

Standard Specification  
for

Corrugated Aluminum Pipe for Sewers and Drains

AASHTO DESIGNATION: M 196/M 196M-92  
(ASTM DESIGNATION: B 745/B 745M-90)

1. SCOPE

1.1 This specification covers corrugated aluminum pipe intended for use for storm water drainage, underdrains, the construction of culverts, and similar uses. Pipe covered by this specification is not normally used for the conveyance of sanitary or industrial wastes.

1.2 This specification does not include requirements for bedding, backfill, or the relationship between earth cover load and sheet thickness of the pipe. Experience has shown that the successful performance of this product depends upon the proper selection of sheet thickness, type of bedding and backfill, controlled manufacture in the plant, and care in the installation. The purchaser must correlate the above factors and also the corrosion and abrasion requirements of the field installation with the sheet thickness. The structural design of corrugated aluminum pipe and the proper installation procedures are given in AASHTO *Standard Specifications for Highway Bridges*.

1.3 This specification is applicable to orders in either inch-pound units as M 196 or SI units as M 196M. Inch-pound units and SI units are not necessarily equivalent. SI units are shown in brackets in the text; they are the applicable values when the material is ordered to M 196M.

2. REFERENCED DOCUMENTS

2.1 *AASHTO Standards:*  
Specifications for Highway Bridges:  
M197/M 197M Aluminum  
Alloy Sheet for Corrugated Aluminum Pipe

M 198 Joints for Circular Concrete Sewer and Culvert Pipe

Using Flexible Water-tight Gaskets

M 232 Zinc Coating (Hot-Dip) on Iron and Steel Hardware

M 291 Carbon and Alloy Steel Nuts

M 291M Carbon and Alloy Steel Nuts (Metric)

M 298 Coatings of Zinc Mechanically Deposited on Iron and Steel

T 249 Test for Helical Lock Seam Corrugated Pipe

2.2 *ASTM Standards:*

A 307 Specification for Carbon Steel Bolts and Studs, 60,000 PSI Tensile Strength

B 221 Specification for Aluminum-Alloy Extruded Bars, Rods, Wire, Shapes, and Tubes

B 221M Specification for Aluminum-Alloy Extruded Bars, Rods, Wire, Shapes, and Tubes [Metric]

B 316 Specification for Aluminum-Alloy Rivet and Cold-Heading Wire and Rods

B 633 Specification for Electrodeposited Coatings of Zinc on Iron and Steel

B 666 Practice for Identification Marking of Aluminum Products

B 666M Practice for Identification Marking of Aluminum Products [Metric]

D 1056 Specification for Flexible Cellular Materials—Sponge or Expanded Rubber

F 467 Specification for Nonferrous Nuts for General Use

F 467M Specification for Nonferrous Nuts for General Use [Metric]

F 468 Specification for Nonferrous Bolts, Hex Cap Screws, and Studs for General Use

F 468M Specification for Nonferrous Bolts, Hex Cap Screws, and Studs for General Use [Metric]

F 568 Specification for Carbon and Alloy Steel Externally Threaded Metric Fasteners

F 593 Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs

F 594 Specification for Stainless Steel Nuts

F 738 Specification for Stainless Steel Metric Bolts, Hex Cap Screws, and Studs

F 836 Specification for Stainless Steel Metric Nuts

3. DESCRIPTIONS OF TERMS SPECIFIC TO THIS STANDARD

3.1 *Fabricator*—the producer of pipe.

3.2 *Manufacturer*—the producer of the sheet.

3.3 *Purchaser*—the purchaser of the finished product.

4. CLASSIFICATION

4.1 The corrugated aluminum pipe covered by this specification is classified as follows:

4.1.1 *Type I*—This pipe shall have a full circular cross-section, with a single thickness of corrugated sheet, fabricated with annular (circumferential) or helical corrugations.

4.1.2 *Type IA*—This pipe shall have a full circular cross-section, with an outer shell of corrugated sheet and an inner liner of smooth (uncorrugated) sheet, fabricated with helical corrugations and lock seams.

4.1.3 *Type IR*—This pipe shall have a full circular cross-section with a single thickness of smooth sheet, fabricated with helical ribs projecting outwardly.

4.1.4 *Type II*—This pipe shall be a Type I pipe which has been reformed into a pipe-arch, having an approximately flat bottom.

4.1.5 *Type IIA*—This pipe shall be a Type IA pipe which has been reformed into a pipe-arch, having an approximately flat bottom.

4.1.6 *Type IIR*—This pipe shall be a Type IR pipe which has been reformed into a pipe-arch, having an approximately flat bottom.

4.1.7 *Type III*—This pipe, intended for use as underdrains or for underground disposal of water, shall be a Type I pipe which has been perforated to permit the in-flow or out-flow of water.

4.1.8 *Type IIIR*—This pipe, intended for the underground disposal of water or for subsurface drainage, shall be a Type IR pipe which has been perforated to permit the outflow or inflow of water.

4.2 Perforations in Type III pipe are classified as Class 1 or Class 2 and perforations in Type IIIR pipe are classified as Class 4, as described in Section 8.3.2.

5. ORDERING INFORMATION

5.1 Orders for material to this specification shall include the following information as necessary, to adequately describe the desired product:

5.1.1 Name of material (corrugated aluminum pipe),

5.1.2 AASHTO designation and year of issue, as M 196-\_\_\_ for inch-pound units or M 196M-\_\_\_ for SI units.

5.1.3 Type of pipe (Section 4.1),

5.1.4 Method of fabrication for Type I and Type II pipe (Section 7.1),

5.1.5 Diameter of circular pipe (Section 8.1.1), or span and rise of pipe-arch section (Section 8.2.1).

5.1.6 Length, either total length or length of each piece and number of pieces,

5.1.7 Description of corrugations (Section 7.2),

5.1.8 Sheet thickness (Section 8.1.2),

5.1.9 Coupling bands, number, and type (Section 9.1) if special type is required,

5.1.10 Gaskets for coupling bands, if required (Section 9.3),

5.1.11 For perforated pipe, the class of perforations. If no class is specified for Type III pipe, Class 1 perforations will be furnished. Type IIIR pipe is furnished with Class 4 perforations only (Section 8.3.2),

5.1.12 Certification, if required (Section 13.1), and

5.1.13 Special requirements.

6. MATERIALS

6.1 *Aluminum Sheet for Pipe*—All pipe fabricated under this specification shall be formed from aluminum-alloy sheet conforming to AASHTO M 197/M 197M.

6.2 *Aluminum Sheet for Coupling Bands*—The sheet used in fabricating coupling bands shall conform to AASHTO M 197/M 197M.

6.3 *Rivets*—The material used for rivets in riveted pipe shall conform to the requirements of ASTM B 316 for alloy 6053-T4, with the following mechanical properties:

Tensile strength, min, ksi [MPa]	25 [170]
Yield strength, min, ksi [MPa]	14 [95]
Shear strength, min, ksi [MPa]	15 [105]
Elongation in 2 in., 50 mm, or 4 × dia., min percent	16

If bolts and nuts are substituted for rivets (see Section 7.3.1), they shall meet the following requirements for either steel bolts and nuts, stainless steel bolts and nuts, or aluminum alloy bolts and nuts:

	Bolts	Nuts
For M 196 pipe:		
(Steel)	A 307	M 291, Gr. A
(Stainless steel)	F 593, Alloy Grp 1, 2, or 3	F 594, Alloy Grp 1, 2, or 3
(Aluminum alloy)	F 468, Alloy 6061-T6	F 467, Alloy 6061-T6
For M 196M pipe:		
(Steel)	F 568, Cl. 4.6	M 291M, Cl. 5
(Stainless steel)	F 738, Alloy Grp A1, A2, or A4	F 836, Alloy Grp A1, A2, or A4
(Aluminum alloy)	F 468M, Alloy 6061-T6	F 467M, Alloy 6061-T6

The steel bolts and nuts shall be hot-dip galvanized in conformance with AASHTO M 232, or be mechanically galvanized in conformance with AASHTO M 298 Class 40.

6.4 *Hardware for Coupling Bands*—Bolts and nuts for coupling bands shall conform to the requirements shown in Section 6.3 except for the coating on steel bolts and nuts. Steel bolts, nuts, and other threaded steel items used with coupling bands shall be zinc coated by one of the following processes: hot-dip process as provided in AASHTO M 232; electroplating process as provided in ASTM B 633, Class Fe/Zn 8; or mechanical process as provided in AASHTO M 298, Class 8. Other steel hardware items used with coupling bands shall be zinc coated by one of the following processes: hot-dip process as provided in AASHTO M 232; electroplating process as provided in ASTM B 633 Class Fe/Zn 25; or mechanical process as provided in AASHTO M 298 Class 25. Aluminum angles and lugs shall conform to the requirements of ASTM B 221 or B 221M for alloy 6063-T6.

6.5 *Gaskets*—If gaskets are used in couplings, they shall be a band of expanded rubber meeting the requirements of ASTM D 1056 for the "RE" closed cell grades, or O-rings meeting the requirements of AASHTO M 198.

7. FABRICATION

7.1 *General Requirements*—Pipe shall be fabricated in full circular cross-section.

7.1.1 Type I pipe shall have annular corrugations with lap joints fastened with rivets or shall have helical corrugations with a continuous lock seam extending from end to end of each length of pipe. As there are important differences in the

structural characteristics of annular, riveted pipe versus helical pipe, it is important for the purchaser to stipulate, for Type I and Type II pipe, the method of fabrication desired. If the method of fabrication is not stated in the ordering information, the fabrication method shall be at the option of the fabricator.

**7.1.2** Type IA pipe shall be fabricated with a smooth liner and helically corrugated shell integrally attached at helical lock seams extending from end to end of each length of pipe. The shell shall have corrugations of nominal  $2\frac{2}{3}$  or 3 in. [68 or 75 mm] pitch.

**7.1.3** Type IR pipe shall be fabricated with helical ribs projecting outward with a continuous lock seam extending from end to end of each length of pipe.

**7.2 Corrugations**—The corrugations shall be either annular or helical as provided in Section 7.1. The direction of the crests and valleys of helical corrugations shall not be less than 60° from the axis of the pipe for pipe diameters larger than 21 in. [500 mm], and not less than 45° from the axis for pipe diameters of 21 in. [500 mm] and smaller.

**7.2.1** For Type I and IA pipe, corrugations shall form smooth continuous curves and tangents. The dimensions of the corrugations shall be in accordance with Table 1 for the size indicated in the order.

**7.2.2** For Type IR pipe, the corrugations shall be essentially rectangular ribs projecting outward from the pipe

**TABLE 2 Rib Requirements for Type IR Pipe**

Nominal Size	Rib			Inside Radius	
	Min <sup>a</sup> Width	Min <sup>b</sup> Depth	Max <sup>c</sup> Spacing	Min	Max
Inches					
$\frac{3}{4} \times \frac{3}{4} \times 7\frac{1}{2}$	0.68	0.71	$7\frac{3}{4}$	0.10	0.17
$\frac{1}{2} \times 1 \times 11\frac{1}{2}$	0.68	0.95	$11\frac{3}{4}$	0.10	0.17
Millimeters					
19 × 19 × 190	17	18	197	2.5	4
19 × 25 × 292	17	24	298	2.5	4

<sup>a</sup> Width is a measurement of the inside of the rib. Alternately it may be measured outside the rib and shall meet or exceed the minimum width plus 2 wall thicknesses— $2t + 0.68$  in., [ $2t + 17$  mm].

<sup>b</sup> Depth is measured as the vertical distance from a straight edge resting on top of the ribs parallel to the axis of the pipe to the outside surface of the flat portion.

<sup>c</sup> Spacing is measured center to center of the ribs, at 90° to the direction of the ribs.

wall. The dimensions and spacings of the ribs shall be in accordance with Table 2 for the size indicated in order. For the 11- $\frac{1}{2}$  in. [292 mm] rib spacing, a stiffener shall be included midway between the ribs if the sheet between the ribs does not include a lock seam. This stiffener shall have a nominal radius of 0.25 in. [6.4 mm] and a minimum height of 0.20 in. [5.1 mm] toward the outside of the pipe.

**NOTE 1**—The nominal dimensions and properties for smooth corrugations and for ribs are given in AASHTO Specifications for Highway Bridges, Division I, Section 12.

**7.3 Riveted Seams**—The longitudinal seams shall be staggered to the extent that no more than three thicknesses of sheet are fastened by any rivet. Pipe

to be reformed into pipe-arch shape shall have seams meeting the longitudinal seam requirement of Section 8.2.2.

**NOTE 2**—Fabrication of pipe without longitudinal seams in 120 deg of arc, so that the pipe may be installed without longitudinal seams in the invert, is subject to negotiation between the purchaser and fabricator.

**7.3.1** The size of rivets, number per corrugation, and width of lap at the longitudinal seam shall be as stated in Table 3, depending on sheet thickness, corrugation size, and diameter of pipe. For pipe with 1 in. [25 mm] deep corrugations,  $\frac{1}{2}$ -in. [Metric M12] diameter bolts and nuts may be used in lieu of rivets on a one-for-one replacement ratio. Circumferential seams shall be riveted using rivets of the same size as for longitudinal seams and shall have a maximum rivet spacing of 6 in. [150 mm], measured on centers, except that six rivets will be sufficient in 12-in. [300 mm] diameter pipe.

**7.3.2** All rivets shall be driven cold in such a manner that the sheets shall be drawn tightly together throughout the entire lap. The center of a rivet shall be no closer than twice its diameter from the edge of the sheet. The distance between the centerlines of the two rows of rivets, where two rows are required, shall not be less than 1 $\frac{1}{2}$  in. [38 mm]. All rivets shall have neat, workmanlike, and full hemispherical heads or heads of a form acceptable to the purchaser, shall be driven without bending, and shall completely fill the hole.

**7.4 Helical Lock Seams**—The lock seam for Type I pipe shall be formed in the tangent element of the corrugation

**TABLE 1 Corrugated Requirements for Types I, IA, II, IIA, and III Pipe**

Nominal Size	Maximum Pitch <sup>a</sup>	Minimum Depth <sup>b</sup>	Inside Radius <sup>c</sup>	
			Nominal	Minimum
<i>M 196—All values in in.</i>				
1 $\frac{1}{2}$ by $\frac{1}{4}$ <sup>e</sup>	1 $\frac{7}{8}$	0.24	$\frac{9}{32}$	0.25
2 $\frac{2}{3}$ by $\frac{1}{2}$	2 $\frac{7}{8}$	0.48 <sup>d</sup>	$\frac{11}{16}$	0.5
3 by 1	3 $\frac{1}{4}$	0.95	$\frac{9}{16}$	0.5
6 by 1	6 $\frac{1}{4}$	0.95	2.2	2.0
<i>M 196M—All values in mm</i>				
38 by 6.5 <sup>e</sup>	48	6.0	7	6.5
68 by 13	73	12 <sup>d</sup>	17	12
75 by 25	83	24	14	12
150 by 25	160	24	56	51

<sup>a</sup> Pitch is measured from crest to crest of corrugations, at 90° to the direction of the corrugations.

<sup>b</sup> Depth is measured as the vertical distance from a straightedge resting on the corrugation crests parallel to the axis of the pipe, to the bottom of the intervening valley.

<sup>c</sup> Minimum inside radius requirements does not apply to a corrugation containing a helical lock seam.

<sup>d</sup> For pipe 12 to 21 in. [300 to 500 mm] dia. inclusive, the minimum corrugation depth shall be 0.42 in. [11 mm].

<sup>e</sup> The corrugation size of 1 $\frac{1}{2}$  by  $\frac{1}{4}$  in. [38 by 6.5 mm] is available only in helically corrugated pipe.

profile with its center near the neutral axis of the corrugation profile. The lock seam for Type IA pipe shall be in the valley of the corrugation, shall be spaced not more than 30 in. [760 mm] apart, and shall be formed from both the liner and the shell in the same general manner as Type I helical lock seam pipe. The lock seam for Type IR pipe shall be formed in the flat zone of the pipe wall, midway between two ribs.

**7.4.1** The edges of the sheets within the cross-section of the lock seam shall lap at least  $\frac{5}{32}$  in. [4.0 mm] for pipe 10 in. [250 mm] or less in diameter and at least  $\frac{5}{16}$  in. [7.9 mm] for pipe greater than 10 in. [250 mm] in diameter, with an occasional tolerance of minus 10 percent of lap width allowable. The lapped surfaces shall be in tight contact. The profile of the sheet shall include a retaining offset adjacent to the 180° fold (as described in AASHTO T 249) of one sheet thickness on one side of the lock seam, or one-half sheet thickness on both sides of the lock seam, at the fabricator's option. There shall be no visual cracks in the metal, loss of metal-to-metal contact, or excessive angularity on the interior of the 180° fold of metal at the completion of forming the lock seam. The lock seam shall be mechanically staked (indented) at periodic intervals, or otherwise specially constructed to prevent slippage.

**7.4.2** Specimens cut from production pipe normal to and across the lock seam shall develop the tensile strength as provided in Table 4, when tested according to AASHTO T 249. For Type IA pipe, the lock seam strength shall be as tabulated based on the thickness of the corrugated shell.

**7.4.3** When the ends of helically corrugated lock seam pipe have been rerolled to form annular corrugations, either with or without a flanged end finish, the lock seam in the rerolled end shall not contain any visible cracks in the base metal and the tensile strength of the lock seam shall be not less than 60 percent of that required in Section 7.4.2.

#### 7.5 End Finish:

**7.5.1** To facilitate field jointing, the ends of individual pipe sections with helical corrugations or ribs may be rerolled to form annular corrugations extending at least two corrugations from the pipe end, or to form an upturned flange meet-

TABLE 3 Riveted Longitudinal Seams

Specified Sheet Thickness		Nominal Corrugation Size					
		$2\frac{2}{3} \times \frac{1}{2}$ in. 75 × 25 mm <sup>A,D</sup>		3 × 1 in. 75 × 25 mm <sup>B,E</sup>		6 × 1 in. 150 × 25 mm <sup>C,E</sup>	
		Rivet Diameters, mm					
in.	mm	in.	mm	in.	mm	in.	mm
0.060	1.52	$\frac{5}{16}$	8.0	$\frac{3}{8}$	9.5	$\frac{1}{2}$	12.7
0.075	1.91	$\frac{5}{16}$	8.0	$\frac{3}{8}$	9.5	$\frac{1}{2}$	12.7
0.105	2.67	$\frac{3}{8}$	9.5	$\frac{1}{2}$	12.7	$\frac{1}{2}$	12.7
0.135	3.43	$\frac{3}{8}$	9.5	$\frac{1}{2}$	12.7	$\frac{1}{2}$	12.7
0.164	4.17	$\frac{3}{8}$	9.5	$\frac{1}{2}$	12.7	$\frac{1}{2}$	12.7

<sup>A</sup> One rivet each valley for pipe diameters 36 in. [900 mm] and smaller. Two rivets each valley for pipe diameters 42 in. [1,000 mm] and larger.

<sup>B</sup> Two rivets each valley for all pipe diameters.

<sup>C</sup> Two rivets each crest and valley for all pipe diameters.

<sup>D</sup> Minimum width of lap  $\frac{1}{2}$  in. [38 mm] for pipe diameters 36 in. [900 mm] and smaller, and 3 in. [75 mm] for pipe diameters 42 in. [1,000 mm] and larger.

<sup>E</sup> Minimum width of lap: 3 in. [75 mm] for pipe of all diameters.

TABLE 4 Specified Aluminum Alloy Sheet Thicknesses and Lock Seam Tensile Strength

Specified Sheet Thickness <sup>A,B</sup>		Lock Seam Tensile Strength, mm	
in.	mm	in.	mm
0.036	0.91	100	17
0.048	1.22	145	25
0.060	1.52	170	30
0.075	1.91	245	43
0.105	2.67	425	74
0.135	3.43	550	96
0.164	4.17	700	122

<sup>A</sup> Thicknesses listed are those included in AASHTO M 197/M 197M.

<sup>B</sup> For Type IA pipe, the lock seam tensile strength requirements shall be based on the thickness of the corrugated shell.

ing the requirements in Section 7.5.3, or both. The diameter of ends shall not exceed that of the pipe barrel by more than the depth of the corrugation. All types of pipe ends, whether rerolled or not, shall be matched in a joint such that the maximum difference in the diameter of abutting pipe ends is  $\frac{1}{2}$  in. [13 mm].

**7.5.2** When pipe with helical corrugations or ribs is rerolled to form annular corrugations in the ends, the usual size of annular corrugations is  $2\frac{2}{3}$  by  $\frac{1}{2}$  in. [68 by 13 mm].

**7.5.3** If a flanged finish is used on the ends of individual pipe sections to facilitate field jointing, the flange shall be uniform in width, be not less than  $\frac{1}{2}$  in. [13 mm] wide, and shall be square to the longitudinal axis of the pipe.

**7.5.4** The ends of all pipe which will form the inlet and outlet of culverts, fabricated of sheets having nominal thicknesses of 0.075 in. [1.91 mm] and less, shall be reinforced in a manner approved by the purchaser, when specified.

## 8. PIPE REQUIREMENTS

### 8.1 Type I, Type IA, and Type IR Pipe:

**8.1.1 Pipe Dimensions**—The nominal diameter of the pipe shall be as stated in the order, selected from the sizes listed in Table 5. The size of corrugations which are standard for each size of pipe are also shown in Table 5. The average inside diameter of circular pipe and pipe to be reformed into pipe-arches shall not vary more than 1 percent or  $\frac{1}{2}$  in. [13 mm], whichever is greater, from the nominal diameter when measured on the inside crest of the corrugations. Alternately, for pipe having annular corrugations, conformance with the inside diameter requirement may be determined by measuring the outside circumference, for which minimum values are given in Table 5.

**NOTE 3**—The outside circumference of helically corrugated pipe is influenced by the corrugation size and the angle of the corrugations, affecting the number of corrugations crossed, therefore no minimum circumferential measurement can be specified.

### 8.1.2 Sheet Thickness

—Sheet thick-

ness shall be specified by the purchaser from the specified sheet thicknesses listed in Table 4 (Notes 4 and 5). For Type IA pipe, the thickness of both the shell and the liner shall be given; the thickness of the corrugated shell shall be at least 60 percent of the thickness of the equivalent Type I pipe; the liner shall have a nominal thickness of at least 0.036 in. [0.91 mm]; and the sum of the specified thicknesses of shell and liner shall equal or exceed the specified thickness of an equivalent pipe of identical corrugations as the shell according to the design criteria in the AASHTO *Standard Specifications for Highway Bridges*.

**NOTE 4**—The sheet thicknesses indicated in Table 4 are the thicknesses listed as available in AASHTO M 197/M 197M.

**NOTE 5**—The purchaser should determine the required thickness for Type I, IA, or IR pipe, or Type II, IIA, or IIR pipe to be reformed into Type II, IIA, or IIR pipe according to the design criteria in AASHTO *Specifications for Highway Bridges*, or other appropriate guidelines. Specified thickness of 0.036 in. [0.91 mm] is generally used only for Type IA pipe.

**8.1.3** When specified by the purchaser, the finished pipe shall be factory elongated to the extent specified. The elongation shall be accomplished by the use of a mechanical apparatus which will produce a uniform deformation throughout the length of the section.

**NOTE 6**—When corrugated aluminum pipe is designed and installed according to AASHTO *Specifications for Highway Bridges*, vertical elongation (factory or field) is not required for structural purposes.

## 8.2 Type II, IIA, and IIR Pipe:

**8.2.1 Pipe-Arch Dimensions**—Pipe furnished as Type II, IIA, or IIR shall be made from Type I, IA, or IR pipe respectively, and shall be reformed to provide a pipe-arch shape. All applicable requirements for Types I, IA, or IR pipe shall be met by finished Types II, IIA, and IIR respectively. Pipe-arches shall conform to the dimensional requirements of Tables 6, 7, or 8 [Tables 6M, 7M, or 8M]. All dimensions shall be measured from the inside crest of corrugations for Type II pipe or from the inside liner or surface for Types IIA or IIR pipe respectively.

TABLE 5 Pipe Sizes

Nominal Inside Diameter		Corrugation Sizes <sup>A</sup>					Minimum Outside Circumference <sup>B</sup>	
		1½ by ¼ in. 38 by 6.5 mm	2⅔ by ½ in. 68 by 13 mm	3 by 1 in. 75 by 25 mm	6 by 1 in. 150 by 25 mm	Ribbed Pipe <sup>C</sup>	in.	mm
4	100	x						
6	150	x						
8	200	x						
10	250	x						
12	300		x				36.5	912
15	400		x			x	46.0	1,226
18	450		x			x	55.4	1,383
21	500		x			x	64.8	1,540
24	600		x			x	74.2	1,854
—	700		x			x	—	2,169
30	800		x	x		x	93.1	2,483
36	900		x	x		x	111.9	2,797
42	1,000		x	x		x	130.8	3,111
48	1,200		x	x	x	x	149.6	3,739
54	1,400		x	x	x	x	168.4	4,364
60	—		x	x	x	x	187.0	—
—	1,600		x	x	x	x	—	4,987
66	—		x	x	x	x	205.7	—
72	1,800		x	x	x	x	224.3	5,609
78	2,000			x	x	x	243.0	6,231
84	2,200			x	x	x	261.7	6,853
90	—			x	x		280.3	—
96	2,400			x	x		299.0	7,475
102	—			x	x		317.6	—
108	2,700			x	x		336.3	8,408
114	—			x	x		355.0	—
120	3,000			x			373.6	9,341

<sup>A</sup> As "X" indicates standard corrugation sizes for each nominal diameter of pipe.

<sup>B</sup> Measured in valley of annular corrugations. Not applicable to helically corrugated pipe.

<sup>C</sup> Rib sizes ¾ by ¾ by 7½ [19 by 19 by 190 mm] and ¾ by 1 by 11½ in. [19 by 25 by 292 mm].

TABLE 6 Pipe-Arch Requirements 2⅔ by ½ in. Corrugations

Pipe Arch Size, in.	Equiv. Dia., in.	Span <sup>A</sup> in.	Rise <sup>A</sup> in.	Min Corner Radius, in.	Max B <sup>B</sup> in.
17 × 13	15	17	13	3	5¼
21 × 15	18	21	15	3	6
24 × 18	21	24	18	3	7¼
28 × 20	24	28	20	3	8
35 × 24	30	35	24	3	9½
42 × 29	36	42	29	3½	10½
49 × 33	42	49	33	4	11½
57 × 38	48	57	38	5	13½
64 × 43	54	64	43	6	15
71 × 47	60	71	47	7	16½
77 × 52	66	77	52	8	18
83 × 57	72	83	57	9	20

<sup>A</sup> A tolerance of ±1 in. or 2 percent of equivalent diameter, whichever is greater, is permissible in span and rise.

<sup>B</sup> B is defined as the vertical dimension from a horizontal line across the widest portion of the arch to the lowest portion of the base.

TABLE 6M Pipe-Arch Requirements—68 by 13 mm Corrugations

Pipe Arch Size, mm	Equiv. Dia., mm	Span <sup>a</sup> mm	Rise <sup>a</sup> mm	Min Corner Radius, mm	Max B <sup>b</sup> mm
450 by 340	400	460	340	75	120
510 by 380	450	510	380	75	125
560 by 420	500	560	420	75	130
680 by 500	600	680	500	75	150
800 by 580	700	800	580	75	185
910 by 660	800	910	660	75	200
1,030 by 740	900	1,030	740	75	250
1,150 by 820	1,000	1,150	820	90	300
1,390 by 970	1,200	1,390	970	125	350
1,630 by 1,120	1,400	1,630	1,120	150	380
1,880 by 1,260	1,600	1,880	1,260	200	450
2,130 by 1,400	1,800	2,130	1,400	225	500

<sup>a</sup> A tolerance of  $\pm 25$  mm or 2 percent of equivalent diameter, whichever is greater, is permissible in span and rise.

<sup>b</sup> B is defined as the vertical dimension from a horizontal line across the widest portion of the arch to the lowest portion of the base.

TABLE 7 Pipe-Arch Requirements—3 by 1 in. Corrugations

Pipe Arch Size, in.	Equiv. Dia., in.	Span <sup>a</sup> in.	Rise <sup>a</sup> in.	Min Corner Radius, in.
53 × 41	48	53 - 2.4	41 + 2.4	7
60 × 46	54	60 - 2.7	46 + 2.7	8
66 × 51	60	66 - 3.0	51 + 3.0	9
73 × 55	66	73 - 3.3	55 + 3.3	12
81 × 59	72	81 - 3.6	59 + 3.6	14
87 × 63	78	87 - 4.4	63 + 4.4	14
95 × 67	84	95 - 4.8	67 + 4.8	16
103 × 71	90	103 - 5.2	71 + 5.2	16
112 × 75	96	112 - 5.6	75 + 5.6	18
117 × 79	102	117 - 5.9	79 + 5.9	18
128 × 83	108	128 - 6.4	83 + 6.4	18
137 × 87	114	137 - 6.9	87 + 6.9	18
142 × 91	120	142 - 7.1	91 + 7.1	18

<sup>a</sup> Negative and positive numbers listed with span and rise dimensions are negative and positive tolerances, zero tolerance in opposite direction.

TABLE 7M Pipe-Arch Requirements—75 by 25 mm Corrugations

Pipe Arch Size, mm	Equiv. Dia., mm	Span <sup>a</sup> mm	Rise <sup>a</sup> mm	Min Corner Radius, mm
1,330 by 1,030	1,200	1,330 - 50	1,030 + 50	175
1,550 by 1,200	1,400	1,550 - 70	1,200 + 70	200
1,780 by 1,360	1,600	1,780 - 85	1,360 + 85	300
2,080 by 1,530	1,800	2,010 - 90	1,500 + 90	350
2,230 by 1,700	2,000	2,230 - 110	1,700 + 110	350
2,500 by 1,830	2,200	2,500 - 130	1,830 + 130	400
2,800 by 1,950	2,400	2,800 - 140	1,950 + 140	450
3,300 by 2,080	2,700	3,300 - 160	2,080 + 160	450
3,650 by 2,280	3,000	3,650 - 170	2,280 + 170	450

<sup>a</sup> Negative and positive numbers listed with span and rise dimensions are negative and positive tolerances, zero tolerance in opposite direction.

**8.2.2 Longitudinal Seams**—Longitudinal seams of riveted pipe-arches shall not be placed in the corner radius.

**8.2.3 Reforming Type IR pipe into Type IIR pipe**—and shall be done in such a manner as to avoid damage to the external ribs.

### 8.3 Type III and IIR Pipe:

**8.3.1 Type III and IIR pipe** shall have a full circular cross-section and shall conform to the requirements for Type I or Type IR pipe, and in addition shall contain perforations conforming to one of the classes described in Section 8.3.2.

**8.3.2 Perforations**—The perforations in Type III pipe shall conform to the requirements for Class 1 or Class 2 as specified in the order and described in Section 8.3.2.1 and Section 8.3.2.2, respectively. The perforations in Type IIR pipe shall conform to the requirements for Class 4 as described in Section 8.3.2.3. Class 1 perforations are for pipe intended to be used for subsurface drainage. Class 2 and Class 4 perforations are for pipe intended to be used for subsurface disposal of water, but pipe containing these classes of perforations may also be used for subsurface drainage.

**8.3.2.1 Class 1 Perforations**—The perforations shall be approximately circular and cleanly cut; shall have nominal diameters of not less than  $\frac{3}{16}$  in. [4.8 mm] nor greater than  $\frac{3}{8}$  in. [9.5 mm]; and shall be arranged in rows parallel to the axis of the pipe. The perforations shall be located on the inside crests or along the neutral axis of the corrugations, with one perforation in each row for each corrugation. Pipe connected by couplings or bands may be unperforated within 4 in. [100 mm] of each end of each length of pipe. The rows of perforations shall be arranged in two equal groups placed symmetrically on either side of a lower unperforated segment corresponding to the flow line of the pipe. The spacing of the rows shall be uniform. The distance between the center lines of rows shall be not less than 1 in. [25 mm]. The minimum number of longitudinal rows of perforations, the maximum heights of the centerlines of the uppermost rows above the bottom of the invert, and the inside chord lengths of the unperforated segments illustrated in Figure 1 shall be as specified in Table 9.

NOTE 7—Pipe with Class 1 perforations

**TABLE 8 Pipe-Arch Requirements— $\frac{3}{4}$  by  $\frac{3}{4}$  by  $7\frac{1}{2}$  in. and  $\frac{3}{4}$  by 1 by  $11\frac{1}{2}$  in. Rib Corrugations**

Pipe Arch Size, in.	Equiv. Dia., in.	Span <sup>a</sup> in.	Rise <sup>a</sup> in.	Min Corner Radius, in.
20 × 16	18	20 - 1.0	16 + 1.0	5
23 × 19	21	23 - 1.0	19 + 1.0	5
27 × 21	24	27 - 1.5	21 + 1.5	5
33 × 26	30	33 - 1.5	26 + 1.5	5
40 × 31	36	40 - 1.8	31 + 1.8	5
46 × 36	42	46 - 2.1	36 + 2.1	6
53 × 41	48	53 - 2.4	41 + 2.4	7
60 × 46	54	60 - 2.7	46 + 2.7	8
66 × 51	60	66 - 3.0	51 + 3.0	9

<sup>a</sup> Negative and positive numbers listed with span and rise dimensions are negative and positive tolerances, zero tolerance in opposite direction.

**TABLE 8M Pipe-Arch Requirements—19 by 19 by 190 mm and 19 by 25 by 292 mm Rib Corrugations**

Pipe Arch Size, mm	Equiv. Dia., mm	Span <sup>a</sup> mm	Rise <sup>a</sup> mm	Min Corner Radius, mm
500 × 400	450	500 - 25	400 + 25	125
550 × 450	500	550 - 25	450 + 25	125
680 × 530	600	680 - 40	530 + 40	125
770 × 630	700	770 - 40	630 + 40	125
880 × 690	800	880 - 40	690 + 40	125
1,000 × 770	900	1,000 - 50	770 + 50	125
1,100 × 850	1,000	1,100 - 50	850 + 50	150
1,330 × 1,030	1,200	1,330 - 50	1,030 + 50	175
1,550 × 1,200	1,400	1,550 - 70	1,200 + 70	200
1,780 × 1,360	1,600	1,780 - 85	1,360 + 85	300

<sup>a</sup> Negative and positive numbers listed with span and rise dimensions are negative and positive tolerances, zero tolerance in opposite direction.

**TABLE 9 Rows of Perforations, Height  $H$  of the Centerline of the Uppermost Rows Above the Invert, and Chord Length  $L$  of Unperforated Segment, for Class I Perforations**

Internal Dia. of Pipe		Rows of Perforations <sup>a</sup>	$H$ , max <sup>b</sup>		$L$ , min <sup>b</sup>	
in.	mm		in.	mm	in.	mm
4	100	2	1.8	46	2.6	64
6	150	4	2.8	69	3.8	96
8	200	4	3.7	92	5.1	128
10	250	4	4.6	115	6.4	160
12	300	6	5.5	138	7.7	192
15	400	6	6.9	184	9.6	256
18	450	6	8.3	207	11.5	288
21	500	6	9.7	230	13.4	320
24 and larger	600 and larger	8	c	c	c	c

<sup>a</sup> Minimum number of rows. A greater number of rows for increased inlet area shall be subject to agreement between purchaser and fabricator. Note that the number of perforations per foot in each row (and inlet area) is dependent on the corrugation pinch.

<sup>b</sup> See Figure 1 for location of dimensions  $H$  and  $L$ .

<sup>c</sup>  $H$  (max) = 0.46D;  $L$  (min) = 0.64D, where  $D$  = internal diameter of pipe, inches or millimetres as appropriate.

is generally available in diameters from 4 to 21 in. [100 to 500 mm] inclusive, although perforated pipe in larger sizes may be obtained.

**8.3.2.2 Class 2 Perforations**—The perforations shall be circular holes with nominal diameters of  $\frac{5}{16}$  to  $\frac{3}{8}$  in. [8.0 to 9.5 mm], or slots with nominal width of  $\frac{3}{16}$  to  $\frac{5}{16}$  in. [4.8 to 8.0 mm] and maximum length of  $\frac{1}{2}$  in. [13 mm]. The perforations shall be uniformly spaced around the full periphery of the pipe. The perforations shall provide an opening area of not less than 3.3 sq in. per sq ft [230 sq cm per sq m] of pipe surface based on nominal diameter and length of pipe.

**NOTE 8**—Thirty perforations,  $\frac{3}{8}$  in. diameter, per square foot [323 perforations, 9.5-mm diameter per square meter] satisfies the inlet area requirement for Class 2 perforations.

**8.3.2.3 Class 4 Perforations**—The perforations shall be circular holes with nominal diameters of  $\frac{5}{16}$  to  $\frac{3}{8}$  in. [8.0 to 9.5 mm], or slots with nominal width of  $\frac{3}{16}$  to  $\frac{5}{16}$  in. [4.8 to 8.0 mm] and maximum length of  $\frac{1}{2}$  in. [12.7 mm]. All perforations shall occur in the flat sheet between spiral ribs or lockseam with the center of any hole no closer than  $\frac{3}{4}$  in. [19.0 mm] from the outside edge of a rib. The perforations shall be uniformly spaced around the full periphery of the pipe. The perforations shall provide an opening area of not less than 2.0 sq in. per sq. ft. [140 sq. cm. per sq. m.] of pipe surface based on nominal diameter and length of pipe.

**NOTE 9**—There is no provision for Class 3 perforations in this specification.

## 9. COUPLING BANDS

**9.1 Types of Coupling Bands**—Field joints for each type of corrugated aluminum pipe shall maintain pipe alignment during construction and prevent infiltration of fill material during the life of the installation.

**9.1.1 Coupling bands** may be of the following types:

**9.1.1.1 Bands with annular corrugations;**

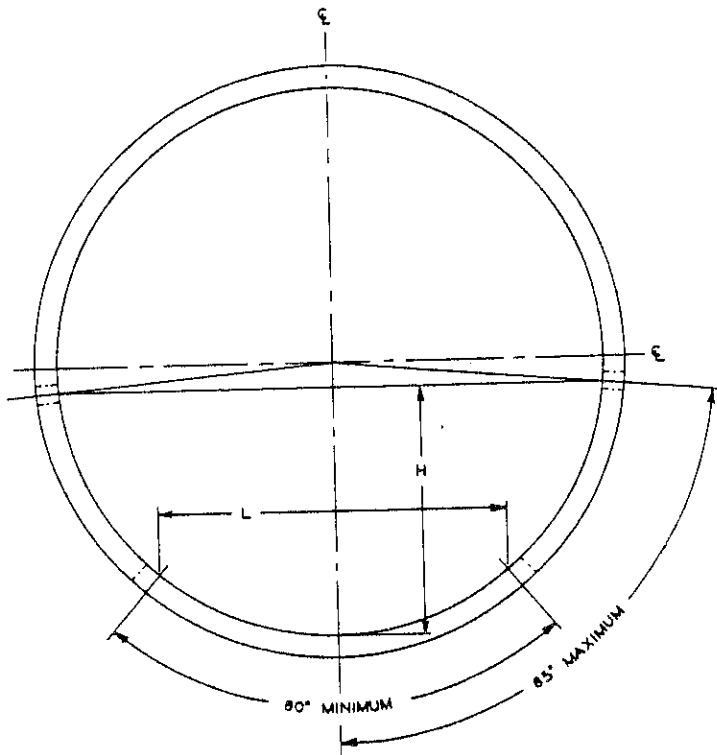


FIGURE 1 Circumferential Location of Class 1 Perforations

- 9.1.1.2 Bands with helical corrugations;
- 9.1.1.3 Bands with projections (dimples);
- 9.1.1.4 Channel bands for upturned flanges, with or without annular corrugations;
- 9.1.1.5 Flat bands; and
- 9.1.1.6 Smooth sleeve-type couplers.

9.1.2 Except as provided in Sections 9.1.3 through 9.1.7, the type of coupling furnished shall be at the option of the fabricator unless the type is specified in the order.

**NOTE 10**—Bands are classified according to their ability to resist shear, moment, and tensile forces as described in AASHTO Specifications for Highway Bridges, and identified as “standard joints” and “special joints”. The four types of bands listed in Sections 9.1.1.1 through 9.1.1.4, and meeting the requirements of Section 9.2, are expected to meet the requirements for “standard joints”. Some may also be able to meet the requirements for “special joints”, but such capability should be determined by analysis or test.

9.1.3 Coupling bands with annular

corrugations shall be used only with pipe with annular corrugations, or helical pipe in which the ends have been rerolled to form annular corrugations. The corrugations in the band shall have the same dimensions as the corrugations in the pipe end, or may be of a special design to engage either the first or second corrugation from the end of each pipe. The band may also include a U-shaped channel to accommodate upturned flanges on the pipe.

9.1.4 Coupling bands with helical corrugations shall be used only with pipe with helically corrugated ends. The corrugations in the bands shall be designed to properly mesh with the corrugations in the pipe.

9.1.5 Coupling bands with projections (dimples) may be used with pipe with either annular or helical corrugations. The bands shall be formed with the projections in annular rows with one projection for each corrugation of helical pipe. Bands 10<sup>1</sup>/<sub>2</sub> in. [265 mm] wide shall have two annular rows of projections, and bands 16<sup>1</sup>/<sub>4</sub> and 26 in. [415 and 660 mm] wide shall have four annular rows of projections.

9.1.6 Channel bands may be used only with pipe having upturned flanges on the pipe ends.

9.1.7 Smooth sleeve-type couplers and flat bands may be used with Type III pipe of 12-in. [300-mm] diameter or smaller.

9.2 Requirements—Coupling bands shall be fabricated to lap on an equal portion of each of the pipe sections to be connected. The ends of the bands shall lap or be fabricated to form a tightly closed joint upon installation. Coupling band thickness shall conform to the requirements in Table 10, based on the sheet thickness of the pipe to be connected, except as provided in Sections 9.2.1 and 9.2.2. The band width shall be not less than as shown in Table 11. The bands shall be connected in a manner approved by the purchaser with suitable aluminum or galvanized steel devices such as: angles, or integrally or separately formed and attached flanges, bolted with bolts as described in Section 6.4; bars and straps; wedge lock and straps; or lugs. Coupling bands shall be fastened with the following size of bolts: pipe diameters 18 in. [450 mm] and less—<sup>3</sup>/<sub>8</sub>-in. [Metric M 10] dia.; pipe diameters 21 in. [500 mm] and greater—<sup>1</sup>/<sub>2</sub>-in. [Metric M 12] dia.

9.2.1 If flanges are provided on the pipe ends, the coupling may also be made by interlocking the flanges with a preformed channel band or other band incorporating a locking channel not less than <sup>3</sup>/<sub>4</sub> in. [19 mm] in width. The depth of the channel shall be not less than <sup>1</sup>/<sub>2</sub> in. [13 mm]. The channel band shall have a minimum nominal thickness of 0.075 in. [1.91 mm].

9.2.2 Smooth sleeve type couplings and flat bands shall be aluminum sheet having a nominal thickness of not less

TABLE 10 Coupling Band Thickness

Nominal Pipe Thickness		Nominal Coupling Band Thickness, minimum	
in.	mm	in.	mm
0.105 and thinner	2.67 and thinner	0.048	1.22
0.135	3.43	0.060	1.52
0.164	4.17	0.075	1.91



TABLE 11 Coupling Band Width Requirements

Nominal Corrugation Size <sup>a</sup>	Nominal Pipe Inside Dia. <sup>b</sup>	Coupling Band Width, min		
		Annular Corrugated Bands	Helically Corrugated Bands	Bands With Projections
<i>M 196—All values in inches</i>				
1 <sup>1</sup> / <sub>2</sub> by 1/4	4 to 10	10 <sup>1</sup> / <sub>2</sub>	7	10 <sup>1</sup> / <sub>2</sub>
2 <sup>2</sup> / <sub>3</sub> by 1/2	12 to 36	7	12	10 <sup>1</sup> / <sub>2</sub>
	42 to 72	10 <sup>1</sup> / <sub>2</sub>	12	10 <sup>1</sup> / <sub>2</sub>
3 by 1	78 to 120 <sup>c</sup>	10 <sup>1</sup> / <sub>2</sub>	12	16 <sup>1</sup> / <sub>4</sub>
	30 to 72	12	14	10 <sup>1</sup> / <sub>2</sub>
6 by 1	78 to 120	12	14	16 <sup>1</sup> / <sub>4</sub>
	48 to 114	24	24	26
<i>M 196M—All values as millimeters</i>				
38 by 65	100 to 250	265	180	265
68 by 13	300 to 900	180	300	265
	1,000 to 1,800	265	300	265
	2,000 to 3,000 <sup>c</sup>	265	300	415
75 by 25	800 to 1,800	300	350	265
	2,000 to 3,000	300	350	415
150 by 25	1,200 to 2,700	600	600	660

<sup>a</sup> For helically corrugated pipe with rerolled ends, the nominal corrugation size refers to the dimensions of the end corrugations in the pipe.

<sup>b</sup> Equivalent diameter of Type II, Type IIA, and Type IIR pipe.

<sup>c</sup> Diameters through 120 in. [3,000 mm] for annular corrugated bands used on rerolled ends of helically corrugated pipe.

than 0.036 in. [0.91 mm], or as an option, may be a plastic sleeve to provide equivalent strength. The coupling shall be close-fitting, to hold the pipe firmly in alignment without the use of sealing compounds or gaskets. The coupling or flat band shall contain a device so that the band or coupling will lap equally on the two pipes being joined. The overall length of the coupling shall be equal to or greater than the nominal diameter of the pipe.

**9.3 Gaskets**—Where infiltration or exfiltration is a concern, the couplings may be required to have gaskets. The closed-cell expanded rubber gaskets shall be a continuous band, approximately 7 in. [180 mm] wide and approximately <sup>3</sup>/<sub>8</sub> in. [9.5 mm] thick. Rubber O-ring gaskets shall be <sup>13</sup>/<sub>16</sub>-in. [20-mm] diameter for pipe diameters of 36 in. [900 mm] or smaller, and <sup>7</sup>/<sub>8</sub>-in. [22-mm] diameter for larger pipe diameters, having <sup>1</sup>/<sub>2</sub> in. [13 mm] deep end corrugations. Rubber O-ring gaskets shall be <sup>13</sup>/<sub>8</sub>-in. [35-mm] diameter for pipe having 1 in. [25 mm] deep end corrugations.

**NOTE 11**—Riveted pipe is not water tight, having small openings at the intersection of longitudinal and circumferential seams. Therefore this type of fabrication should not

be used where water tightness is a concern unless the pipe is bituminous coated or lined prior to installation.

**9.4** Other types of coupling bands or fastening devices which are equally effective as those described, and which comply with the joint performance criteria of AASHTO *Specifications for Highway Bridges*, may be used when approved by the purchaser.

## 10. WORKMANSHIP

**10.1** The completed pipe shall show careful, finished workmanship in all particulars. Pipe which has been damaged, either during fabrication or in shipping, may be rejected unless repairs are made which are satisfactory to the purchaser. Among others, the following defects shall be considered as constituting poor workmanship:

**10.1.1** Variation from a straight centerline;

**10.1.2** Elliptical shape in pipe intended to be round;

**10.1.3** Dents or bends in the metal;

**10.1.4** Lack of rigidity;

**10.1.5** Illegible markings on the aluminum sheet;

**10.1.6** Ragged or diagonal sheared edges;

**10.1.7** Uneven laps in riveted pipe;

**10.1.8** Loose, unevenly lined, or unevenly spaced rivets; and

**10.1.9** Loosely formed lockseams.

## 11. INSPECTION

**11.1** When agreement is made as part of the purchase contract, the purchaser or representative shall have free access to the fabricating plant for inspection, and every facility shall be extended for this purpose. This inspection shall include an examination of the pipe for the items in Section 10.1 and the specific requirements of this specification applicable to the type of pipe and method of fabrication.

**11.2** On a random basis, samples may be taken for chemical analysis and mechanical property determination for check purposes. These samples will be secured from fabricated pipe or from sheets or coils of the material used in fabrication of the pipe. Testing shall be as described in AASHTO M 197/M 197M.

## 12. REJECTION

**12.1** Pipe failing to conform to the requirements of this specification may be rejected. This requirement applies not only to the individual pipe, but to any shipment as a whole where a substantial number of pipe are defective. If the average deficiency in length of any shipment of pipe is greater than 1 percent, the shipment may be rejected.

## 13. CERTIFICATION

**13.1** When specified in the purchase order or contract, a manufacturer's or fabricator's certification, or both, shall be furnished to the purchaser stating that samples representing each lot have been tested and inspected in accordance with this specification and have been found to meet the requirements for the material described in the order. When specified in the order, a report of the mechanical test results and chemical composition limits shall be furnished.

**NOTE 12**—As the identity of the sheet is not maintained from the original ingot production, if numerical results are required by the purchaser, tests should be performed on the finished sheet.

#### 14. PRODUCT MARKING

**14.1** If the aluminum alloy sheet was not marked by the manufacturer as indicated in AASHTO M 197/M 197M, it shall be marked by the fabricator as de-

scribed in Section 14.2, during the course of corrugating the sheet and fabricating the pipe.

**14.2** Each corrugated sheet used in annular corrugated pipe, and each 2 to 5 ft [0.6 to 1.5 m] of coiled sheet used in helically corrugated pipe, shall be identified by the fabricator showing the following:

**14.2.1** Name of sheet manufacturer,

**14.2.2** Identification of the pipe fabricator, if different than the sheet manufacturer,

**14.2.3** Alloy and temper,

**14.2.4** Specified thickness,

**14.2.5** Fabricator's date of corrugating or forming into pipe by a six-digit number indicating in order the year, month, and day of the month, and

**14.2.6** AASHTO designation number.

**14.3** The marking shall be applied to the sheet by a permanent method such as coining in accordance with ASTM B 666 or B 666M. This identification shall appear on the outside of the pipe.