



Designation: C361M-05 Designation: C 361M - 08

Standard Specification for Reinforced Concrete Low-Head Pressure Pipe (Metric)¹

This standard is issued under the fixed designation C 361M; 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 reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reappraisal.

This standard has been approved for use by agencies of the 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 375 kPa.

1.2 This ~~metric~~ specification is the ~~equivalent~~ SI companion to Specification ~~E361 and~~ C 361. It is compatible in technical content.

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

A 27/A 27M Specification for Steel Castings, Carbon, for General Application

A 36/A 36M Specification for Carbon Structural Steel

A 82/A 82M Specification for Steel Wire, Plain, for Concrete Reinforcement

A 185/A 185M Specification for Steel Welded ~~Wire~~, Wire Reinforcement, Plain, for Concrete

A 283/A 283M Specification for Low and Intermediate Tensile Strength Carbon Steel Plates

A 496/A 496M ~~Specification for Steel Wire Reinforcement, Deformed, for Concrete~~ Specification for Steel Wire, Deformed, for Concrete Reinforcement

~~A 497/A 497M Specification for Steel Welded Wire Fabric, Deformed, for Concrete Reinforcement~~

~~A 570/A 570M Specification for Steel, Sheet and Strip, Carbon, Hot-Rolled~~ 497/A 497M Specification for Steel Welded Wire Reinforcement, Deformed, for Concrete

A 575 Specification for Steel Bars, Carbon, Merchant Quality, M-Grades

A 576 Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality ~~A 611 Specification for Structural Steel, Sheet, Carbon, Cold-Rolled³~~

~~A 615/A 615M Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement~~ n-c361m-08

~~A 675/A 675M Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality; Mechanical Properties~~ Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties

A 1008/A 1008M Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Solution Hardened, and Bake Hardenable

A 1011/A 1011M 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

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field

C 33 Specification for Concrete Aggregates

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 150 Specification for Portland Cement

C 260 Specification for Air-Entraining Admixtures for Concrete

C 309 Specification for Liquid Membrane-Forming Compounds for Curing Concrete

C 497M Test Methods for Concrete Pipe, Manhole Sections, or Tile ~~(Metric)~~ [Metric]

C 595 Specification for Blended Hydraulic Cements

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.

Current edition approved July 1, 2005. Published August 2005. Originally approved in 1978. Last previous edition approved in 2003 as C361M-03a^{ε1}.

Current edition approved Nov. 15, 2008. Published December 2008. Originally approved in 1978. Last previous edition approved in 2005 as C 361M - 05.

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.

C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
 C 822 Terminology Relating to Concrete Pipe and Related Products ~~D395 Test Methods for Rubber Property—Compression Set~~
~~D412 Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension~~
~~D471 Test Method for Rubber Property—Effect of Liquids~~
~~D573 Test Method for Rubber—Deterioration in an Air Oven~~
 C 1619 Specification for Elastomeric Seals for Joining Concrete Structures
 D 698 Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft³ (600 kN-m/m³))
~~D1149 Test Method for Rubber Deterioration—Surface Ozone Cracking in a Chamber~~
~~D2240 Test Method for Rubber Property—Durometer Hardness~~
 D 4253 Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table
 D 4254 Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density
 2.2 *Other Standard:*
 ACI Code 318 Standard Building Code Requirements for Reinforced Concrete
~~AISI-C1012³~~
~~AISI-C1012⁴~~

3. Terminology

3.1 *Definitions*—For definitions of terms relating to concrete pipe, see Terminology C 822.

4. Classification

4.1 Pipe manufactured according to this specification shall be for hydrostatic heads of 75, 150, 225, 300, and 375 kPa measured to the centerline of the pipe. Designs are provided in Table 1 for the above hydrostatic heads combined with external loadings of 1.5, 3.0, 4.5, and 6.0 (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 C 150.

6.2.1.2 ~~*Blended Cement*~~ *Blended Hydraulic Cement*—Blended cement shall conform to the requirements of Specification C 595 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 C 618.

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,

6.2.3.3 Portland pozzolan cement only, or

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).

³ Withdrawn.

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

⁴ Available from the American Concrete Institute, 38800 Country Club Dr., Farmington Hills, MI 48331.

⁴ Available from the American Iron and Steel Institute (AISI), 1140 Connecticut Ave. NW, Suite 705, Washington D.C. 20036, <http://www.steel.org>.

6.3 *Aggregates*—Aggregates shall conform to Specification C 33, 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 C 260. 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 A 82/A 82M, Specification A 496/A 496M, or of wire fabric reinforcement conforming to Specification A 185/A 185M or Specification A 497/A 497M, or of bars of Grade 300 steel conforming to Specification A 615/A 615M/A615M.

6.6 *Steel for Joint Rings:*

6.6.1 Steel strips for bell rings less than 6 mm thick shall conform to Grade ~~SS30~~ of Specification ~~A570A 1011/A 1011M/A570M~~ or Grade Designation 1012 of Specification A 575. Steel that meets the requirements of AISI-C1012 for chemical components will be acceptable provided it conforms to Grade ~~SS30~~ of Specification ~~A570A 1011/A 1011M/A570M~~ in other respects.

6.6.2 Steel plate for bell rings 6 mm or more in thickness and special shapes for spigot joint rings shall conform to Specification A ~~36/A 36M/A36M~~, or to Grade A of Specification A 283/A 283M/A283M, or to Grade Designation 1012 of Specification A 576, or to Grade 50 of Specification A ~~675/A 675M/A675M~~. Steel that meets the requirements of AISI-C1012 for chemical components will be acceptable provided it conforms to Specification A ~~36/A 36M/A36M~~ or to Specification A ~~283/A 283M/A283M~~ in other respects.

6.7 *Steel Castings for Fittings* —Steel castings for fittings shall conform to Grade 70-36, Normalized, of Specification A ~~27/A 27M/A27M~~.

6.8 *Steel Plates and Sheets for Specials and Fittings*—Steel plates for specials and fittings shall conform to Specification A ~~36/A 36M/A36M~~ or to Grade B or C of Specification A 283/A 283M/A283M or Grade ~~SS30~~ or ~~SS33~~ of Specification ~~A570A 1011/A 1011M/A570M~~ or Grade ~~BSS30~~ of Specification ~~A611A 1008/A 1008M~~.

6.9 *Rubber Gaskets:*

6.9.1 *Composition and Properties* —All rubber gaskets shall be extruded or molded and cured in such a manner that any cross section will be dense, homogeneous, and free of porosity, blisters, pitting, and other imperfections. The gaskets shall be of a solid circular cross section and shall be extruded or molded to the specified size within a diametrical tolerance of ± 0.4 mm or $\pm 1.5\%$ of the diameter, whichever is larger. The basic polymer shall be natural rubber, synthetic rubber, or a blend of both. The properties enumerated below shall be determined in accordance with 10.5.

6.9.1.1—All rubber gaskets shall comply with Specification C 1619 in terms of material and manufacture. The gaskets shall be of a solid circular cross section and shall be extruded or molded to the specified size within a diametrical tolerance of ± 0.4 mm or $\pm 1.5\%$ of the diameter, whichever is larger.

6.9.1.1 *Standard Gasket Requirements* —The compound shall meet the following physical requirements (see also Test Methods D412):

Tensile strength, min, MPa	16
Elongation at break, min, %	425
Shore durometer hardness, nominal:	
Min	40 ^A
Max	60 ^A
Compression set, max, % of original deflection	20
Accelerated aging, max, % of original	
Decrease in tensile strength	15
Decrease in elongation	20
Liquid immersion, max, % weight increase	
Water absorption	5
Ozone resistance	no visible cracking in accordance with Test Method D1149

^AAllowable variation ± 5 from manufacturers' specified nominal hardness.

6.9.1.2—All rubber gaskets shall meet the dimensions, tolerances, and physical requirements of Specification C 1619, Class A.

6.9.1.2 *Oil Resistant Gasket Requirements* —The compound shall contain not less than 50% by volume oil-resistant polymer and shall meet the following physical requirements:

Tensile strength, min, MPa	10	
Elongation at break, min, %	350	
Shore durometer hardness, nominal:		
Min	40	A
Max	60	A
Durometer aging, max increase	+15	
Compression set, max, % of original deflection	20	
Accelerated aging, max, % of original (96 h at 70°C)		
Decrease in tensile strength	20	
Decrease in elongation	40	
Liquid immersion, max, % volume change		
Oil, in ASTM #3 (70 h at 100°C)	80	

Water absorption
Ozone resistance, 72 h exposure in 50 PPHM ozone concentration at 40°C

15
no visible cracking in accordance with Test Method D1149

^aAllowable variation ± 5 from manufacturers specified nominal hardness. —All rubber gaskets shall meet the dimensions, tolerances, and physical requirements of Specification C 1619, Class B.

6.9.1.3 *Durometer Hardness*—The shore hardness shall be in the range of from 35 to 50 for concrete spigots and 35 to 65 for steel spigots where the range includes the allowable variation as given in 6.9.1.1 and 6.9.1.2.

6.9.2 *Storage*—All rubber shall be stored in as cool a place as practicable, preferably at 21°C or less, and in no case shall the rubber for joints be exposed to the direct rays of the sun for more than 72 h. —The shore hardness shall be in the range of from 35 to 50 for concrete spigots and 35 to 65 for steel spigots where the range includes the allowable variation ± 5 from the manufacturer’s specified hardness, provided the actual hardness is within the limits of 35 to 65.

6.10 *Gasket Lubricants:*

6.10.1 Where the joint design utilizing a rubber gasket dictates the use of a lubricant to facilitate assembly, the lubricant composition shall have no detrimental effect on the performance of the gasket and joint due to prolonged exposure.

6.10.2 *Storage*—The lubricant shall be stored in accordance with the lubricant manufacturer’s recommended temperature range.

6.10.3 *Certification*—When requested by the owner, the manufacturer shall furnish written certification that the joint lubricant conforms to all requirements of this specification for the specific gaskets supplied.

6.10.4 *Marking*—The following information shall be clearly marked on each container of lubricant.

6.10.4.1 Name of lubricant manufacturer.

6.10.4.2 Usable temperature range for application and storage.

6.10.4.3 Shelf life.

6.10.4.4 Lot or batch number.

7. Design

7.1 *Design Tables*— The diameter, wall thickness, compressive strength of the concrete, and the area of circumferential reinforcement shall be as prescribed for the classes of combined hydrostatic head and external loading given in Table 1 subject to the provisions of 7.2, 7.4, 7.5, 10.3, 11.1, 11.2, and 11.5.

7.2 *Modified and Special Design* —Manufacturers shall submit to the owner, for approval prior to manufacture, detailed designs for loading or installation conditions other than those shown in Table 1. Such pipe must meet all of the tests and performance requirements specified by the owner in accordance with Section 5.

7.3 *Laying Lengths*— The maximum laying lengths of pipe units that will be acceptable are as follows and are subject to the provisions of 11.4:

Internal Diameter of Pipe, mm	Maximum Laying Length of Pipe, m
300 to 375	3.66
450	4.27
525 to 600	4.88
675 to 750	5.49
825 to 900	6.10
975 and larger	7.32

7.4 *Placement of Reinforcement* —The circumferential reinforcement shall be a single-cage circular, double-cage circular, or elliptical cage as shown in Table 1. Elliptical reinforcement will be permitted for 75 and 150-kPa head classes only and only in pipe 450 to 1800 mm in diameter, inclusive. All pipe with a wall thickness of less than 82 mm shall be reinforced with either a circular cage or a single elliptical cage of steel as provided in Table 1. All pipe with wall thickness of 82 mm and greater shall be reinforced with either two separate cages or a single elliptical cage of steel as provided in Table 1, except that for pipe sizes 900 mm and less with wall thicknesses equal to or greater than 82 mm, a single circular cage is not prohibited if the steel area is equal to or greater than the least area shown for a single circular cage for the particular class of pipe. The areas of circumferential reinforcement shown in Table 1 are the design requirements for each of the wall thicknesses shown in the table. Where single-cage circular reinforcement is used, the center-line of the reinforcement shall be placed from 40 to 50 % of the wall thickness from the inner surface of the pipe, provided that the minimum concrete cover specified below shall be maintained. Where two separated circular cages of reinforcement are used, the inner and outer cages shall be placed so that the concrete cover, measured radially, over the circumferential reinforcement will be as follows:

Pipe Diameter, mm	Minimum Cover, mm	Maximum Cover, mm
1125 and less	19	25
1200 through 1500	19	29
1575 through 1725	19	32
1800 through 2700	25	38

7.4.1 These limits on minimum and maximum cover are applicable to elliptical steel at the horizontal and vertical axes of the pipe. The circumferential reinforcement at each end of the pipe unit shall consist of one complete coil or ring in which the end is lapped or welded as prescribed in 7.6. The clear distance of the end coil or ring shall not be less than 13 mm or more than 25

mm from the end of the pipe unit, except this requirement does not apply to the inner layer of circumferential reinforcement in joints utilizing steel bell and spigot rings, provided that the clear distance restrictions will not apply for a distance of 20 bar diameters measured circumferentially from the end of the lap or weld.

7.4.2 A cage of circumferential reinforcement with Table 1 areas greater than 950 mm²/linear m of pipe shall be composed of one or two layers of reinforcement, and cage areas greater than 1910 mm²/linear m of pipe shall be composed of one, two, or three layers. The layers shall not be separated by more than the thickness of one longitudinal plus 6 mm. The layers shall be fastened together to form a single rigid cage. Where inner and outer cages are used, the minimum clear spacing between the two cage systems shall be 0.25 times the wall thickness. All other specification requirements such as laps, welds, concrete cover, and tolerances of placement in the wall of the pipe, etc., shall apply to this method for fabrication of a cage of reinforcement.

7.5 *Longitudinal Reinforcement*—Each layer of circumferential reinforcement shall be assembled into a cage supported by longitudinal bars that extend the full length of the pipe. The minimum concrete cover for longitudinal steel shall be 13 mm, except that the longitudinal bars or rods are not prohibited from extending to either or both ends of the pipe unit to form supports for holding the circumferential cage in proper position. Not less than four longitudinal bars at approximately equal spacing shall be provided for each cage, and additional bars used in the barrel of the pipe shall be provided as necessary so that the circumferential spacing between longitudinal bars shall not exceed 1050 mm in any cage. Where the pipe joint construction requires the use of a bell, the minimum number of longitudinal bars shall be provided in the bell and shall be continuous bars or spliced to the main longitudinal bars. The circumferential bars of each cage shall be spaced and supported by welding or tying each hoop to the longitudinal bars. Spacer bars, chairs, or other methods shall be provided to maintain the reinforcement cage or cages in proper position within the forms during the placement and consolidation of the concrete. The spacer bars or chairs are not prohibited from extending to the finished concrete surfaces of the pipe.

7.6 *Laps, Welds, and Spacing*—If the splices are not welded, the reinforcement shall be lapped not less than 20 diameters for deformed bars and deformed cold-worked wire, and 40 diameters for plain bars and cold-drawn wire. In addition, where lapped cages of welded wire fabric reinforcement are used without welding, the lap shall contain a longitudinal wire. Lapped or butt welded splices shall develop a tensile strength of not less than 280 MPa based on the nominal cross-sectional area of the bar or wire. Lapped welds shall have a minimum lap of 50 mm. The spacing center-to-center of adjacent rings of circumferential reinforcement in a cage shall not exceed 100 mm. The continuity of the circumferential reinforcing steel shall not be destroyed during the manufacture of the pipe.

8. Joints

8.1 Joints shall utilize steel joint rings, steel bells and concrete spigots, or be formed entirely of concrete. Joint assemblies shall be so formed and accurately manufactured that when the pipes are drawn together the pipe shall form a continuous watertight conduit with a smooth and uniform interior surface and shall provide for slight movements of any pipe unit in the pipeline due to expansion, contraction, settlement, or lateral displacement. The rubber gasket shall be the sole element of the joint depended upon to provide watertightness. The joint shall be so designed that the gaskets will not be required to support the weight of the pipe, but will keep the joint tight under all normal conditions of service. The ends of the pipe shall be in planes at right angles to the longitudinal centerline of the pipe, except where bevel-end pipe for deflections up to 5° is specified or indicated for bends.

8.2 Joints utilizing collars instead of bells cast as an integral part with the pipe barrel shall comply with the requirements for bell-and-spigot joints given in 8.4.1 through 8.4.8. The collar shall be flared at each end to facilitate entrance of the gasket when closing the joint. The straight section between the flares at either end shall be a true cylinder of such length that at the position of normal joint closure, the parallel surfaces upon which the gasket bears during closure will extend not less than 19 mm away from the edges of the gasket. Each end of the pipe shall have a groove formed on its outer surface of suitable dimensions to contain a circular rubber gasket.

8.3 Joints utilizing steel bell-and-spigot rings shall comply with the requirements for bell-and-spigot joints given in 8.4.1, 8.4.3, and 8.4.5. The bell ring shall have a minimum thickness of 5 mm and width sufficient to provide for adequate embedment in the pipe. It shall be flared at one end and is not prohibited from being tapered at the other end. The remainder of the bell ring shall be a true cylinder of such length that at the position of normal joint closure, the parallel surface upon which the gasket bears during the closure will extend not less than 25 mm away from the edge of the gasket. The spigot ring shall be formed from a specially shaped section of steel with a groove of suitable dimensions to contain a circular rubber gasket. The difference in circumference of the inside of the bell ring and the outside of the spigot ring shall not exceed 5 mm for gaskets of 17-mm diameter or less, and 6 mm for gaskets greater than 17-mm diameter.

8.4 In pipe utilizing bell-and-spigot joints, the joint shall be designed and manufactured so that the spigot and gasket will readily enter the bell of the pipe. In all-concrete joints the manufacturer shall provide sufficient reinforcement in the bell to resist the hydrostatic, hydrodynamic, and gasket pressures. The shape and dimensions of the joint shall be such as to provide the minimum requirements given in 8.4.1 through 8.4.8.

8.4.1 For design pressures greater than 75 kilopascals, the rubber gaskets shall be solid gaskets of circular cross section. For design pressures less than or equal to 75 kilopascals, the gaskets shall be solid gaskets of circular or non-circular cross section. All gaskets shall be confined in an annular space formed by shoulders on the bell and spigot or in a groove in the spigot of the pipe so that movement of the pipe or hydrostatic and hydrodynamic pressure cannot displace the gasket. When the joint is assembled, the gasket shall be compressed to form a watertight seal.

8.4.2 In joints that utilize spigot grooves, the volume of the annular space provided for the gasket, with the engaged joint at normal joint closure in concentric position, and neglecting ellipticity of the bell and spigot, shall be not less than the design volume of the gasket furnished. The cross-sectional area of the annular space shall be calculated for minimum bell diameter, maximum spigot diameter, minimum width of groove at surface of spigot, and minimum depth of groove. The volume of the annular space shall be calculated considering the centroid of the cross-sectional area to be at the midpoint between the inside bell surface and the surface of the groove on which the gasket is seated at the centerline of the groove.

8.4.3 In joints that utilize spigot grooves, if the average volume of the gasket furnished is less than 75 % of the volume of the annular space in which the gasket is to be contained with the engaged joint at normal joint closure in concentric position, the gasket shall not be stretched more than 20 % of its unstretched length when seated on the spigot or not more than 30 % if the design volume of the gasket is 75 % or more of the volume of the annular space. For determining the volume of the annular space, the cross-sectional area of the annular space shall be calculated for average bell diameter, average spigot diameter, average width of groove at surface of spigot, and average depth of groove. The volume of the annular space shall be calculated considering the centroid of the cross-sectional area to be at the midpoint between the inside bell surface and the surface of the groove on which the gasket is seated at the centerline of the groove. It is further specified that when the design volume of the gasket is less than 75 % of the volume of the annular space, as calculated above, the gasket shall be of such diameter that when the outer surface of the spigot and the inner surface of the bell come into contact at some point in their periphery, the deformation in the gasket shall not exceed 50 % at the point of contact nor be less than 15 % at any point. If the design volume of the gasket is 75 % or more of the volume of the annular space, the deformation of the gasket, as prescribed above, shall not exceed 50 % nor be less than 15 %. When determining the maximum percent deformation of the gasket, the maximum groove width, the minimum depth of groove, and the stretched gasket diameter shall be used and calculations made at the centerline of the groove. When determining the minimum percent deformation of the gasket, the minimum groove width, the maximum bell diameter, the minimum spigot diameter, the maximum depth of groove, and the stretched gasket diameter shall be used and calculations made at the centerline of the groove. For gasket deformation calculations, stretched gasket diameter shall be determined as being the design diameter of the gasket divided by the square root of $(1 + x)$ where x equals the design percent of gasket stretch divided by 100.

8.4.4 In joints that utilize shoulders on the bell and spigot to confine the gasket, the gasket shall not be stretched more than 20 % of its unstretched length when seated on the spigot. It is further specified that the gasket shall be of such diameter that when the outer surface of the spigot and the inner surface of the bell come into contact at some point in their periphery, the deformation in the gasket shall not exceed 50 % at the point of contact nor be less than 15 % at any point. When determining the maximum percent deformation of the gasket, the minimum depth of shoulders and the stretched gasket diameter shall be used. When determining the minimum percent deformation of the gasket, the maximum depth of shoulders, the maximum bell diameter, the minimum spigot diameter, and the stretched gasket diameter shall be used. For gasket deformation calculations, the stretched diameter shall be determined as described for joints that utilize spigot grooves.

8.4.5 Each gasket shall be manufactured to provide the volume of rubber required by the pipe manufacturer's joint design with a tolerance of $\pm 3\%$ for gaskets up to and including 13 mm in diameter and $\pm 1\%$ for gaskets of 25-mm diameter and larger. The allowable percentage tolerance shall vary linearly between $\pm 3\%$ and $\pm 1\%$ for gasket diameters between 13 and 25 mm.

8.4.6 The tolerances permitted in the construction of the joint shall be those stated in the pipe manufacturer's design as approved.

8.4.7 The taper on all surfaces of the bells and spigots, on which the rubber gasket bears during closure of the joint and at any degree of partial closure, except within the gasket groove, shall form an angle of not more than 2° with the longitudinal axis of the pipe. The joint shall be so designed and manufactured that at the position of normal joint closure, the parallel surfaces upon which the gasket bears during closure will extend not less than 19 mm away from the edges of the gasket.

8.4.8 The surfaces of the bell and spigot in contact with the gasket, and adjacent surfaces that may come in contact with the gasket within a joint movement range, shall be free from airholes, chipped or spalled concrete, laitance, or other defects. The inside surface of the bell adjacent to the bell face shall be flared to facilitate joining the pipe sections without damaging or displacing the gasket.

8.5 *Alternative Joint Designs*—It is not prohibited for the manufacturer to submit to the owner, detailed designs for joints and gaskets other than those described in Section 8. Design submissions shall include joint geometry, tolerances, gasket characteristics, proposed plant tests, gasket splice bend tests, and such other information as required by the owner to evaluate the joint design for field performance. Joints and gaskets of alternate joint designs shall meet all test requirements of this specification and shall maintain at least 15 % deformation of the rubber gasket when out-of-roundness and off-center position of the joint is considered. Alternative joint designs shall be acceptable provided the designs are approved by the owner prior to manufacture and provided the test pipe comply with the specified tests.

9. Materials and Manufacture

9.1 *Concrete Mixture*— The aggregates shall be graded, proportioned, and thoroughly mixed with the proportions of cementitious material and water that will produce a workable, uniform, homogeneous concrete mixture of such quality that the pipe will conform to the test and design requirements of this specification. Batching shall be accomplished by weighing. If the concrete materials are weighed accumulatively, the cementitious material shall be weighed before the other ingredients. Cementitious materials shall be as specified in 6.2 and shall be added to the mix in a proportion not less than 330 kg/m^3 .

9.1.1 *Placement of Concrete*—The transporting and placement of concrete shall be by methods that will prevent separation of the concrete materials and the displacement of the reinforcement steel from its proper position in the form.

9.2 *Curing of Pipe*— The method and extent of curing shall be established by testing not less than five cylinders cured in the same manner as the pipe until they have attained an average strength of 25 MPa. After a satisfactory curing method and period have been established, they shall not be changed without approval of the owner. If required by the owner, each day's run of pipe shall be cured until a companionate test cylinder cured in the same manner as the pipe has attained a strength of 25 MPa. Pipe shall be protected from temperatures below 5°C from the time the concrete is placed until the curing period is completed. Curing shall be by any method or combination of methods described below or by any other method approved by the owner.

9.2.1 *Steam Curing*— After the pipe has been cast, it shall be placed in an enclosure of such nature as to protect the pipe from outside drafts and to allow full circulation of saturated vapor around the inside and outside of the pipe. The rise in the ambient temperature shall not exceed 22°C in any 1 h; nor shall the ambient temperature exceed 37°C during the 2 h immediately following concrete placement. At no time shall the ambient temperature exceed 66°C. Following the periods of steam curing, the pipe shall be protected from rapid drops in temperature which are capable of injuring the pipe.

9.2.2 *Water Curing*— Concrete in pipe shall be water-cured by any method that will keep the pipe moist during the curing period.

9.2.3 *Membrane Curing*— The sealing compound used for membrane curing shall conform to the requirements of Specification C 309. The pipe surfaces shall be kept moist prior to application of the compound, and at the time of application the surfaces shall be moist and the temperature of the concrete shall be within 6°C of the atmospheric temperature. If the membrane is damaged, it shall be repaired immediately with additional compound.

10. Physical Requirements

10.1 *Test Specimens*— The specified number of pipe required for the tests shall be furnished without charge by the manufacturer and shall be selected at random by the owner, and shall be pipe that would not otherwise be rejected under this specification. The selection shall be made at the point or points designated by the owner when placing the order. Pipe units that satisfactorily pass the required tests shall be acceptable for use.

10.2 Number and Type of Test Required for Various Delivery Schedules:

10.2.1 *Preliminary Tests for Extended Delivery Schedules*—An owner of pipe, whose needs require shipments at intervals over extended periods of time, shall be entitled to such tests, preliminary to delivery of pipe, as are required in Section 5, of not more than three sections of pipe covering each size in which he is interested. The strength of concrete shall be determined from test cylinders made from the concrete used in making the pipe as provided in 10.3.

10.2.2 *Additional Tests for Extended Delivery Schedules*—After the preliminary tests described in 10.2.1 an owner shall be entitled to additional tests in such numbers and at such times as he may deem necessary, provided that the total number of pipe shall not exceed 1 % of each size and class of pipe manufactured in each test period, except that at least one hydrostatic and joint leakage test shall be made for each size and class.

10.2.3 *Length of Test Period*—For the purpose of testing the pipe units, the length of the test period will be set at the number of days the plant of the pipe manufacturer is normally operated in a calendar week. The test period will include any shutdown of the plant that does not exceed a 24-h period due to failure of the plant or equipment. The length of the test period shall be reduced, at the discretion of the owner, if there is a significant change in the materials used in the pipe, in the mix proportions, or in the production procedures or by numerous shutdowns of the plant due to failures of the plant or equipment. The length of the test period shall be increased at the discretion of the owner when results of tests for successive periods indicate that the manufacturer's operations are productive of uniformly acceptable pipe.

10.3 Concrete Strength:

10.3.1 *Compressive Strength*—Compression tests for satisfying the design concrete strength shall be made on cured concrete cylinders. The concrete shall have a minimum crushing compressive strength as specified in 10.3.3. Compression tests of such cylinders shall be made in accordance with Test Method C 39/C 39M.

10.3.2 *Number of Compression Tests* —At least five standard test cylinders shall be prepared from each day's production of concrete. Test cylinders shall be prepared in conformance with Practice C 31/C 31M, except it is not prohibited that cylinders be prepared by methods comparable to those used to consolidate and cure concrete in the actual pipe manufactured, or for concrete of a consistency too stiff for compaction by rodding or internal vibration, the alternative method described in the cylinder strength test method of Test Methods C 497M may be used.

10.3.3 *Compression Test Requirements* —The average 28-day compressive strength of all cylinders tested shall be equal to or greater than the design strength of the concrete. Not more than 10 % of the cylinders tested shall fall below the design strength. In no case shall any cylinder tested fall below 80 % of the specified design strength. These compressive strength requirements refer to standard 150 by 300-mm concrete test cylinders. Where the strength of 150 by 300-mm concrete test cylinders exceeds the capacity of the normal field testing machine (900 kN), 75 by 150-mm test cylinders will be permitted with correction for size of cylinder.

10.4 Hydrostatic Tests:

10.4.1 *Hydrostatic Testing of Pipe* —Hydrostatic tests on pipe shall be made in accordance with the provisions of Test Methods C 497M. Before the test pressure is applied, the pipe shall be allowed, at the option of the manufacturer, to stand under reduced

pressure, but not for more than 48 h. Acceptance hydrostatic tests shall be made to 120 % of the specified internal working pressure for which the pipe is designed. The pipe shall withstand the percentage of working pressure prescribed above for at least 20 min without cracking and with no leakage appearing on the exterior surface. Moisture appearing on the surface of the pipe in the form of patches or beads adhering to the surface will not be considered as leakage. Slow-forming beads of water that result in minor dripping which can be proven to seal and dry up upon retesting under the prescribed test pressure will be considered acceptable.

10.4.2 *Hydrostatic Testing of Rubber Gasket Joints*—

Hydrostatic pressure tests on joints shall be made on joints assembled of two sections of pipe, properly connected in accordance with the joint design. Suitable bulkheads shall be provided with the pipe adjacent to and on either side of the joint, or the manufacturer shall bulkhead the outer ends of joined pipe sections and conduct hydrostatic tests on both the pipe and pipe joint concurrently. No mortar or concrete coatings, fillings, or packings shall be placed prior to watertightness tests. After the pipe sections are fitted together with the rubber gasket or gaskets in place, the watertightness of the joints shall be tested under hydrostatic heads of 120 % of the pressure for which the pipe is designed, and there shall be no water leakage through the rubber gasket joint. On completion of the above straight alignment tests, the assembly shall be loaded to cause maximum joint annular space to occur. The load shall be applied such that a minimum differential load across the non-bulkheaded joint of 26.3 KN per mm of diameter is obtained or concrete to concrete contact occurs. The assembly shall then be retested as set forth in 10.4.1 and 10.4.2.

10.4.3 *Retests of Pipe or Pipe Joints Not Meeting the Hydrostatic Test Requirements*—In the event that a pipe or pipe joint fails the required tests, the manufacturer shall have the right to test two other sections of the pipe selected by the owner from the same period's run from which the original was selected. If these two pipe successfully pass the test, the remainder of the pipe in that period's run will be accepted. If either of these pipe fails, the remainder in that period's run will not be accepted until each pipe has satisfactorily passed this test.

10.5 *Rubber Gasket Compound*:

10.5.1 *Test Methods*— Laboratory tests to determine the physical properties of the rubber gaskets to be furnished under this specification shall be performed on test specimens taken from the finished rubber product, except that, at the option of the pipe manufacturer, specimens shall be furnished in accordance with the appropriate ASTM method.

10.5.1.1 *Tensile Strength and Elongation*— Test Methods D412.

10.5.1.2 *Hardness*— Test Method D2240 (with the exception of the Summary of Test Methods Section). The determination shall be taken directly on the gasket. The presser foot shall be applied on areas that are 6 mm or greater in thickness. If 6 mm or greater in thickness is not available in the gasket, thinner samples shall be plied up to obtain this thickness.

10.5.1.3 *Compression Set*— The Compression Set under Constant Deflection in Air Method of Test Methods D395. The specimens shall be a 13-mm long section of gasket with a minimum diameter of 13 mm, deflected axially. Test conditions shall be 22 h at 70°C.

10.5.1.4 *Accelerated Aging*— Test Method D573. Test conditions shall be 96 h at 70°C.

10.5.1.5 *Water Absorption*— Test Method D471. Use distilled water for the standard test liquid. When a 25-mm wide test specimen cannot be obtained, use the greatest width obtainable from the test sample. Test conditions shall be 48 h at 70°C.

10.5.1.6 *Splices*— If a splice is used in the manufacture of the gasket, the strength shall be such that the gasket shall withstand 100% elongation over the part of the gasket that includes the splice with no visible separation of the splice. While in the stretched position, the gasket shall be rotated in the spliced area a minimum of 180° in each direction in order to inspect for separation. Any portion of the splice shall be capable of passing a bend test without visible separation. The bend test for circular gaskets is defined as wrapping the portion of the unstretched gasket containing the splice a minimum of 180° and a maximum of 270° around a rod of a diameter equal to the cross section diameter of the gasket.

10.5.1.7 *Ozone Resistance*— Determine the resistance to ozone in accordance with Test Method D1149. Specimens shall be the test specimen of the finished gasket cross-section. Conduct test for 72 h in 50 PPHM with specimens stressed to 20% extension.

10.5.2 *Test Reports*— The manufacturer shall, if required, furnish certified copies of test reports of the rubber compound used in all rubber gaskets.

10.6— *In the event that a pipe or pipe joint fails the required tests, the manufacturer shall have the right to test two other sections of the pipe selected by the owner from the same period's run from which the original was selected. If these two pipe successfully pass the test, the remainder of the pipe in that period's run will be accepted. If either of these pipe fails, the remainder in that period's run will not be accepted until each pipe has satisfactorily passed this test.*

10.5 *Test Equipment*— Every manufacturer furnishing pipe under the specifications shall furnish all facilities and personnel necessary to carry out the tests described in this specification.

11. Permissible Variations

11.1 *Internal Diameter*— Permissible variations in internal diameter shall be as prescribed in Table 2. In order to obtain continuity of the interior surfaces of the pipeline, the maximum offset at the joints shall not exceed 0.75 % of the internal diameter of the pipe.

11.2 *Wall Thickness*— The wall thickness shall not be less than that intended in the design by more than 5 % at any point.

11.3 *Length of Two Opposite Sides*— Variations in laying lengths (see L in Figs. 1 and Figs. 2 of Test Methods C 497M) of two opposite sides of pipe shall not be more than 10 mm/m of diameter, with a maximum of 16 mm in any length of pipe, except where

beveled-end pipe for laying on curves is specified by the owner.

11.4 *Length of Pipe*— The underrun or overrun in length of a section of pipe shall not be more than 10 mm/m with a maximum of 13 mm in any length of pipe.

11.5 *Area of Reinforcement*—The area of steel reinforcement shall be not less than 97 % of the design steel area of each cage ring. Steel areas greater than those required in the design shall not be cause for rejection.

11.6 The average diameter of any bell or spigot shall be within the minimum and maximum limits used in Section 8 (except 8.3 for design of the joint). The average diameter of a bell will be determined by taking the average of four equally spaced diametric measurements. The average spigot diameter will be determined by dividing the measured circumference by 3.1416.

11.6.1 An additional tolerance referred to as “inspection” tolerance is allowed during inspection of completed pipe units. This tolerance quantitatively is two times the minimum design joint clearance. The minimum design joint clearance is one half of the difference between the maximum design spigot diameter and the minimum design bell diameter. This “inspection” tolerance shall be apportioned to the bell and to the spigot in a ratio elected by the manufacturer. This tolerance, when applied, defines the minimum acceptable bell diameter on any pipe unit, measured diametrically, to be the minimum design bell diameter minus that part of the “inspection” tolerance apportioned to the bell. Similarly, the maximum acceptable spigot diameter on any pipe unit, measured diametrically, is defined to be the maximum design spigot diameter plus that part of the “inspection” tolerance apportioned to the spigot.

12. Workmanship, Finish, and Appearance

12.1 Pipe shall be substantially free of fractures, excessive surface crazing, pits, air holes, laitance, excessive brush marks, and interior surface roughness.

13. Repairs

13.1 It is not prohibited for pipe to be repaired if made necessary because of imperfections in manufacture or damage during handling, and will be considered acceptable if, in the opinion of the owner, the defects do not subject the pipe unit to rejection as specified in Section 15, and the repairs are sound and properly finished and cured. Air holes in the gasket-bearing area shall be repaired. Such fillings shall be kept moist under wet burlap for at least 48 h. Hydrostatic testing of repaired pipe shall be required if deemed necessary by the owner, and such testing shall be at no additional cost to the owner.

14. Inspection

14.1 The quality of all materials, the process of manufacture, and the finished pipe shall be subject to inspection and approval by the owner.

15. Rejection

15.1 It is not prohibited for pipe to be subject to rejection on account of failure to conform to any of the specification requirements or on account of any of the following:

15.1.1 Defects that indicate imperfect mixing and molding,

15.1.2 Surface defects indicating honeycombed or open texture, that would adversely affect the performance of the pipe, and

15.1.3 Damaged ends where such damage would prevent making a satisfactory joint.

16. Product Marking

16.1 The following shall be legibly marked on the interior surface of the pipe:

16.1.1 Specification designation, class, and size as indicated in Table 1.

16.1.2 Date of manufacture,

16.1.3 Name or trademark of the manufacturer, and

16.1.4 One end of each section of pipe with elliptical reinforcement shall be clearly marked, during the process of manufacturing or immediately thereafter, on the inside and the outside of opposite walls along the minor axes of the elliptical reinforcing. Markings shall be indented on the pipe section or painted thereon with waterproof paint.

TABLE 1 Design Requirements for Reinforced Concrete Low-Head Pressure Pipe^A [300 to 2700 mm Diameter], Concrete Design Strength 31 MPa

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 1.5, 3.0, 4.5, and 6.0 m of earth cover over top of pipe. Figures 75, Figures 150, Figures 225, etc. for class of pipe, denote hydrostatic pressure heads in kilopascals measured to centerline of pipe.

Internal Designated Dia., mm	450						525			600			675					
	Circular			Elliptical			Circular			Elliptical			Circular			Elliptical		
	50	75	50	75	57	75	60	75	63	75	63	75	66	79	82	107	66	82
140	120	200	250	220	250	290	270	310	310	330	330	430	390	290	220	150	370	370
200	150	300	370	300	250	440	400	480	480	510	520	720	610	440	320	170	600	440
260	190	400	510	400	310	610	540	670	670	700	730	1030	840	590	420	190	840	590
330	230	520	660	500	390	800	690	860	860	910	960	...	1110	740	510	220	1120	740
220	220	290	360	330	520	610	400	440	440	480	700	600	560	410	340	260	780	780
270	230	390	480	420	520	610	530	610	610	660	700	890	780	560	430	280	780	780
330	260	500	620	510	610	730	670	800	800	850	860	1200	1010	710	530	300	980	780
400	300	610	770	610	750	920	820	1010	1010	1060	1090	...	1280	860	620	330	1260	860
350	350	440	520	520	...	...	610	610	610	690	...	780	780	540	450	370	...	...
350	350	480	600	600	...	...	740	740	740	890	...	1050	950	690	550	390	...	...
410	350	590	730	620	...	...	800	930	930	1140	...	1360	1180	830	640	410	...	...
480	380	710	880	720	...	...	950	1140	1140	1430	...	...	1440	980	730	440	...	...
490	490	620	740	740	...	...	860	860	860	980	...	1100	1100	660	600	500	...	...
490	490	620	740	740	...	...	870	870	870	1040	...	1220	1120	810	620	510	...	...
490	490	680	840	740	...	...	1060	1060	1060	1280	...	1530	1350	950	750	530	...	...
550	490	800	1000	840	...	...	1270	1270	1270	1580	...	...	1610	1100	840	550	...	...
660	660	830	990	990	...	...	1150	1150	1150	1310	...	1480	1480	800	680	680	...	...
660	660	830	990	990	...	...	1150	1150	1150	1310	...	1480	1480	940	820	660	...	...
660	660	830	990	990	...	...	1190	1190	1190	1430	...	1700	1510	1080	860	640	...	...
660	660	890	1110	990	...	...	1400	1400	1400	1730	...	...	1780	1230	860	660	...	...