Designation: C361 – 16

Standard Specification for Reinforced Concrete Low-Head Pressure Pipe[1]

This standard is issued under the fixed designation C361; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This specification covers reinforced concrete pipe intended to be used for the construction of pressure pipelines with low internal hydrostatic heads generally not exceeding 125 ft.

1.2 This specification is the inch-pound companion to Specification C361; therefore, no SI equivalents are presented in the specification.

NOTE 1—Field tests on completed portions of the pipeline are not covered by this specification for the manufacture of the pipe but should be included in specifications for pipe laying.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A27/A27M Specification for Steel Castings, Carbon, for General Application

A36/A36M Specification for Carbon Structural Steel

A283/A283M Specification for Low and Intermediate Tensile Strength Carbon Steel Plates

A575 Specification for Steel Bars, Carbon, Merchant Quality, M-Grades

A576 Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality

A615/A615M Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement

A675/A675M Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties

A706/A706M Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement

A1008/A1008M Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Solution Hardened, and Bake Hardenable

A1011/A1011M Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength

A1064/A1064M Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field

C33/C33M Specification for Concrete Aggregates

C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C150/C150M Specification for Portland Cement

C260/C260M Specification for Air-Entraining Admixtures for Concrete

C309 Specification for Liquid Membrane-Forming Compounds for Curing Concrete

C497M Test Methods for Concrete Pipe, Manhole Sections, or Tile (Metric)

C595/C595M Specification for Blended Hydraulic Cements

C618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

C655 Specification for Reinforced Concrete D-Load Culvert, Storm Drain, and Sewer Pipe

C822 Terminology Relating to Concrete Pipe and Related Products

C1602/C1602M Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete

C1619 Specification for Elastomeric Seals for Joining Concrete Structures

D698 Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3))

D4253 Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table

[1] This specification is under the jurisdiction of ASTM Committee C13 on Concrete Pipe and is the direct responsibility of Subcommittee C13.04 on Low Head Pressure Pipe.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

D4254 Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density

2.2 *Other Standards:*

ACI Code 318 Standard Building Code Requirements for Reinforced Concrete[3]

AISI-C 1012[4]

ASCE 15-93 Standard Practice for Direct Design of Buried Precast Concrete Pipe Using Standard Installations (SIDD)

3. Terminology

3.1 *Definitions*—For definitions of terms relating to concrete pipe, see Terminology C822.

4. Classification

4.1 Pipe manufactured according to this specification shall be for hydrostatic heads of 25, 50, 75, 100, and 125 ft measured to the centerline of the pipe. Designs are provided in Table 1 for the above hydrostatic heads combined with external loadings of 5, 10, 15, and 20 ft (designated *A*, *B*, *C*, and *D* in Table 1) of earth cover over the top of the pipe under specific installation conditions. The specific installation conditions are covered in Appendix X1. Where the hydrostatic head, external loadings, and installation conditions vary from those given in Table 1 and Appendix X1, detailed design calculations shall be made. The design criteria for Table 1 are presented in Appendix X2.

5. Basis of Acceptance

5.1 Acceptability of the pipe in all diameters and classes shall be determined by the results of such material tests as are required in 6.2 through 6.9 by crushing tests on cured concrete cylinders, by hydrostatic pressure tests on units of the pipe, by joint leakage tests, and by inspection during or after manufacture to determine whether the pipe conforms to this specification as to design and freedom from defects.

5.2 *Age for Acceptance*—Pipe shall be considered ready for acceptance when they conform to the requirements, as indicated by the specified tests.

6. Materials

6.1 *Reinforced Concrete*—The reinforced concrete shall consist of portland cement, mineral aggregates, and water, in which steel has been embedded in such a manner that the steel and concrete act together. Fly ash or pozzolan is not prohibited when used as a partial cement replacement; see 9.1.

6.2 *Cementitious Materials:*

6.2.1 *Cement:*

6.2.1.1 *Portland Cement*—Portland cement shall conform to the requirements of Specification C150/C150M.

6.2.1.2 *Blended Hydraulic Cement*—Blended cement shall conform to the requirements of Specification C595/C595M for Type IS portland blast furnace slag cement or Type IP portland pozzolan cement, except that the pozzolan constituent in the Type IP portland pozzolan cement shall not exceed 20 % by weight.

6.2.2 *Fly Ash or Pozzolan*—Fly ash or pozzolan shall conform to the requirements of Specification C618.

6.2.3 *Allowable Cementitious Materials*—The combination of cementitious materials used in the concrete shall be one of the following:

6.2.3.1 Portland cement only,

6.2.3.2 Portland blast furnace slag cement only, or

6.2.3.3 Portland pozzolan cement only.

6.2.3.4 A combination of portland cement and fly ash or pozzolan, wherein the proportion of fly ash or pozzolan is between 5 and 20 % by weight of total cementitious material (portland cement plus fly ash or pozzolan).

6.3 *Aggregates*—Aggregates shall conform to Specification C33/C33M, except that the requirements for grading are waived.

6.4 *Admixtures*—Admixtures, except for air-entraining agents, shall not be added to the concrete unless permitted by the owner. At the option of the manufacturer, or if specified by the owner, the concrete in precast concrete pipe placed by the cast-and-vibrated method shall contain an air-entraining agent conforming to Specification C260/C260M. The amount of air-entraining agent used shall be such as will affect the entrainment of not more than 3 % air by volume of concrete as discharged from the mixer.

6.5 *Steel Reinforcement*—Reinforcement shall consist of wire conforming to Specification A1064/A1064M, or of bars of Grades 40 or 60 steel conforming to Specification A615/A615M or of Grade 40 steel conforming to Specification A36/A36M, or Grade 60 steel conforming to Specification A706/A706M.

6.6 *Steel for Joint Rings:*

6.6.1 Steel strips for bell rings less than ¼ in. thick shall conform to Grade SS30 of Specification A1011/A1011M or Grade Designation 1012 of Specification A575. Steel that meets the requirements of AISI-C1012 for chemical components will be acceptable provided it conforms to Grade SS30 of Specification A1011/A1011M in other respects.

6.6.2 Steel plate for bell rings ¼ in. or more in thickness and special shapes for spigot joint rings shall conform to Specification A36/A36M, or to Grade A of Specification A283/A283M, or to Grade Designation 1012 of Specification A576, or to Grade 50 of Specification A675/A675M. Steel that meets the requirements of AISI-C1012 for chemical components will be acceptable provided it conforms to Specification A36/A36M or to Specification A283/A283M Min other respects.

6.7 *Steel Castings for Fittings*—Steel castings for fittings shall conform to Grade 70-36, Normalized, of Specification A27/A27M.

6.8 *Steel Plates and Sheets for Specials and Fittings*—Steel plates for specials and fittings shall conform to Specification A36/A36M or to Grade B or C of Specification A283/A283M or Grade SS30 or SS33 of Specification A1011/A1011M or Grade SS30 of Specification A1008/A1008M.

[3] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.concrete.org.

[4] Available from American Iron and Steel Institute (AISI), 1140 Connecticut Ave., NW, Suite 705, Washington, DC 20036, http://www.steel.org.

TABLE 1 Design Requirements for Reinforced Concrete Low-Head Pressure Pipe [12 Through 144 in. Diameter], Concrete Design Strength 5000 psi except as noted, Steel Reinforcement Yield Strength 40 000 psi

NOTE 1—See Appendix for specific installation conditions and design criteria conditions required in conjunction with the use of Table 1.

NOTE 2—Designations, A, B, C, and D, for class of pipe, denote 5, 10, 15, and 20 ft of earth cover over top of pipe. Figures 25, Figures 50, Figures 75, etc. for class of pipe, denote hydrostatic pressure heads in feet measured to centerline of pipe.

NOTE 3—An "s" in place of a steel area indicates the pipe class is a special design requiring stirrup reinforcement. Stirrups may be eliminated by changing wall thickness, main reinforcement, concrete strength, or a combination thereof.

NOTE 4—The **boldfaced** value denotes 6000 psi concrete strength required.

Circumferential reinforcement, in.²/linear ft of pipe																								
Internal Designated Dia, in.	12		15		18				21				24				27							
Type of Reinforcement	Circular		Circular		Circular		Elliptical		Circular		Elliptical		Circular		Elliptical		Circular						Elliptical	
Wall Thickness, in.	2	3	2	3	2¼	3	2¼	3	2⅜	3	2⅜	3	2½	3	2½	3	2⅝	3⅛	3¼		4¼		2⅝	3¼
Layers of Reinforcement	Single	Single	Single	Single	Single	Single	Single	Single	Single	Single	Single	Single	Single	Single	Single	Single	Single	Single	Inner	Outer	Inner	Outer	Single	Single
Class																								
A-25	0.07	0.06	0.09	0.08	0.12	0.10	0.12	0.12	0.15	0.13	0.15	0.14	0.18	0.17	0.18	0.17	0.22	0.20	0.14	0.09	0.11	0.07	0.22	0.17
B-25	0.10	0.08	0.14	0.11	0.18	0.15	0.18	0.15	0.23	0.20	0.23	0.20	0.29	0.25	0.29	0.25	0.35	0.30	0.21	0.13	0.16	0.10	0.35	0.21
C-25	0.13	0.10	0.20	0.15	0.25	0.20	0.25	0.20	0.33	0.27	0.33	0.27	0.41	0.35	0.41	0.35	0.50	0.42	0.28	0.17	0.21	0.12	0.50	0.28
D-25	0.17	0.13	0.26	0.18	0.33	0.26	0.33	0.26	0.43	0.34	0.43	0.34	0.55	0.45	0.55	0.45	0.68	0.55	0.36	0.21	0.26	0.14	0.68	0.36
A-50	0.10	0.10	0.13	0.13	0.16	0.15	0.25	0.25	0.20	0.18	0.29	0.29	0.24	0.22	0.33	0.33	0.28	0.26	0.18	0.14	0.15	0.12	0.37	0.37
B-50	0.13	0.11	0.18	0.15	0.23	0.20	0.25	0.25	0.29	0.25	0.29	0.29	0.35	0.31	0.35	0.33	0.41	0.37	0.25	0.18	0.20	0.14	0.41	0.37
C-50	0.16	0.13	0.23	0.18	0.30	0.25	0.30	0.25	0.38	0.32	0.38	0.32	0.47	0.41	0.47	0.41	0.56	0.49	0.33	0.21	0.25	0.16	0.56	0.37
D-50	0.20	0.15	0.29	0.22	0.37	0.30	0.37	0.30	0.48	0.40	0.48	0.40	0.60	0.51	0.60	0.51	0.74	0.62	0.40	0.25	0.30	0.19	0.74	0.40
A-75	0.16	0.16	0.20	0.20	0.24	0.24			0.28	0.28			0.33	0.33			0.37	0.37	0.23	0.19	0.20	0.16		
B-75	0.16	0.16	0.22	0.20	0.27	0.24			0.34	0.30			0.41	0.37			0.48	0.44	0.30	0.22	0.25	0.18		
C-75	0.19	0.16	0.27	0.22	0.34	0.29			0.43	0.37			0.53	0.46			0.63	0.55	0.37	0.26	0.30	0.21		
D-75	0.23	0.18	0.33	0.26	0.42	0.34			0.53	0.45			0.66	0.57			0.81	0.68	0.45	0.30	0.35	0.23		
A-100	0.23	0.23	0.29	0.29	0.35	0.35			0.40	0.40			0.46	0.46			0.52	0.52	0.28	0.24	0.28	0.24		
B-100	0.23	0.23	0.29	0.29	0.35	0.35			0.40	0.40			0.46	0.46			0.55	0.52	0.35	0.27	0.29	0.23		
C-100	0.23	0.23	0.31	0.29	0.39	0.35			0.48	0.42			0.58	0.52			0.70	0.62	0.42	0.31	0.34	0.25		
D-100	0.26	0.23	0.37	0.29	0.46	0.39			0.58	0.50			0.72	0.62			0.87	0.75	0.49	0.34	0.39	0.27		
A-125	0.31	0.31	0.39	0.39	0.46	0.46			0.54	0.54			0.62	0.62			0.69	0.69	0.37	0.32	0.37	0.32		
B-125	0.31	0.31	0.39	0.39	0.46	0.46			0.54	0.54			0.62	0.62			0.69	0.69	0.39	0.32	0.38	0.31		
C-125	0.31	0.31	0.39	0.39	0.46	0.46			0.54	0.54			0.64	0.62			0.76	0.69	0.46	0.35	0.39	0.30		
D-125	0.31	0.31	0.40	0.39	0.51	0.46			0.64	0.55			0.78	0.68			0.94	0.81	0.54	0.39	0.43	0.31		

TABLE 1 *Continued*

Circumferential reinforcement, in.²/linear ft of pipe																				
Internal Designated Dia, in.	30										33									
Type of Reinforcement	Circular								Elliptical		Circular								Elliptical	
Wall Thickness, in.	2¾	3⅛	3¼		3½		4¾		2¾	3½	2⅞	3⅛	3¼		3¾		4¾		2⅞	3¾
Layers of Reinforcement	Single	Single	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single	Single	Single	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single
Class																				
A-25	0.25	0.23	0.16	0.11	0.15	0.10	0.12	0.08	0.25	0.19	0.29	0.27	0.19	0.13	0.17	0.11	0.14	0.09	0.29	0.21
B-25	0.41	0.37	0.25	0.16	0.23	0.15	0.18	0.11	0.41	0.23	0.48	0.45	0.30	0.19	0.26	0.16	0.21	0.13	0.48	0.26
C-25	0.60	0.52	0.34	0.21	0.31	0.19	0.23	0.13	0.60	0.31	0.71	0.64	0.41	0.25	0.34	0.21	0.27	0.16	0.71	0.34
D-25	0.82	0.69	0.44	0.26	0.40	0.23	0.28	0.16	0.82	0.40	**0.92**	0.87	0.53	0.32	0.44	0.26	0.34	0.19	**0.92**	0.44
A-50	0.32	0.30	0.21	0.16	0.20	0.15	0.17	0.13	0.41	0.41	0.37	0.35	0.24	0.19	0.22	0.17	0.19	0.15	0.45	0.45
B-50	0.49	0.45	0.30	0.21	0.28	0.20	0.22	0.15	0.49	0.41	0.56	0.53	0.35	0.25	0.31	0.22	0.26	0.18	0.56	0.45
C-50	0.67	0.60	0.39	0.26	0.36	0.24	0.28	0.18	0.67	0.41	0.79	0.72	0.46	0.31	0.40	0.26	0.32	0.21	0.79	0.45
D-50	0.90	0.77	0.49	0.31	0.44	0.28	0.33	0.20	0.90	0.44	**1.00**	0.95	0.58	0.37	0.49	0.31	0.39	0.24	**1.00**	0.49
A-75	0.41	0.41	0.27	0.22	0.25	0.21	0.22	0.18			0.45	0.45	0.30	0.24	0.27	0.22	0.25	0.20		
B-75	0.56	0.52	0.35	0.26	0.33	0.25	0.27	0.20			0.64	0.61	0.41	0.30	0.36	0.27	0.31	0.23		
C-75	0.74	0.67	0.44	0.31	0.41	0.29	0.32	0.22			0.87	0.80	0.52	0.36	0.45	0.32	0.37	0.26		
D-75	0.97	0.84	0.53	0.36	0.49	0.33	0.38	0.25			**1.08**	1.03	0.63	0.43	0.54	0.36	0.44	0.29		
A-100	0.58	0.58	0.32	0.27	0.31	0.26	0.31	0.27			0.64	0.64	0.36	0.30	0.34	0.29	0.34	0.29		
B-100	0.63	0.59	0.41	0.31	0.38	0.30	0.32	0.25			0.72	0.69	0.47	0.36	0.42	0.32	0.36	0.28		
C-100	0.82	0.74	0.49	0.36	0.46	0.34	0.37	0.27			0.95	0.88	0.57	0.42	0.50	0.37	0.42	0.31		
D-100	1.04	0.91	0.58	0.41	0.54	0.38	0.42	0.29			**1.16**	1.11	0.69	0.48	0.59	0.42	0.49	0.34		
A-125	0.77	0.77	0.41	0.36	0.41	0.36	0.41	0.36			0.85	0.85	0.46	0.39	0.45	0.39	0.45	0.40		
B-125	0.77	0.77	0.46	0.37	0.43	0.35	0.43	0.35			0.85	0.85	0.52	0.42	0.47	0.38	0.47	0.38		
C-125	0.89	0.81	0.54	0.41	0.51	0.39	0.44	0.33			1.03	0.96	0.63	0.48	0.56	0.42	0.48	0.37		
D-125	1.12	0.99	0.63	0.46	0.59	0.43	0.47	0.34			**1.24**	1.19	0.74	0.54	0.65	0.47	0.54	0.39		

TABLE 1 *Continued*

Circumferential reinforcement, in.²/linear ft of pipe																										
Internal Designated Dia, in.	36									39								42								
Type of Reinforcement	Circular							Elliptical		Circular						Elliptical		Circular						Elliptical		
Wall Thickness, in.	3⅛	3¼		4		5		3⅛	4	3½		4¼		5¼		3½	4¼	3¾		4½		5½		3¾	4½	
Layers of Reinforcement	Single	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single	
Class																										
A-25	0.32	0.22	0.15	0.18	0.12	0.15	0.10	0.32	0.23	0.23	0.16	0.20	0.13	0.17	0.11	0.25	0.25	0.25	0.17	0.21	0.15	0.19	0.13	0.27	0.27	
B-25	0.54	0.35	0.23	0.28	0.18	0.23	0.14	0.54	0.28	0.38	0.24	0.31	0.19	0.26	0.16	0.38	0.31	0.40	0.26	0.33	0.21	0.28	0.17	0.40	0.33	
C-25	0.78	0.49	0.30	0.38	0.23	0.30	0.18	0.78	0.38	0.52	0.32	0.41	0.25	0.34	0.20	0.52	0.41	0.55	0.34	0.45	0.27	0.37	0.22	0.55	0.45	
D-25	**1.01**	0.63	0.38	0.48	0.28	0.38	0.21	**1.01**	0.48	0.67	0.40	0.52	0.31	0.42	0.24	0.67	0.52	0.71	0.43	0.56	0.34	0.46	0.26	0.71	0.56	
A-50	0.40	0.28	0.21	0.24	0.18	0.21	0.16	0.49	0.49	0.30	0.23	0.26	0.20	0.23	0.17	0.53	0.53	0.32	0.24	0.28	0.21	0.25	0.19	0.57	0.57	
B-50	0.62	0.41	0.29	0.34	0.24	0.29	0.20	0.62	0.49	0.44	0.31	0.37	0.26	0.31	0.22	0.53	0.53	0.47	0.32	0.40	0.28	0.34	0.24	0.57	0.57	
C-50	0.87	0.54	0.36	0.43	0.29	0.36	0.23	0.87	0.49	0.58	0.38	0.47	0.31	0.39	0.25	0.58	0.53	0.61	0.41	0.51	0.34	0.43	0.28	0.61	0.57	
D-50	**1.10**	0.69	0.44	0.53	0.34	0.43	0.27	**1.10**	0.53	0.73	0.47	0.58	0.37	0.47	0.30	0.73	0.58	0.77	0.49	0.63	0.40	0.52	0.32	0.77	0.63	
A-75	0.49	0.34	0.28	0.30	0.24	0.27	0.22			0.36	0.29	0.32	0.26	0.29	0.24			0.38	0.31	0.34	0.28	0.31	0.25			
B-75	0.71	0.47	0.35	0.40	0.29	0.34	0.25			0.50	0.37	0.43	0.32	0.37	0.28			0.53	0.39	0.46	0.34	0.41	0.30			
C-75	0.96	0.60	0.42	0.49	0.34	0.41	0.29			0.64	0.45	0.53	0.37	0.45	0.31			0.68	0.47	0.57	0.40	0.49	0.34			
D-75	**1.19**	0.74	0.50	0.59	0.40	0.48	0.32			0.79	0.53	0.64	0.43	0.53	0.35			0.83	0.56	0.69	0.46	0.58	0.39			
A-100	0.69	0.40	0.34	0.38	0.32	0.38	0.32			0.43	0.36	0.41	0.34	0.41	0.34			0.45	0.38	0.44	0.37	0.44	0.37			
B-100	0.80	0.53	0.41	0.45	0.35	0.40	0.31			0.57	0.44	0.49	0.38	0.43	0.33			0.60	0.46	0.53	0.41	0.47	0.36			
C-100	1.04	0.66	0.48	0.55	0.40	0.47	0.34			0.70	0.51	0.59	0.43	0.51	0.37			0.74	0.54	0.64	0.46	0.55	0.40			
D-100	**1.28**	0.80	0.56	0.65	0.45	0.54	0.38			0.85	0.59	0.70	0.49	0.59	0.41			0.90	0.63	0.75	0.53	0.64	0.45			
A-125	0.93	0.50	0.43	0.50	0.43	0.50	0.43			0.54	0.46	0.54	0.47	0.54	0.47			0.58	0.50	0.58	0.50	0.58	0.50			
B-125	0.93	0.60	0.47	0.51	0.41	0.51	0.41			0.63	0.50	0.56	0.45	0.56	0.45			0.67	0.53	0.60	0.48	0.60	0.48			
C-125	1.13	0.72	0.54	0.60	0.46	0.53	0.40			0.77	0.58	0.65	0.49	0.57	0.43			0.81	0.61	0.70	0.53	0.62	0.47			
D-125	**1.36**	0.86	0.62	0.70	0.51	0.59	0.43			0.91	0.65	0.76	0.55	0.65	0.47			0.96	0.69	0.81	0.59	0.70	0.51			

TABLE 1 *Continued*

Circumferential reinforcement, in.²/linear ft of pipe																								
Internal Designated Dia, in.	45								48								51							
Type of Reinforcement	Circular						Elliptical		Circular						Elliptical		Circular						Elliptical	
Wall Thickness, in.	3⅞		4¾		5¾		3⅞	4¾	4⅛		5		5¾		4⅛	5	4¼		5¼		6		4¼	5¼
Layers of Reinforcement	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single
Class																								
A-25	0.27	0.19	0.23	0.16	0.20	0.14	0.29	0.29	0.29	0.20	0.25	0.17	0.23	0.15	0.31	0.31	0.32	0.22	0.27	0.18	0.25	0.17	0.33	0.33
B-25	0.44	0.28	0.36	0.23	0.31	0.19	0.44	0.36	0.48	0.31	0.39	0.25	0.35	0.22	0.48	0.39	0.52	0.33	0.42	0.26	0.37	0.23	0.52	0.42
C-25	0.60	0.38	0.48	0.29	0.40	0.24	0.60	0.48	0.65	0.41	0.53	0.32	0.46	0.27	0.65	0.53	0.71	0.44	0.56	0.34	0.49	0.30	0.71	0.56
D-25	0.78	0.47	0.61	0.36	0.50	0.29	0.78	0.61	0.84	0.51	0.66	0.40	0.57	0.33	0.84	0.66	0.92	0.56	0.71	0.42	0.62	0.36	0.92	0.71
A-50	0.34	0.26	0.30	0.23	0.27	0.20	0.61	0.61	0.37	0.28	0.32	0.25	0.30	0.23	0.65	0.65	0.40	0.30	0.35	0.26	0.32	0.24	0.70	0.70
B-50	0.51	0.35	0.43	0.30	0.37	0.26	0.61	0.61	0.55	0.38	0.47	0.32	0.42	0.29	0.65	0.65	0.60	0.41	0.50	0.34	0.45	0.31	0.70	0.70
C-50	0.67	0.45	0.55	0.36	0.47	0.30	0.67	0.61	0.73	0.48	0.60	0.39	0.53	0.34	0.73	0.65	0.79	0.52	0.64	0.42	0.57	0.37	0.79	0.70
D-50	0.85	0.54	0.67	0.43	0.56	0.35	0.85	0.67	0.91	0.59	0.73	0.47	0.64	0.40	0.91	0.73	0.99	0.64	0.78	0.50	0.69	0.43	0.99	0.78
A-75	0.42	0.33	0.37	0.30	0.34	0.27			0.45	0.36	0.40	0.32	0.37	0.30			0.48	0.38	0.42	0.34	0.40	0.32		
B-75	0.58	0.43	0.50	0.37	0.44	0.32			0.63	0.46	0.54	0.40	0.49	0.36			0.68	0.50	0.57	0.42	0.52	0.38		
C-75	0.74	0.52	0.61	0.43	0.53	0.37			0.80	0.56	0.67	0.47	0.60	0.42			0.86	0.60	0.71	0.50	0.64	0.45		
D-75	0.91	0.61	0.74	0.50	0.63	0.42			0.98	0.66	0.80	0.54	0.71	0.47			1.07	0.71	0.85	0.57	0.76	0.51		
A-100	0.49	0.41	0.47	0.39	0.47	0.40			0.53	0.44	0.50	0.42	0.50	0.42			0.56	0.47	0.54	0.45	0.53	0.45		
B-100	0.65	0.50	0.57	0.43	0.51	0.39			0.70	0.54	0.61	0.47	0.56	0.43			0.76	0.58	0.65	0.50	0.60	0.46		
C-100	0.81	0.59	0.68	0.50	0.60	0.44			0.87	0.63	0.74	0.54	0.67	0.49			0.94	0.68	0.79	0.57	0.72	0.52		
D-100	0.98	0.68	0.80	0.56	0.69	0.48			1.05	0.73	0.87	0.61	0.78	0.54			1.14	0.79	0.93	0.65	0.83	0.58		
A-125	0.62	0.53	0.62	0.54	0.62	0.54			0.67	0.57	0.66	0.57	0.66	0.57			0.71	0.60	0.71	0.61	0.71	0.61		
B-125	0.73	0.57	0.64	0.51	0.64	0.51			0.78	0.62	0.69	0.55	0.69	0.55			0.84	0.66	0.73	0.58	0.73	0.58		
C-125	0.88	0.66	0.75	0.57	0.66	0.50			0.95	0.71	0.81	0.61	0.74	0.56			1.02	0.76	0.86	0.65	0.79	0.60		
D-125	1.05	0.75	0.87	0.63	0.76	0.55			1.13	0.81	0.94	0.68	0.85	0.62			1.21	0.87	1.00	0.72	0.91	0.66		

TABLE 1 *Continued*

Circumferential reinforcement, in.²/linear ft of pipe																								
Internal Designated Dia, in.	54								57								60							
Type of Reinforcement	Circular						Elliptical		Circular						Elliptical		Circular						Elliptical	
Wall Thickness, in.	4½		5½		6¼		4½	5½	4¾		5¾		6½		4¾	5¾	5		6		6¾		5	6
Layers of Reinforcement	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single
Class																								
A-25	0.33	0.23	0.29	0.19	0.26	0.18	0.35	0.35	0.35	0.24	0.30	0.21	0.28	0.19	0.37	0.37	0.37	0.25	0.32	0.22	0.30	0.20	0.39	0.39
B-25	0.54	0.35	0.44	0.28	0.40	0.25	0.54	0.44	0.56	0.36	0.47	0.30	0.42	0.26	0.56	0.47	0.58	0.38	0.49	0.31	0.45	0.28	0.58	0.49
C-25	0.74	0.46	0.60	0.36	0.53	0.32	0.74	0.60	0.78	0.49	0.63	0.39	0.57	0.34	0.78	0.63	0.81	0.51	0.67	0.41	0.60	0.36	0.81	0.67
D-25	0.96	0.59	0.75	0.45	0.66	0.39	0.96	0.75	1.00	0.61	0.80	0.48	0.70	0.41	1.00	0.80	1.05	0.64	0.85	0.51	0.75	0.44	1.05	0.85
A-50	0.42	0.31	0.37	0.28	0.34	0.26	0.74	0.74	0.44	0.33	0.39	0.29	0.37	0.27	0.78	0.78	0.46	0.35	0.41	0.31	0.39	0.29	0.82	0.82
B-50	0.62	0.43	0.52	0.36	0.48	0.33	0.74	0.74	0.65	0.45	0.55	0.38	0.50	0.35	0.78	0.78	0.67	0.47	0.58	0.40	0.53	0.37	0.82	0.82
C-50	0.82	0.55	0.68	0.44	0.61	0.40	0.82	0.74	0.86	0.57	0.72	0.47	0.65	0.42	0.86	0.78	0.90	0.60	0.76	0.50	0.69	0.45	0.90	0.82
D-50	1.04	0.66	0.83	0.53	0.74	0.46	1.04	0.83	1.08	0.69	0.88	0.56	0.78	0.49	1.08	0.88	1.13	0.72	0.93	0.59	0.83	0.53	1.13	0.93
A-75	0.50	0.40	0.45	0.36	0.42	0.34			0.53	0.42	0.48	0.38	0.45	0.36			0.55	0.44	0.50	0.40	0.48	0.38		
B-75	0.71	0.52	0.60	0.44	0.55	0.41			0.73	0.54	0.63	0.47	0.59	0.43			0.76	0.56	0.67	0.49	0.62	0.45		
C-75	0.90	0.63	0.75	0.52	0.68	0.47			0.94	0.66	0.80	0.55	0.73	0.50			0.99	0.68	0.84	0.58	0.77	0.53		
D-75	1.11	0.74	0.91	0.61	0.81	0.54			1.16	0.78	0.96	0.64	0.86	0.58			1.21	0.81	1.01	0.68	0.91	0.61		
A-100	0.59	0.49	0.57	0.47	0.57	0.47			0.62	0.51	0.60	0.50	0.60	0.50			0.65	0.53	0.63	0.52	0.63	0.52		
B-100	0.79	0.60	0.68	0.52	0.63	0.49			0.82	0.63	0.72	0.55	0.67	0.51			0.85	0.65	0.76	0.58	0.71	0.54		
C-100	0.98	0.71	0.83	0.61	0.76	0.55			1.03	0.74	0.88	0.64	0.81	0.59			1.07	0.77	0.93	0.67	0.86	0.62		
D-100	1.19	0.83	0.98	0.69	0.89	0.62			1.24	0.86	1.04	0.72	0.94	0.66			1.29	0.90	1.09	0.76	1.00	0.70		
A-125	0.75	0.64	0.75	0.64	0.75	0.64			0.79	0.67	0.79	0.68	0.79	0.68			0.84	0.71	0.83	0.71	0.83	0.71		
B-125	0.87	0.69	0.77	0.61	0.77	0.62			0.91	0.71	0.82	0.65	0.82	0.65			0.94	0.74	0.86	0.68	0.86	0.68		
C-125	1.07	0.79	0.91	0.69	0.84	0.63			1.11	0.83	0.96	0.72	0.89	0.67			1.16	0.86	1.02	0.76	0.94	0.71		
D-125	1.27	0.91	1.06	0.77	0.97	0.70			1.32	0.95	1.12	0.81	1.02	0.74			1.38	0.99	1.18	0.85	1.08	0.78		

TABLE 1 *Continued*

Circumferential reinforcement, in.²/linear ft of pipe																								
Internal Designated Dia, in.	63								66								69							
Type of Reinforcement	Circular						Elliptical		Circular						Elliptical		Circular						Elliptical	
Wall Thickness, in.	5¼		6¼		7		5¼	6¼	5½		6½		7¼		5½	6½	5¾		6¾		7½		5¾	6¾
Layers of Reinforcement	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single
Class																								
A-25	0.39	0.27	0.35	0.24	0.32	0.22	0.41	0.41	0.41	0.28	0.37	0.25	0.34	0.23	0.43	0.43	0.43	0.30	0.39	0.26	0.36	0.24	0.44	0.44
B-25	0.62	0.40	0.52	0.33	0.48	0.30	0.62	0.52	0.64	0.41	0.55	0.35	0.50	0.31	0.64	0.55	0.67	0.43	0.58	0.37	0.53	0.33	0.67	0.58
C-25	0.87	0.54	0.72	0.44	0.65	0.39	0.87	0.72	0.90	0.56	0.76	0.46	0.69	0.41	0.90	0.76	0.94	0.58	0.80	0.49	0.72	0.44	0.94	0.80
D-25	1.11	0.68	0.90	0.54	0.81	0.47	1.11	0.90	1.16	0.70	0.95	0.57	0.85	0.50	1.16	0.95	1.20	0.73	1.00	0.60	0.90	0.53	1.20	1.00
A-50	0.49	0.37	0.44	0.33	0.42	0.31	0.86	0.86	0.51	0.38	0.47	0.35	0.44	0.33	0.90	0.90	0.54	0.40	0.49	0.36	0.46	0.34	0.94	0.94
B-50	0.71	0.49	0.62	0.43	0.57	0.39	0.86	0.86	0.74	0.51	0.65	0.45	0.60	0.41	0.90	0.90	0.77	0.53	0.67	0.47	0.63	0.43	0.94	0.94
C-50	0.96	0.63	0.81	0.53	0.74	0.48	0.96	0.86	1.00	0.66	0.85	0.56	0.78	0.51	1.00	0.90	1.04	0.68	0.89	0.59	0.82	0.53	1.04	0.94
D-50	1.20	0.77	0.99	0.63	0.89	0.56	1.20	0.99	1.24	0.80	1.04	0.66	0.94	0.59	1.24	1.04	1.29	0.83	1.09	0.70	0.99	0.63	1.29	1.09
A-75	0.59	0.47	0.54	0.43	0.51	0.40			0.62	0.49	0.56	0.45	0.54	0.42			0.64	0.51	0.59	0.47	0.56	0.45		
B-75	0.81	0.59	0.71	0.52	0.66	0.48			0.84	0.61	0.74	0.54	0.69	0.51			0.87	0.63	0.77	0.57	0.73	0.53		
C-75	1.05	0.73	0.90	0.62	0.83	0.57			1.09	0.76	0.94	0.65	0.87	0.60			1.13	0.78	0.99	0.69	0.92	0.63		
D-75	1.28	0.86	1.08	0.72	0.98	0.65			1.33	0.89	1.13	0.76	1.03	0.69			1.38	0.93	1.19	0.79	1.09	0.72		
A-100	0.69	0.57	0.66	0.55	0.66	0.55			0.72	0.59	0.70	0.57	0.70	0.57			0.75	0.61	0.73	0.60	0.73	0.60		
B-100	0.90	0.69	0.80	0.61	0.75	0.58			0.94	0.71	0.84	0.64	0.79	0.60			0.97	0.74	0.88	0.67	0.82	0.63		
C-100	1.14	0.82	0.99	0.72	0.92	0.66			1.19	0.85	1.04	0.75	0.96	0.70			1.23	0.89	1.09	0.78	1.01	0.73		
D-100	1.37	0.95	1.17	0.81	1.07	0.74			1.42	0.99	1.22	0.85	1.12	0.78			1.48	1.02	1.28	0.89	1.18	0.82		
A-125	0.88	0.74	0.88	0.74	0.88	0.74			0.92	0.78	0.92	0.78	0.92	0.78			0.96	0.81	0.96	0.81	0.96	0.81		
B-125	1.00	0.78	0.90	0.72	0.90	0.72			1.04	0.81	0.95	0.75	0.95	0.75			1.07	0.84	0.99	0.78	0.99	0.78		
C-125	1.23	0.92	1.08	0.81	1.01	0.75			1.28	0.95	1.13	0.85	1.06	0.79			1.33	0.99	1.19	0.89	1.11	0.83		
D-125	1.46	1.04	1.26	0.90	1.16	0.83			1.52	1.08	1.32	0.95	1.22	0.88			1.57	1.12	1.38	0.99	1.28	0.92		

TABLE 1 *Continued*

Circumferential reinforcement, in.²/linear ft of pipe																				
Internal Designated Dia, in.	72								78						84					
Type of Reinforcement	Circular						Elliptical		Circular						Circular					
Wall Thickness, in.	6		7		7¾		6	7	6½		7½		8¼		7		8		8¾	
Layers of Reinforcement	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer
Class																				
A-25	0.48	0.33	0.43	0.29	0.40	0.27	0.48	0.46	0.52	0.35	0.47	0.32	0.44	0.30	0.57	0.38	0.52	0.35	0.49	0.33
B-25	0.73	0.47	0.63	0.40	0.58	0.36	0.73	0.63	0.79	0.50	0.69	0.44	0.63	0.40	0.84	0.54	0.74	0.47	0.69	0.43
C-25	1.05	0.65	0.88	0.54	0.80	0.48	1.05	0.88	1.12	0.69	0.96	0.58	0.87	0.53	1.18	0.73	1.02	0.63	0.94	0.57
D-25	1.34	0.81	1.10	0.66	0.99	0.58	1.34	1.10	1.43	0.87	1.20	0.72	1.09	0.64	**1.49**	**0.91**	1.30	0.78	1.19	0.70
A-50	0.60	0.44	0.54	0.40	0.51	0.38	0.98	0.98	0.65	0.48	0.59	0.44	0.56	0.41	0.70	0.51	0.64	0.47	0.61	0.45
B-50	0.84	0.58	0.74	0.51	0.68	0.47	0.98	0.98	0.90	0.62	0.80	0.55	0.75	0.51	0.96	0.66	0.87	0.59	0.81	0.56
C-50	1.15	0.76	0.98	0.64	0.90	0.59	1.15	0.98	1.23	0.81	1.07	0.70	0.98	0.64	1.30	0.85	1.14	0.75	1.06	0.69
D-50	1.44	0.92	1.21	0.77	1.09	0.69	1.44	1.21	1.53	0.98	1.31	0.83	1.20	0.75	**1.61**	**1.03**	1.42	0.90	1.30	0.82
A-75	0.71	0.56	0.65	0.51	0.62	0.49			0.77	0.60	0.71	0.55	0.68	0.53	0.82	0.64	0.77	0.60	0.74	0.57
B-75	0.95	0.70	0.85	0.62	0.79	0.58			1.02	0.74	0.92	0.67	0.86	0.63	1.09	0.79	0.99	0.72	0.93	0.68
C-75	1.26	0.87	1.09	0.75	1.00	0.69			1.34	0.92	1.18	0.81	1.09	0.75	1.42	0.98	1.26	0.87	1.17	0.81
D-75	1.54	1.02	1.31	0.87	1.19	0.79			1.64	1.09	1.42	0.94	1.30	0.87	**1.72**	**1.15**	1.53	1.02	1.42	0.94
A-100	0.82	0.67	0.76	0.62	0.76	0.62			0.89	0.72	0.83	0.67	0.83	0.67	0.95	0.77	0.89	0.73	0.89	0.72
B-100	1.07	0.81	0.96	0.73	0.90	0.69			1.14	0.86	1.03	0.79	0.98	0.74	1.21	0.92	1.11	0.84	1.06	0.80
C-100	1.36	0.98	1.19	0.86	1.11	0.80			1.46	1.04	1.29	0.93	1.20	0.86	1.54	1.10	1.38	0.99	1.29	0.93
D-100	1.64	1.13	1.41	0.98	1.29	0.90			1.75	1.21	1.53	1.06	1.41	0.98	**1.84**	**1.27**	1.65	1.14	1.53	1.06
A-125	1.01	0.85	1.01	0.85	1.00	0.85			1.09	0.91	1.09	0.92	1.09	0.92	1.18	0.98	1.18	0.98	1.18	0.98
B-125	1.18	0.92	1.07	0.84	1.03	0.82			1.26	0.98	1.15	0.90	1.12	0.88	1.34	1.05	1.24	0.97	1.21	0.95
C-125	1.47	1.09	1.30	0.97	1.21	0.90			1.57	1.16	1.40	1.04	1.31	0.98	1.66	1.23	1.50	1.11	1.41	1.05
D-125	1.74	1.24	1.51	1.08	1.40	1.00			1.86	1.32	1.64	1.17	1.52	1.09	**1.96**	**1.40**	1.76	1.26	1.65	1.18

TABLE 1 *Continued*

Circumferential reinforcement, in.²/linear ft of pipe																						
Internal Designated Dia, in.	90				96				102				108				120		132		144	
Type of Reinforcement	Circular				Circular				Circular				Circular				Circular		Circular		Circular	
Wall Thickness, in.	7½		8		8		8½		8½		9		9		9½		10		11		12	
Layers of Reinforcement	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer
Class																						
A-25	0.62	0.41	0.59	0.39	0.67	0.45	0.64	0.43	0.72	0.48	0.69	0.46	0.77	0.51	0.75	0.49	0.89	0.58	1.01	0.66	1.14	0.74
B-25	0.90	0.57	0.85	0.54	0.96	0.61	0.91	0.58	1.02	0.65	0.97	0.62	1.08	0.69	1.04	0.66	1.22	0.77	1.36	0.86	1.52	0.96
C-25	1.25	0.77	1.16	0.72	1.31	0.81	1.23	0.76	1.39	0.86	1.31	0.81	1.46	0.90	1.38	0.85	1.62	1.00	1.78	1.10	1.96	1.21
D-25	**1.59**	**0.97**	1.50	0.91	**1.69**	**1.03**	1.61	0.97	**1.79**	**1.09**	**1.69**	**1.02**	**1.88**	**1.15**	**1.77**	**1.07**	S	S	S	S	S	S
A-50	0.75	0.55	0.72	0.53	0.81	0.59	0.78	0.57	0.87	0.63	0.84	0.61	0.93	0.67	0.90	0.65	1.06	0.76	1.19	0.85	1.34	0.94
B-50	1.03	0.71	0.98	0.67	1.09	0.75	1.04	0.71	1.16	0.80	1.11	0.76	1.23	0.84	1.18	0.81	1.38	0.94	1.54	1.04	1.71	1.15
C-50	1.37	0.90	1.29	0.85	1.44	0.95	1.36	0.90	1.52	1.00	1.45	0.95	1.60	1.05	1.53	1.00	1.77	1.16	1.95	1.28	2.14	1.40
D-50	**1.71**	**1.10**	1.62	1.03	**1.82**	**1.16**	1.73	1.10	**1.93**	**1.23**	**1.82**	**1.16**	**2.02**	**1.29**	**1.91**	**1.22**	S	S	S	S	S	S
A-75	0.89	0.69	0.86	0.66	0.95	0.73	0.92	0.71	1.02	0.78	0.99	0.76	1.08	0.83	1.06	0.81	1.23	0.93	1.38	1.03	1.54	1.14
B-75	1.16	0.84	1.11	0.80	1.23	0.89	1.18	0.85	1.31	0.94	1.26	0.91	1.38	1.00	1.34	0.96	1.55	1.11	1.72	1.23	1.90	1.35
C-75	1.49	1.03	1.41	0.97	1.58	1.09	1.50	1.03	1.66	1.14	1.58	1.09	1.75	1.20	1.67	1.15	1.93	1.33	2.12	1.46	2.33	1.59
D-75	**1.83**	**1.22**	1.74	1.16	**1.95**	**1.30**	1.86	1.24	**2.06**	**1.37**	**1.96**	**1.30**	**2.16**	**1.44**	**2.06**	**1.37**	S	S	S	S	S	S
A-100	1.02	0.82	0.99	0.80	1.09	0.88	1.06	0.85	1.17	0.93	1.14	0.91	1.24	0.99	1.21	0.96	1.40	1.10	1.56	1.22	1.74	1.35
B-100	1.29	0.97	1.24	0.94	1.37	1.03	1.32	1.00	1.45	1.09	1.40	1.06	1.54	1.15	1.49	1.12	1.71	1.28	1.90	1.41	2.09	1.55
C-100	1.62	1.16	1.54	1.10	1.71	1.22	1.63	1.17	1.80	1.29	1.72	1.24	1.90	1.36	1.82	1.30	2.09	1.49	2.30	1.64	2.51	1.79
D-100	**1.96**	**1.35**	1.86	1.29	**2.08**	**1.43**	1.99	1.37	**2.20**	**1.52**	**2.09**	**1.45**	**2.30**	**1.59**	**2.20**	**1.52**	S	S	S	S	S	S
A-125	1.27	1.05	1.26	1.05	1.35	1.12	1.35	1.12	1.44	1.18	1.44	1.18	1.53	1.25	1.53	1.25	1.70	1.38	1.88	1.52	2.06	1.65
B-125	1.42	1.11	1.37	1.07	1.51	1.17	1.46	1.14	1.60	1.24	1.55	1.20	1.69	1.31	1.64	1.27	1.88	1.45	2.08	1.60	2.29	1.75
C-125	1.75	1.29	1.67	1.24	1.84	1.36	1.77	1.31	1.94	1.44	1.87	1.38	2.04	1.51	1.97	1.46	2.25	1.66	2.47	1.82	2.70	1.98
D-125	**2.08**	**1.48**	1.99	1.41	**2.21**	**1.57**	2.27	1.50	**2.34**	**1.66**	**2.23**	**1.59**	**2.45**	**1.74**	**2.35**	**1.67**	S	S	S	S	S	S