Ductile Iron Pipe Research Association

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DESIGN

Design of Ductile Iron Pipe on Supports

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Design procedures for Ductile Iron Pipe in normal underground service have been well established. The standard design considers hoop stresses in the pipe wall due to internal hydrostatic pressure as well as bending stresses and deflection in the pipe due to external loads of earth and traffic above the buried pipe.[1]

Neither Ductile Iron Pipe nor any other type of pipe is designed specifically as a beam for normal buried service. It is always assumed that the pipe will be uniformly supported along its length by the soil beneath it. Erosion, excessive traffic loading, frost, expansive soils, and poor installation sometimes result in beam loading on buried pipe. In fact, these conditions, individually or in combination, probably are responsible for many failures in buried pipelines. Because of Ductile Iron Pipe's great beam strength, beam failures in buried Ductile Iron Pipe are virtually unknown.

In some situations, it is necessary or desirable to use supports at designated intervals along pipelines. Aboveground, supported pipe is needed to transport water and other fluids within treatment plants and buildings. Also, pipe on piers is utilized to cross natural or man-made objects. Sometimes, unstable soil conditions or other factors necessitate the installation of pipe on piers or pilings underground.

This article reviews the pertinent design considerations for both aboveground and underground Ductile Iron Pipe-on supports installations. Bridge-crossing installations, which are not specifically addressed, require special attention to their unique situations. Specific procedures, recommended design limits, and allowable stresses are outlined in the example problem. Design tables based on Ductile Iron Pipe data and suggested loads are also provided.

Beam Span for Ductile Iron Pipe on Supports

Ductile Iron Pipe is normally manufactured in 18- or 20-foot nominal* lengths, depending on the pipe manufacturer and pipe size. The most common joints used with Ductile Iron Pipe are the push-on type joint and the mechanical joint. Both of these rubber-gasketed joints allow a certain amount of deflection and longitudinal displacement while maintaining their hydrostatic seal. This makes these pipe joints ideally suited for normal underground installation. The flexibility of the joints reduces the chance of excessive beam stresses occurring. For pipe supported at intervals, however, flexible joints usually require that at least one support be placed under each length of pipe for stability.

Various schemes have been successfully used to obtain longer spans where particular installation conditions presented the need, but these are special design situations and are not specifically addressed in this article. The design presented herein is based upon support per length of pipe.

Ductile Iron Pipe is well-suited for use in pipe-on-supports applications due to its tremendous beam strength.

Support Location

System security is maximized by positioning the supports immediately behind the pipe bells. When the support is placed near the bell, the bell section contributes beneficial ring stiffness where it is most needed. This ring stiffness, in turn, reduces the effect of support loads and localized stress. Supports should normally not be placed under spigots adjacent to bells, due to possible undesirable effects on joints.

Saddle Angle and Support Width

Pipe supports should cradle the pipe in a saddle (see Figure 1). This cradling, which should follow the contour of the pipe, minimizes stress concentrations at the supports. It is recommended that the saddle angle (ß) of the support be between 90° and 120°. Little or no benefit is gained by increasing the saddle angle more than 120°. With angles smaller than 90°, the maximum stress tends to increase rapidly with decreasing saddle angle.[3] There are some differences among published theories and data regarding the importance of axial support width for saddles. The most accepted formulas are found to be completely independent of saddle width. Some test data, however, show a decrease in measured stresses with an increase in saddle width. There is little effect on the maximum stress when saddle support width is increased more than $\sqrt{2Dt_e}$.[4] Therefore, for saddle supports, the minimum width (b) is determined by Equation (1):

$$b = \sqrt{2Dt_e}$$

where:
b = minimum (axial) saddle width (inches)
D = actual outside diameter of pipe (inches)
t_e = nominal pipe wall thickness (inches), see Table 1

TABLE 1
Nominal Thickness for Standard Pressure Classes of Ductile Iron Pipe

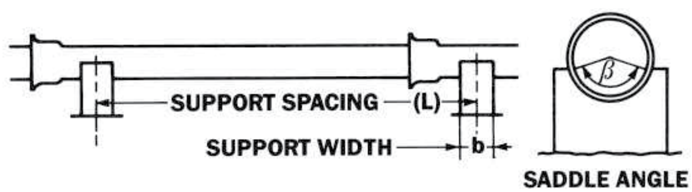
Size in.	Outside Diameter in.	Pressure Class 150	200	250	300	350
		Nominal Thickness (in.)				
3	3.96	—	—	—	—	0.25*
4	4.80	—	—	—	—	0.25*
6	6.90	—	—	—	—	0.25*
8	9.05	—	—	—	—	0.25*
10	11.10	—	—	—	—	0.26
12	13.20	—	—	—	—	0.28
14	15.30	—	—	0.28	0.30	0.31
16	17.40	—	—	0.30	0.32	0.34
18	19.50	—	—	0.31	0.34	0.36
20	21.60	—	—	0.33	0.36	0.38
24	25.80	—	0.33	0.37	0.40	0.43
30	32.00	0.34	0.38	0.42	0.45	0.49
36	38.30	0.38	0.42	0.47	0.51	0.56
42	44.50	0.41	0.47	0.52	0.57	0.63
48	50.80	0.46	0.52	0.58	0.64	0.70
54	57.56	0.51	0.58	0.65	0.72	0.79
60	61.61	0.54	0.61	0.68	0.76	0.83
64	65.67	0.56	0.64	0.72	0.80	0.87

*Calculated thicknesses for these sizes and pressure ratings are less than those shown above. These are the lowest nominal thicknesses currently available in these sizes.

Support Design

Additionally, supports, piles, and/or foundations should be adequately designed from a structural and soil-engineering standpoint to safely handle any loads transferred from the pipe.

FIGURE 1
Saddle Angle and Width



*Ductile Iron Pipe may be furnished in shorter lengths per AWWA C151.[2] If exact lengths are required to fit on pre-built piers, this should be specified.

Loads on Pipe

For underground pipe-on-supports design calculations, the total load normally includes the prism earth load plus the weight of the pipe and contents. When buried pipe is installed on supports, it is usually because of unstable ground conditions. There should, in most cases, be no vehicle loading. Thus, truck loads (per ANSI/AWWA C150) should be used in design calculations only where they are likely to occur. For aboveground design calculations, the total load includes the weight of the pipe and contents. If the designer expects greater loads to occur on aboveground or underground installations, these loads should be incorporated into the design and are not in the scope of this procedure.

Pipe Wall Thickness Calculations

Design calculations include localized stress at supports, hoop stress due to internal pressure, and flexural stress and beam deflection at the center of the span. Due to the conservative approach of this design procedure, and in the interest of simplicity, combinations of external load and internal pressure to obtain principal stresses have not been considered. The design engineer may elect to investigate principal stresses due to extraordinary circumstances, e.g., very high internal pressure, etc.

TABLE 2
Allowances for Casting

Sizing (in.)	Casting Tolerance (in.)
3–8	0.05
10–12	0.06
14–42	0.07
48	0.08
54–64	0.09

Localized Stress at Supports

The supported pipe is subjected to localized stresses at the support that are a function of the total reaction at the support and the shape (saddle angle) of the support. This maximum stress may be longitudinal or circumferential in nature and is predicted by the following equation proposed by Roark:[5]

$$f_r = K\left(\frac{wL}{t_n^2}\right)\ln\left(\frac{D}{2t_n}\right)$$

where:

f_r = localized stress due to support reaction (48,000 psi maximum)

L = span length (feet)

D = pipe outside diameter (inches), see Table 1

w = unit load per linear foot (lb./ft.)

K = saddle coefficient

t_n = design wall thickness of pipe (inches), see Table 3

For aboveground applications:

t_n = minimum manufacturing thickness of pipe
= nominal pipe wall thickness–casting tolerance

For underground applications:

t_n = net pipe wall thickness
= nominal pipe wall thickness–casting tolerance–0.08" service allowance

Recent research involving Ductile Iron Pipe has established that the function

$$K = 0.03 - 0.00017\ (ß - 90°)$$

provides excellent correlation between the ring stresses predicted by Equation (2) and the actual stress as measured when ß is between 90° and 120°.[3]

The maximum calculated localized stress should be limited to 48,000 psi. This value is equal to the minimum yield strength in bending for Ductile Iron Pipe (72,000 psi) divided by a safety factor of 1.5. It is the same limiting value of bending stress employed in the American National Standard for the Thickness Design of Ductile Iron Pipe, ANSI/AWWA C150/A21.50.[1]

Hoop Stress Due to Internal Pressure

The net thickness required for internal pressure can be determined by using the equation for hoop stress:

$$t = \frac{P_i D}{2S}$$

where:

t = net pipe wall thickness (inches)

P_i = design internal pressure (psi)
= 2 (P_w + P_s)

P_w = working pressure (psi)

P_s = surge allowance (100 psi)

D = outside diameter of pipe (inches)

S = minimum yield strength in tension
= 42,000 psi
If anticipated surge pressures are greater than 100 psi, the maximum anticipated pressure must be used.

Flexural Stress at Center of Span

With one support per length of pipe positioned immediately behind the bells, each span can conservatively be treated as a simply supported beam. The joints being slightly offset from the supports causes some of the simple beam moment and stress to distribute itself from the center of the span to the support. This makes the simple beam approach conservative. The following formula represents the flexural stress at the center of the span of a uniformly loaded, simply supported beam:

$$f_b = \frac{15.28\ DwL^2}{D^4 - d^4}$$

where:

f_b = allowable flexural stress (48,000 psi maximum)

D = pipe outside diameter (inches)

w = unit load per linear foot (lb./ft.)

L = length of span (feet)

d = D-2t_n (inches)

Beam Deflection at Center of Span

Computations for beam deflection are also based on the simply supported beam concept. This is likewise conservative due to the reality of offset joints.

The maximum allowable deflection at mid-span to prevent damage to the cement-mortar lining is limited to:

$$y_r = \frac{L}{10}$$

where:

y_r = maximum allowable deflection at center of span (inches)

L = length of span (feet)

Less deflection may be desired. The deflection of the beam may be significant for aesthetic reasons in aboveground installations or possibly for hydraulic reasons in gravity-flow pipelines. Limitations on the deflection, if any, should be determined by the designer as appropriate to a specific installation.

The beam deflection at center span for a uniformly loaded, simply supported beam can be calculated using the following formula:

$$y = \frac{458.4\ w\ L^4}{E(D^4 - d^4)}$$

where:

y = deflection at center of span (inches)

w = unit load per linear foot (lb./ft.)

L = length of span (feet)

E = modulus of elasticity (24 x 10^6 psi)

D = pipe outside diameter (inches)

d = D-2t_n (inches)

Aboveground Installations

For aboveground installations with one support per length of pipe (i.e., a span length of 18 or 20 feet), the minimum pressure class of Ductile Iron Pipe manufactured in all sizes is more than adequate to support the weight of the pipe and water it contains when analyzed in accordance with the suggestions of this procedure.

Other design considerations for pipes supported aboveground may include the carrying capacity of the supports themselves, the strength of the structure from which a pipe may be suspended, and/or unusual or additional loads not in the scope of this article. Such loading may include seismic, frequency or resonance of vibrations, wind, water current, and other special design considerations.

It is also necessary to assure a minimum of lateral and vertical stability at the supports for aboveground piping. Deflected pipe joints can result in thrust forces of hydrostatic or hydrodynamic origin, and if not laterally and vertically restrained, unbalanced forces may result in additional joint deflection and possible failure of the pipeline.

Thermal expansion of Ductile Iron Pipelines supported aboveground is not usually of concern in correctly designed and installed systems because of the nature of the push-on or mechanical joint. A 100-degree Fahrenheit change in temperature results in expansion or contraction of a 20-foot length of Ductile Iron Pipe of approximately 0.15 inches. This is easily accommodated by correctly installed pipe and joints. Occasionally, where structures from which Ductile Iron Pipe is to be suspended are expected to have significantly different behavior than the pipeline, special considerations for expansion, contraction, and supports may be necessary. For reference, the following are coefficients of thermal expansion for various materials:

Ductile Iron Pipe: 6.2 x 10^{-6} inch/inch degree Fahrenheit
Steel: 6.5 x 10^{-6} inch/inch degree Fahrenheit
Concrete: 7.0 x 10^{-6} inch/inch degree Fahrenheit

Design Procedure

Step A. Select the length of span (18 feet or 20 feet), saddle angle (90°-120°), and pipe diameter.

Step B. Determine the unit load per linear foot (w) based on the minimum pressure class pipe manufactured.

1. For aboveground installations: $w = (W_p + W_w)$
2. For underground installations:
   - 2.1 No truck loads
     $w = (W_p + W_w) + 12\ D\ P_e$
   - 2.2 Truck loads included
     $w = (W_p + W_w) + 12\ D\ (P_e + P_t)$

Note: For D see Table 1
For P_e and P_t see Table 4
For $(W_p + W_w)$ see Table 3

Step C. Determine if the design thickness (t_n), corresponding to the pipe pressure class selected in Step B and found in Table 3, results in an acceptable localized stress less than or equal to 48,000 psi.

1. /Calculate the saddle coefficient (K) using Equation (3).
2. Calculate fr using Equation (2). If fr exceeds 48,000 psi, increase t_n to the next greater pressure class and re-calculate starting with Step B. Repeat until the resulting fr is less than or equal to 48,000 psi.

Step D. Determine the pipe pressure class required due to internal pressure.

1. Calculate the net thickness (t) required for hoop stress due to internal pressure using Equation (4).
2. Determine the total calculated thickness (T) due to internal pressure.
   For aboveground applications: T = t + casting tolerance
   For underground applications: T = t + casting tolerance + 0.08
3. Using Table 1, select a standard pressure class thickness. When the total calculated thickness is between two standard thicknesses, select the larger of the two.
   Note: For aboveground applications, the standard pressure class selected from Table 1 may be less than the design working pressure due to the 0.08 service allowance not being required.

Step E. Calculate the flexural stress (f_b) at mid-span using Equation (5) and the greater pressure class pipe required in Step C or D along with its corresponding t_n and w values. If f_b exceeds 48,000 psi, increase t_n to the next class and re-calculate f_b using the new pressure class thickness and corresponding tn and w values. Repeat until the resulting f_b is less than or equal to 48,000 psi.

Step F. Check deflection at mid-span.

1. Calculate the deflection at mid-span (y) using Equation (7) and the greater pressure class pipe required in Step C, D, or E along with its corresponding tn and w values.
2. Calculate the maximum allowable deflection at mid-span (yr) using Equation (6). (Note: Less deflection may be desired.) If the deflection y is greater than the deflection y_r, increase tn to the next greater pressure class and recalculate y using the new pressure class thickness and corresponding tn and w values. Repeat until the resulting y is less than or equal to y_r. G. Choose the greater pressure class corresponding to the largest t_n required in Step C, D, E, or F and calculate the minimum saddle width using Equation (1).

Design Example

Find the required pipe pressure class for 24-inch Ductile Iron Pipe installed on 20-foot-spaced piers under 3 feet of earth cover with 120° saddles and an operating pressure of 150 psi. Assume no truck load.

Step A.

20-foot span (L)
120° saddle angle (ß)
24-inch diameter Ductile Iron Pipe

Step B.

$w = (W_p + W_w) + 12\ D\ P_e$
$(W_p + W_w)$ = 306 lb./ft. (Table 3)
D = 25.8” (Table 1)
P_e = 2.5 psi (Table 4)
w = 306 + 12 (25.8) (2.5) = 1080 lb.ft.

Step C.

K = 0.03-0.00017 (ß-90°)
K = 0.03-0.00017 (120-90°) = 0.025

$$f_r = \quad f_r = K\left(\frac{wL}{t_n^2}\right)\ln\left(\frac{D}{2t_n}\right)$$

t_n = 0.18 (Table 3)

$$f_r = 0.025\left(\frac{(1088)(20)}{(0.18)^2}\right)\ln\left(\frac{25.8}{2(0.18)}\right) = 71{,}200\text{ psi}$$

71,200 psi > 48,000 psi
∴ try next thickest pressure class (Pressure Class 250)
For Pressure Class 250:
(From Table 3)
t_n = 0.22”
w = 314 + 12 (25.8) (2.5) = 1088 lb./ft.

$$f_r = 0.025\left(\frac{(1088)(20)}{(0.22)^2}\right)\ln\left(\frac{25.8}{2(0.22)}\right) = 45{,}761\text{ psi}$$

45,761 psi < 48,000 psi ∴ OK

Step D.

$$t = \frac{P_i D}{2S}$$

$P_i = 2(P_w + P_s) = 2\ (150 + 100) = 500$ psi

$$t = \frac{500\ (25.8)}{2(42{,}000)} = 0.15''$$

Total calculated thickness (T) = t + casting tolerance + 0.08

Casting tolerance = 0.07 (Table 2)

T = 0.15 + 0.07 + 0.08 = 0.30"

From Table 1, Pressure Class 200 is adequate for internal pressure design.

Step E. Using Pressure Class 250 determined in Step C:

$$f_b = \frac{15.28\ DwL^2}{D^4 - d^4}$$

$d = D - 2t_n = 25.8 - 2\ (0.22) = 25.36''$

$$f_b = \frac{15.28(25.8)(1088)(20)^2}{(25.8)^4 - (25.36)^4} = 5{,}824 \text{ psi}$$

5,824 psi < 48,000 psi ∴ OK

Step F. Using Pressure Class 250 determined in Step C:

$$y = \frac{458.4\ w\ L^4}{E\ (D^4 - d^4)}$$

$$y = \frac{458.4(1088)(20)^4}{(24\times10^6)(25.8^4 - 25.36^4)} = 0.11''$$

$$yr = \frac{L}{10} = \frac{20}{10} = 2''$$

0.11" < 2" ∴ OK

Step G. Using Pressure Class 250 determined in Step C:

$b = \sqrt{2Dt_e} = \sqrt{2(25.8)(0.37)} = 4.37''$

Therefore, use Pressure Class 250 pipe with minimum saddle width of 4.37."

Nomenclature

b — Minimum saddle width (inches)
D — Pipe outside diameter (inches)
d — Pipe design inside diameter (inches)
E — Modulus of elasticity for Ductile Iron Pipe (24×10^6 psi)
f_b — Allowable flexural stress (48,000 psi)
f_r — Localized stress due to support reaction (48,000 psi maximum)
K — Saddle coefficient [0.03-0.00017 (ß-90°)]
L — Span length (feet)
P_e — Earth load (psi)
P_i — Design internal pressure (psi)
P_s — Surge allowance (psi)
P_t — Truck load (psi)
P_w — Working pressure (psi)
S — Minimum yield strength in tension for Ductile Iron Pipe (42,000 psi)
T — Total calculated pipe wall thickness (inches)
t — Net pipe wall thickness (inches)
t_e — Nominal pipe wall thickness (inches)
t_n — Design pipe wall thickness (inches)
w — Unit load per linear foot (lb./ft.)
W_p— Unit load of pipe per linear foot (lb./ft.)
W_w— Unit load of water in pipe per linear foot (lb./ft.)
y — Deflection at center of span (inches)
y_r — Maximum recommended deflection at center of span (inches)
ß — Saddle angle (degrees; 90° to 120° is recommended)

References

1. American National Standard For Thickness Design of Ductile Iron Pipe, ANSI/AWWA C150/A21.50.
2. American National Standard For Ductile Iron Pipe, Centrifugally Cast, For Water, ANSI/AWWA C151/A21.51.
3. Evces, C.R. and O'Brien, J.M, "Stresses in Saddle-Supported Ductile Iron Pipe," Journal AWWA, November 1984.
4. Wilson, W.M., and Olson, E.D., "Tests on Cylindrical Shells," Engineering Experiment Station, University of Illinois Bulletin, 331, 1941. 5. Roark, R.J., Formulas For Stress and Strain, McGraw- Hill, New York, Fifth Edition, 1975.

TABLE 3
Pipe Plus Water Weight ($W_p + W_w$) and Design Wall Thickness (t_n)

Size in.	Pressure Class	$W_p + W_w$ Lb./Linear Foot	t_n (in.) Aboveground Applications	t_n (in.) Underground Applications
3	350	14	.20	.12
4	350	18	.20	.12
6	350	31	.20	.12
8	350	48	.20	.12
10	350	68	.20	.12
12	350	92	.22	.14
14	250	119	.21	.13
	300	122	.23	.15
	350	123	.24	.16
16	250	151	.23	.15
	300	154	.25	.17
	350	157	.27	.19
18	250	185	.24	.16
	300	190	.27	.19
	350	193	.29	.21
20	250	225	.26	.18
	300	230	.29	.21
	350	233	.31	.23
24	200	306	.26	.18
	250	314	.30	.22
	300	320	.33	.25
	350	326	.36	.28
30	150	453	.27	.19
	200	462	.31	.23
	250	473	.35	.27
	300	481	.38	.30
	350	491	.42	.34
36	150	637	.31	.23
	200	650	.35	.27
	250	665	.40	.32
	300	677	.44	.36
	350	693	.49	.41
42	150	848	.34	.26
	200	869	.40	.32
	250	887	.45	.37
	300	905	.50	.42
	350	927	.56	.48
48	150	1099	.38	.30
	200	1124	.44	.36
	250	1148	.50	.42
	300	1173	.56	.48
	350	1197	.62	.54
54	150	1403	.42	.34
	200	1436	.49	.41
	250	1468	.56	.48
	300	1501	.63	.55
	350	1533	.70	.62
60	150	1608	.45	.37
	200	1643	.52	.44
	250	1678	.59	.51
	300	1717	.67	.59
	350	1752	.74	.66
64	150	1817	.47	.39
	200	1860	.55	.47
	250	1902	.63	.55
	300	1945	.71	.63
	350	1982	.78	.70

Notes: Approximate pipe weight based on push-on joint cement-mortar lined pipe. Weight of water based on actual I.D.

TABLE 4
Earth Loads P_e and Truck Loads P_t — psi

Depth of cover ft.	P_e	3-Inch Pipe P_t	4-Inch Pipe P_t	6-Inch Pipe P_t	8-Inch Pipe P_t	10-Inch Pipe P_t	12-Inch Pipe P_t	14-Inch Pipe P_t	16-Inch Pipe P_t	18-Inch Pipe P_t
2.5	2.1	9.9	9.9	9.9	9.8	9.7	9.6	8.7	8.2	7.8
3	2.5	7.4	7.4	7.3	7.3	7.2	7.2	6.6	6.2	5.9
4	3.3	4.4	4.5	4.4	4.4	4.4	4.4	4.4	4.1	3.9
5	4.2	3.0	3.0	3.0	3.0	2.9	2.9	2.9	2.8	2.6
6	5.0	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.0	1.9
7	5.8	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.5	1.4
8	6.7	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
9	7.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
10	8.3	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
12	10.0	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.5
14	11.7	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
16	13.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
20	16.7	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
24	20.0	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
28	23.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
32	26.7	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Depth of cover ft.	P_e	20-Inch Pipe P_t	24-Inch Pipe P_t	30-Inch Pipe P_t	36-Inch Pipe P_t	42-Inch Pipe P_t	48-Inch Pipe P_t	54-Inch Pipe P_t	60-Inch Pipe P_t	64-Inch Pipe P_t
2.5	2.1	7.5	7.1	6.7	6.2	5.8	5.4	5.0	4.8	4.5
3	2.5	5.7	5.4	5.2	4.9	4.6	4.4	4.1	3.9	3.8
4	3.3	3.9	3.6	3.5	3.4	3.3	3.1	3.0	2.9	2.8
5	4.2	2.6	2.4	2.4	2.3	2.3	2.2	2.1	2.1	2.1
6	5.0	1.9	1.7	1.7	1.7	1.7	1.6	1.6	1.6	1.5
7	5.8	1.4	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.2
8	6.7	1.1	1.1	1.1	1.1	1.0	1.0	1.0	1.0	1.0
9	7.5	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.8
10	8.3	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
12	10.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
14	11.7	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
16	13.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
20	16.7	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
24	20.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
28	23.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
32	26.7	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

For more information contact DIPRA or any of its member companies.

Ductile Iron Pipe Research Association

An association of quality producers dedicated to the highest pipe standards through a program of continuing research and service to water and wastewater professionals.

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Social Media

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Visit our website, **www.dipra.org/videos,** and click on the YouTube icon for informational videos on Ductile Iron Pipe's ease of use, economic benefits, strength and durability, advantages over PVC, and more.

Member Companies

AMERICAN Ductile Iron Pipe
P.O. Box 2727
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Canada Pipe Company, Ltd.
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McWane Ductile
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United States Pipe and Foundry Company
Two Chase Corporate Drive
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Ductile Iron Pipe is SMART certified

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