

Section 909. DRAINAGE PRODUCTS

909.01. General Requirements. Use the pipe materials shown in Table 401-1 and Table 402-1 for culverts or sewers, if only the size and class are specified by the contract documents. Construct drainage structures and underdrains as required.

Provide galvanized corrugated steel or aluminum structural plates as required. Galvanized corrugated steel structural plates must meet the requirements of AASHTO M 167. Corrugated aluminum structural plates must meet the requirements of ASTM B 790 or Section 12 of the AASHTO LRFD Bridge Specifications.

Provide sanitary sewer or industrial waste systems in accordance with the contract. Install sanitary sewer or industrial waste systems using a compression gasket as specified in subsection 909.03.

909.02. Testing. Test drainage products in accordance with AASHTO or ASTM specifications, unless otherwise specified in this section.

Ensure each concrete pipe manufacturer provides a calibrated standard testing machine to determine the strength of the product. Ensure the manufacturer provides labor and materials to perform strength tests.

909.03. Watertight Joints for Sewers and Culverts. Provide watertight joint systems selected from the Qualified Products List. Ensure watertight joint systems meet the pressure test requirements of MTM 723 and the specifications for the materials used in assembling the pipe system.

Use flexible rubber compression gaskets meeting the requirements of ASTM C 443 for concrete pipe, ASTM F 477 for plastic pipe, or AASHTO M 36 for metal pipe. As an alternative to the AASHTO M 36 requirements for metal pipe, the Contractor may use gasket material meeting the low temperature flexibility and elevated temperature flow test requirements of ASTM C 990 and AASHTO M 198, excluding the requirements for softening point, flashpoint and fire point.

External rubber gaskets, mastic, and protective film must meet the requirements of ASTM C 877.

909.04. Concrete Pipe Products.

A. Reinforced Concrete Circular Pipe. Provide reinforced concrete circular pipe meeting the requirements of AASHTO M 170 or AASHTO M 242. If using AASHTO M 242 pipe, ensure the design loads meet the requirements of AASHTO M 170.

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If using AASHTO M 170 pipe, apply the following exceptions and additions:

1. The Contractor may use the circular pipe designs specified in Table 909-1, Table 909-2, Table 909-3, and Table 909-4 in addition to the circular pipe designs in Table 2, Table 3, Table 4, and Table 5 of AASHTO M 170.
2. Cast or drill lift holes and seal with concrete plugs after installing the pipe. Cast lift holes in circular pipe with elliptical reinforcing along the top centerline of the pipe.
3. Use circular reinforcement in circular pipe for use in pipe culverts and sewers jacked in place. The Engineer will waive the absorption test requirements of the concrete if the load required to produce the 0.01 inch crack exceeds the minimum load by at least 20 percent.

If using stirrup supports, use indentations or waterproof paint to mark the top and bottom centerline of the pipe, inside and out, on each end of the pipe. Symmetrically place stirrup supports around the centerline in the top and bottom portion of the pipe. Pass stirrups around, and in contact with each inside circumferential reinforcing member. Space the stirrups in accordance with Table 909-2, Table 909-3, and Table 909-4. Do not use more than three sections of stirrup material in one support line. Ensure a section length of at least 30 inches for each stirrup.

B. Reinforced Concrete Elliptical Pipe. Provide reinforced concrete elliptical pipe meeting the requirements of AASHTO M 207. The Engineer will waive the concrete absorption test requirement if the load required to produce the 0.01 inch crack exceeds the required minimum load by at least 20 percent.

The Contractor may use the horizontal elliptical pipe designs specified in Table 909-5 and Table 1 of AASHTO M 207.

C. Non-Reinforced Concrete Pipe. Provide non-reinforced concrete pipe meeting the requirements of AASHTO M 86. Place required markings on the barrel of the pipe near the socket. Ensure the markings remain legible during delivery of the pipe to the project.

D. Precast Concrete Box Sections. Use precast concrete box sections as required and in accordance with ASTM C 1577.

E. Concrete End Sections. Provide precast concrete end sections fabricated using material meeting the requirements of AASHTO M 170, for Class II, and as shown on the plans. Provide wet-cast concrete for end sections with an entrained air content of 6.0 percent to 8.5 percent. Ensure concrete for end sections made using the dry-cast process contains at least 658 pounds of cement per cubic yard of concrete and

uses a liquid air entraining agent at the dosage recommended by the manufacturer for dry cast concrete.

Use tongue and groove joints to make connections to pipe culverts.

F. **Pipe Culverts Jacked in Place.** For pipe culverts jacked in place, use reinforced concrete pipe at least 36 inches in diameter, meeting the requirements of AASHTO M170, for Class IV or Class V, Wall C.

G. **Precast Concrete Three-Sided and Arch Sections.** Use precast concrete three-sided and arch sections as required and in accordance with ASTM C 1504.

909.05. Metal Pipe Products. For metal pipe products, refer to Table 909-6 for the minimum wall thickness, or refer to Table 909-7 through Table 909-17, and Table 909-20 to determine the required wall thickness.

Refer to Table 909-19 for gauge equivalents for specified nominal thicknesses.

A. **Corrugated Steel Pipe.** Provide circular and pipe arch corrugated steel pipe meeting the requirements of AASHTO M 36 for metallic coated pipe. For polymer-precoated pipe, provide circular and pipe arch corrugated steel pipe meeting the requirements of AASHTO M 245 and using an ethylene acrylic acid film selected from the Qualified Products List.

The Contractor may use Type IA and Type IIA dual wall polymer-precoated galvanized corrugated steel pipe of the wall thicknesses specified in Table 909-6 and specified in subsection 909.05.

1. **Steel Sheet.** Provide corrugated steel pipe from zinc coated sheets meeting the requirements of AASHTO M 218 or from aluminum coated sheets meeting the requirements of AASHTO M 274. Do not use the continuous welded seam process if using aluminum coated sheets for pipe.

On zinc coated steel sheet for polymer-precoated corrugated steel pipe, use ethylene acrylic acid film selected from the Qualified Products List meeting the requirements of AASHTO M 246, for Grade 250/250 polymer. Only use lock seam pipe. Do not use riveted pipe.

Ensure the metallic coating weight on individual samples of fabricated pipe or steel sheet meets the single spot and triple spot test requirements in accordance with AASHTO M 218. Refer to Table 909-6, Table 909-7, Table 909-8, Table 909-9, Table 909-10,

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and Table 909-11 for the specified nominal sheet thickness for a given diameter, class, and size of corrugation of culvert or sewer pipe.

Provide pipe from 6 inches to 12 inches in diameter, fabricated from steel sheet with a minimum thickness of at least 0.064 inch (16 gage).

2. **Corrugations.** For required pipe at least 12 inches in diameter, do not use pipe with 1½ inch by ¼ inch corrugations.
3. **End Finish for Helical Corrugated Pipe.** For helical corrugated pipe, except perforated pipe, with diameters of at least 12 inches, reroll the pipe ends to form at least two circumferential corrugations, or to form an upturned flange, in accordance with AASHTO M 36 or AASHTO M 245. This end treatment for perforated pipe and pipe with diameters less than 12 inches is optional for the fabricator.
4. **Coupling Bands.** To connect sections of pipe and to attach end sections to culvert pipe with diameters of at least 12 inches, except perforated pipe, provide coupling bands circumferentially corrugated with the same size corrugations as on the ends of the pipe. As an alternative, use preformed channel bands on pipe ends with flanges meeting the requirements of AASHTO M 36 or AASHTO M 245 and the details shown on the plans.

For coupling bands with diameters no greater than 10 inches, use coupling bands with corrugations matching the pipe corrugations.

The Contractor may connect perforated pipe with a diameter no greater than 12 inches, with smooth sleeve-type couplers. For perforated pipe with diameters greater than 12 inches, use coupling bands with corrugations matching the pipe corrugations.

Provide coupling band connections as specified in subsection 401.03 and meeting the requirements of AASHTO M 36 or AASHTO M 245.

B. Corrugated Aluminum Alloy Pipe. Provide corrugated aluminum alloy pipe meeting the requirements of AASHTO M 196, except fabricate pipe from aluminum sheet with the nominal thickness specified in Table 909-12, Table 909-13, Table 909-14, Table 909-15, Table 909-16, and Table 909-17.

Only use Type IA and Type IIA corrugated aluminum alloy pipe if directed by the Engineer.

C. Steel End Sections. Provide steel end sections with coupling bands or hardware as shown on the plans. Ensure metallic coating on the end

sections is the same as the metallic coating on the pipe. The Contractor may use zinc coated steel end sections with aluminum coated steel pipe and polymer coated steel pipe. Provide metal end sections meeting the requirements of AASHTO M 36.

D. Steel Pipe for Jacking in Place. Provide steel pipe for jacking in place meeting the requirements of ASTM A 53, for Type E or Type S, Grade B or ASTM A 139, for Grade B. For field welding at joints, prepare the ends of steel pipe for jacking in place.

909.06. Plastic Pipe Products. Provide Smooth-Lined Corrugated Polyethylene Pipe (CPE) and required fittings meeting the requirements of AASHTO M 294, for Type S.

Provide Corrugated Polyvinyl Chloride Pipe (CPV) and required fittings meeting the requirements of AASHTO 304. The Engineer will test CPV in accordance with MTM 728.

If providing a separate fitting or coupling to ensure a watertight joint in corrugated plastic pipe culverts and sewers, use non-corrugated, solid sleeve, fabricated from Polyethylene (PE) or Polyvinyl Chloride (PVC) with a gasket meeting the requirements of subsection 909.03 on both sides of the joint. Do not use split collar couplers.

Ensure a pipe indentation in each sleeve in the center to ensure positioning of the pipe sections in the field. Factory install sleeves on one end of the pipe sections and place a removable protective material over the exposed gaskets. Lubricate gaskets and sleeves before insertion, as required by the manufacturers.

909.07. Pipe for Underdrains.

A. Smooth Plastic Pipe for Underdrain. Provide smooth plastic pipe for underdrain, fabricated from PVC pipe meeting the requirements of AASHTO M 278. For pipes no greater than 6 inches in diameter, the Contractor may use acrylonitrile-butadiene-styrene (ABS) pipe meeting the requirements of ASTM D 2751, for SDR 35, with perforations meeting the requirements of AASHTO M 278, except the joint tightness requirements do not apply.

B. Corrugated Plastic Tubing for Underdrain. Provide corrugated plastic tubing for underdrain meeting the requirements of AASHTO M 252 for PE tubing, or ASTM F 949 for PVC tubing. Ensure the perforations for PE and PVC tubing meet the requirements of AASHTO M 252.

C. Underdrain Outlets. Provide PVC pipe underdrain outlets meeting one of the following requirements:

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1. ASTM D 1785 Schedule 40;
2. ASTM D 2665;
3. ASTM D 3034, for Type SDR 23.5; or
4. Corrugated steel pipe in accordance with subsection 909.05.A.

D. Connections. Obtain the Engineer's approval of fittings and connections for the underdrain system before installing the underdrain.

Seal connections with tape recommended by the manufacturer for underground service conditions. Provide tape resistant to moisture and organic growth.

909.08. Pipe for Downspouts.

A. Bridge Deck Downspouts. Provide bridge deck downspouts of PE pipe meeting the requirements of ASTM D 2447, PE 3406, Schedule 40. The Contractor may provide bridge deck downspouts of fiberglass Reinforced Thermosetting Resin Pipe (RTRP) with a short-term rupture hoops tensile stress of at least 30,000 psi, in accordance with ASTM D 2996.

B. Culvert, Downspouts. If shown on the plans, provide other culvert downspouts made from one of the following:

1. Corrugated steel pipe as specified in subsection 909.05.A;
2. Corrugated aluminum alloy pipe as specified in subsection 909.05.B;
- or
3. Corrugated Polyethylene Pipe (CPP) meeting the requirements of AASHTO M 294, for Type C.

Provide fittings required for CPP meeting the requirements of AASHTO M 294.

Seal joints between lengths of pipe, as recommended by the pipe manufacturer, to form silt-tight joints. Provide end sections as shown on the plans and specified in subsection 909.04.D or subsection 909.05.C.

C. Bridge Deck Drain Extensions. Provide bridge deck drain extensions as an integral component of the drain casting assembly in accordance with Standard Plan B-101 Series.

909.09. Cold-Applied Pipe Joint Sealer. The Engineer will test cold-applied pipe joint sealers in accordance with section 904 as modified by this subsection.

The Engineer will use the cone method penetration test in accordance with ASTM D 1191, except the Engineer will test the material as received. The Contractor may trowel the material into the ointment can. The Engineer will perform the flow test in accordance with

ASTM D 1851, except the Contractor may trowel the material into the test mold.

Ensure the asphaltic material for sealing joints in concrete or clay pipe can spread on the joints with a trowel at an air temperature from 14 °F to 100 °F. Ensure the material adheres to the concrete or clay to make a watertight seal. Ensure the material does not flow, crack, or become brittle if exposed to the atmosphere.

Provide asphaltic sealer meeting the following requirements:

- A. Penetration with cone from 175 dmm to 300 dmm, at 77 °F, for 5 seconds, 150 grams;
- B. Loss on heating maximum of 1.50 percent at 325 °F, for 5 hours, 50 grams;
- C. Minimum solubility in trichloroethylene, 70 percent;
- D. Ash from 15 percent to 25 percent; and
- E. Flow of 0 centimeter maximum at 60 °C.

Deliver the sealer to the project in sealed containers. Protect the sealer from contamination. Mark the container with "Cold-Applied Pipe Joint Sealer" and the brand name, net volume or weight, and the application requirements.

909.10. Drainage Marker Posts. Provide drainage marker posts meeting the requirements for plastic or steel delineator posts as specified in section 919 or the requirements for steel line fence posts in section 907, except provide posts at least 6 feet long. The Contractor may submit alternate post materials to the Engineer for approval.

909.11. Rodent Screens. Provide rodent screens of hardware cloth meeting the requirements of ASTM A 740 with an opening size no greater than 0.30 inch, except provide wire of a nominal size of 0.057 inch and a minimum zinc coating weight of 0.59 ounce per square foot of uncoated wire surface, applied after weaving. The Contractor may substitute fabric made of Type 304 stainless steel wire with an opening no greater than 0.30 inch and a 0.057 inch nominal wire diameter. The Contractor may submit other screens with openings no greater than 0.30 inch to the Engineer for approval.

Form the screen using a punch and die. After shaping ensure the fabric forms a cylinder slightly larger than the inside diameter of the outlet pipe.

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Table 909-1 Additional Designs For Class II Reinforced Concrete Pipe (AASHTO M 170 Table 2 Extended)					
Internal Diameter of Pipe, (in)	Minimum Wall Thickness, (in)	Reinforcement per foot of Pipe Wall, (sq in)			
		Circular Reinforcement in Circular Pipe		Elliptical Reinforcement in Circular Pipe	
		Inner Cage	Outer Cage	Inner Circular Cage	Elliptical Cage
114	9.5	0.56	0.34	0.22	0.34
120	10	0.61	0.37	0.24	0.37
126	10.5	0.65	0.39	0.26	0.39
132	11	0.70	0.42	0.28	0.42
144	12	0.80	0.48	0.32	0.48
Note: D-Load = pound-force per linear foot per foot of diameter. D-Load to produce a 0.01 in crack 1,000. D-Load to produce the ultimate load, 1,500. Concrete Strength, 5,000 psi					

Table 909-2 Additional Designs For Class III Reinforced Concrete Pipe(AASHTO M 170 Table 3 Extended)											
Internal Diameter of Pipe, (in)	Minimum Wall Thickness, (in)	Reinforcement per foot of Pipe Wall, (sq in)				Stirrup Support System					
		Circular Reinforcement in Circular Pipe		Elliptical Reinforcement in Circular Pipe		Minimum Area per Support Element, (sq in) (a)	No. of Lines (b)	Long. Spacing, (in)	Circum. Spacing on Inner Cage, (in)	Amplitude of Supports, (in) (c)	Ave. Area (sq in per ft per line) (d)
		Inner Cage	Outer Cage	Inner Circular Cage	Elliptical Cage						
114	9½	0.69	0.41	0.28	0.41	0.041	5	2	6½	6.68	0.242
120	10	0.74	0.44	0.30	0.44	0.041	5	2	6½	7.16	0.242
126	10½	0.79	0.47	0.32	0.47	0.041	5	2	6½	7.68	0.242
132	11	0.85	0.51	0.34	0.51	0.041	5	2	7¼	8.16	0.242
144	12	0.97	0.58	0.39	0.58	0.041	5	2	8	9.16	0.242

Note: D-Load = pound-force per linear foot per foot of diameter.
D-Load to produce a 0.01 in crack 1,350.
D-Load to produce the ultimate load 2000.
Concrete Strength 5000 psi.
Where a stirrup system is shown for a given size, it must be used with the circumferential reinforcement design selected.

a. Two times the cross-sectional area of the wire used in the stirrup support system using 2 in × 8 in pattern for inner cage steel.
b. Number of longitudinal lines required in the top and in the bottom portions of the pipe.
c. Overall width of each line of stirrup support system using 2 in × 8 in pattern for inner cage steel. (Use with Shearlock stirrups or S-stirrups or equal)
d. Minimum area per support times number of supports per foot using 2 in × 8 in pattern for inner cage steel.

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Table 909-3 Additional Designs For Class IV Reinforced Concrete Pipe(AASHTO M 170 Table 4 Extended)											
Internal Diameter of Pipe, (in)	Minimum Wall Thickness, (in)	Reinforcement, per foot of Pipe Wall, (sq in)				Stirrup Support System					
		Circular Reinforcement in Circular Pipe		Elliptical Reinforcement in Circular Pipe		Minimum area per Support Element (sq in) (a)	Number of Lines (b)	Long. Spacing, (in)	Circum. Spacing on Inner Cage, (in)	Amplitude of Supports, (in) (c)	Ave. Area, (sq in per ft per line) (d)
		Inner Cage	Outer Cage	Inner Circular Cage	Elliptical Cage						
		Concrete Strength, 5,500 psi									
78	7½	0.87	0.52	0.35	0.52						
84	8	1.00	0.60	0.40	0.64						
—	—	Concrete Strength, 5,000 psi									
78	7½	0.69	0.41	0.28	0.41	0.028	11	2	4½	4.67	0.167
84	8	0.74	0.44	0.30	0.44	0.028	11	2	4½	5.17	0.167
90	8	0.85	0.51	0.34	0.51	0.028	11	2	4½	5.17	0.167
96	8½	0.91	0.55	0.36	0.55	0.028	11	2	5½	5.67	0.167
102	8½	1.02	0.61	0.41	0.61	0.033	11	2	5½	5.67	0.195
108	9	1.07	0.64	0.43	0.64	0.043	11	2	5½	6.17	0.260
114	9½	1.02	0.61	0.41	0.61	0.047	11	2	6½	6.67	0.279
120	10	1.10	0.66	0.44	0.66	0.050	11	2	6½	7.17	0.298
126	10½	1.17	0.70	0.47	0.70	0.053	11	2	6½	7.67	0.316
132	11	1.25	0.75	0.50	0.75	0.056	11	2	7¼	8.17	0.335
144	12	1.42	0.85	0.57	0.85	0.064	11	2	8	9.17	0.381

Note: D-Load = pound-force per linear foot per foot of diameter.
D-Load to produce a 0.01 inch crack, 2,000.
D-Load to produce the ultimate load, 3,000.
Where a stirrup system is shown for a given size, it must be used with the circumferential reinforcement design selected.

a. Two times the cross-sectional area of the wire used in the S-stirrups.
b. Number of longitudinal lines required in the top and in the bottom portions of the pipe.
c. Overall width of each line of stirrup support system using 2 in x 8 in pattern for inner cage steel. (Use with Shearlock stirrups or S-stirrups or equal.)
d. Minimum area per support times number of supports per foot using 2 in x 8 in pattern for inner cage steel.

Table 909-4 Additional Designs for Class V Reinforced Concrete Pipe (AASHTO M 170 Table 5 Extended)											
Internal Diameter of Pipe, (in)	Wall Thickness, (in min)	Reinforcement, sq in per foot of Pipe Wall				Stirrup Support System					
		Circular Reinforcement in Circular Pipe		Elliptical Reinforcement in Circular Pipe		Minimum Area per Support Element, (sq in) (a)	Number of Lines (b)	Long. Spacing, (in)	Circum. Spacing on Inner Cage, (in)	Amplitude of Supports, (in) (c)	Ave. Area, (sq in per ft per line) (d)
		Inner Cage	Outer Cage	Inner Circular Cage	Elliptical Cage						
54	5½	0.64	0.38	0.26	0.38	0.028	15	2	2½	2.68	0.167
60	6	0.70	0.42	0.28	0.42	0.028	14	2	2¾	3.20	0.167
66	6½	0.79	0.47	0.32	0.47	0.028	13	2	3¼	3.68	0.167
72	7	0.87	0.52	0.35	0.52	0.028	12	2	3⅝	4.16	0.167
78	7½	0.92	0.55	0.37	0.55	0.028	11	2	4¼	4.68	0.167
84	8	0.99	0.59	0.40	0.59	0.033	11	2	4⅝	5.16	0.195
90	8	1.13	0.68	0.45	0.68	0.040	11	2	4¾	5.16	0.248
96	8½	1.20	0.72	0.48	0.72	0.043	11	2	5¼	5.68	0.260
102	8½	1.34	0.80	0.54	0.80	0.051	11	2	5⅝	5.68	0.307
108	9	1.51	0.91	0.60	0.91	0.061	11	2	5¾	6.16	0.363
114	9½	1.51	0.91	0.60	0.91	0.062	11	2	6¼	6.68	0.372
120	10	1.62	0.97	0.65	0.97	0.067	11	2	6½	7.16	0.400
126	10½	1.73	1.04	0.69	1.04	0.070	11	2	6¾	7.68	0.419
132	11	1.84	1.10	0.74	1.10	0.074	11	2	7¼	8.16	0.446
144	12	2.09	1.25	0.84	1.25	0.082	11	2	8	9.16	0.493

Note: D-Load = pound-force per linear foot per foot of diameter.
D-Load to produce a 0.01 inch crack, 3, 000.
D-Load to produce the ultimate load, 3, 750.
Concrete Strength, 6,000 psi.
Where a stirrup system is shown for a given size, it must be used with the circumferential reinforcement design selected.

a. Two times the cross-sectional area of the wire used in the Stirrups Support System using 2 in × 8 in pattern for inner cage steel. (Use with Shearlock stirrups or S-stirrups or equal.)
b. Number of longitudinal lines required in the top and in the bottom portions of the pipe.
c. Overall width of each line of stirrups.
d. Minimum area per support times number of supports per foot using 2 in × 8 in pattern for inner cage steel.

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Table 909-5 Additional Designs for Horizontal Elliptical Pipe																	
Specified Diameter, Equivalent Round Size (in)	Specified Rise by Span (in)	Min Wall Thick (in)	Reinforcement, sq in per foot														
			Class HE-A		Class HE-I		Class HE-II		Class HE-III		Class HE-IV						
			D-Loads		Stirrup Support System												
			0.01 = 600		0.01 = 800		0.01 = 1000		0.01 = 1350		0.01 = 2000		Min Area per Support Element (sq in)	Number of Lines (a)	Long. Spacing (in)	Circum. Spacing on Inner Cage (in) (b)	
			Ult = 900		Ult = 1200		Ult = 1500		Ult = 2000		Ult = 3000						
In Cage	Out Cage	In Cage	Out Cage	In Cage	Out Cage	In Cage	Out Cage	In Cage	Out Cage	In Cage	Out Cage	In Cage	Out Cage				
48	38 × 60	5½	—	—	—	—	—	—	—	—	—	0.70	0.70	0.13	15	2	3.000
54	43 × 68	6	—	—	—	—	—	—	—	—	—	0.82	0.82	0.15	15	2	3.375
60	48 × 76	6½	—	—	—	—	—	—	—	—	—	0.94	0.94	0.17	15	2	3.750
66	53 × 83	7	—	—	—	—	—	—	—	—	—	0.99	0.99	0.17	15	2	4.125
72	58 × 91	7½	—	—	—	—	—	—	—	—	—	1.11	1.11	0.19	15	2	4.500
84	63 × 98	8	—	—	—	—	—	—	—	—	—	1.21	1.21	0.21	15	2	4.875
78	68 × 106	8½	—	—	—	—	—	—	—	—	—	1.33	1.33	0.22	15	2	5.250
90	72 × 113	9	0.28	0.28	0.40	0.40	0.58	0.58	—	0.84	1.43	1.43	0.24	15	2	5.625	
96	77 × 121	9½	0.30	0.30	0.45	0.45	0.65	0.65	0.92	0.92	1.56	1.56	0.26	15	2	6.000	
102	82 × 128	9¾	0.33	0.33	0.52	0.52	0.73	0.73	1.03	1.03	1.72	1.72	0.28	15	2	6.188	
108	87 × 136	10	0.36	0.36	0.60	0.60	0.83	0.83	1.16	1.16	1.92	1.92	0.30	15	2	6.375	
114	92 × 143	10½	0.40	0.40	0.64	0.64	0.88	0.88	1.23	1.23	2.02	2.02	0.32	15	2	6.750	
120	97 × 151	11	0.44	0.44	0.70	0.70	0.96	0.96	1.32	1.32	2.16	2.16	0.34	15	2	7.125	
132	106 × 166	12	0.53	0.53	0.81	0.81	1.09	1.09	1.49	1.49	2.40	2.40	0.38	15	2	7.875	
144	116 × 180	13	0.61	0.61	0.91	0.91	1.21	1.21	1.64	1.64	2.62	2.62	0.42	15	2	8.625	
Concrete Strength, psi			4,000		4,000		4,000		5,000		48 in, 54 in, 60 in 4,000 66 in – 144 in 5,000						

Note: Where a stirrup system is shown for a given size, it must be used with the circumferential reinforcement design selected.
a. Number of longitudinal lines required in the top and in the bottom portions of the pipe.
b. Overall width of each line of stirrups.

Table 909-6 References for Spiral Ribbed and Corrugated Metal Pipes			
Pipe Material Type	Driveway Culverts and Downspouts	Culverts	Sewers
	Minimum Design Life		
	25 years	50 years	70 years
Galvanized Spiral Ribbed Metal Pipe	Table <u>909-8</u>	0.109	0.168
Aluminized Type 2 Spiral Ribbed Metal Pipe	Table <u>909-8</u>	Table <u>909-11</u>	0.138
Polymer-Precoated Spiral Ribbed Metal Pipe	Table <u>909-8</u>	Table <u>909-8</u>	Table <u>909-8</u>
Galvanized Corrugated Metal Pipe	Table <u>909-7</u>	Table <u>909-9</u>	0.168 (a)
Aluminized Type 2 Corrugated Metal Pipe	Table <u>909-7</u>	Table <u>909-10</u>	0.138 (a)
Polymer-Precoated Corrugated Galvanized Pipe	Table <u>909-7</u>	Table <u>909-7</u>	Table <u>909-7</u> (a)
Aluminum pipe	Table <u>909-12</u>	Table <u>909-13</u>	Table <u>909-14</u>
Aluminum Spiral Ribbed Pipe	Table <u>909-15</u>	Table <u>909-16</u>	Table <u>909-17</u>
Dual Wall Polymer-Precoated Galvanized Corrugated Steel Pipe	Table <u>909-20</u>	Table <u>909-20</u>	Table <u>909-20</u>
<p>Note: Minimum wall thickness in inches to meet structural and durability requirements for various metal pipes to meet the design life.</p> <p>Numbers represent the minimum durability gage requirements for the specific pipe material.</p> <p>Table <u>909-7</u> represents the minimum structural gauge thickness requirements for corrugated steel pipe.</p> <p>Table <u>909-8</u> represents the minimum structural gauge thickness requirements for spiral ribbed steel pipe.</p> <p>a. Permitted for 12 in to 18 in diameter $2\frac{2}{3}$ in \times $\frac{1}{2}$ in helically corrugated pipe only.</p>			

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Table 909-7 Wall Thickness Requirements in Inches, Based on Diameter Class of Pipe, and Size of Corrugation								
Pipe Diameter, (in)	0 ft – 16 ft		>16 ft – 24 ft			>24 ft – 32 ft		
	Corrugation Size, (in)		Corrugation Size, (in)			Corrugation Size, (in)		
	2 $\frac{2}{3}$ × 1/2	3 × 1, 5 × 1	2 $\frac{2}{3}$ × 1/2	3 × 1	5 × 1	2 $\frac{2}{3}$ × 1/2	3 × 1	5 × 1
12–30	0.064	—	0.064	—	—	0.064	—	—
36–48	0.064	0.064	0.064	0.064	0.064	0.064 ^a	0.064	0.064
54	0.079	0.064	0.079	0.064	0.064	0.079	0.064	0.064
60	0.109	0.064	0.109	0.064	0.064	0.109	0.064 (a)	0.064
66	0.138	0.064	0.138	0.064	0.064	0.138	0.064 (a)	0.064
72	0.138	0.064	0.138	0.064 (a)	0.064	0.138	0.064 (a)	0.064
78	0.168	0.064	0.168	0.064 (a)	0.064	0.168	0.064 (b)	0.064
84	0.168	0.064	0.168	0.064 (a)	0.064	0.168	0.064 (b)	0.079
90	—	0.064	—	0.064 (b)	0.064	—	0.079 (a)	0.079
96	—	0.079	—	0.079 (a)	0.079	—	0.079 (a)	0.079
102	—	0.079	—	0.079 (a)	0.079	—	0.079 (a)	0.109
108–120	—	0.109	—	0.109	0.109	—	0.109 (a)	0.109
126	—	0.138	—	0.138	0.138	—	0.138	0.138
130–136	—	0.138	—	0.138	0.138	—	0.138 (a)	0.138
144	—	0.168	—	0.168	0.168	—	0.168 (c)	0.168

Note: For pipe-arch shape corrugated steel pipe, use the gage requirement for the circular pipe equal to or next larger than the span of the pipe-arch.

a. Increase the wall thickness by one gage for riveted or spot welded longitudinal seams.

b. Increase the wall thickness by two gages for riveted or spot welded longitudinal seams.

c. Not allowed for riveted or spot welded longitudinal seams. Riveted or spot welded seams not permitted for 5 in × 1 in corrugations.

Table 909-8						
Wall Thickness Requirements in Inches Based on Diameter, Class of Pipe, and Size of Ribs						
Pipe Diameter, (in)	0 ft – 16 ft		>16 ft – 24 ft		>24 ft – 32 ft	
	Corrugation Size, (in)		Corrugation Size, (in)		Corrugation Size, (in)	
	$\frac{3}{4} \times \frac{3}{4} \times 7\frac{1}{2}$	$\frac{3}{4} \times 1 \times 11\frac{1}{2}$	$\frac{3}{4} \times \frac{3}{4} \times 7\frac{1}{2}$	$\frac{3}{4} \times 1 \times 11\frac{1}{2}$	$\frac{3}{4} \times \frac{3}{4} \times 7\frac{1}{2}$	$\frac{3}{4} \times 1 \times 11\frac{1}{2}$
18–36	0.064	0.064	0.064	0.064	0.064	0.064
42	0.064	0.064	0.064	0.064	0.064	0.079
48	0.064	0.064	0.064	0.079	0.064	0.079
54	0.079	0.064	0.079	0.079	0.079	0.109
60	0.079	0.079	0.079	0.079	0.079	0.109
66	0.109	0.079	0.109	0.109	0.109	0.109
72–78	0.109	0.109	0.109	0.109	0.109	0.109
84	—	0.109	—	0.109	—	0.109

Note: For pipe-arch shape corrugated steel pipe, use the gage requirement for the circular pipe equal to or next larger than the span of the pipe-arch.

Table 909-9 Wall Thickness Requirements in Inches Based on Class of Pipe and Size of Corrugation							
Pipe Diameter, (in)	Class A and Class B		Class C		Class D		
	Corrugation Size, (in)		Corrugation Size, (in)		Corrugation Size, (in)		
	2 $\frac{2}{3}$ × 1 $\frac{1}{2}$	3 × 1, 5 × 1	2 $\frac{2}{3}$ × 1 $\frac{1}{2}$	3 × 1, 5 × 1	2 $\frac{2}{3}$ × 1 $\frac{1}{2}$	3 × 1	5 × 1
12–30	0.109	—	0.109	—	0.109	—	—
36–60	0.109	0.109	0.109	0.109	0.107	0.109	0.109
66–72	0.138	0.109	0.138	0.109	0.138	0.109	0.109
78–84	0.168	0.109	0.168	0.109	0.168	0.109	0.109
90–102	—	0.109	—	0.109	—	0.109	0.109
108–120	—	0.109	—	0.109	—	0.109 (a)	0.109
126	—	0.138	—	0.138	—	0.138	0.138
130–136	—	0.138	—	0.138	—	0.138 (a)	0.138
144	—	0.168	—	0.168	—	0.168 (b)	0.168

Note: For pipe-arch shape corrugated steel pipe, use the gage requirement for the circular pipe equal to or next larger than the span of the pipe-arch.

a. Increase the wall thickness by one gage for riveted or spot welded longitudinal seams.

c. Not allowed for riveted or spot welded longitudinal seams. Riveted or spot welded seams not permitted for 5 in × 1 in corrugations.

Table 909-10 Wall Thickness Requirements in Inches Based on Diameter, Class of Pipe and Size of Corrugation								
Pipe Diameter, (in)	Class A and B		Class C			Class D		
	Corrugation Size, (in)		Corrugation Size, (in)			Corrugation Size, (in)		
	$2\frac{2}{3} \times \frac{1}{2}$	$3 \times 1, 5 \times 1$	$2\frac{2}{3} \times \frac{1}{2}$	3×1	5×1	$2\frac{2}{3} \times \frac{1}{2}$	3×1	5×1
12-30	0.079	—	0.079	—	—	0.079	—	—
36-54	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079
60	0.109	0.079	0.109	0.079	0.079	0.109	0.079	0.079
66-72	0.138	0.079	0.138	0.079	0.079	0.138	0.079	0.079
78-84	0.168	0.079	0.168	0.079	0.079	0.168	0.079 (a)	0.079
90-96	—	0.079	—	0.079 (a)	0.079	—	0.079 (a)	0.079
102	—	0.079	—	0.079 (a)	0.079	—	0.079 (a)	0.109
108-120	—	0.109	—	0.109	0.109	—	0.109 (a)	0.109
126	—	0.138	—	0.138	0.138	—	0.138	0.138
130-136	—	0.138	—	0.138	0.138	—	0.138 (a)	0.138
144	—	0.168	—	0.168	0.168	—	0.168 (b)	0.168

Note: For pipe-arch shape corrugated steel pipe, use the gage requirement for the circular pipe equal to or next larger than the span of the pipe-arch.

a. Increase the wall thickness by one gage for riveted or spot welded longitudinal seams.

b. Not allowed for riveted or spot welded longitudinal seams. Riveted or spot welded seams not permitted for $5 \text{ in} \times 1 \text{ in}$ corrugations.

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Table 909-11
Wall Thickness Requirements in Inches Based on Diameter, Class of Pipe, and Size of Ribs

Pipe Diameter, (in)	Class A and B		Class C		Class D	
	Corrugation Size, (in)		Corrugation Size, (in)		Corrugation Size, (in)	
	$\frac{3}{4} \times \frac{3}{4} \times 7\frac{1}{2}$	$\frac{3}{4} \times 1 \times 11\frac{1}{2}$	$\frac{3}{4} \times \frac{3}{4} \times 7\frac{1}{2}$	$\frac{3}{4} \times 1 \times 11\frac{1}{2}$	$\frac{3}{4} \times \frac{3}{4} \times 7\frac{1}{2}$	$\frac{3}{4} \times 1 \times 11\frac{1}{2}$
18–48	0.079	0.079	0.079	0.079	0.079	0.079
54–60	0.079	0.079	0.079	0.079	0.079	0.109
66–78	0.109	0.109	0.109	0.109	0.109	0.109
84	—	0.109	—	0.109	—	0.109

Note: For pipe-arch shape corrugated steel pipe, use the gage requirement for the circular pipe equal to or next larger than the span of the pipe-arch.

Table 909-12
Wall Thickness Requirements in Inches, Based on Class of Pipe and Size of Corrugation, Lock Seam Pipe Only

Pipe Diameter, (in)	0 ft – 16 ft		>16 ft – 24 ft		>24 ft – 32 ft	
	Corrugation Size, (in)		Corrugation Size, (in)		Corrugation Size, (in)	
	$2\frac{2}{3} \times \frac{1}{2}$	3×1	$2\frac{2}{3} \times \frac{1}{2}$	3×1	$2\frac{2}{3} \times \frac{1}{2}$	3×1
12–27	0.060	0.060	0.060	0.060	0.060	0.060
30–36	0.075	0.060	0.075	0.060	0.075	0.060
42–54	0.105	0.060	0.105	0.060	0.105	0.060
60	0.135	0.075	0.135	0.075	0.135	0.075
66–72	0.164	0.075	0.164	0.075	0.164	0.075
78	—	0.075	—	0.075	—	0.075
84–96	—	0.105	—	0.105	—	0.105
102–108	—	0.135	—	0.135	—	0.135
112–120	—	0.164	—	0.164	—	0.164

Note: For pipe-arch shape corrugated aluminum pipe, use the gage requirement for the circular pipe equal to or next larger than the span of the pipe-arch.

Table 909-13		
Wall Thickness Requirements in Inches, Based on Class of Pipe and Size of Corrugation, Lock Seam Pipe Only		
Pipe Diameter, (in)	Class A, B, C, D	
	Corrugation Size, (in)	
	2$\frac{2}{3}$ × 1$\frac{1}{2}$	3 × 1
12–36	0.075	0.075
42–54	0.105	0.075
60	0.135	0.075
66–72	0.164	0.075
78	—	0.075
84–96	—	0.105
102–108	—	0.135
112–120	—	0.164

Note: For pipe-arch shape corrugated aluminum pipe, use the gage requirement for the circular pipe equal to or next larger than the span of the pipe-arch.

Table 909-14		
Wall Thickness Requirements in Inches, Based on Class of Pipe and Size of Corrugation, Lock Seam Pipe Only		
Pipe Diameter, (in)	Class A, B, C, D	
	Corrugation Size, (in)	
	2$\frac{2}{3}$ × 1$\frac{1}{2}$	3 × 1
12–54	0.105	0.105
60	0.135	0.105
66–72	0.164	0.105
78–96	—	0.105
102–108	—	0.135
112–120	—	0.164

Note: For pipe-arch shape corrugated aluminum pipe, use the gauge requirement for the circular pipe equal to or next larger than the span of the pipe-arch.

Table 909-15	
Wall Thickness Requirements in Inches, Based on Diameter, Class of Pipe, and Size of Rib, Lock Seam Pipe Only	
Pipe Diameter, (in)	Class F
	$\frac{3}{4}$ × $\frac{3}{4}$ × 7$\frac{1}{2}$
18–24	0.060
30–36	0.075
42–54	0.105
60–66	0.135

Note: For pipe-arch shape corrugated aluminum pipe, use the gage requirement for the circular pipe equal to or next larger than the span of the pipe-arch.

Table 909-16	
Wall Thickness Requirements in inches, Based on Diameter, Class of Pipe, and Size of Rib, Lock Seam Pipe Only	
Pipe Diameter, (in)	Class A, B, C, D
	$\frac{3}{4} \times \frac{3}{4} \times 7\frac{1}{2}$
18-36	0.075
42-54	0.105
60-66	0.135

Note: For pipe-arch shape corrugated aluminum pipe, use the gage requirement for the circular pipe equal to or next larger than the span of the pipe-arch.

Table 909-17	
Wall Thickness Requirements in Inches, Based on Diameter, Class of Pipe, and Size of Rib, Lock Seam Pipe Only	
Pipe Diameter, (in)	Class A, B, C, D
	$\frac{3}{4} \times \frac{3}{4} \times 7\frac{1}{2}$
18-54	0.105
60-66	0.135

Note: For pipe-arch shape corrugated aluminum pipe, use the gage requirement for the circular pipe equal to or next larger than the span of the pipe-arch.

Table 909-18		
Nominal OD and Wall Thickness in Inches Jacked In Place Steel Pipe		
Nominal Size	Nominal Outside Diameter	Wall Thickness
2	2.375	0.154
4	4.500	0.188
6	6.625	0.188
8	8.625	0.188
10	10.750	0.188
12	12.750	0.188
14	14.000	0.250
16	16.000	0.250
18	18.000	0.250
20	20.000	0.250
24	24.000	0.250
30	30.000	0.312
36	36.000	0.312
42	42.000	0.438
48	48.000	0.500
54	54.000	0.563

Sheet Gauge Number	Nominal Thickness	
	Galvanized	Aluminum Alloy
18	0.052	0.048
16	0.064	0.060
14	0.079	0.075
12	0.109	0.105
10	0.138	0.135
8	0.168	0.164
7	0.188	—
5	0.218	—
3	0.249	—
1	0.280	—

Diameter of Pipe, (in)	Corrugation Size, (in)		Corrugation Size, (in)	
	$2\frac{2}{3} \times \frac{1}{2}$		3 x 1	
	Shell	Liner	Shell	Liner
36-48	0.064	0.052	0.064	0.052
54	0.079	0.052	0.064	0.052
60	0.109	0.052	0.064	0.052
66-72	0.138	0.052	0.064	0.052
78-84	0.168	0.052	0.064	0.052
90-102	—	—	0.079	0.052
108-120	—	—	0.109	0.052
126-136	—	—	0.138	0.052
144	—	—	0.168	0.052