American Water Works Association

AWWA C301-72
Revision of
AWWA C301-64

AWWA STANDARD

for

PRESTRESSED CONCRETE PRESSURE PIPE, STEEL CYLINDER TYPE, FOR WATER AND OTHER LIQUIDS

First edition approved by Board of Directors Nov. 21, 1949.
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AMERICAN WATER WORKS ASSOCIATION
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Three subcommittees were instrumental in the revision of this standard.

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Approved by the AWWA Board of Directors, Jan. 28, 1974	**Addenda to AWWA Standard for Prestressed Concrete Pressure Pipe, Steel Cylinder Type, for Water and Other Liquids and AWWA Standard for Reinforced Concrete Water Pipe—Steel Cylinder Type, Pretensioned**	**AWWA C301a–74** Supplement to C301–72 and **AWWA C303a–74** Supplement to C303–70 **American Water Works Association**

Add the following to C301, paragraph *2.7.1*:

Steel sheets or coils conforming to the requirements of "Specifications for Steel, Cold-Rolled Sheet, Carbon, Structural" (ASTM Designation A611), Grade B, C or E, may also be utilized for pipe cylinders.

Add the following to C303, paragraph *2.5.1*:

Steel sheets or coils conforming to the requirements of "Specifications for Steel, Cold-Rolled Sheet, Carbon, Structural" (ASTM Designation A611), Grade B or C may also be utilized for pipe cylinders.

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Foreword

This foreword is for information only and is not part of AWWA C301-72

History of Standard

Prestressed-concrete steel-cylinder pipe, as described in this standard, provides an optimum utilization of steel and concrete with minimal weight under given design conditions and gives excellent performance under various internal and external pressure conditions.

There are two types of prestressed-concrete steel-cylinder pipe: (1) the lined-cylinder type with a core composed of a steel cylinder lined with concrete and subsequently wire-wrapped directly on the steel cylinder and coated with mortar; and (2) the embedded-cylinder type with a core composed of a steel cylinder encased in concrete and subsequently wire-wrapped on the exterior concrete surface and coated with concrete or mortar. The lined-cylinder type, which was first used in the US in 1942, is furnished in sizes from 16 to 48 in. The embedded-cylinder type, which was developed later and first installed in 1953, is manufactured in sizes 24 in. and larger.

Both types are designed for the specific combination of internal pressure and external load required for the project in accordance with the procedures outlined in the appendices of this standard. Lined-cylinder type is designed generally for pressures up to 250 psi and embedded-cylinder type, up to 350 psi, but both types have been designed and constructed for substantially higher pressures.

Prestressed-concrete steel-cylinder pipe is used for transmission mains, distribution feeder mains, pressure siphons (including river crossings), penstocks, industrial pressure lines, water intake lines, sewer force mains, and sewer outfall lines.

In the manufacture of lined-cylinder pipe, the first step is to make and hydraulically test the steel cylinder with joint rings attached. The cylinder is then centrifugally lined with dense concrete to constitute the core. The concrete lining is cured and high-tensile wire is wrapped around the core directly on the steel cylinder. For a selected wire size, the tension and spacing of the wire are controlled to produce a predetermined residual compression in the core to meet design requirements. The wrapped core is then covered with a dense premixed mortar coating about ¾ in. thick, applied by a mechanical impact method.

In the manufacture of embedded-cylinder pipe, the cylinder and joint rings are constructed and tested in the same manner as for lined-cylinder pipe. The cylinder is encased in concrete by vertical casting and mechanical vibration to constitute the core. After curing, the wire reinforcement is wound, under tension, in one or more layers around the outside of the concrete core containing the cylinder, instead of directly on the cylinder. The exterior coating of premixed mortar or concrete is placed by an impact method or by vertical casting. Embedded-cylinder construction has been found to be superior for large sizes and for pipe designed for comparatively high pressures.

The first edition of this standard was approved as "Tentative" on Nov. 21, 1949. It was revised and made "Standard" on Jun. 13, 1952. The second edition was approved as "Tentative" on Jun. 17, 1955, and made "Standard" on Jun. 26, 1958. Substantial changes, including the addition of combined loading procedures, were included in the third edition, which was made "Standard" as of Jan. 27, 1964.

Installation of this pipe is covered by AWWA Manual M-9, *Installation of Concrete Pipe.*

Information Regarding Use of This Standard

When purchasing pipe under the provisions of this standard, the purchaser shall furnish supplementary specifications to include specific details concerning the following:

1. Standard used; that is, AWWA C301-72
2. Type of pipe, either lined-cylinder pipe or embedded-cylinder pipe (Sec. 1.3)
3. Manner of storage and delivery, if required of the manufacturer
4. Whether there is any internal operating pressure, transient pressure, external earth load, or trench bedding condition in excess of that provided for in Sec. 3.2 (Sec. 1.2.8, 1.2.9, 1.4.1, and 1.5.2)
5. Whether pipe may not be supplied from inventory (Sec. 1.5.1)
6. Whether a tabulated layout schedule (Sec. 1.5.2) will be required
7. Identification marks required (Sec. 1.6)
8. Whether the purchaser desires to inspect the pipe and fittings at the manufacturer's plant (Sec. 1.7.1)
9. Whether steel test reports (Sec. 1.9.3) and test specimens (Sec. 1.9.4) will be required
10. Whether submission of rubber gasket material test reports (Sec. 1.9.5 and 2.11.8) will be required
11. Whether an affidavit of compliance (Sec. 1.10) will be required
12. Type of cement required, if there is a preference (Sec. 2.1.1)
13. Whether aggregate samples (Sec. 2.4) will be required
14. Whether submission of manufacturer's design calculations (Sec. 3.2.1) will be required
15. Type of protective coating on exposed portions of joint rings (Sec. 3.3)
16. Whether submission for approval of details of materials and methods of welding (Sec. 3.5.2) will be required
17. Whether a specific seal coat (Sec. 3.11) will be required
18. Details of fittings (Sec. 4.1)
19. Testing of steel cylinders for fittings (Sec. 4.2 and 4.3)
20. Whether lining and coating of structural-steel connections (Sec. 4.5) will be required

Major Revisions

The major revisions in this edition consist of the following:

1. The title has been changed to reflect the scope of the standard more accurately. The phrase "water pipe" has been changed to "pressure pipe" and the following phrase was added: "For water and other liquids"
2. The entire standard was carefully reviewed and changes were made in most of the sections to improve understanding and readability
3. Use of the standard was improved by the addition of titles to all sections

4. The scope, which formerly provided for pipe sizes from 16 in. to 96 in., was enlarged to provide for sizes from 16 to 144 in.

5. A minimum cylinder thickness of 18 gage is permitted for pipe 48 in. and smaller; and of 16 gage for pipe 54 in. and larger

6. Provision has been made that the minimum design thickness of the core, including the thickness of the cylinder, shall be $\frac{1}{16}$ of the design pipe diameter. This provision eliminates the need for Table 3 in the previous edition of AWWA C301. In that table the core thickness for embedded-cylinder pipe larger than 48 in. in diameter was based, for manufacturing reasons, on using the outside form for AWWA C300 pipe of the same diameter to cast the concrete embedment over the steel cylinder.

7. Multiple layers of circumferential reinforcement are expressly provided for in Sec. 3.8. This is necessary when high pressures are involved and the required amount of wire cannot be furnished in one layer because of insufficient space

8. The requirements for "ordinary" bedding, as specified in Sec. 3.2.2, have been provided. The previous edition specified "ordinary" bedding, but did not define the requirements

9. The extra circumferential wrap of wire required at each end of the core may now be applied at one half the design tension. This will most benefit embedded pipe where the wire anchorage has usually been embedded in the concrete and, at times, has pulled loose at the beginning of the wrapping process

10. The minimum time required for steam curing has been reduced from 32 to 24 hr. The actual time used will depend on temperature, which may vary from 110F to 150F, and other conditions. This does not relax the concrete strength requirements. The wrapping with high-tensile wire cannot begin until the concrete has reached minimum specified seven-day compressive strength and the initial compression in the concrete shall not exceed 55 per cent of the compressive strength of the concrete at the time of wrapping.

American Water Works Association

AWWA C301-72

Revision of
AWWA C301-64

AWWA Standard for

Prestressed Concrete Pressure Pipe, Steel Cylinder Type, for Water and Other Liquids

Section 1—General

Sec. 1.1—Scope

This standard covers the manufacture of circumferentially prestressed concrete water pipe with a steel cylinder and wire reinforcement in sizes from 16 to 144 in., inclusive. The standard covers two types of prestressed pipe: (1) lined-cylinder pipe with a core composed of a steel cylinder lined with concrete and subsequently wire-wrapped and coated with premixed mortar; and (2) embedded-cylinder pipe with a core in which a steel cylinder is encased in concrete and subsequently wire-wrapped and coated with premixed concrete or mortar. This standard does not include requirements for handling, delivery, laying, field testing, or disinfection of the pipe.

Sec. 1.2—Definitions

In this standard the following definitions shall apply:

1.2.1—*Purchaser.* The word "purchaser" shall mean a person, firm, corporation, or government subdivision entering into a contract or agreement to purchase pipe and fittings according to this standard.

1.2.2—*Contractor.* The word "contractor" shall mean the person, firm, or corporation executing the contract or agreement with the purchaser to furnish pipe and fittings according to this standard.

1.2.3—*Manufacturer.* The word "manufacturer" shall mean the person, firm, or corporation who actually manufactures the pipe, acting either directly as the contractor or as a subcontractor or supplier. If the manufacturer is acting as a subcontractor under the contractor or otherwise as a supplier to the contractor, the obligations of the manufacturer under this standard shall be considered as obligations of the contractor, and the contractor shall be responsible for their performance.

1.2.4—*ASTM.* The term "ASTM" shall mean the American Society for Testing and Materials. When specific ASTM specifications are cited without dates, the designation shall be construed to refer to the latest revision under the same specification number, or to superseding specifications under a new number, except for provisions in the revised specifications that clearly are inapplicable.

1.2.5—*ANSI.* The term "ANSI" shall mean the American National Standards Institute.

1.2.6—*Approved.* The term "approved" shall mean having received the approval of the purchaser.

1.2.7—*Design pressure.* The design pressure shall be the maximum sustained internal hydrostatic pressure to which the pipe is to be subjected. Generally, the design pressure for each pipe, or portion of the pipeline, shall be the operating pressure established by the hydraulic gradient or the static head specified by the purchaser, whichever results in the greater pressure.

1.2.8—*Surge pressures.* Surge pressures are internal pressure overloads of relatively short duration.

1.2.9—*External loads.* The term "external loads" shall mean all superimposed live and dead loads applied to the outside of the pipe after installation.

1.2.10—*Normal operating conditions.* Normal operating conditions are defined as a combination of design pressure and external dead loads.

1.2.11—*Transient conditions.* Transient conditions are conditions due to surge pressures or live loads that exceed normal operating conditions and are of short duration.

1.2.12—*Pipe diameter.* The term "pipe diameter" or "size" shall mean the design inside (waterway) diameter of the pipe.

Sec. 1.3—Essential Requirements

The pipe shall have the following principal features: a welded steel cylinder with steel joint rings welded to its ends; for lined-cylinder pipe, a core consisting of a lining of concrete within the steel cylinder, or for embedded-cylinder pipe, a core consisting of the steel cylinder encased in concrete; reinforcement consisting of high-tensile wire wound around the outside of the core in one or more layers at a predetermined stress and securely fastened at its ends; a coating of dense mortar or concrete covering the core and wire, except for the necessarily exposed surfaces of the joint rings; a self-centering joint with a preformed gasket of rubber, so designed that the joint will be watertight under all conditions of service. Lined-cylinder pipe shall be used for pipe sizes up to and including 20 in. and may be used for pipe sizes up to and including 48 in. Embedded-cylinder pipe may be used for pipe sizes 24–48 in. and shall be used for larger pipe. For embedded-cylinder pipe, at least one third of the total core thickness shall be outside the cylinder.

Sec. 1.4—Plans and Data To Be Furnished by Purchaser

1.4.1—*Design data.* The purchaser shall designate the design pressure for which the pipe shall be manufactured. If the pipe is to be used under conditions where the external loads or surge pressure will be in excess of that stated in Sec. 3.2 as provided for in the normal design of the pipe, the purchaser shall designate the external load or surge-pressure conditions for which the pipe shall be designed. For external loads in excess of those provided for in

Sec. 3.2, a statement or detail of bedding and backfilling procedures shall be included.

1.4.2—*Plans.* At least 1 month prior to manufacture, the purchaser shall furnish the contractor with plans and profiles showing: alignment and grades; location of all outlets, connections, and special appurtenances; design pressures for each part of the line; and such special details or information as are necessary for the manufacture of the pipe and fittings in accordance with this standard and with the specific requirements of the work for which the pipe is made.

Sec. 1.5—Data To Be Submitted by Manufacturer

1.5.1—*Detail drawings and schedules.* The manufacturer shall submit, for approval by the purchaser, drawings and schedules showing full details of reinforcement, concrete, and joint dimensions for the pipe and fittings. All pipe and fittings shall be fabricated in accordance with these approved drawings and schedules. Pipe may be supplied from inventory unless the purchaser has indicated otherwise.

1.5.2—*Tabulated layout schedule.* When specifically required, the data submitted by the manufacturer shall include a tabulated layout schedule, with reference to the stationing and grade line shown on the drawings supplied by the purchaser. The schedule shall show pressure zones, each of which shall be designated by the design pressure and transient pressure applicable therein, and the point of change from one zone to the next shall be clearly indicated by station number. The diameter of the pipe, the design pressure and transient pressure, and the thickness of pipe wall and area of steel (per linear foot of pipe) in the reinforcing wire and steel cylinder shall be listed for each portion of pipeline.

Sec. 1.6—Marking

Each length of straight and special pipe and each fitting shall have plainly marked inside, on the bell or spigot end, the identification marks specified by the purchaser. These shall include, as specified, either the pressure for which the pipe or fitting is designed or the area of effective circumferential reinforcement per foot of pipe wall. Special marks of identification, sufficient to show the proper location of the pipe or fitting in the line by reference to layout drawings and schedules specified under Sec. 1.5, shall be placed on the pipe if specifically required. All beveled pipe shall be marked with the amount of the bevel, and the point of maximum pipe length shall be marked on the beveled end.

Sec. 1.7—Inspection and Testing by Purchaser

1.7.1—*Inspection at manufacturer's plant.* If the purchaser desires to inspect pipe and fittings at the manufacturer's plant, he shall so specify in the contract or agreement, stating the conditions (such as time, and the extent of inspection) under which the inspection shall be made.

1.7.2—*Access to work.* The purchaser 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 purchaser's use such gages as are necessary for inspection. The manufacturer shall provide the purchaser with assistance as necessary for the handling of pipe and fittings.

1.7.3—*Responsibility*. Inspection by the purchaser, or failure of the purchaser to provide inspection, shall not relieve the contractor of his responsibility to furnish materials and to perform work in accordance with this standard.

1.7.4—*Tests*. Tests under Sec. 1.9, made by the purchaser on material samples, shall be carried out without delay. If any sample fails to meet the requirements, the manufacturer shall be notified immediately. Material affected by the test results shall be set aside pending final disposition. The manufacturer may request a review of test procedures and additional tests on the material. Duplicate samples, the number of which is to be agreed upon, should be tested by the purchaser and by the manufacturer. The manufacturer's tests shall be performed by a commercial testing laboratory or in the manufacturer's laboratory, with proper certification. Tests by either party may be witnessed by the other. If the duplicate samples meet the test requirements, the material shall be accepted. If the material is rejected after retesting, the manufacturer shall pay all costs of retesting.

1.7.5—*Rejection*. Material, fabricated parts, and pipe that are discovered to be defective, or that do not conform to the requirements of this standard, will be subject to rejection at any time prior to final acceptance of the pipe. Rejected material and pipe shall be removed promptly from the site of the work.

Sec. 1.8—Material and Workmanship

All material furnished by the manufacturer shall be new and of the quality specified. All work shall be done in a thorough, workmanlike manner by mechanics skilled in their various trades. When a lower limit or minimum dimension is given herein for a steel component, the minus tolerance (as stated in the applicable ASTM specification) for such limit or dimension shall be understood to define the true lower limit or dimension.

Sec. 1.9—Tests

1.9.1—*Cylinder assembly*. Each completed cylinder with joint rings welded to its ends shall be subjected to a hydrostatic test as specified herein under Sec. 3.5.3.

1.9.2—*Concrete*. Samples of the mixed concrete shall be taken for making compression test cylinders as specified under Sec. 3.6.5 and 3.6.6.

1.9.3—*Steel reports*. Mill test reports or plant test reports on each heat from which the steel is rolled shall be obtained by the manufacturer and made available to the purchaser on request.

1.9.4—*Steel specimens*. The manufacturer shall provide test specimens, cut from each shipment of steel for cylinders and high-tensile wire, if required by the purchaser.

1.9.5—*Gasket rubber*. Test reports showing the physical properties of rubber used in the gaskets, as specified in Sec. 2.11.8, shall be obtained by the manufacturer and shall be made available to the purchaser on request.

1.9.6—*Expense*. The expense of testing the materials and of submitting to the purchaser test reports in accordance with this standard and the purchaser's supplementary specifications referred to in the foreword, and the expense of testing the completed steel cylinder in accordance with Sec. 1.9.1 and of testing concrete in accordance with Sec. 1.9.2, shall be borne by the manufacturer. All other tests shall be made by the purchaser at the purchaser's expense, except as otherwise specifically provided.

Sec. 1.10—Affidavit of Compliance

The purchaser may require an affidavit from the manufacturer that the pipe and fittings furnished under the purchaser's contract or agreement comply with all applicable provisions of this standard.

Section 2—Material Specifications

Sec. 2.1—Cement

2.1.1—*Type.* Cement for concrete work shall conform to the "Specifications for Portland Cement" (ASTM Designation C150). Either Type I or Type II may be used unless the purchaser specifies a particular type. Sampling and testing shall conform to the individual ASTM specifications designated therein.

2.1.2—*Inspection.* Satisfactory facilities shall be provided for identifying, inspecting, and sampling cement at the mill, the warehouse, and the site of the work. The purchaser shall have the right to inspect the cement and obtain samples for testing at any of these points.

2.1.3—*Storage.* Cement shall be stored in a weathertight, dry, well-ventilated structure.

2.1.4—*Unusable.* Cement salvaged by cleaning cement sacks, mechanically or otherwise, shall not be used in the work. Cement containing lumps shall be rejected and shall immediately be removed from the site of the work.

2.1.5—*Temperature.* If the temperature of the cement exceeds 150F, it shall be stored until cooled to that temperature.

Sec. 2.2—Fine Aggregate

2.2.1—*General.* Fine aggregate for concrete and mortar shall consist of clean, hard, durable, and uncoated particles of natural sand or of sand prepared from the product obtained by crushing stone or gravel. At the time of use the fine aggregate shall be entirely free of frozen material.

2.2.2—*Gradation.* Fine aggregate shall be well graded from coarse to fine and, when tested by means of laboratory sieves in accordance with the "Method of Test for Sieve or Screen Analysis of Fine and Coarse Aggregates" (ASTM Designation C136), shall conform to the gradation requirements in Table 1.

TABLE 1

Gradation Requirements for Fine Aggregate

Sieve Size	Total Passing, by Weight, %	
	Concrete Sand	Mortar Coating Sand
⅜ in.	100	100
No. 4	95–100	100
No. 8	65–98	93–100
No. 16	45–80	70–90
No. 30	20–70	45–65
No. 50	5–50	12–35
No. 100	2–10	3–12
No. 200	0–5	0–5

These gradation requirements represent the extreme limits for determining the suitability of fine aggregate under this standard. To maintain uniformity of gradation for aggregate from any given source, a fineness modulus determination shall be made upon representative samples from that source. Thereafter the fineness modulus of all shipments therefrom shall not vary more than ±0.20 from the fineness modulus of the representative sample, unless suitable approved mix adjustments are made.

2.2.3—*Impurities.* Fine aggregate shall be free from injurious amounts of organic impurities and shall conform to Sec. 4.2 of "Specifications for Concrete Aggregates" (ASTM Designation C33-71a).

Sec. 2.3—Coarse Aggregate

2.3.1—*General.* Coarse aggregate for concrete shall consist of hard, durable particles of crushed stone or crushed or uncrushed gravel, conforming to the requirements and tests given in Sec. 2.3.2 through 2.3.3.

2.3.2—*Gradation.* Coarse aggregate shall be well graded from coarse to fine. The maximum size and gradation shall be subject to the approval of the purchaser and shall be such that the concrete can be readily placed in the core or poured coating, by the particular method used in placing it, to provide a solid, compact, homogeneous wall with a smooth surface. Tests for gradation of coarse aggregate shall be in accordance with the "Method of Test for Sieve or Screen Analysis of Fine and Coarse Aggregates" (ASTM Designation C136). Thin and elongated pieces, the maximum dimension of which exceeds five times the minimum, shall not be in excess of 10 per cent of the coarse aggregate by weight.

2.3.3—*Impurities.* Deleterious substances in coarse aggregate shall not exceed the amounts given in Table 2, as determined by sampling and testing procedures listed in the "Specifications for Concrete Aggregates" (ASTM Designation C33).

TABLE 2

Permissible Amounts of Deleterious Substances in Coarse Aggregate

Material	Maximum Weight Limit, %
Soft particles	5.00
Coal and lignite	0.50
Clay lumps	0.25
Material finer than 200 sieve	1.00
Combined total of above items	5.00

Sec. 2.4—Samples of Aggregates

At least 4 weeks prior to mixing concrete, the manufacturer, if required, shall provide in suitable containers, for preliminary approval, samples of not less than 1 cu ft each of fine and coarse aggregate. All samples shall be plainly labeled to indicate the source of the material, the date, and the name of the collector. Methods of sampling aggregates shall be in accordance with the "Methods of Sampling Stone, Slag, Gravel, Sand, and Stone Block for Use as Highway Materials" (ASTM Designation D75).

Sec. 2.5—Water

Water used for concrete and for curing pipe shall be fresh water and shall be clean and free from oil, acid, strong alkalies, or vegetable matter.

Sec. 2.6—Admixtures

At the option of the manufacturer, the concrete may contain a water-reducing, set-controlling admixture conforming to the "Specification for Chemical Admixtures for Concrete" (ASTM Designation C494). No admixture shall contain calcium chloride. The type and amount of admixture shall be subject to the purchaser's approval.

Sec. 2.7—Steel for Cylinders and Fittings

2.7.1—*Steel sheets.* Steel sheets for pipe cylinders and fittings may be in cut lengths or coils and shall meet the requirements of the "Specification for Hot-Rolled Carbon Steel Sheets and Strip, Structural Quality" (ASTM Designation A570), Grade B or C, or "Specifications for Hot-Rolled Carbon Steel Sheets and Strip, Commercial Quality" (ASTM Designation A569), except that for ASTM A569 steel, the maximum carbon content may be 0.25 per cent and the minimum yield point shall be 27,000 psi.

2.7.2—*Steel plates.* Steel plates for pipe cylinders and fittings shall conform to "Specifications for Low and Intermediate Tensile Strength Carbon Steel Plates of Structural Quality" (ASTM Designation A283), Grade B or C.

Sec. 2.8—Steel for Wire, Bar and Wire-Mesh Reinforcement

2.8.1—*Prestressing wire.* The wire for circumferential reinforcement shall conform to "Specifications for Steel Wire, Hard-Drawn for Mechanical Springs" (ASTM Designation A227). Wire with specified minimum tensile strengths exceeding those in A227, Class II, may be used if the wire meets the other requirements for Class II in that specification, and the pipe design may be based on these higher strengths.

2.8.2—*Wire mesh.* Wire-mesh reinforcement for mortar coating for fittings shall conform to the "Specifications for Welded Steel Wire Fabric for Concrete Reinforcement" (ASTM Designation A185).

2.8.3—*Bars.* Steel-bar reinforcement for concrete for fittings shall conform to "Specifications for Carbon Steel Bars Subject to Mechanical Property Requirements" (ASTM Designation A306), Grade 80, or to "Specifications for Deformed Billet-Steel Bars for Concrete Reinforcement" (ASTM Designation A615–68), Grade 40, except that for plain bars supplied under ASTM A615–68, (1) the requirements of Sec. 6, 7, and 14.3 shall not apply; (2) intermediate bar diameters shall meet the requirements of the next smaller bar number designation; and (3) bar diameters less than No. 3 shall meet the requirements for No. 3 bar.

Sec. 2.9—Steel for Joint Rings

Steel for bell rings less than ¼ in. thick shall conform to "Specifications for Hot-Rolled Carbon Steel Sheets and Strip, Structural Quality" (ASTM Designation A570), Grade A, or to "Specifications for Hot-Rolled Carbon Steel Sheets and Strip, Commercial Quality" (ASTM Designation A569). Special shapes for spigot joint rings and steel for bell rings ¼ in. or more in thickness shall conform to "Specifications For Carbon Steel Bars Subject to Mechanical Property Requirements" (ASTM Designation A306), Grade 50, or to "Specifications for Low and Intermediate Tensile Strength Carbon Steel Plates of Structural Quality" (ASTM Designation A283), Grade A, or to "Specifications for Merchant Quality Hot-Rolled Carbon Steel Bars" (ASTM Designation A575), Grade 1012, or to "Specifications for Special Quality Hot-Rolled Carbon Steel Bars"

(ASTM Designation A576), Grade 1012, or to "Specifications for Steel Sheet and Strip, Carbon, Hot-Rolled Commerical Quality, Heavy-Thickness Coils (Formerly Plate)" (ASTM Designation A635).

Sec. 2.10—Steel Castings for Fittings

Steel castings for fittings shall conform to the "Specifications for Mild to Medium Strength Carbon Steel Castings for General Application" (ASTM Designation A27), Grade 70-36, normalized.

Sec. 2.11—Rubber for Gaskets

2.11.1—*General.* The gasket shall have smooth surfaces free from pitting, blisters, porosity, and other imperfections. The rubber compound shall contain not less than 50 per cent by volume of first-grade natural crude or first-grade synthetic rubber. The remainder of the compound shall consist of pulverized fillers free from rubber substitutes, reclaimed rubber, and deleterious substances. The compound shall meet the following physical requirements when tested in accordance with the indicated conditions and designated ASTM test methods.

2.11.2—*Tensile strength.* The tensile strength of the compound shall be at least 2,700 psi for natural rubber gaskets and 2,000 psi for synthetic rubber gaskets—"Method of Tension Testing of Vulcanized Rubber" (ASTM Designation D412).

2.11.3—*Elongation at rupture.* The elongation at rupture shall be at least 400 per cent for natural rubber gaskets and 350 per cent for synthetic rubber gaskets—"Method of Tension Testing of Vulcanized Rubber" (ASTM Designation D412).

2.11.4—*Specific gravity.* The specific gravity shall not vary more than ±0.05 within the range 0.95–1.45—"Methods for Chemical Analysis of Rubber Products" (ASTM Designation D297).

2.11.5—*Compression set.* The percentage of compression set shall not exceed 20. The compression set determination shall be made in accordance with "Methods of Test for Compression Set of Vulcanized Rubber" (ASTM Designation D395) Method B, with the exception that the disc shall be a ½-in.-thick section of the rubber gasket stock.

2.11.6—*Tensile strength after aging.* After being subjected to an accelerated aging test for 96 hr in air at 70C in accordance with "Method of Test for Accelerated Aging of Vulcanized Rubber by the Oven Method" (ASTM Designation D573) or in a pressure chamber for 48 hr at 70C in an oxygen atmosphere at 300 psi in accordance with "Method of Test for Accelerated Aging of Vulcanized Rubber by the Oxygen-Pressure Method" (ASTM Designation D572), the tensile strength of the compound shall be not less than 80 per cent of the tensile strength before aging.

2.11.7—*Shore durometer.* The Shore A durometer hardness shall be in the range of 50 to 65 and shall be determined in accordance with "Method of Test for Indentation Hardness of Rubber and Plastics by Means of a Durometer" (ASTM Designation D2240–68) with the exception of Sec. 4 thereof. The determination shall be taken directly on the gasket.

2.11.8—*Test reports.* If required by the purchaser, the manufacturer shall submit test reports showing the physical properties of the rubber compound used in the manufacture of the gaskets.

Section 3—Design and Fabrication of Pipe

Sec. 3.1—General Requirements

3.1.1—*Minimum laying length.* In general, pipe shall have a minimum nominal laying length of 16 ft unless shorter lengths are required by weight or other considerations.

3.1.2—*Diameter tolerances.* Pipe shall be round and true and shall have a smooth and dense interior surface. The mean internal diameter of any portion of each piece of pipe shall not be less than the design diameter or size specified by more than ¼ in. for 36-in. and smaller pipe; by more than ⅜ in. for 42-in. and 48-in. pipe; by more than ½ in. for 54- to 78-in. pipe; or by more than ¾ in. for 84-in. and larger pipe.

3.1.3—*Core and coating tolerances.* The minimum design thickness of the core, including the thickness of the cylinder, shall be $\frac{1}{16}$ of the design pipe diameter for normal applications. Thickness of cores shall be not less than the design thickness by more than ⅛ in. for 36-in. and smaller pipe; by more than $\frac{3}{16}$ in. for 42-in. and 48-in. pipe; by more than ¼ in. for 54- to 72-in. pipe; or by more than ⅜ in. for pipe larger than 72 in. The thickness of the mortar coating shall provide a minimum cover of ⅝ in. over the wire. The thickness of cast concrete coatings shall be 1½ in. and shall provide a minimum cover of 1 in. over the core.

Sec. 3.2—Design of Pipe

3.2.1—*General.* The reinforcement of the pipe shall consist of a welded steel cylinder in the core and high-tensile wire helically wrapped around the core under measured and uniform tension after the concrete in the core has been placed and cured. The minimum thickness of the cylinder shall be 18 gage up to and including 48-in. pipe and shall be 16 gage for 54-in. pipe and larger. The size of the high-tensile wire and the spacing and tension under which it is wound shall be such that the conditions required by the design methods in Appendix A or B are met. The designs shall fully recognize all losses due to elastic and inelastic deformations, such as relaxation of the wire and plastic strains in the concrete. The average gross wrapping stress in the high-tensile wire shall not exceed 75 per cent of the minimum ultimate tensile strength of the wire. The wire shall not be smaller than 0.162 in. in diameter. The minimum centerline spacing of the wire shall be that which produces a clear distance of $\frac{3}{16}$ in. between wires in the same layer of reinforcement. The centerline spacing of the wire shall not exceed 1½ in. For lined-cylinder pipe with wire larger than 0.192 in., the maximum centerline spacing of the wire shall be 1 in. The manufacturer shall submit design calculations for approval prior to the manufacture of any pipe, if required by the purchaser.

3.2.2—*Requirements for normal operating conditions.* Normal operating conditions shall be defined as a combination of internal design pressure (as defined in Sec. 1.2.7) and external earth (dead) load.

All pipe shall be designed for a combination of internal design pressure of at least 40 psi and at least 6 ft of earth cover with "ordinary" * bedding, or such greater pressures and earth loads

* "Ordinary" bedding is defined as Class C in "Design and Construction of Sanitary and Storm Sewers," Manual of Engineering Practice No. 37, ASCE, Rev. 1969, pp. 212–213.

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as may be specified in the supplementary specifications or as shown on the purchaser's drawings. The combination design shall be as described in either Appendix A or B in accordance with standard practice. Maximum internal design pressures for lined-cylinder pipe using minimum core thicknesses, 18-gage cylinders, and centrifugal concrete strengths required by Sec. 3.6.8 shall be 250 psi for 16- to 20-in. pipe; 200 psi for 24- to 36-in. pipe; 175 psi for 42-in. pipe; and 150 psi for 48-in. pipe. Higher internal design pressures are permissible using thicker cores, heavier cylinders, or higher concrete strengths, either singly or in combination. Maximum internal design pressures for embedded-cylinder pipe are limited only by the strength requirements of the component materials.

3.2.3—*Provisions for transient conditions.* The design methods for normal operating conditions under Appendix A or B provide for surge pressures of at least 40 per cent of design pressure and for live load (including impact) at least equal to American Assn. of State Highway Officials H20 loading. If surge pressure or live load exceeds these limits for a given design condition, such greater value shall be stated in the supplementary specifications.

In all designs the following combinations shall not exceed the design limits for the transient-condition requirements of Appendix A or B: (1) design or normal operating pressure plus surge pressure in combination with earth dead load; or (2) design or normal operating pressure in combination with earth dead load plus external live load, including impact.

Sec. 3.3—Joint Rings

The steel bell and spigot joint rings shall be so designed and fabricated that when the pipe is laid it will be self-centered. The rings shall be accurately formed and finished to obtain a close, sliding fit for the self-centered surfaces. Each ring shall be formed by one or more pieces of steel butt-welded together, either by a resistance welder or by a hand electric weld. Welds on gasket contact surfaces shall be ground smooth and flush with the adjacent surfaces. The rings shall be expanded by a press beyond their elastic limits so that they are accurately sized.

On the finished pipe, the circumference of the inside bell-ring contact surface shall not exceed the circumference of the outside spigot-ring contact surface by more than $\frac{3}{16}$ in. for gaskets $\frac{21}{32}$ in. in diameter or less and $\frac{1}{4}$ in. for gaskets greater than $\frac{21}{32}$ in. in diameter. The out-of-roundness of either contact surface, measured as the difference between the maximum and minimum joint-ring diameters, shall not exceed 0.5 per cent of the average of these diameters. The minimum thickness of the completed bell rings shall be $\frac{3}{16}$ in. for 36-in. and smaller pipe and $\frac{1}{4}$ in. for pipe larger than 36 in. The rings shall conform to the details submitted by the manufacturer and approved by the purchaser. The joint rings shall be so designed that, when the pipe is laid and the joint completed, the gasket will be enclosed on all four sides. The contact surfaces shall be such as to prevent cutting of the rubber gasket during installation. The portions of the joint rings that will be exposed on the completed pipe shall be protected from corrosion by an approved coating.

Sec. 3.4—Rubber Gaskets

Joints shall be sealed with a continuous solid-ring rubber gasket having a circular cross section with a diametral tolerance of $\pm\frac{1}{64}$ in. Gaskets shall be of sufficient volume substantially to fill the recess provided when the pipe joint is assembled, so that the gasket will be compressed to form a pressure-tight seal. The gasket shall be the sole element depended upon to make the joint watertight.

Sec. 3.5—Fabrication of Steel Cylinders

3.5.1—*General.* The cylinders shall be formed by shaping and welding together cut lengths or coils of specified material and thickness. The cylinders shall be accurately shaped to the size required and the joint rings shall be welded to the ends before testing.

3.5.2—*Welding.* Butt welding or offset lap welding of the longitudinal and circumferential or helical seams shall be used to produce a smooth and continuous external surface when wire is to be wrapped directly on the cylinder. The manufacturer may use either butt welding or lap welding for longitudinal and circumferential or helical welds, if the cylinder is encased in the concrete core. Prior to welding, the sheets shall be fitted closely and shall be held firmly during welding. The manufacturer shall submit for approval, if required, the specific details of materials and methods he proposes to use before any welding is done.

3.5.3—*Hydrostatic test.* Each steel cylinder, with joint rings welded to its ends, shall be subjected to a hydrostatic test. When the cylinder is tested in a horizontal position, the stress shall be at least 20,000 psi but not greater than 25,000 psi. When the cylinder is tested in a vertical position, the stress at the lower end shall be 25,000 psi. While under pressure test, all welds shall be thoroughly inspected and all parts showing leakage shall be marked. Cylinders that show any leakage under test shall be rewelded at the points of leakage and subjected to another hydrostatic test. The finished cylinder, with joint rings attached, shall not be used in the work unless it is completely watertight under the required test pressure.

3.5.4—*Cleaning steel surfaces.* Before the concrete core and mortar coating are placed, each steel cylinder shall be cleaned to remove loose or other foreign matter that would interfere with the bonding of the concrete and mortar.

Sec. 3.6—Concrete for Pipe Core

3.6.1—*General.* The concrete in the cores may be placed by the centrifugal method, by the vertical casting method, or by other approved methods.

3.6.2—*Proportioning.* The proportions of cement, fine aggregate, coarse aggregate, and water used in concrete for pipe cores shall be subject to the approval of the purchaser. The proportions shall be determined and controlled as the work proceeds to obtain homogeneous, dense, workable, durable concrete of specified strength in the walls of the pipe and a minimum of defects in the surface of the pipe. The proportions shall be those that will give the best overall results with the particular materials and method of placing used for the work. A minimum of six bags of cement shall be used for each cubic yard of concrete. The water-cement ratio shall be such as to assure that the concrete will meet the strength requirements.

3.6.3—*Measurement of materials.* A barrel of cement shall be considered as 4 cu ft or 376 lb and a bag of cement shall be considered as 1 cu ft or 94 lb. Cement in standard sacks need not be weighed, but bulk cement shall be weighed. Water for mixing shall be measured by volume or by weight. Concrete aggregates for each batch shall be measured separately by weighing. The proportions of aggregates shall be computed on the saturated and surface-dry basis and the water-cement ratio shall be exclusive of water within the aggregates and absorbed by them. The equivalent unit weights for both fine and coarse aggregates shall be determined in accordance with the "Method of Test for Unit Weight of Aggregate" (ASTM Designation C29). The equipment and devices for weighing and measuring shall at all times be accurate within 1 per cent.

3.6.4—*Mixing*. The mixing shall be done thoroughly by a mixer of approved type. Mixing time shall be consistent with the type of mixer used. Transit mixing shall not be used except by written authorization and under specific requirement of the purchaser.

3.6.5—*Standard test cylinders*. A set of at least four standard test cylinders shall be taken from each day's pour of the mixed concrete for pipe cores made by the centrifugal method, the vertical casting method, or other approved methods. Standard test cylinders shall be made in conformance with the "Method for Making and Curing Concrete Compressive and Flexural Test Specimens in the Field" (ASTM Designation C31). The curing of the test cylinders shall be in conformity with the curing of the pipe cores.

3.6.6—*Centrifugal test cylinders*. Centrifugally cast test cylinders may be substituted for standard test cylinders, at the option of the manufacturer, when the centrifugal method is used for making cores. A set of at least four test cylinders shall be taken each day from the mixed concrete for cores. Test cylinders shall be centrifugally cast in 6-in.-diameter by 12-in.-long steel molds spun about their longitudinal axes, at a speed that will simulate the compaction of concrete in the cores, to produce a spun-cylinder wall thickness of about 2 in. The curing of the test cylinders shall be in conformity with the curing of the cores. The net area of the hollow cylinder shall be used to determine its compressive strength.

3.6.7—*Testing cylinders*. All test cylinders shall be tested by an approved testing laboratory at the expense of the manufacturer, unless the manufacturer has approved testing facilities at the site of the work. In such an event, the tests shall be made by and at the expense of the manufacturer in the presence of the purchaser, or, if permitted by the purchaser, certified test reports may be submitted by the manufacturer.

3.6.8.—*Strength of concrete*. Standard concrete cylinders shall attain a minimum compressive strength of 3,000 psi in seven days and 4,500 psi in 28 days. Centrifugal test specimens shall attain a minimum compressive strength of 4,000 psi in seven days and 6,000 psi in 28 days. The compressive strength at the time of wrapping shall conform to the requirements in Sec. 3.8. To conform to the requirements of this section, the average of any ten consecutive strength tests of cylinders representing each type of concrete shall be equal to or greater than the specified strength, and not more than 20 per cent of the strength tests shall have values less than the specified strength. Pipe made from concrete that does not meet the strength tests in accordance with the foregoing shall be subject to rejection.

3.6.9.—*Placing concrete by centrifugal method*. The steel pipe cylinder with joint rings attached shall be placed horizontally in a spinning machine and may be held by a spinning frame. The spinning machine shall be capable of revolving the cylinders at speeds that will produce concrete meeting the requirements of Sec. 3.6.8 and 3.8. The method of placing concrete in the cylinder and the speed of rotation during placing shall be such that the concrete will be evenly distributed and well compacted at the specified thickness throughout the length of the pipe. After the concrete has been deposited, the rotation shall be continued at a speed and for a length of time sufficient to provide the specified strength and sufficient compaction and bond to permit removal from the spinning machine without injury to the pipe core. Excess water and laitance shall be removed from the interior surfaces of the pipe in an approved manner so that the surface is solid, straight, and true.

3.6.10—*Placing concrete by vertical casting method.* The concrete lining or core shall be cast on end on a cast-iron or steel base ring with rigid steel collapsible forms for the concrete surfaces. The forms shall be so designed that they will have smooth contact surfaces and tight joints and will be firmly and accurately held in proper position without distortion during the placing of the concrete. The forms shall be provided with top and bottom stiffening rings and shall be designed to permit removal without injury to the inside surface of the pipe. The forms shall be thoroughly cleaned and oiled before each use. The transporting and placing of concrete shall be carried out by approved methods that will not cause the separation of concrete materials and the displacement of the steel cylinder or forms from their proper position. Approved methods of mechanical vibrating shall be used to compact the concrete in the forms and to secure satisfactory interior surfaces. Forms shall not be removed until the concrete has set sufficiently to avoid spalling or damage to the pipe during the process of form removal.

3.6.11—*Other methods of placing the lining.* If the manufacturer proposes to employ a method other than the centrifugal or vertical casting method for placing the concrete lining or core, he shall submit for approval complete details of the methods and equipment he proposes to use.

Sec. 3.7—Curing of Core

3.7.1—*General.* The purpose of curing pipe cores as specified next is to obtain concrete of the strength specified for test cylinders under Sec. 3.6.8. The cores shall be cured by steam or by water unless otherwise specifically permitted. Water and steam curing may be used interchangeably on a time ratio basis of 4 hr of water curing to 1 hr of steam curing, except that water curing may be used only if the minimum ambient temperature exceeds 40F.

3.7.2—*Steam curing.* The cores shall be placed in the steam-curing chamber or otherwise covered by a suitable enclosure that will allow proper circulation of steam. A delay period of from 1 to 4 hr shall be allowed before moist steam is admitted in contact with the cores. The temperature within the enclosure shall be gradually raised to at least 110F and not more than 150F for a period of at least 24 hr. The preset time shall be included in the 24-hr period. Curing by steam shall be continuous except during a period sufficient to remove the forms or supporting rings. The forms shall not be removed until at least 6 hr after the beginning of curing. After this minimum 6-hr period, the cores may be "tipped" from their bases and curing shall be continued by either steam or water.

3.7.3—*Water curing.* The cores shall be kept moist by intermittent water spraying for a period of at least 32 hr. The water-curing period shall be continued 1 hr for each hour, in the first 24, during which the ambient temperature is below 50F. Following this minimum period, they may be "tipped" from their bases and removed to the storage yard where they shall be kept continuously moist by intermittent spraying for an additional period of at least three days.

Sec. 3.8—Placing of Wire Reinforcement

The high-tensile wire shall not be wound around the core until the concrete has reached the minimum seven-day compressive strength specified under Sec. 3.6.8 of this standard. The initial compression in the concrete shall not exceed 55 per cent of the compressive strength of the concrete at the time of wrapping. Methods and equipment for applying the wire shall be such that it will be wrapped around the core in a helical form at the designed predetermined spacing and tension for the full length of the core, except that at the ends of the core there shall be an extra complete circumferential wrap of wire that may be applied at one half the design tension. The number of coils in any 2-ft length of core shall be not less than required by the design. Wire splices shall be capable of withstanding a force equal to the minimum specified ultimate tensile strength of the wire. Anchorages of the wire at the ends of the core shall be capable of resisting a force equal to 75 per cent of the specified minimum ultimate tensile strength of the wire.

If multiple layers of circumferential reinforcement are used, each layer but the last shall be coated with cement mortar applied in accordance with Sec. 3.9 to provide a minimum cover over the reinforcement at least equal to the diameter of the wire and steam-cured in accordance with Sec. 3.10.2 for a period of not less than 8 hr. The first layer of reinforcement shall be wound on the surface of the core, and subsequent layers shall be wound over the previous layers of cement mortar as specified in this section. The final coating of cement mortar shall be applied in accordance with Sec. 3.9, shall provide the minimum cover over the reinforcement specified in Sec. 3.1.3, and shall be cured in accordance with Sec. 3.10.

Sec. 3.9—Pipe Coating

3.9.1—*General.* After the core has been wrapped with high-tensile wire, an exterior mortar or concrete coating shall be applied.

3.9.2—*Mortar coating.* Mortar for coating shall consist of one part cement to not more than three parts fine aggregate. Cement and fine aggregate shall conform to Sec. 2.1 and 2.2 herein. Rebound not to exceed one fourth of the total mix weight may be used, but the resulting mix proportions shall not be leaner than those just specified. Rebound not used within 1 hr shall be discarded. The mortar shall be thoroughly mixed, and, after mixing is completed, it shall be deposited under impact by an approved method so that a dense, durable encasement is obtained. Concurrently with the mortar coating, a cement slurry consisting of one sack of cement to not more than 8 gal of water shall be applied to the core just ahead of the mortar coating.

3.9.3—*Concrete coating.* Concrete for coating shall be of an approved mix. The proportions shall be those that will give the best overall results with the particular materials and methods of placing used for the work. A minimum of seven bags of cement shall be used for each cubic yard of concrete. The fine and coarse aggregates and cement shall meet the requirements of Sec. 2.1, 2.2 and 2.3 of this standard, except that the grading of coarse aggregate shall be such that it will all pass a ⅜-in. laboratory sieve. The concrete shall be placed and compacted by approved methods and equipment to produce a dense, durable coating.

3.9.4—*Strength.* Concrete for coating shall develop a minimum compressive strength of 3,000 psi in seven days and 4,500 psi in 28 days in accordance with Sec. 3.6.8.

Sec. 3.10—Curing of Coating

3.10.1—*General.* The coating outside the core shall be cured by steam or by water unless otherwise specifically permitted. Water and steam curing may be used interchangeably on a time ratio basis of 4 hr of water curing to 1 hr of steam curing, except that water curing may be used only if the minimum ambient temperature exceeds 40F. Adequate space and facilities shall be provided for proper curing.

3.10.2—*Steam curing.* The coated pipe shall be placed in the curing chamber as soon as practicable after placing the coating and shall be steam-cured as specified under Sec. 3.7.2 for a period of at least 12 hr. The pipe shall be handled in such a manner as to avoid injury to the coating during transportation to and from the curing chamber.

3.10.3—*Water curing.* As soon as the coating has set sufficiently, it shall be kept moist by intermittent spraying for a period of at least four days. The water-curing period shall be continued 1 hr for each hour, in the first 24, during which the ambient temperature is below 50F.

Sec. 3.11—Seal Coat

If the purchaser specifically orders a bituminous seal coat, the materials and application shall comply with the appropriate provisions of AWWA C104 (ANSI A21.4) insofar as they are applicable. The material shall be applied after the pipe is cured.

Section 4—Fittings and Special Pipe

Sec. 4.1—General

Fittings and special pipe shall include closures, connections to main line valves, bends, tees, wyes, beveled pipe for curves, and pipe with outlets required for manholes, air valves, and blowoffs as shown on the purchaser's drawings or ordered by the purchaser. Fittings shall conform to the details furnished by the purchaser, or, if required, to the details furnished by the manufacturer and approved by the purchaser. Fittings shall be either type as described in Sec 4.2 or 4.3 at the option of the manufacturer and shall be designed for the same conditions as the pipe.

Sec. 4.2—Fittings (Type A)

Type A fittings are composed of steel cylinders, concrete or mortar lining, and reinforced concrete or mortar exterior coating. The steel for the cylinder shall be cut, shaped, and welded to form the properly shaped bend, tee, reducer, or fitting. The welds shall be inspected and the completed cylinder shall be tested for tightness by the dye penetrant or other approved method, if specifically required by the purchaser. A cage or cages of steel reinforcement with approved cross-sectional areas shall be formed around the cylinder and openings. Longitudinal reinforcement sufficient for additional stresses in the fitting walls shall be provided. The interior and exterior concrete or mortar shall be placed in an approved manner. Curing shall be as specified in Sec. 3.10 herein.

Sec. 4.3—Fittings (Type B)

Type B fittings are composed of cut and welded steel plate of approved thickness, with mortar coating on interior and exterior surfaces.

4.3.1—*Steel plate.* The steel for the fabricated steel plate fittings shall be cut, shaped, and welded so that the finished fitting shall have the required shape and interior dimensions. The deflection angle between adjacent segments of a bend shall be not greater than 22½ deg. Adjacent segments shall be joined by lap or butt welding. Fabrication and welding shall conform to the requirements of Sec. 3.5.1 and 3.5.2 of this standard. The welds shall be inspected and the completed cylinder shall be tested for tightness by the dye penetrant or other approved method, if specifically required by the purchaser.

4.3.2—*Reinforcement.* Wire mesh reinforcing shall be applied to the interior and exterior surfaces of the fabricated fitting. Mesh shall be 2- by 4-in. W1 welded-wire fabric, held ⅜ in. from the surfaces of the steel plate. The members on the 2-in. spacing shall extend circumferentially around the fitting with ends overlapped 4 in. and tied together. Longitudinal splices shall be staggered.

4.3.3—*Mortar.* Steel plate fittings shall be lined with mortar at least ¾ in. thick, except at adapter ends or outlets but under no conditions shall the lining be less than ⅜ in. thick. The exterior shall be coated with mortar at least 1 in. thick. The mortar shall contain not less than one part cement to three parts sand, of a grading approved for the method of application used.

4.3.4—*Curing.* Mortar-coated fittings shall be cured by water spraying, by steam, or by curing compounds.

Sec. 4.4—Curves, Bends, and Closures

Long-radius curves and small angular changes in pipe alignment shall be formed by deflecting joints, by straight pipe with beveled ends, by bevel adapters, or by a combination of these. Pipe ends may be beveled up to 5 deg. Short-radius curves and closures shall be formed by fittings.

Sec. 4.5—Openings and Connections

Manholes and flanges, spigot or bell connections for air valves, blowoffs, or connections to other pipe shall be built into the walls of the concrete pipe at locations shown on the purchaser's drawings or ordered by the purchaser. Wall openings shall be suitably reinforced. The high-tensile wire shall be securely fastened on each side of the outlet or shall be wrapped continuously from one side of the opening to the other. The casting or fabricated outlet shall be welded to the saddle plate or saddle neck after the hole is cut through the plate, cylinder, and concrete. If required, the interior and exterior surfaces of structural-steel connections shall be lined and coated with mortar. Alternative outlet designs may be used, if specifically approved by the purchaser.

Appendix A

Cubic Parabola Design Method

This appendix is for information only and is not part of AWWA C301-72

The wire area, tension, and spacing under which the wire is wound and the core thickness shall be varied so that the specific combination of design pressure and earth load will fall on or under the design curves in Fig. A (a and b). The resulting design has a transient-load capacity equal to the difference between the design pressure or earth load and the value determined from the extension of the appropriate line for surge pressure or live load until it intersects the transient-load curve. If surge pressure exceeds 40 per cent of design pressure or live load (including impact) exceeds the American Association of State Highway Officials H-20 loading, this greater value should be stated in the supplementary specifications.

The design curve is defined by the following equation:

$$w = \frac{W_o}{\sqrt[3]{P_o}}\left[\sqrt[3]{P_o - p}\right]$$

in which P_o is the internal pressure required to overcome all compression in the core concrete, exclusive of the effect of external load; W_o is nine tenths of the three-edge-bearing load producing incipient cracking in the core, with no internal pressure; p is the maximum design pressure in combination with three-edge-bearing load, w, and is not to exceed 0.8 P_o for lined cylinder pipe [Fig. A (a)]; w is the maximum three-edge-bearing load, equivalent to earth load, in combination with design pressure p.

Three-edge-bearing values of W_o used for design shall be conservatively based on the manufacturer's accumulated test results. Supporting test data shall be provided if required by the engineer.

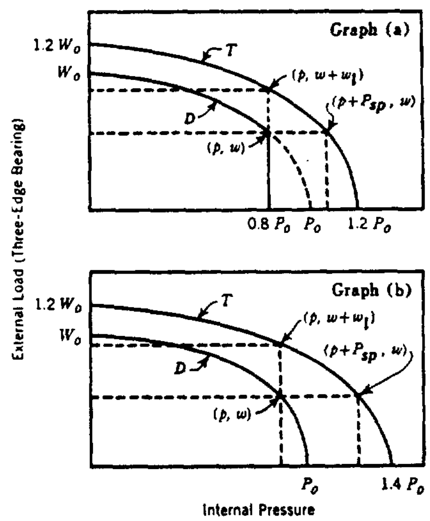

Fig. A. Design and Transient-Capacity Curves for Lined and Embedded Cylinder Pipe Using Cubic Parabola Design Method

Graph (a) is for lined- and Graph (b) for embedded-cylinder pipe. In both graphs, T designates the transient-load curve and D the design curve; w_l is for the three-edge-bearing load equivalent to live load; and P_{sp} is for surge pressure in excess of the normal operating or design pressure.

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Appendix B

Stress Analysis Design Method

This appendix is for information only and is not part of AWWA C301–72

The wire area, tension, and spacing under which the wire is wound and the core thickness shall be varied so that the specific combination of design pressure and earth load will fall on or under the design curve illustrated in Fig. B (a and b). The resulting design has a transient-load capacity equal to the difference between the design pressure or earth load and the value determined from the extension of the appropriate line for surge pressure or live load until it intersects the transient-load curve. If surge pressure exceeds 40 per cent of design pressure, or live load (including impact) exceeds the American Association of State Highway Officials H-20 loading, this greater value should be stated in the supplementary specifications.

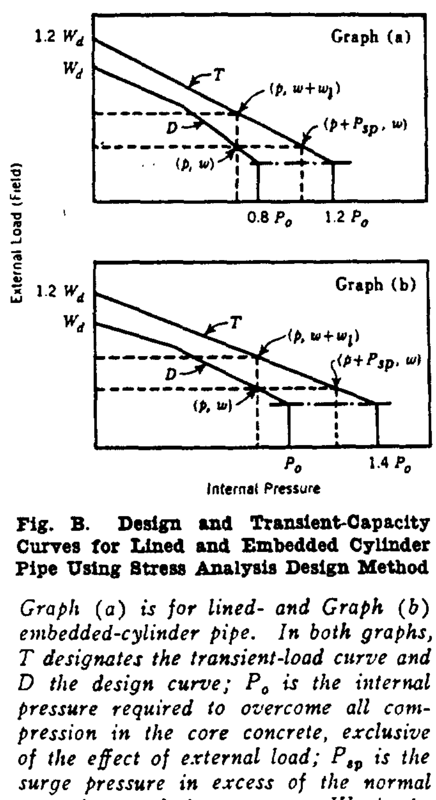

Fig. B. Design and Transient-Capacity Curves for Lined and Embedded Cylinder Pipe Using Stress Analysis Design Method

Graph (a) is for lined- and Graph (b) embedded-cylinder pipe. In both graphs, T designates the transient-load curve and D the design curve; P_o is the internal pressure required to overcome all compression in the core concrete, exclusive of the effect of external load; P_{sp} is the surge pressure in excess of the normal operating or design pressure; W_d is the maximum design field external load with internal pressure equal to zero; and w_l is the live load in excess of the external dead load.

The design curve is defined by the following equation:

$$p = \left[f_{cr} + 7.5\sqrt{f'_c} - \frac{M}{S} \pm \frac{F}{A_t}\right]\frac{A_t}{12R_y}$$

in which p is the maximum design pressure in combination with field external load, w, and is not to exceed 0. P_o for lined-cylinder pipe [Fig. B(a)]; f_{cr} is the resultant induced compression; $7.5\sqrt{f'_c}$ is the allowable tensile stress where f'_c is the specified 28-day compressive strength of the concrete; M is the total moment in the pipe section due to pipe weight, water weight, and external load; F is the total thrust in the pipe section due to pipe weight, water weight, and external load; S is the section modulus of the control pipe section based on the total pipe wall at the crown and invert sections and on the core only at the side section; A_t is the transformed cross-sectional area of the control section based on the total pipe wall at the crown and invert sections and on the core only at the side section; and R_y is the outside radius of steel cylinder.

The coefficients for moment and thrust calculations shall be from recognized and accepted theories, examples of which are to be found in "Coefficients for Large Horizontal Pipes," by J. H. Paris [*Eng. News-Record,* vol. 87, p. 768 (1921)]; and "Stress Analysis of Concrete Pipe," by H. C. Olander [Eng. Monograph No. 6 US Bureau of Reclamation, Dept. of the Interior, Washington, D.C.].

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