of any single area does not exceed the nominal diameter in the circumferential direction and in longitudinal direction does not exceed the nominal diameter or 12 in., whichever is greater.

Longitudinal cracks less than 9 in. in length or less than the nominal diameter, whichever is greater, are accept-

able. Circumferential cracks of any length are acceptable. Surface crazing is acceptable.

Repair of any unacceptable condition is permitted in the field, in accordance with Sec. 4-7.3.

Sec. 4-14—Seal Coat

4-14.1. *General.* Unless otherwise specified, the cement lining shall be given a seal coat of bituminous 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.

4-14.2. *Seal coat characteristics.* The seal coat shall be continuous and shall adhere to the mortar lining at all points. The seal coat, after drying for at least 48 hr, shall have no deleterious effect upon the quality, color, taste, or odor of potable water.

4-14.3. *Limit of toxic substances.*

4-14.3.1. *Requirements.* The seal coat material shall not yield chloroform-soluble extractives, corrected for zinc extractives as zinc oleate, in excess of 18 mg per sq in. of surface exposed or of 50 ppm by weight of the water capacity of the test container.

4-14.3.2. *Frequency of test.* The seal coat material shall be tested at sufficiently frequent intervals to determine that it meets the requirements prescribed in Sec. 4-14.3.1.

4-14.3.3. *Method of testing.* The procedure used in the determination of the amount of toxic substances shall be in accordance with the FDA "Method of Testing for Toxicity of Coating Material Intended for Use in Transporting or Holding Food or Potable Water," as described in *Food Additives Amendment and Code of Federal Regulations*, pp. 13.0 through 13.8, April 16, 1963, Food and Drug

Administration, US Department of Health, Education and Welfare. The seal coat material shall be extracted with distilled or demineralized water at 120F for 24 hr.

4-14.4. *Leaching resistance.*

4-14.4.1. *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.

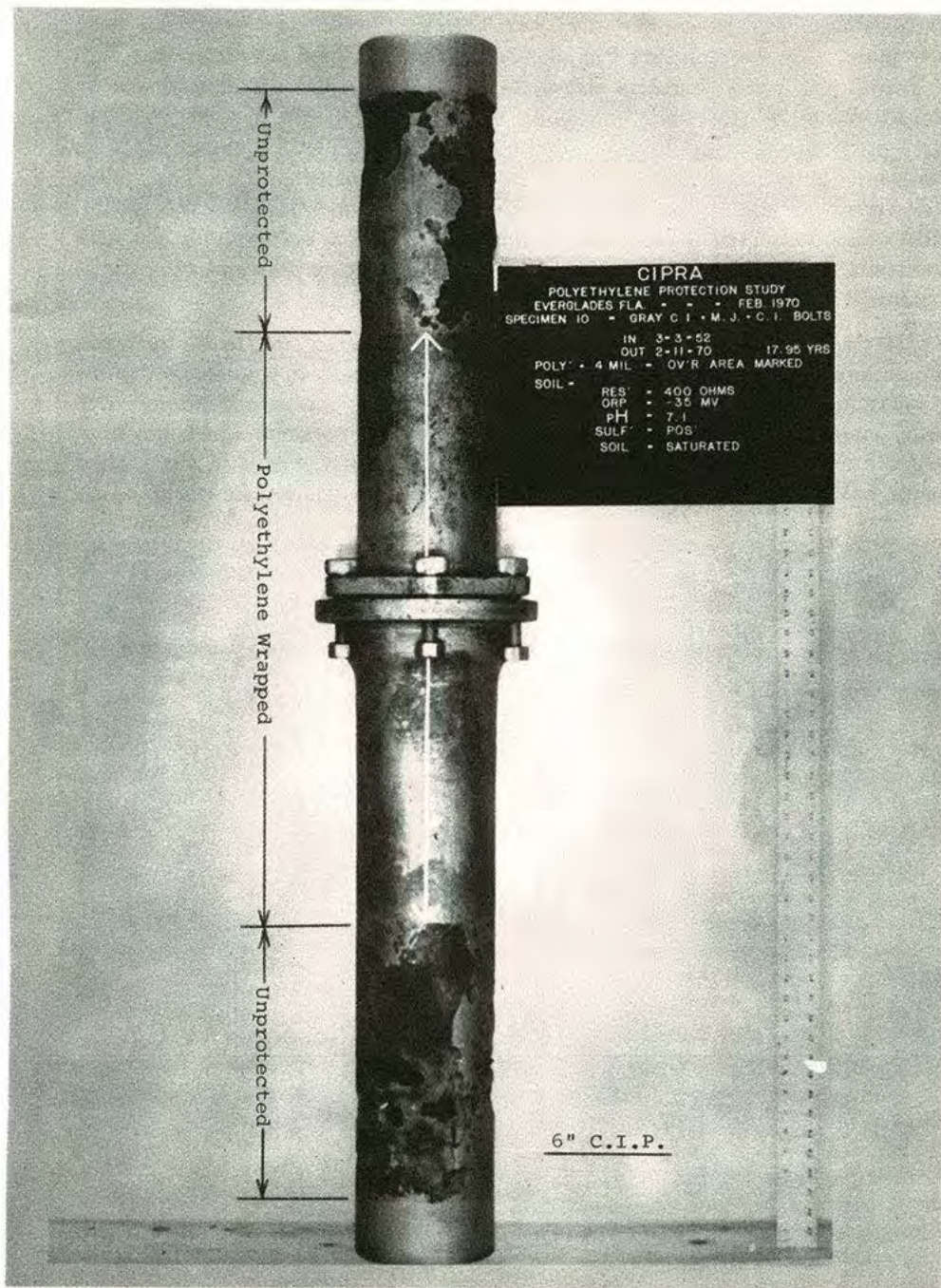
4-14.4.2. *Frequency of test and records.* Leaching tests shall be made at sufficiently frequent intervals to assure compliance. The results of one test each month shall be filed for reference for 1 year.

4-14.4.3. *Method of testing.* The seal-coated pipe shall be tested as follows:

The test specimen shall be at least 6 in. 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.

In either case, the water in the specimen shall be changed and tested after 24-hr contact on each of 3 successive days. The methods 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, thirteenth edition, 1971.

END OF STANDARD



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External Corrosion

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 greater than that of gray iron pipe. In a recent survey of water utility officials throughout the United States, it was found that about 5 percent of the soils in water distribution systems are corrosive to these pipe materials. CIPRA has developed a system for evaluation of soil corrosivity based on many years of experience. The system is described in detail in the Appendix to ANSI Standard A21.5 (AWWA C105). 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.

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If the environment of a proposed pipeline is determined to be corrosive due to any of these causes, economical corrosion prevention is available by the installation of 8-mil thick, loose polyethylene encasement in accordance with ANSI Standard A21.5 (AWWA C105). This protection system, which has been in use for over 20 years in severely corrosive pipe environments in the United States, has proven successful and has been accepted throughout the world.



ANSI A21.5-1972
(AWWA C105-72)
First Edition

AMERICAN NATIONAL STANDARD
for
**POLYETHYLENE ENCASEMENT FOR
GRAY AND DUCTILE CAST-IRON PIPING
FOR WATER AND OTHER LIQUIDS**

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ADMINISTRATIVE SECRETARIAT
AMERICAN WATER WORKS ASSOCIATION

Co-SECRETARIATS
AMERICAN GAS ASSOCIATION
NEW ENGLAND WATER WORKS ASSOCIATION

First edition approved by American National Standards Institute, Inc., Dec. 27, 1972

NOTICE

This Standard has been especially printed by the American Water Works Association for incorporation into this volume. It is current as of December 1, 1975. 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

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American Society of Civil Engineers
American Society of Mechanical Engineers
American Society for Testing and Materials
American Water Works Association
Cast Iron Pipe Research Association

Manufacturers' Standardization Society of
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Naval Facilities Engineering Command,
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Foreword

This foreword is provided for information and is not a part of ANSI A21.5-1972 (AWWA C105-72).

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 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 No. 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 No. 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 No. 4 has

1. Developed Standard ANSI A21.5-1972 (AWWA C105-72) for Polyethylene Encasement for Gray and Ductile Cast-Iron Piping for Water and Other Liquids.

2. Developed Appendix A outlining soil-investigation procedures.

History

Loose polyethylene encasement was first used experimentally in the US 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 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 US 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.

Research

Research by the Cast Iron Pipe Research Assn. (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.

Useful Life of Polyethylene

Tests on polyethylene used in the protection of gray and ductile cast-iron pipe have shown that after 19 years of exposure to severely corrosive soils, strength loss and elongation reduction are insignificant. Studies by the Bureau of Reclamation of the US Dept. of the Interior* on polyethylene film used underground showed that tensile

*US Dept. of the Interior, Bureau of Reclamation, "Laboratory and Field Investigations of Plastic Films," Rept. No. ChE-82, Sep. 1968.

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.

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 is anticipated, Class C material should be used (see Sec. 5-3.1.1).

Options

This standard includes certain options, which, if desired, must be specified. These are

1. Class of polyethylene material (Sec. 5-3).
2. Installation method A, B, or C (Sec. 5-4) if there is a preference.

American National Standard for

**Polyethylene Encasement for Gray and Ductile
Cast-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 gray and ductile cast-iron pipe. This standard also may be used for polyethylene encasement of fittings, valves, and other appurtenances to gray and ductile cast-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-1248-68—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	1,200 psi minimum	4
Elongation	300 per cent minimum	6
Dielectric strength ..	800 V/mil thickness minimum	1

5-3.2. *Thickness.* Polyethylene film shall have a minimum nominal thickness of 0.008 in. (8 mils). The minus tolerance on thickness shall not exceed 10 per cent of the nominal thickness.

5-3.3. *Tube size or sheet width.* Tube or sheet size 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.	
	Flat Tube	Sheet
3	14	28
4	16	32
6	20	40
8	24	48
10	27	54
12	30	60
14	34	68
16	37	74
18	41	82
20	45	90
24	54	108
30	67	134
36	81	162
42	95	190
48	108	216
54	121	242

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 air- 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 for the 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.* Cut polyethylene tube to a length approximately 2 ft longer than that of the pipe section. Slip the tube around the pipe, centering it to provide a 1-ft 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 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.* Cut polyethylene tube to a length approximately 1 ft shorter than that of the pipe section. Slip the tube around the pipe, centering it to provide 6 in. 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 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 length of polyethylene over the joint, overlapping the polyethylene previously installed on each adjacent section of pipe by at least 1 ft; 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.* Cut polyethylene sheet to a length approximately 2 ft longer than that of the pipe section. Center the cut length to provide a 1-ft overlap on each adjacent pipe section, bunching it 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.

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. 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 AWWA Standard C600-64, or the latest revision thereof.

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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 and is not a part of ANSI A21.5-1972 (AWWA C105-72).

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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 weighting each factor to determine whether polyethylene encasement should be used are subsequently described.

Soil Survey Tests and Observations

1. Earth resistivity
 - (a) Four-pin Vibroground
 - (b) Single-probe Vibroground
 - (c) Soil-box Vibroground
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
 - (d) Mine 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 top soil is underlain with wetter soils and where soil types vary with depth. The Wenner configuration is used in connection with a Vibroground (Associated Research, Inc.), 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 afore-mentioned 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.

If there is question concerning whether the soil is typically wet, a sample can be removed for resistivity measurement in a Miller soil box. The principle is the same as with the four-pin method; however, sampling permits introduction of water, to saturation, prior to testing to simulate saturated field conditions. This equipment is universally accepted and has the

advantage of yielding a direct reading on the Vibroground.

Interpretation of resistivity results is extremely important. To base an opinion on a four-pin reading with dry top soil 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 ground-water table, presence of shallow ground water, 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 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 A1 (p. 7) 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.

A Beckman model N or an Electromate portable pH meter is suitable for both field and laboratory pH determinations. In this test, calomel 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 Beckman meter, with platinum and calomel electrodes inserted into the soil sample, which permits a reading of potential between the two electrodes. It

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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.

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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 per cent 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, 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 in-

clude 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 proposed 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, 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 actual observation of existing installations.

Soil-Test Evaluation

Using the soil-test procedures described herein, 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 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 A1 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 need for polyethylene encasement.

TABLE A1
*Soil-Test Evaluation**

Soil Characteristics	Points
Resistivity— <i>ohm-cm</i> (based on single probe at pipe depth or water-saturated Miller soil box):	
<700	10
700-1,000	8
1,000-1,200	5
1,200-1,500	2
1,500-2,000	1
>2,000	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

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* 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.



Expanding Soils & Their Effect on Underground Pipe

Expanding Soils & Their Effect on Underground Pipe

First, a definition.

An expansive soil might be defined as any soil that swells or shrinks significantly upon wetting or (especially) upon drying, thus showing a volume change. Expansive soils are, in fact, usually 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.

Field identification of expansive soils.

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 water 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 sure way—laboratory testing.

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.

Cast Iron Pipe Research Association (CIPRA) has used this Soil Meter for nearly four years, testing hundreds of samples from many areas of the U.S., including Alaska and Hawaii.

Interpreting the test.

A Potential Volume Change Number is assigned to each swell index value obtained from tests with the meter. Here are the ranges:

Swell Index (psf)	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.

Distribution of expansive soils.

The swell index tests performed by CIPRA 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:

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Location	Swell Index (psf)	Location	Swell Index (psf)	Location	Swell Index (psf)
Arkansas	3,069	Michigan	3,968	Ohio	2,890
California	6,070	Missouri	8,604	Pennsylvania	3,726
California	4,958	Missouri	7,666	South Dakota	8,604
California	4,790	Mississippi	17,260	South Dakota	5,043
Hawaii (Oahu)	10,061	Minnesota	2,800	Texas	10,061
Illinois	6,245	North Carolina	3,248	Texas	8,989
Illinois	4,048	Oklahoma	4,460	Texas	7,042
Kansas	2,851				

Damage by expansive soils.

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. Several utilities in areas with highly expansive soils indicate that damage does occur: 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.

What to watch for.

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, for a long period, attract water. Covering the trench with pavement, etc. also invites water invasion. Soil-volume changes are likely.

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.

About corrosion problems:

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.

Our ongoing involvement.

CIPRA 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?

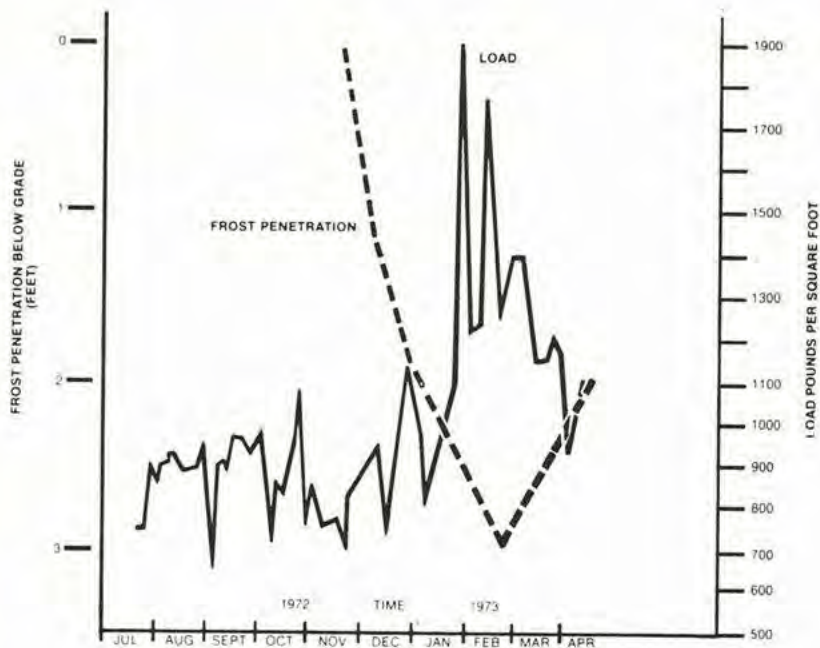
Frost Penetration - Loads on Underground Pipe

A seasonal story.

It is common, particularly in northern areas, for municipal water systems to experience a number of pipe failures during the winter months. And one cause is frost penetration. It is a known fact that soil moisture, when frozen, expands the soil. And that causes increased vertical forces on buried pipe during the winter. Until now, there were no published data on this problem. The whole subject needed study.

A cooperative effort.

Recently an investigation was started in the Portland, Maine Water District. Ideally located for such research. The District and the Cast Iron Pipe Research Association (CIPRA) entered into a joint study on the effects of frost penetration. Test data for two winters in the Portland District have been collected and analyzed. Here is a summary of the results.



The test site.

An 8-inch cast iron pipe buried at a depth of 3.75 feet was selected as the test subject. The data collection system consisted of:

Four electronic load cells placed beneath the pipe.

A separate cell independent of the pipe, measuring direct soil load.

Five temperature sensors placed at 1-foot intervals to a depth of 5 feet.

Strip-charts for recording all load and temperature sensors.

The data.

To save space and also because the results of the second winter's study were more precise, we have reproduced here a plot of the data obtain during the second winter.

As the curve of earth load (the higher solid line) dramatically shows, load began to increase as frost penetration began in December. And as frost penetration increased to almost 3 feet in depth, the load had practically doubled the December 5 value. Also note the effect of increased moisture content on earth load. Points on the curve where significant rainfall is indicated represent marked decreases in earth load. This change in load with precipitation may be due to a change in soil friction angle or in soil cohesion.

What happens when a live load is added.

Another significant finding in the Portland CIPRA study was the effect of live loads on the test pipe. In a summer month, a loaded gravel truck of known weight caused an increase of about 2100 pounds on one of the load cells. And when an equivalently weighted truck passed over the pipe when winter's frost had reached 3 feet of penetration, the live load was only about 5% less. The difference was most likely due to wider distribution of the live load by the frost layer.

A clearer picture of frost penetration effects.

Live loads added to earth loads when frost is present are a logical explanation for the greater incidence of water main breaks during winter. Of course, the presence of much colder water in the main also causes some stresses on the pipe in wintertime.

In "normal" pipeline installations, it is also unlikely that uniform bedding can be achieved beneath the pipe. Increased external loading from frost penetration can cause beam breaks where bedding is not uniform. A piece of stone or rock beneath the pipe could act as a fulcrum. Soft portions of the bedding may permit excessive deflection caused by frost or live loads (or both).

The solution lies in the pipe.

Cold climates, where frost penetration is a recurring menace, require pipe of sufficient ductility, beam strength, and joint flexibility to withstand winter's stresses. Ductile iron pipe fits all these requirements with strength to spare. Serious consideration should therefore be given to ductile iron water systems for frost-prone areas.

Our ongoing involvement.

The Portland Water District and CIPRA have agreed to continue studying frost penetration. Even more severe winters, where frost reaches down to 4 feet, will hopefully yield further data.

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Section IX
ENGINEERING DATA

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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

**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

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**Heads of Water in Feet, Corresponding to Pressures
in Pounds per Square Inch**

Pressure Lbs. per Sq. in.	0	1	2	3	4
0	.....	2.309	4.619	6.928	9.238
10	23.095	25.404	27.714	30.023	32.333
20	46.189	48.499	50.808	53.118	55.427
30	69.284	71.594	73.903	76.213	78.522
40	92.379	94.688	96.998	99.307	101.62
50	115.47	117.78	120.09	122.40	124.71
60	138.57	140.88	143.19	145.50	147.81
70	161.66	163.97	166.28	168.59	170.90
80	184.76	187.07	189.38	191.69	194.00
90	207.85	210.16	212.47	214.78	217.09
	5	6	7	8	9
0	11.547	13.857	16.166	18.476	20.785
10	34.642	36.952	39.261	41.570	43.880
20	57.737	60.046	62.356	64.665	66.975
30	80.831	83.141	85.450	87.760	90.069
40	103.93	106.24	108.55	110.85	113.16
50	127.02	129.33	131.64	133.95	136.26
60	150.12	152.42	154.73	157.04	159.35
70	173.21	175.52	177.83	180.14	182.45
80	196.31	198.61	200.92	203.23	205.54
90	219.40	221.71	224.02	226.33	228.64

At 62° F., 1 foot head = 0.433 lb. per square inch; $0.433 \times 144 = 62.355$ 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.

CONTENTS OF PIPE

Capacities in Cubic Feet and in United States Gallons
(231 Cubic Inches) per Foot of Length

Diameter, Inches	Diameter, Feet	For 1 Foot Length		Diameter, Inches	Diameter, Feet	For 1 Foot Length		Diameter, Inches	Diameter, Feet	For 1 Foot Length	
		Cubic Feet, Also Area in Sq. Ft.	U. S. Gal. (231 Cu. In.)			Cubic Feet, Also Area in Sq. Ft.	U. S. Gal. (231 Cu. In.)			Cubic Feet, Also Area in Sq. Ft.	U. S. Gal. (231 Cu. In.)
¼	.0208	.0003	.0026	6.75	.5625	.2485	1.859	19.0	1.583	1.969	14.73
⅓	.0260	.0005	.0040	7.00	.5833	.2673	1.999	19.5	1.625	2.074	15.52
½	.0313	.0008	.0057	7.25	.6042	.2868	2.144	20.0	1.666	2.182	16.32
⅔	.0365	.0010	.0078	7.50	.6250	.3068	2.295	20.5	1.708	2.292	17.15
¾	.0417	.0014	.0102	7.75	.6458	.3275	2.450	21.0	1.750	2.405	17.99
⅞	.0469	.0017	.0129	8.00	.6667	.3490	2.611	21.5	1.792	2.521	18.86
1	.0521	.0021	.0159	8.25	.6875	.3713	2.777	22.0	1.833	2.640	19.75
1 1/16	.0573	.0026	.0193	8.50	.7083	.3940	2.948	22.5	1.875	2.761	20.65
1 ¼	.0625	.0031	.0230	8.75	.7292	.4175	3.125	23.0	1.917	2.885	21.58
1 ½	.0677	.0036	.0270	9.00	.7500	.4418	3.305	23.5	1.958	3.012	22.53
1 ⅝	.0729	.0042	.0312	9.25	.7708	.4668	3.492	24.0	2.000	3.142	23.50
1 ¾	.0781	.0048	.0359	9.50	.7917	.4923	3.682	25.0	2.083	3.409	25.50
1.00	.0833	.0055	.0408	9.75	.8125	.5185	3.879	26.0	2.166	3.687	27.58
1.25	.1042	.0085	.0638	10.00	.8333	.5455	4.081	27.0	2.250	3.976	29.74
1.50	.1250	.0123	.0918	10.25	.8542	.5730	4.286	28.0	2.333	4.276	31.99
1.75	.1458	.0168	.1250	10.50	.8750	.6013	4.498	29.0	2.416	4.587	34.31
2.00	.1667	.0218	.1632	10.75	.8958	.6303	4.714	30.0	2.500	4.909	36.72
2.25	.1875	.0276	.2066	11.00	.9167	.6600	4.937	31.0	2.583	5.241	39.21
2.50	.2083	.0341	.2550	11.25	.9375	.6903	5.163	32.0	2.666	5.585	41.78
2.75	.2292	.0413	.3085	11.50	.9583	.7213	5.395	33.0	2.750	5.940	44.43
3.00	.2500	.0491	.3673	11.75	.9792	.7530	5.633	34.0	2.833	6.305	47.17
3.25	.2708	.0576	.4310	12.00	1.000	.7854	5.876	35.0	2.916	6.681	49.98
3.50	.2917	.0668	.4998	12.50	1.042	.8523	6.375	36.0	3.000	7.069	52.88
3.75	.3125	.0767	.5738	13.00	1.083	.9218	6.895	37.0	3.083	7.468	55.86
4.00	.3333	.0873	.6528	13.50	1.125	.9940	7.435	38.0	3.166	7.876	58.92
4.25	.3542	.0985	.7370	14.00	1.167	1.069	7.997	39.0	3.250	8.296	62.06
4.50	.3750	.1105	.8263	14.50	1.208	1.147	8.578	40.0	3.333	8.728	65.29
4.75	.3958	.1231	.9205	15.00	1.250	1.227	9.180	41.0	3.416	9.168	68.58
5.00	.4167	.1364	1.020	15.50	1.292	1.310	9.801	42.0	3.500	9.620	71.96
5.25	.4375	.1503	1.124	16.00	1.333	1.396	10.44	43.0	3.583	10.084	75.43
5.50	.4583	.1650	1.234	16.50	1.375	1.485	11.11	44.0	3.666	10.560	79.00
5.75	.4792	.1803	1.349	17.00	1.417	1.576	11.79	45.0	3.750	11.044	82.62
6.00	.5000	.1963	1.469	17.50	1.458	1.670	12.50	46.0	3.833	11.540	86.32
6.25	.5208	.2130	1.594	18.00	1.500	1.767	13.22	47.0	3.916	12.048	90.12
6.50	.5417	.2305	1.724	18.50	1.542	1.867	13.97	48.0	4.000	12.566	94.02

1 Cubic foot of water weighs 62.35 pounds; 1 gallon (U. S.) weighs 8.335 pounds.

LINEAR EXPANSION OF DUCTILE IRON PIPE

The coefficient of linear expansion of ductile iron may be taken as 0.000062 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	0.014	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

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Linear Expansion of Cast Iron Pipe

The coefficient of linear expansion of cast iron may be taken as 0.000058 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

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)	$2.930\ 711 \times 10^{-3}$
Btu (International Table) in./s.ft ² .°F (k, thermal conductivity)	watt/metre-kelvin (W/m-K)	$5.192\ 204 \times 10^3$
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	$t_{\text{c}} = (t_{\text{f}} - 32)/1.8$
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)	$2.259\ 697 \times 10^{-3}$
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)	$7.460\ 000^* \times 10^3$
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)	$3.390\ 575 \times 10^{-3}$
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 × 10
quart (U.S. liquid)	metre ³ (m ³)	$9.463\ 529 \times 10^{-4}$
ton (short, 2000 lbm)	kilogram (kg)	$9.071\ 847 \times 10^3$
torr (mm Hg)	pascal (Pa)	$1.333\ 22 \times 10^3$
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

4
8
4

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 Ounces	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

4
8
6

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

4
8
8

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 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 Cubic Meters	
To	Multiply by
Pecks	113.510 4
Bushels	28.377 59

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 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 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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