SECTION 17

AMERICAN Engineering Data

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Energy Savings With Ductile Iron Pipe

All sizes of standard thickness cement-lined ductile iron pipe in minimum pressure classes and all special thickness classes through Special Thickness Class 52 in 4"-54" sizes have greater than nominal inside diameters. **Head losses in piping are directly related to inside diameters, and energy consumption and accompanying pumping costs are directly related to head losses. Therefore, the use of ductile iron piping having inside diameters greater than nominal can result in significant energy savings over the years. In addition to helping to keep operating costs and utility rates reasonable, this conservation of energy is also helpful to the environment.**

Graphs and tables pertaining to this can be found in "Manual For Computation of Energy Savings With Ductile Iron Pipe" published by the Ductile Iron Pipe Research Association (DIPRA). Formulas for calculating pumping costs are as follows:

$$PC = 1.65\, H_L\, Q\, \frac{a}{E}$$

where:

PC = Pumping cost in $/Year/ 1000 ft of pipe based on 24 Hr./day Pump Operation

H_L = Hydraulic Gradient or Head Loss in ft/1000 ft.

Q = Flow in Gallons/Minute (GPM)

a = Unit Cost of Electricity in $/KWH

E = Total Efficiency of Pump System (pump, motor, transmission — always a number less than one)

and:

$$H_L{}^* = 1000 \left[\frac{V}{1.318C\,(r)^{0.63}} \right]^{1.852}$$

where:

V = Velocity in ft/sec (fps)

C = Hazen-Williams "C" Factor (140 for ductile iron pipe)**

r = Hydraulic Radius in ft (inside diameter in ft ÷ 4 for pipe flowing full)

and:

$$V^* = \frac{Q}{448.8A}$$

where:

Q = Flow in Gallons/Minute (GPM)

A = Cross sectional area of pipe in ft^2

and:

$$A^{***} = \frac{\pi d^2}{4}$$

where:

d*** = Inside diameter in ft

*See Table No. 17-1 for values of H_L and V for standard minimum pressure class cement-lined ductile iron pipe.
**The Hazen-Williams flow coefficient C=140 has been used for cement-lined cast iron and ductile iron pipe for many years. The quality of recent, high-performance cement linings for ductile iron pipe, smooth proprietary linings, and the availability of even larger pipe sizes may justify the use of significantly higher values for C. This may be particularly applicable to the intermediate and larger pipe sizes in clean water service. (See pg 17-4.)
***See Table No. 17-4 for values of A and d for standard minimum pressure class cement-lined ductile iron pipe.

Present Value of Money

The present value of money compounded annually at a given investment rate and an assumed inflation rate over a given period can be calculated by the following formulas:

$$PV = \frac{(1 + i)^n - 1}{i(1 + i)^n}$$

where:

PV = Present Value per $1

i = Effective interest rate (%/100)

n = Number of compounding periods (years)

and $i = \frac{j - i'}{1 + i'}$

where:

j = Investment rate (%/100)

i' = Inflation rate (%/100)

Example:

Given:

50,000' 36" Pressure Class 150 pipe
Design flow — 14,000 GPM
Unit Power Cost — $.05 KWH
Pump Operation — 24 Hrs/Day
Pump System Efficiency — 70%
Hazen-Williams "C" Factor — 140

Using the Pumping Cost formula on page 17-2, Pressure Class 150, cement-lined, ductile iron pipe will save approximately $18,075/year in Pumping Costs over a substitute material pipe with a nominal inside diameter.

The Present Value of the $18,075 annual savings, over a 50-year time period, and assuming an investment rate of 8% and an inflation rate of 4%, is $397,650 ($18,075 x 22).

Flow of Water In Ductile Iron Pipe

The carrying capacity of a given pipeline is limited by its internal resistance to the flow of water. This resistance to flow causes a loss of head or drop in pressure as the water moves through the line. The amount of head loss depends on (1) the velocity of the water, (2) the roughness of the interior surface of the pipe, (3) the internal diameter, and (4) the length of the line. These factors have been related in the widely used Hazen-Williams formula for computing head losses, pipe sizes and carrying capacities in distribution lines. This formula is as follows:

$$V = C \times r^{0.63} \times S^{0.54} \times 0.001^{-0.04}$$

in which

- V = velocity of water through the pipe in feet per second
- C = factor depending on the roughness of the interior surface
- r = hydraulic radius which is ¼ the internal diameter (for pipe flowing full), in feet
- S = hydraulic slope or head loss in feet per foot of pipe

The factor C is well known as the Hazen-Williams "C" or flow coefficient "C," and its value must be estimated in flow calculations. Numerous tests have shown that cement-lined pipe installed many years ago maintains a nearly constant "C" of 140 even in tuberculating waters. The quality of more recent, high-performance AMERICAN cement linings and the availability of even larger pipe sizes may justify the use of significantly higher values for C, particularly in intermediate and larger pipe sizes. Multiple hydraulic flow tests of 42" AMERICAN "high performance" cement-mortar-lined pipeline (with standard, high-speed spun cement lining for that pipe size) conducted in 2001 at the flow facility at Utah State University resulted in an experimentally determined average "C" value slightly greater than 152, with flow velocities in the 3-13 fps (1-4 m/sec) range. A range of Mannings "n" values of 0.0089-0.010 for clean water was also determined for this same high-performance cement lining in this same 42" Utah State testing program. The Utah State data also showed the resulting Darcy friction factors "f" for the high-performance cement lining, when plotted vs. Reynolds number, very closely approximate the "smooth pipe curve" as shown on the Moody diagram.

Flow of Water in Ductile Iron Pipe

Hazen-Williams C=140*

Loss of Head shown is per 1,000 feet of pipeline. Table is based on 4"-64" AWWA C104 single-thickness cement-lined ductile iron pipe. Nominal thickness for minimum standard pressure classes noted.

Table No. 17-1

Flow in Gallons per 24 Hours	4" Pipe, Class 350		6" Pipe, Class 350		8" Pipe, Class 350		10" Pipe, Class 350		12" Pipe, Class 350	
	Vel. in ft. per sec.	Loss of Head (ft)	Vel. in ft. per sec.	Loss of Head (ft)	Vel. in ft. per sec.	Loss of Head (ft)	Vel. in ft. per sec.	Loss of Head (ft)	Vel. in ft. per sec.	Loss of Head (ft)
20,000	.33	.14								
30,000	.49	.29								
40,000	.65	.50								
50,000	.81	.75	.36	.10						
60,000	.98	1.05	.43	.14						
70,000	1.14	1.40	.50	.19						
80,000	1.30	1.79	.58	.25						
90,000	1.46	2.23	.65	.31						
100,000	1.63	2.71	.72	.37						
110,000	1.79	3.23	.79	.44						
120,000	1.95	3.79	.86	.52						
140,000	2.28	5.05	1.01	.69						
160,000	2.60	6.46	1.15	.89						
180,000	2.93	8.04	1.30	1.11						
200,000	3.25	9.77	1.44	1.34	.80	.32				
220,000	3.58	11.66	1.58	1.60	.88	.38				
240,000	3.91	13.70	1.73	1.88	.96	.45				
260,000	4.23	15.88	1.87	2.18	1.04	.52				
280,000	4.56	18.22	2.02	2.50	1.12	.60				
300,000	4.88	20.70	2.16	2.85	1.20	.68	.78	.24	.54	.10
320,000	5.21	23.33	2.31	3.21	1.28	.76	.83	.27	.58	.11
340,000	5.53	26.11	2.45	3.59	1.36	.85	.88	.30	.62	.12
360,000	5.86	29.02	2.59	3.99	1.44	.95	.93	.33	.65	.14
380,000	6.18	32.08	2.74	4.41	1.52	1.05	.99	.37	.69	.15
400,000	6.51	35.27	2.88	4.85	1.60	1.15	1.04	.40	.72	.17
450,000	7.32	43.87	3.24	6.03	1.80	1.44	1.17	.50	.82	.21
500,000	8.14	53.32	3.60	7.33	2.00	1.75	1.30	.61	.91	.25
550,000	8.95	63.61	3.96	8.74	2.20	2.08	1.43	.73	1.00	.30
600,000	9.76	74.74	4.32	10.27	2.40	2.45	1.56	.85	1.09	.36
650,000	10.58	86.68	4.68	11.91	2.60	2.84	1.69	.99	1.18	.41
700,000			5.04	13.67	2.80	3.25	1.82	1.14	1.27	.47
750,000			5.40	15.53	3.00	3.70	1.95	1.29	1.36	.54
800,000			5.76	17.50	3.20	4.17	2.08	1.46	1.45	.61
900,000			6.48	21.77	3.60	5.18	2.34	1.81	1.63	.75
1,000,000			7.20	26.46	4.00	6.30	2.60	2.20	1.81	.92
1,200,000			8.65	37.08	4.80	8.83	3.11	3.09	2.17	1.29
1,400,000			10.09	49.33	5.60	11.75	3.63	4.10	2.54	1.71
1,600,000					6.39	15.04	4.15	5.26	2.90	2.19
1,800,000					7.19	18.71	4.67	6.54	3.26	2.72
2,000,000					7.99	22.74	5.19	7.95	3.62	3.31
2,200,000					8.79	27.13	5.71	9.48	3.98	3.95
2,400,000					9.59	31.87	6.23	11.14	4.35	4.64
2,600,000					10.39	36.96	6.75	12.92	4.71	5.38
2,800,000							7.27	14.82	5.07	6.17
3,000,000							7.79	16.84	5.43	7.01
3,500,000							9.08	22.40	6.34	9.33
4,000,000							10.38	28.68	7.24	11.95
4,500,000									8.15	14.86
5,000,000									9.06	18.06
5,500,000									9.96	21.54
6,000,000									10.87	25.31

*The Hazen-Williams flow coefficient C=140 has been used for cement-lined cast iron and ductile iron pipe for many years. The quality of recent high-performance cement lining for ductile iron pipe and the availability of even larger pipe sizes may justify the use of significantly higher values for C, particularly in the intermediate and larger pipe sizes. (See pg 17-4.)

The design of systems outside common water velocities, i.e. 2-5 fps, may involve special design considerations (for example, the generation of substantial surge pressures as a result of valve closure or other water column effects, sedimentation at extremely low velocities, etc.).

Flow of Water in Ductile Iron Pipe

Hazen-Williams C=140*

Loss of Head shown is per 1,000 feet of pipeline. Table is based on 4"-64" AWWA C104 single-thickness cement-lined ductile iron pipe. Nominal thickness for minimum standard pressure classes noted.

Table No. 17-1—Continued

Flow in Gallons per 24 Hours	14" Pipe, Class 250		16" Pipe, Class 250		18" Pipe, Class 250		20" Pipe, Class 250	
	Vel. in ft. per sec.	Loss of Head (ft)	Vel. in ft. per sec.	Loss of Head (ft)	Vel. in ft. per sec.	Loss of Head (ft)	Vel. in ft. per sec.	Loss of Head (ft)
300,000	.40	.05						
400,000	.54	.08	.41	.04	.32	.02		
500,000	.67	.12	.51	.06	.41	.04		
600,000	.80	.17	.62	.09	.49	.05	.40	.03
700,000	.94	.23	.72	.12	.57	.07	.46	.04
800,000	1.07	.29	.82	.15	.65	.09	.53	.05
900,000	1.21	.36	.93	.19	.73	.11	.59	.06
1,000,000	1.34	.44	1.03	.23	.81	.13	.66	.08
1,100,000	1.47	.52	1.13	.28	.89	.15	.72	.09
1,200,000	1.61	.62	1.23	.32	.97	.18	.79	.11
1,300,000	1.74	.71	1.34	.38	1.06	.21	.86	.13
1,400,000	1.88	.82	1.44	.43	1.14	.24	.92	.15
1,500,000	2.01	.93	1.54	.49	1.22	.28	.99	.17
1,600,000	2.14	1.05	1.64	.55	1.30	.31	1.05	.19
1,700,000	2.28	1.17	1.75	.62	1.38	.35	1.12	.21
1,800,000	2.41	1.31	1.85	.69	1.46	.39	1.19	.23
1,900,000	2.55	1.44	1.95	.76	1.54	.43	1.25	.26
2,000,000	2.68	1.59	2.06	.83	1.62	.47	1.32	.28
2,200,000	2.95	1.89	2.26	.99	1.79	.56	1.45	.34
2,400,000	3.21	2.23	2.47	1.17	1.95	.66	1.58	.40
2,500,000	3.35	2.40	2.57	1.26	2.03	.71	1.65	.43
2,600,000	3.48	2.58	2.67	1.35	2.11	.76	1.71	.46
2,800,000	3.75	2.96	2.88	1.55	2.27	.87	1.84	.53
3,000,000	4.02	3.36	3.08	1.76	2.44	.99	1.98	.60
3,500,000	4.69	4.47	3.60	2.35	2.84	1.32	2.31	.79
4,000,000	5.36	5.73	4.11	3.01	3.25	1.69	2.63	1.02
4,500,000	6.03	7.13	4.63	3.74	3.65	2.11	2.96	1.27
5,000,000	6.70	8.66	5.14	4.55	4.06	2.56	3.29	1.54
5,500,000	7.37	10.33	5.65	5.42	4.47	3.05	3.62	1.83
6,000,000	8.04	12.14	6.17	6.37	4.87	3.59	3.95	2.16
6,500,000	8.71	14.08	6.68	7.39	5.28	4.16	4.28	2.50
7,000,000	9.38	16.15	7.19	8.48	5.68	4.77	4.61	2.87
7,500,000	10.05	18.35	7.71	9.63	6.09	5.42	4.94	3.26
8,000,000			8.22	10.85	6.49	6.11	5.27	3.67
8,500,000			8.74	12.14	6.90	6.84	5.60	4.11
9,000,000			9.25	13.50	7.31	7.60	5.93	4.57
9,500,000			9.76	14.92	7.71	8.40	6.26	5.05
10,000,000			10.28	16.41	8.12	9.24	6.59	5.55
11,000,000					8.93	11.02	7.25	6.62
12,000,000					9.74	12.95	7.90	7.78
13,000,000					10.55	15.01	8.56	9.02
14,000,000							9.22	10.35
15,000,000							9.88	11.76
16,000,000							10.54	13.25

*The Hazen-Williams flow coefficient C=140 has been used for cement-lined cast iron and ductile iron pipe for many years. The quality of recent high-performance cement lining for ductile iron pipe and the availability of even larger pipe sizes may justify the use of significantly higher values for C, particularly in the intermediate and larger pipe sizes. (See pg 17-4.)

The design of systems outside common water velocities, i.e. 2-5 fps, may involve special design considerations (for example, the generation of substantial surge pressures as a result of valve closure or other water column effects, sedimentation at extremely low velocities, etc.).

Flow of Water in Ductile Iron Pipe

Hazen-Williams C=140*

Loss of Head shown is per 1,000 feet of pipeline. Table is based on 4"-64" AWWA C104 single-thickness cement-lined ductile iron pipe. Nominal thickness for minimum standard pressure classes noted.

Table No. 17-1—Continued

Flow in Gallons per 24 Hours	24" Pipe, Class 200		30" Pipe, Class 150		36" Pipe, Class 150		42" Pipe, Class 150	
	Vel. in ft. per sec.	Loss of Head (ft)	Vel. in ft. per sec.	Loss of Head (ft)	Vel. in ft. per sec.	Loss of Head (ft)	Vel. in ft. per sec.	Loss of Head (ft)
1,000,000	.46	.03						
1,200,000	.55	.04						
1,400,000	.64	.06						
1,500,000	.68	.07	.44	.02	.31	.01		
1,600,000	.73	.08	.47	.03	.33	.01		
1,800,000	.82	.09	.53	.03	.37	.01		
2,000,000	.91	.11	.59	.04	.41	.02		
2,500,000	1.14	.17	.73	.06	.51	.02		
3,000,000	1.37	.24	.88	.08	.61	.03	.45	.02
3,500,000	1.59	.32	1.03	.11	.71	.05	.53	.02
4,000,000	1.82	.41	1.18	.14	.82	.06	.60	.03
4,500,000	2.05	.52	1.32	.18	.92	.07	.68	.03
5,000,000	2.28	.63	1.47	.22	1.02	.09	.75	.04
5,500,000	2.51	.75	1.62	.26	1.12	.11	.83	.05
6,000,000	2.73	.88	1.76	.30	1.22	.12	.90	.06
6,500,000	2.96	1.02	1.91	.35	1.33	.14	.98	.07
7,000,000	3.19	1.17	2.06	.40	1.43	.17	1.05	.08
7,500,000	3.42	1.33	2.20	.46	1.53	.19	1.13	.09
8,000,000	3.64	1.50	2.35	.51	1.63	.21	1.20	.10
8,500,000	3.87	1.67	2.50	.58	1.73	.24	1.28	.11
9,000,000	4.10	1.86	2.64	.64	1.84	.26	1.35	.13
9,500,000	4.33	2.06	2.79	.71	1.94	.29	1.43	.14
10,000,000	4.56	2.26	2.94	.78	2.04	.32	1.50	.15
11,000,000	5.01	2.70	3.23	.93	2.24	.38	1.65	.18
12,000,000	5.47	3.17	3.53	1.09	2.45	.45	1.80	.21
13,000,000	5.92	3.68	3.82	1.26	2.65	.52	1.96	.25
14,000,000	6.38	4.22	4.11	1.45	2.86	.60	2.11	.28
15,000,000	6.83	4.79	4.41	1.65	3.06	.68	2.26	.32
16,000,000	7.29	5.49	4.70	1.86	3.26	.76	2.41	.36
18,000,000	8.20	6.72	5.29	2.31	3.67	.95	2.71	.45
20,000,000	9.11	8.17	5.88	2.81	4.08	1.15	3.01	.55
22,000,000	10.02	9.74	6.46	3.35	4.49	1.38	3.31	.66
24,000,000			7.05	3.93	4.90	1.62	3.61	.77
26,000,000			7.64	4.56	5.30	1.88	3.91	.89
28,000,000			8.23	5.23	5.71	2.15	4.21	1.02
30,000,000			8.82	5.95	6.12	2.45	4.51	1.16
32,000,000			9.40	6.70	6.53	2.76	4.81	1.31
34,000,000			9.99	7.50	6.94	3.08	5.11	1.47
36,000,000			10.58	8.34	7.34	3.43	5.41	1.63
38,000,000					7.75	3.79	5.72	1.80
40,000,000					8.16	4.17	6.02	1.92
45,000,000					9.18	5.18	6.77	2.47
50,000,000					10.20	6.30	7.52	3.00
55,000,000							8.27	3.58
60,000,000							9.02	4.20
65,000,000							9.78	4.87
70,000,000							10.53	5.59

*The Hazen-Williams flow coefficient C=140 has been used for cement-lined cast iron and ductile iron pipe for many years. The quality of recent high-performance cement lining for ductile iron pipe and the availability of even larger pipe sizes may justify the use of significantly higher values for C, particularly in the intermediate and larger pipe sizes. (See pg 17-4.)

The design of systems outside common water velocities, i.e. 2-5 fps, may involve special design considerations (for example, the generation of substantial surge pressures as a result of valve closure or other water column effects, sedimentation at extremely low velocities, etc.).

Flow of Water in Ductile Iron Pipe

Hazen-Williams C=140*

Loss of Head shown is per 1,000 feet of pipeline. Table is based on 4"-64" AWWA C104 single-thickness cement-lined ductile iron pipe. Nominal thickness for minimum standard pressure classes noted.

Table No. 17-1—Continued

Flow in Gallons per 24 Hours	48" Pipe, Class 150		54" Pipe, Class 150		60" Pipe, Class 150		64" Pipe, Class 150	
	Vel. in ft. per sec.	Loss of Head (ft)	Vel. in ft. per sec.	Loss of Head (ft)	Vel. in ft. per sec.	Loss of Head (ft)	Vel. in ft. per sec.	Loss of Head (ft)
3,000,000	.35	.01						
4,000,000	.46	.01						
5,000,000	.58	.02						
6,000,000	.69	.03	.54	.02	.47	.01	.41	.01
7,000,000	.81	.04	.63	.02	.55	.02	.48	.01
8,000,000	.92	.05	.72	.03	.62	.02	.55	.01
9,000,000	1.04	.07	.81	.04	.70	.03	.62	.02
10,000,000	1.15	.08	.90	.04	.78	.03	.69	.02
12,000,000	1.38	.11	1.07	.06	.94	.04	.82	.03
14,000,000	1.61	.15	1.25	.08	1.09	.06	.96	.04
16,000,000	1.84	.19	1.43	.10	1.25	.07	1.10	.05
18,000,000	2.07	.24	1.61	.13	1.41	.09	1.24	.07
20,000,000	2.30	.29	1.79	.16	1.56	.11	1.37	.08
22,000,000	2.53	.34	1.97	.19	1.72	.13	1.51	.10
24,000,000	2.76	.40	2.15	.22	1.87	.16	1.65	.11
26,000,000	2.99	.47	2.33	.25	2.03	.18	1.78	.13
28,000,000	3.22	.53	2.51	.29	2.19	.21	1.92	.15
30,000,000	3.46	.61	2.69	.33	2.34	.24	2.06	.17
32,000,000	3.69	.68	2.86	.37	2.50	.27	2.20	.19
34,000,000	3.92	.77	3.04	.41	2.65	.30	2.33	.22
36,000,000	4.15	.85	3.22	.46	2.81	.33	2.47	.24
38,000,000	4.38	.94	3.40	.51	2.97	.37	2.61	.27
40,000,000	4.61	1.04	3.58	.56	3.12	.40	2.74	.29
45,000,000	5.18	1.29	4.03	.70	3.51	.50	3.09	.36
50,000,000	5.76	1.57	4.48	.85	3.90	.61	3.43	.44
55,000,000	6.33	1.87	4.92	1.01	4.29	.72	3.77	.53
60,000,000	6.91	2.19	5.37	1.19	4.68	.85	4.12	.62
65,000,000	7.49	2.54	5.82	1.38	5.07	.99	4.46	.72
70,000,000	8.06	2.92	6.27	1.58	5.46	1.13	4.80	.83
75,000,000	8.64	3.32	6.71	1.80	5.86	1.29	5.15	.94
80,000,000	9.21	3.74	7.16	2.02	6.25	1.45	5.49	1.06
85,000,000	9.79	4.18	7.61	2.26	6.64	1.62	5.83	1.18
90,000,000	10.37	4.65	8.06	2.52	7.03	1.80	6.18	1.32
95,000,000			8.51	2.78	7.42	1.99	6.52	1.46
100,000,000			8.95	3.06	7.81	2.19	6.86	1.60
105,000,000			9.40	3.35	8.20	2.40	7.20	1.75
110,000,000			9.85	3.65	8.59	2.61	7.55	1.91
115,000,000			10.30	3.96	8.98	2.84	7.89	2.07
120,000,000					9.37	3.07	8.23	2.24
125,000,000					9.76	3.31	8.58	2.42
130,000,000					10.15	3.56	8.92	2.60
135,000,000							9.26	2.79
140,000,000							9.61	2.98
145,000,000							9.95	3.18
150,000,000							10.29	3.39

*The Hazen-Williams flow coefficient C=140 has been used for cement-lined cast iron and ductile iron pipe for many years. The quality of recent high-performance cement lining for ductile iron pipe and the availability of even larger pipe sizes may justify the use of significantly higher values for C, particularly in the intermediate and larger pipe sizes. (See pg 17-4.)

The design of systems outside common water velocities, i.e. 2-5 fps, may involve special design considerations (for example, the generation of substantial surge pressures as a result of valve closure or other water column effects, sedimentation at extremely low velocities, etc.).

Gravity Flow in Pipe
Manning Formula

FORMULAS:

— for pipe flowing full —

$$Q = \frac{0.276}{n} \times D^{8/3} \times S^{1/2}$$

$$V = \frac{0.1125}{n} \times D^{2/3} \times S^{1/2}$$

Q = Flow in gallons per minute

D = Pipe diameter in inches

S = Slope in feet per foot

V = Velocity in feet per second

Protecto 401-lined Ductile Iron pipe has an approximate "n" value of n = 0.011*.

Example:

For a 20" Ductile Iron Protecto 401-lined pipe, Pressure Class 250, with a slope of 4.5 feet per 1000 feet, find the flow "Q" and the velocity "V" when the pipe is flowing full. The roughness coefficient "n" is 0.011.

$$Q = \frac{.276}{0.011} \times (20.86)^{8/3} \times (0.0045)^{1/2}$$

Q = 5550 gals./min.

$$V = \frac{.1125}{0.011} \times (20.86)^{2/3} \times (0.0045)^{1/2}$$

V = 5.20 feet/sec.

Nominal Size	Nominal I.D.	Thickness Class
64"	64.47"	Class 150
60"	60.45"	Class 150
54"	56.46"	Class 150
48"	49.80"	Class 150
42"	43.60"	Class 150
36"	37.46"	Class 150
30"	31.24"	Class 150
24"	25.06"	Class 200
20"	20.86"	Class 250
18"	18.80"	Class 250
16"	16.72"	Class 250
14"	14.66"	Class 250
12"	12.56"	Class 350
10"	10.50"	Class 350
8"	8.47"	Class 350
6"	6.32"	Class 350

Ductile Nominal Minimum Pressure Class Thickness Protecto 401-Lined Pipe

Fig. 17-1

Note: *Per Protecto 401 Web site at: http://www.protecto401.com/n-cfactor.htm

Equivalent Pipe Diameters

Table No. 17-2

Nominal Dia. of Pipe "A"	Nominal Dia. of Pipe "B" 2	3	4	6	8	10	12	14	16
2	2.6	3.36	4.23	6.12	8.08				
3		3.90	4.63	6.35	8.23	10.16			
4			5.21	6.71	8.47	10.33	12.25		
6				7.81	9.26	10.92	12.70	14.56	16.45
8					10.41	11.83	13.43	15.14	16.94
10						13.02	14.41	15.97	17.63
12							15.62	17.00	18.52
14								18.22	19.59
16									20.82
18									
20									
24									
30									
36									
42									
48									
54									
60									
64									

Table No. 17-2—Continued

Nominal Dia. of Pipe "A"	Nominal Dia. of Pipe "B" 18	20	24	30	36	42	48	54	60	64
2										
3										
4										
6										
8	18.78	20.66	24.50	30.35	36.26					
10	19.37	21.17	24.89	30.62	36.47	42.36				
12	20.14	21.84	25.41	31.00	36.75	42.59	48.47	54.39	60.33	64.30
14	21.09	22.68	26.06	31.48	37.11	42.87	48.71	54.58	60.49	64.44
16	22.19	23.66	26.86	32.07	37.57	43.23	49.00	54.83	60.70	64.63
18	23.43	24.79	27.78	32.76	38.11	43.67	49.35	55.12	60.95	64.86
20		26.03	28.83	33.57	38.74	44.18	49.77	55.47	61.25	65.13
24			31.24	35.49	40.29	45.43	50.81	56.35	61.99	65.80
30				39.05	43.24	47.90	52.89	58.12	63.52	67.19
36					46.86	51.00	55.56	60.43	65.53	69.03
42						54.67	58.78	63.26	68.03	71.34
48							62.47	66.57	70.98	74.08
54								70.28	74.36	77.24
60									78.09	80.76
64										83.30

All figures are in inches.

Example: In parallel, a 6-inch and an 8-inch main are only equivalent to one pipe 9.26 inches in diameter.

The equivalent size pipe required to equal, at the same head, the carrying capacity of two smaller pipes is tabulated in this table. This evaluation is based on the comparative nominal diameters raised to the 2.63 power.

Equivalent Number of Pipelines

Tabulated below are the approximate number of pipes of a given size equal in carrying capacity to one pipe of a larger size. At the same velocity of flow the volume delivered by two pipes of different sizes is proportional to the squares of their diameters. With the same head, however, the velocity is less in the smaller pipe, and the volume delivered varies approximately as the diameters to the 2.63 power. This table is calculated on this basis using nominal diameters. The figure opposite the intersection of any two sizes is the number of the smaller-sized pipes required to equal one of the larger; thus one 4-inch pipe equals 6.2 two-inch pipes.

Table No. 17-3

Dia. in.	1/2	3/4	1	2	3	4	5	6	7	8	10	12
2	38.3	13.2	6.2	1.0								
3	111.3	38.3	18.0	2.9	1.0							
4	237.2	81.7	38.3	6.2	2.1	1.0						
6	689.0	237.2	111.3	18.0	6.2	2.9	1.6	1.0				
8		505.5	237.2	38.3	13.2	6.2	3.4	2.1	1.4	1.0		
10		909.1	426.6	68.9	23.7	11.1	6.2	3.8	2.6	1.8	1.0	
12			689.0	111.3	38.3	18.0	10.0	6.2	4.1	2.9	1.6	1.0
14				167.0	57.5	27.0	15.0	9.3	6.2	4.3	2.4	1.5
16				237.2	81.7	38.3	21.3	13.2	8.8	6.2	3.4	2.1
18				323.3	111.3	52.2	29.0	18.0	12.0	8.4	4.7	2.9
20				426.6	146.9	68.9	38.3	23.7	15.8	11.1	6.2	3.8
24				689.0	237.2	111.3	61.9	38.3	25.5	18.0	10.0	6.2
30						200.2	111.3	68.9	45.9	32.3	18.0	11.1
36								111.3	74.2	52.2	29.1	18.0
42										78.3	43.6	27.0
48											61.9	38.3
54												52.2
60												68.9
64												81.7

Table No. 17-3—Continued

Dia. in.	14	16	18	20	24	30	36	42	48	54	60	64
2												
3												
4												
6												
8												
10												
12												
14	1.0											
16	1.4	1.0										
18	1.9	1.4	1.0									
20	2.6	1.8	1.3	1.0								
24	4.1	2.9	2.1	1.6	1.0							
30	7.4	5.2	3.8	2.9	1.8	1.0						
36	12.0	8.4	6.2	4.7	2.9	1.6	1.0					
42	18.0	12.7	9.3	7.0	4.4	2.4	1.5	1.0				
48	25.5	18.0	13.2	10.0	6.2	3.4	2.1	1.4	1.0			
54	34.8	24.5	18.0	13.6	8.4	4.7	2.9	1.9	1.4	1.0		
60	45.9	32.3	23.7	18.0	11.1	6.2	3.8	2.6	1.8	1.3	1.0	
64	54.4	38.3	28.1	21.3	13.2	7.3	4.5	3.0	2.1	1.6	1.2	1.0

Diameters, Circumferences, Areas and Volumes for Standard Minimum Pressure Classes of Ductile Iron Single-Thickness Cement-Lined Pipe

Table No. 17-4

Nominal Size in.	Outside Diameter in.	Inside Diameter in.	Cross Sectional Areas Based on O.D. sq. in.	Cross Sectional Areas Based on I.D. sq. in.	O.D. Circum-ference in.	I.D. Circum-ference in.	Approx. Outside Surface Area* sq. ft.	Volume Gallons per linear ft.	Volume† Gallons per 20' nom. length
4	4.80	4.17	18.10	13.66	15.08	13.10	26	0.71	14.19
6	6.90	6.27	37.39	30.88	21.68	19.70	37	1.60	32.08
8	9.05	8.42	64.33	55.68	28.43	26.45	48	2.89	57.85
10	11.10	10.45	96.77	85.77	34.87	32.83	59	4.46	89.11
12	13.20	12.51	136.85	122.92	41.47	39.30	70	6.39	127.71
14	15.30	14.55	183.85	166.27	48.07	45.71	82	8.64	172.75
16	17.40	16.61	237.79	216.69	54.66	52.18	93	11.26	225.13
18	19.50	18.69	298.65	274.35	61.26	58.72	105	14.25	285.04
20	21.60	20.75	366.44	338.16	67.86	65.19	116	17.57	351.34
24	25.80	24.95	522.79	488.91	81.05	78.38	138	25.40	507.96
30	32.00	31.07	804.25	758.18	100.83	97.61	172	39.39	787.72
36	38.30	37.29	1152.10	1092.13	120.32	117.15	206	56.73	1134.68
42	44.50	43.43	1555.29	1481.39	139.80	136.44	240	76.96	1539.11
48	50.80	49.63	2026.83	1934.55	159.59	155.92	275	100.50	2009.92
54	57.56	56.29	2602.15	2488.59	180.83	176.84	312	129.28	2585.55
60	61.61	60.28	2981.22	2853.89	193.55	189.37	334	148.25	2965.08
64	65.67	64.30	3387.08	3247.23	206.31	202.00	357	168.69	3373.75

*This value is roughly calculated as the outside surface area of a cylinder with an O.D. equal to the standard barrel O.D. of the pipe and length equal to the overall length of a "full-length" Fastite® pipe. Obviously, cut or trim pipe would have less surface area. Also, if one wanted to include the flare effects on area as a result of the sloping bell contour or the area of the radial bell face, this would increase the areas very slightly from the tabular values shown.

†This value may also be helpful in a rough determination of the "buoyancy" of a ductile iron pipe full of air. (Buoyancy force is roughly equivalent to weight of fresh or salt water, etc., displaced.) See also Section 9 for buoyancy of 4"-36" Flex-Ring pc 350 pipe.

Weights for Pipeline Design, Weights of Ductile Iron Pipe and Contained Water

Table No. 17-5

Size in.	Weight—Pounds per Foot Pipe	Weight—Pounds per Foot Water	Weight—Pounds per Foot Total	Size in.	Weight—Pounds per Foot Pipe	Weight—Pounds per Foot Water	Weight—Pounds per Foot Total
4	12	6	18	24	93	212	305
6	18	13	31	30	123	329	452
8	24	24	48	36	163	473	636
10	30	37	67	42	206	642	848
12	39	53	92	48	261	838	1099
14	47	72	119	54	325	1078	1403
16	57	94	151	60	371	1237	1608
18	66	119	185	64	410	1407	1817
20	78	147	225				

These weights are based on minimum pressure classes Ductile Iron Fastite® pipe with minimum thickness standard cement lining as specified in AWWA C104 and on weight of water of 62.4 pounds per cubic foot. All weights are as "in air" at sea level with no buoyancy effects considered. The inside diameters are given in Table No. 17-4.

Pounds of water per foot = 0.3403 x (I.D. in inches)^2.

Ductile Iron = 0.255 pounds per cubic inch.

Axial Bulkhead or Dead-End Thrust Due to Pressure*

Table No. 17-6

Nominal Pipe Size in.	Pipe O.D. For Pressure Area Calc.	Pressure (psi)														
		0	15	50	100	150	200	225	250	300	350	375	400	450	500	525
4	4.80	0	300	900	1,800	2,700	3,600	4,100	4,500	5,400	6,300	6,800	7,200	8,100	9,000	9,500
6	6.90	0	600	1,900	3,700	5,600	7,500	8,400	9,300	11,200	13,100	14,000	15,000	16,800	18,700	19,600
8	9.05	0	1,000	3,200	6,400	9,600	12,900	14,500	16,100	19,300	22,500	24,100	25,700	28,900	32,200	33,800
10	11.10	0	1,500	4,800	9,700	14,500	19,400	21,800	24,200	29,000	33,900	36,300	38,700	43,500	48,400	50,800
12	13.20	0	2,100	6,800	13,700	20,500	27,400	30,800	34,200	41,100	47,900	51,300	54,700	61,600	68,400	71,800
14	15.30	0	2,800	9,200	18,400	27,600	36,800	41,400	46,000	55,200	64,300	68,900	73,500	82,700	91,900	96,500
16	17.40	0	3,600	11,900	23,800	35,700	47,600	53,500	59,400	71,300	83,200	89,200	95,100	107,000	118,900	124,800
18	19.50	0	4,500	14,900	29,900	44,800	59,700	67,200	74,700	89,600	104,500	112,000	119,500	134,400	149,300	156,800
20	21.60	0	5,500	18,300	36,600	55,000	73,300	82,400	91,600	109,900	128,200	137,400	146,600	164,900	183,200	192,400
24	25.80	0	7,800	26,100	52,300	78,400	104,600	117,600	130,700	156,800	183,000	196,000	209,100	235,200	261,400	274,500
30	32.00	0	12,100	40,200	80,400	120,600	160,800	181,000	201,100	241,300	281,500	301,600	321,700	361,900	402,100	422,200
36	38.30	0	17,300	57,600	115,200	172,800	230,400	259,200	288,000	345,600	403,200	432,000	460,800	518,400	576,000	604,800
42	44.50	0	23,300	77,800	155,500	233,300	311,000	349,900	388,800	466,600	544,300	583,200	622,100	699,900	777,600	816,500
48	50.80	0	30,400	101,300	202,700	304,000	405,400	456,000	506,700	608,000	709,400	760,000	810,700	912,000	1,013,400	1,064,100
54	57.56	0	39,000	130,100	260,200	390,300	520,400	585,500	650,500	780,600	910,700	975,800	1,040,800	1,170,900	1,301,000	1,366,100
60	61.61	0	44,700	149,100	298,100	447,200	596,200	670,800	745,300	894,300	1,043,400	1,117,900	1,192,400	1,341,500	1,490,600	1,565,100
64	65.67	0	50,800	169,300	338,700	508,000	677,400	762,100	846,700	1,016,100	1,185,400	1,270,100	1,354,800	1,524,100	1,693,500	1,778,200

*This value represents the force in pounds that will be exerted on a test bulkhead (plug, cap, blind flange, etc.), a closed valve (disk, gate, ball, wedge, cone, etc.), or the back of a full-opening tee by the aggregate effect of internal pressure acting over the pressure area (PA). The tabular numbers do not include any provision for safety factors nor momentum effects such as surge pressures in line filling or operation over the pressure values shown. The manual "Thrust Restraint Design for Ductile Iron Pipe" contains a more comprehensive discussion on the subjects of thrust forces and thrust restraint.

Standard Abbreviations and Acronyms

Listed below are many of the standard abbreviations AMERICAN uses on quotations, line drawings, sales order contracts, shipping lists and invoices.

Table No. 17-7

Product or Term Identification or Description	Standard Abbreviation
A	
Accessories	ACC
Adjustment	ADJ
Air Test	A/T
Allocated	ALLOC
Alloy	ALLOY
Alloy Steel Bolts THHN	BOLT THHN
All Mechanical Joint Tee.	MJ TEE
American Cast Iron Pipe Company	ACIPCO
American-Darling Valve	ADV
American Ductile Iron Pipe Division	ADIP
American Fastite Pipe, Ductile Iron	FST PIPE
American Flex-Lok Ball & Socket Pipe, Ductile Iron	FLEXLOK PIPE (or FLXLK)
American Flow Control Division	AFC
Armor TIP (MJ)	MJARMT
Asphaltic Coated Inside & Outside	CTD
Asphaltic Coated Outside & Cement Lined Inside	C/L
Asphaltic Coated Outside & Double Thickness Cement Lined Inside	DBL C/L
Assembled	ASSEMB
Assigned Not Shipped	ANS
As Soon As Possible	ASAP
Atlanta District Office	ATL
B	
Back Face	BF
Ball End	BALL
Base Faced & Drilled	BA F&D
Base Drilled	BA DR
Base (Tee or Bend)	BASE
Bell Gland	BG
Bell Joint Clamp	BELL JT CLAMP
Bell Joint Clamp Gasket	BELL JT CLAMP GSK
Bell & Spigot	BS (Designate GA)
Bend	BEND
Beveled	BEV
Bill of Lading	B/L
Bill of Material	BOM
Birmingham District Office	BHM
Blind	BLD
Blind Flange	BLD FLG
Blind Flange Tap 1″ (NPT or IPS) at Invert	BLD FLG TAP 1 INV
Blind Flange Tap 1″ in Center	BLD FLG TAP 1
Blue Print	B/P

Standard Abbreviations and Acronyms

Table No. 17-7 - Continued

Product or Term Identification or Description	Standard Abbreviation
Bolt Circle	B/C
Both Flanges Hand Tight	BOTH FHT
Bolt Holes	BH
Bolts, Alloy Steel THHN	BOLT THHN
Boss & Tap	B&T
Branch	BR
Bronze	BRZ
C	
Cement Lined	C/L
Center	CTR
Centerline	CTR/L
Center to End and/or Center to Flare	CE
Center to Face	CF
Center to Face-Center to PE	CFPE
Center to Face-Center to SKT	CFS
Center to SKT-Center to Face	CSF
Certificate	CERT
Chaplets	CHAP
Change Sheet	CS
Chicago District Office	CHI
Class	CL
Clockwise	CW
Coal Tar Epoxy	CTE___MILS
Coated	CTD
Combination	COMB
Common	COM
Compact	CMPT
Companion Flange	COMP FLG
Compression Resilient Seated	CRS
Concentric Reducer	RED
Conductive Jumper Strip	COND JUMPER
Copper Clip	CC
Counter Clockwise	CCW
Coupling	CPLG
Coupling Gland End	CGE
Cross	CROSS
Customer	CUST
Cut to Suit in Field	CTSIF
Cylinder	CYL
D	
Dallas District Office	DAL
Delivery	DEL
Department	DEPT
Description	DESC
Destination	DEST
Diameter	DIA

Standard Abbreviations and Acronyms

Table No. 17-7 - Continued

Product or Term Identification or Description	Standard Abbreviation
Difference	DIFF
Double	DBL
Double Cement Lined	DCL
Drill	DR
Duck Back Duck Tip	DT
Ductile Iron	DI
Ductile Iron Centrifugally Cast Pipe or Pipe Fabricated from Centrifugally Cast Pipe	PIPE
Ductile Iron Pipe	DIP
Ductile Iron Pipe Research Association	DIPRA
E	
Each	EA
Eccentric	ECC
Eccentric Reducer	ECC RED
Electric	ELECT
Extension	EXT
F	
Face & Drill	F&D
Face & Tap	F&T
Fast-Grip	FAST-GRIP
Fastite Conductive Gasket	FST PRCE GSK
Fastite Extra Deflection Socket	FST XDF
Fastite Joint Clamp	FST JT CLAMP
Fastite Lubricant	FST LUBE
Fastite Neoprene Gasket	FST NP GSK
Fastite Pipe	FST PIPE
Fastite Plain Rubber Gasket	FST GSK
Fastite Socket	FST
Feet	FT
Field Flex-Ring	FFR
Fitting	FTG
Flange(d)	FLG or F
Flange Back Outlet	FLG BACK OUTLET
Flange Filler	FLG FILLER
Flange Flange Flange Casting, Ductile (Statically Cast)	FFF WALL CASTING DI
Flange Flange Flange Tee	FLG TEE
Flange-Thrust Collar-Flange Wall Pipe, Ductile screwed-on Flanges, Welded-on Thrust Collar, Thrust Collar Centered	F-TC-F WALL PIPE
Flange Flange Pipe, Ductile Iron (Fabricated)	FF PIPE
Flange Flange Pipe, Ductile Iron (Statically Cast)	FF SPOOL DI
Flange Flange 90 Bend	FLG 90 BEND
Flange Hand Tight	FHT or FLG-HT
Flange Heel Outlet	FHO
Flange & Plain End Pipe, Ductile Iron (Fabricated)	FPE PIPE (Designate GA)
Flange Side Outlet	FSO
Flare	FLARE
Flexible	FLEX
Flexible Grooved End	VGE (F)
Flex-Lok Ball	FLXBALL
Flex-Lok Pipe	FLEXLOK PIPE (or FLXLK)

Standard Abbreviations and Acronyms

Table No. 17-7 - Continued

Product or Term Identification or Description	Standard Abbreviation
Flex-Lok Socket	FLXSKT
Flex-Ring	FR or XR
Flex-Ring End	FRE or XRE
Fluoroelastomer (Fluorel, Viton)*	FKM
For your information	FYI
Freight	FRT
Full Length	FL
12x10 Flange 90 Reducing Base Bend Base Opposite 12" Flange	12x10 FLG 90 BASE BEND 12 CF 250 LEUP
G	
Galvanized	GALV
Gasket	GSK
Gauge Caulk Joint	GACJ
Gauge Dresser (____OD)	GADR____OD
Gauge Fastite	GAFST
Gauge Full Length	GAFL
Gauge MJ	GAMJ
Gland	GLD
Gravity Microtunneling	GMT
Gravity Microtunneling End	GMTE
Gray Cast Iron	GI
Grooved End, Grooved End Pipe, Ductile Iron	VGE VGE PIPE (R or F)
H	
Hex Head Bolt Black Machine	HHHN BL MACH
Hex Head Hex Nut	HHHN
Hole	H (HOLE)
Hydrant	HYD
Hydrostatic Test	HYDRO/T
I	
Inside Diameter	ID
Invert	INV
Iron Body Bronze Mounted	IBBM
J	
Joint Material	JT MTL
K	
Kansas City District Office	KC
L	
Large End	LE
Laying Length	LL
Length	LGT
Less Than Truckload	LTL
Lever and Spring	L&S
Lever and Weight	L&W
Lining, Coating, Testing	LCT

*These are "brand" or "trade" names. Abbreviation is the acronym for the generic designation.

Standard Abbreviations and Acronyms

Table No. 17-7 - Continued

Product or Term Identification or Description	Standard Abbreviation
Lok-Ring Bell	LKR
Lok-Ring End	LKRE
Lok-Ring Pipe (Cut Pipe)	LKR LKRE PIPE
Lok-Ring Pipe (Full Length)	LKR PIPE
Long Pattern	LG PAT
Long Radius	LR
Lubricant	LUBE
Pound	LB
M	
Manufacture	MFG
Maximum	MAX
Mechanical Joint	MJ
Mechanical Joint Coupled Joint End	MJCJE
Mechanical Joint Tee	MJ TEE
Microtunneling	MT
Millimeter	MM
Minimum	MIN
Minneapolis District Office	MPLS
MJ & Plain End, Ductile (Cut Pipe)	MJPE PIPE
MJ & Plain End, Ductile (Full Length)	MJ PIPE
MJ Armor Tip	MJARMT
MJ Fabricated Bell	MJ-FAB
MJ MJ 90 Bend	MJ 90 BEND
Monoloy	MON
Scrap Metal Index	M/I
N	
Neoprene	NP
Nitrile-Butadiene (Hycar, Buna-N, Crynac, Chemigum)*	NBR
No Sealcoat	NSC
Nominal	NOM
Non Rising Stem	NRS
Not Coated	NOT CTD
O	
On Hand	OH
One Flange Hand Tight	1FHT
Operator	OPER
Original Order	ORIG ORDER
Orlando District Office	ORL
Outside Diameter	OD
Outside Screw and Yoke	OS & Y
Overall Length	OA

*These are "brand" or "trade" names. Abbreviation is the acronym for the generic designation.

Standard Abbreviations and Acronyms

Table No. 17-7 - Continued

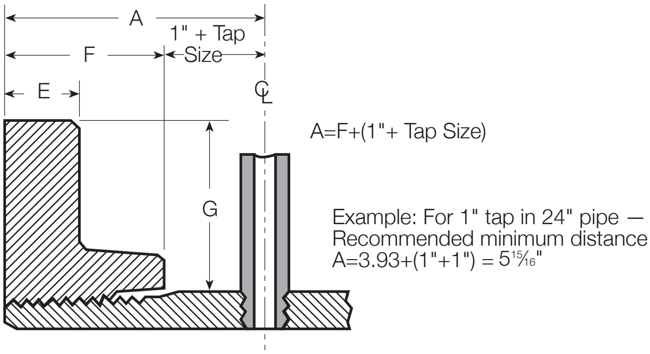
Product or Term Identification or Description	Standard Abbreviation
P	
Pittsburgh District Office	PITT
Plain End Gauge Dresser	DRPE
Plain End Gauge Fastite	FSTPE
Plain End Gauge Fastite & Dresser	FTDRPE
Plain End Gauge MJ	MJPE
Plain End No Gauge	PE
Plain End Gauge Push-On	POPE
Plain Rubber	PR
Position	POS
Pound	LB
Projected On Hand	POH
Purchase Order/Push-On Socket	PO
Push-On Joint	POJ
Q	
Quantity	QTY
R	
Required	REQD
Retainer	RET
Retainer Gland	RET GLD
Rigid Grooved End	VGE (R)
Concentric Reducer	RED
S	
Sacramento District Office	SAC
Scrap Metal Index	M/I
Service	SRVC
Shipping List	S/L
Sleeve	SLV
Small End	SE
Socket	SKT
Solid Sleeve	SLV
Special	SPL
Spigots	SPGT
Split Sleeve	SPLIT SLV
Split Tapping Sleeve	SPLIT TAP SLV
Statically Cast Flange Flange Pipe	SPOOL
Statically Cast Wall Pipe	WALL CASTING
Studs	STUDS
Style	ST
Victaulic Shoulder End	VSE
T	
Tap	TAP
Tap 1" Mueller	TAP 1 MUELLER
Tap 1" NPT	TAP 1
Tap___At Position___	TAP___POS___
Tap For Studs	TFS

Standard Abbreviations and Acronyms

Table No. 17-7 - Continued

Product or Term Identification or Description	Standard Abbreviation
Tapping Saddle Gasket	TAP SADDLE GSK
Tee	TEE
Tee-Head Hex Nut	THHN
Temporary End Fabrication	TEFAB
Test Certificates	TEST CERT
Thick	THK
Threaded	THRD
Thrust Collar	TC
Top Dead Center	TDC
Transition Sleeve	TRAN SLV
Truck	TRK
U	
Uncoated	NOT CTD
Underwater Lubricant	U/W LUBE
V	
Grooved End & Grooved End Pipe	VGE PIPE
Victaulic	VICT
Victaulic Grooved End (Flexible or Rigid)	VGE (F) or (R)
Victaulic Shoulder End Style___(41 or 44)	VSE ST___
W	
Statically Cast Wall Pipe	Wall Casting
Wall Collar	W/C
Wall Collar (Not in Center)	W/C___From___
Wye	WYE
X	
Y	
Z	

Taps in Ductile Iron Pipe*



Recommended Minimum Distance — for Small-Diameter Tap — From Face of Pipe Flange to Centerline of Tap

Table No. 17-8

Parent Pipe Size in.	Dimensions in Inches			Parent Pipe Size in.	Dimensions in Inches		
	E	F	G		E	F	G
4	.94	1.88	2.10	24	1.88	3.93	3.10
6	1.00	2.06	2.05	30	2.12	4.50	3.38
8	1.12	2.25	2.23	36	2.38	5.12	3.85
10	1.19	2.44	2.45	42	2.62	5.75	4.25
12	1.25	2.68	2.90	48	2.75	6.38	4.35
14	1.38	2.87	2.85	54	3.00	7.00	4.58
16	1.44	3.06	3.05	60	3.12	7.38	5.70
18	1.56	3.31	2.75	64	3.38	7.38	7.17
20	1.69	3.50	2.95				

* While this table provides specific rules governing the placement of individual taps relative to threaded companion flanges on flanged pipe, designers must also respect the positioning of taps relative to other pipe features (bells, wall collars, welded-on thrust collars, other taps, welded-on outlets, etc.). Contact AMERICAN for detailed information if necessary for specific applications.

Figures are based on AWWA C115 Flanges.

If closer tolerance needed, submit details of layout for recommendations.

Standard Pipe Taps—Outside Diameters

Table No. 17-9

Pipe Tap Size in.	Actual Outside Diameter in.	Pipe Tap Size in.	Actual Outside Diameter in.	Pipe Tap Size in.	Actual Outside Diameter in.
1/4	.540	1	1.315	2 1/2	2.875
3/8	.675	1 1/4	1.660	3	3.500
1/2	.840	1 1/2	1.900	-	-
3/4	1.050	2	2.375	-	-

Above data is based on direct tap into wall of pipe; see Table Nos. 17-10 and 17-11.

Taps in Ductile Iron Pipe
ANSI/ASME B1.20.1

Thickness that will affect two, three and four full threads for different size taps with ANSI/ASME B1.20.1 Standard Taper Pipe Threads.

Table No. 17-10

Pipe Size in.	No. of Threads	Tap Size - in.									
		1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4
		Pipe Thickness - in.									
3	2	.18	.21	.28							
3	3	.26	.29	.37							
3	4	.33	.36	.46							
4	2	.17	.19	.26	.31						
4	3	.25	.27	.35	.40						
4	4	.32	.34	.44	.49						
6	2	.17	.18	.23	.27	.30					
6	3	.25	.26	.32	.36	.39					
6	4	.32	.33	.41	.45	.48					
8	2	.16	.17	.22	.24	.27	.33				
8	3	.24	.25	.31	.33	.36	.42				
8	4	.31	.32	.40	.42	.45	.51				
10	2	.15	.17	.21	.23	.25	.30	.44			
10	3	.23	.25	.30	.32	.34	.39	.56			
10	4	.30	.32	.39	.41	.43	.48	.69			
12	2	.15	.16	.20	.22	.24	.28	.40	.48		
12	3	.23	.24	.29	.31	.33	.37	.52	.60		
12	4	.30	.31	.38	.40	.42	.46	.65	.73		
14	2	.15	.16	.20	.22	.23	.26	.38	.45	.51	.58
14	3	.23	.24	.29	.31	.32	.35	.50	.58	.64	.70
14	4	.30	.31	.38	.40	.41	.44	.63	.70	.76	.83
16	2	.15	.16	.20	.21	.22	.25	.37	.43	.48	.54
16	3	.23	.24	.29	.30	.31	.34	.50	.56	.60	.66
16	4	.30	.31	.38	.39	.40	.43	.62	.68	.73	.79
18	2	.15	.15	.19	.21	.22	.24	.35	.41	.46	.51
18	3	.23	.23	.28	.30	.31	.33	.48	.54	.58	.64
18	4	.30	.30	.37	.39	.40	.42	.60	.66	.71	.76
20	2	.15	.15	.19	.20	.21	.23	.34	.39	.44	.49
20	3	.23	.23	.28	.29	.30	.32	.46	.52	.56	.62
20	4	.30	.30	.37	.38	.39	.41	.59	.64	.69	.74
24	2	.14	.15	.19	.20	.21	.22	.32	.37	.40	.45
24	3	.22	.23	.28	.29	.30	.31	.44	.50	.52	.58
24	4	.29	.30	.37	.38	.39	.40	.57	.62	.65	.70
30	2	.14	.15	.19	.19	.20	.21	.31	.34	.37	.41
30	3	.22	.23	.28	.28	.29	.30	.44	.46	.50	.54
30	4	.29	.30	.37	.37	.38	.39	.56	.59	.62	.66
36	2	.14	.14	.18	.19	.20	.21	.30	.33	.35	.38
36	3	.22	.22	.27	.28	.29	.30	.42	.46	.48	.50
36	4	.29	.29	.36	.37	.38	.39	.55	.58	.60	.63
42	2	.14	.14	.18	.19	.19	.20	.29	.32	.34	.36
42	3	.22	.22	.27	.28	.28	.29	.42	.44	.46	.48
42	4	.29	.29	.36	.37	.37	.38	.54	.57	.59	.61
48	2	.14	.14	.18	.18	.19	.20	.29	.31	.32	.35
48	3	.22	.22	.27	.27	.28	.29	.42	.44	.44	.48
48	4	.29	.29	.36	.36	.37	.38	.54	.56	.57	.60
54	2	.15	.15	.18	.19	.19	.20	.28	.30	.32	.34
54	3	.22	.22	.27	.27	.28	.28	.41	.43	.44	.46
54	4	.29	.29	.35	.36	.36	.37	.53	.55	.57	.59
60	2	.14	.14	.18	.19	.19	.20	.28	.30	.31	.33
60	3	.22	.22	.27	.27	.28	.28	.41	.42	.44	.46
60	4	.29	.29	.35	.36	.36	.37	.53	.55	.56	.58
64	2	.14	.14	.18	.18	.19	.20	.28	.30	.31	.33
64	3	.22	.22	.27	.27	.27	.28	.41	.42	.44	.45
64	4	.29	.29	.35	.36	.36	.37	.53	.55	.56	.50

Based on data in Appendix of AWWA C151.

Taps in Ductile Iron Pipe
AWWA C800 Standard

Thickness that will affect two, three and four full threads for different size taps with AWWA C800 Standard Corporation Stop Threads.*

Table No. 17-11

Pipe Size in.	No. of Threads	Tap Size - in.						
		1/2	5/8	3/4	1	1 1/4	1 1/2	2
		Pipe Thickness - in.						
3	2	.21	.24	.25	.33			
3	3	.29	.32	.33	.41			
3	4	.36	.39	.40	.49			
4	2	.19	.22	.23	.30	.36		
4	3	.27	.30	.31	.38	.45		
4	4	.34	.37	.38	.46	.54		
6	2	.18	.20	.20	.26	.30	.35	
6	3	.26	.28	.28	.34	.39	.44	
6	4	.33	.35	.35	.42	.48	.53	
8	2	.17	.18	.19	.24	.27	.31	.39
8	3	.25	.26	.27	.32	.36	.40	.48
8	4	.32	.33	.34	.40	.45	.49	.57
10	2	.17	.17	.18	.23	.25	.28	.35
10	3	.25	.25	.26	.31	.34	.37	.44
10	4	.32	.32	.33	.39	.43	.46	.53
12	2	.16	.17	.17	.22	.24	.26	.32
12	3	.24	.25	.25	.30	.33	.35	.41
12	4	.31	.32	.32	.38	.42	.44	.50
14	2	.16	.17	.17	.21	.23	.25	.30
14	3	.24	.25	.25	.29	.32	.34	.39
14	4	.31	.32	.32	.37	.41	.43	.48
16	2	.16	.16	.17	.21	.22	.24	.28
16	3	.24	.24	.25	.29	.31	.33	.37
16	4	.31	.31	.32	.37	.40	.42	.46
18	2	.15	.16	.16	.20	.21	.23	.27
18	3	.23	.24	.24	.28	.30	.32	.36
18	4	.30	.31	.31	.36	.39	.41	.45
20	2	.15	.16	.16	.20	.21	.23	.26
20	3	.23	.24	.24	.28	.30	.32	.35
20	4	.30	.31	.31	.36	.39	.41	.44
24	2	.15	.15	.16	.19	.21	.22	.24
24	3	.23	.23	.24	.27	.30	.31	.33
24	4	.30	.30	.31	.35	.39	.40	.42
30	2	.15	.15	.16	.19	.20	.21	.23
30	3	.23	.23	.24	.27	.29	.30	.32
30	4	.30	.30	.31	.35	.38	.39	.41
36	2	.14	.15	.15	.19	.20	.20	.22
36	3	.22	.23	.23	.27	.29	.29	.31
36	4	.29	.30	.30	.35	.38	.38	.40
42	2	.14	.14	.15	.18	.19	.20	.21
42	3	.22	.22	.23	.26	.28	.29	.30
42	4	.29	.29	.30	.34	.37	.38	.39
48	2	.14	.14	.15	.18	.18	.19	.20
48	3	.22	.22	.23	.26	.27	.28	.29
48	4	.29	.29	.30	.34	.36	.37	.38
54	2	.14	.14	.14	.17	.18	.19	.20
54	3	.22	.22	.22	.25	.27	.28	.29
54	4	.29	.29	.29	.34	.36	.36	.38
60	2	.14	.14	.14	.17	.18	.19	.20
60	3	.22	.22	.22	.25	.27	.28	.29
60	4	.29	.29	.29	.34	.36	.36	.38
64	2	.14	.14	.15	.17	.18	.19	.20
64	3	.22	.22	.22	.25	.27	.28	.29
64	4	.29	.29	.29	.34	.36	.36	.38

*This thread is commonly known to the trade as the Mueller thread. Based on data in Appendix of AWWA C151.

Linear Expansion of Ductile Iron Pipe

The coefficient of linear expansion of ductile iron may be taken as 0.0000062 (.62 x 10^{-5}) per degree Fahrenheit. The expansion or contraction in inches that will take place in a line of given length with various temperature changes is shown in the following table:

Table No. 17-12

Temp Difference °F	Length of Line in Feet				
	20'	100'	500'	1000'	5280'
	Expansion or Contraction in Inches				
5	0.007	0.04	0.19	0.37	1.96
10	0.015	0.07	0.37	0.74	3.93
20	0.030	0.15	0.74	1.49	7.86
30	0.045	0.22	1.12	2.23	11.78
40	0.060	0.30	1.49	2.98	15.71
50	0.074	0.37	1.86	3.72	19.64
60	0.089	0.45	2.23	4.46	23.57
70	0.104	0.52	2.60	5.21	27.50
80	0.119	0.60	2.98	5.95	31.43
90	0.134	0.67	3.35	6.70	35.35
100	0.149	0.74	3.72	7.44	39.28
120	0.179	0.89	4.46	8.93	47.14
150	0.223	1.12	5.58	11.16	58.92

Note: For related information, the approximate coefficient of linear expansion of other pipe and construction materials are as follows:

Concrete - .7 x 10^{-5} in./in./°F
HDPE - 10 to 12 x 10^{-5} in./in./°F
PVC - 3.1 x 10^{-5} in./in./°F
Steel - .65 x 10^{-5} in./in./°F

This bridge crossing illustrates design/construction advantages, including the deflection capabilities of AMERICAN Flex-Ring Joint Pipe.

Pipe Length Calculations for Offset Connections

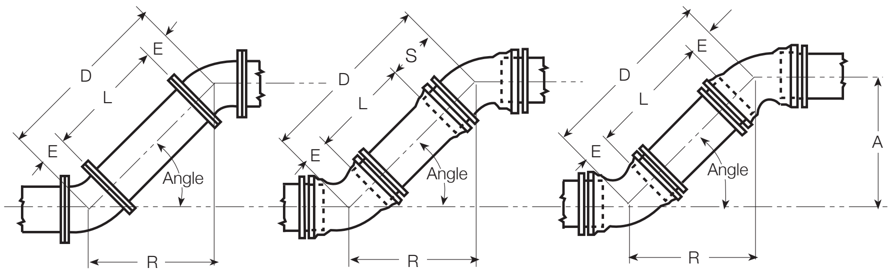


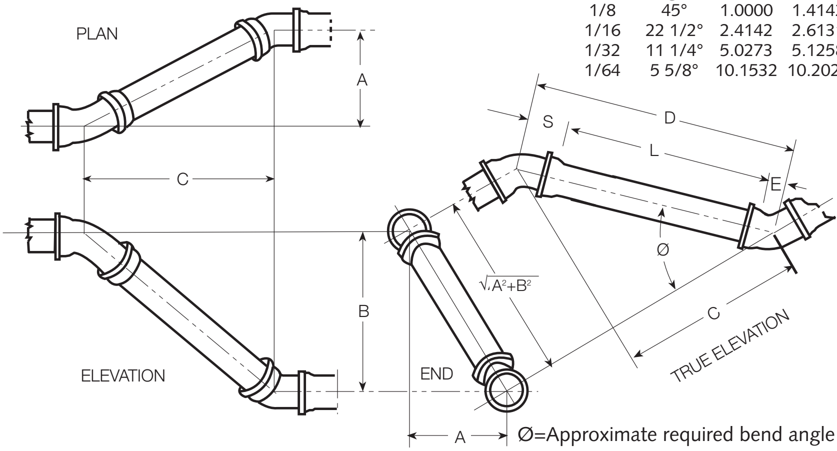
Table No. 17-13

Angle	D Equals	R Equals	L Equals	
			Flg Pipe	FST Pipe
45°	A x 1.41	A x 1.00	D - (2 x E)	D - (2 x E) or D - (E + S)
22 1/2°	A x 2.61	A x 2.41	D - (2 x E)	D - (2 x E) or D - (E + S)
11 1/4°	A x 5.13	A x 5.03	D - (2 x E)	D - (2 x E) or D - (E + S)
5 5/8°	A x 10.20	A x 10.15	D - (2 x E)	D - (2 x E) or D - (E + S)

Allowance in flange joint (usually 1/8" for gasket) and in Fastite joint (usually 1/4") should be taken into account in determination of required pipe length. Likewise, extension of restrained joints subjected to thrust load in installation and/or service should be considered as well.

Pipe Length Calculations for Inclined Diagonal Runs

Bend	Degree	Cot.	CSC.
1/8	45°	1.0000	1.4142
1/16	22 1/2°	2.4142	2.6131
1/32	11 1/4°	5.0273	5.1258
1/64	5 5/8°	10.1532	10.2023



Sketch explanatory of formulas for lengths of pipe for diagonal runs and angle of fittings

The following examples illustrate means of determining lengths of pipe and tie rods on inclined diagonal runs, and finding the approximate angle, Ø, required when the dimensions in three planes are known.

A. — When measurements in two planes are known and angle of fitting Ø decided upon, then

$C = \sqrt{A^2 + B^2} \times \text{Cot } Ø$ Formula (I)

$D = \sqrt{A^2 + B^2} \times \text{Csc } Ø$ Formula (II)

Example: If A = 8'-0", B = 9'-6", Ø = 45°
Find C and length of pipe required on 12" line.

$D = \sqrt{(8)^2 + (9.5)^2} \times \text{Csc } 45°$

$= \sqrt{64 + 90.25} \times 1.4142$

$= 17.56' = 17'\text{-}6\tfrac{3}{4}"$

$C = \sqrt{(8)^2 + (9.5)^2} \times \text{Cot } 45°$

$= \sqrt{64 + 90.25} \times 1$

$= 12.42 \times 1 = 12.42' = 12'\text{-}5"$

$L = D - (E + S)$

$= 17'\text{-}6\tfrac{3}{4}" - (5\tfrac{1}{2}" + 13\tfrac{1}{2}")$

$= 15'\text{-}11\tfrac{3}{4}"$

B. — When measurements in three planes are known, then

$D = \sqrt{A^2 + B^2 + C^2}$ Formula (III)

$\text{Tan } Ø = \dfrac{\sqrt{A^2 + B^2}}{C}$ Formula (IV)

Example: If A = 5'-6", B = 3'-0", C = 14'-9"

Find Ø and length of pipe required on 8" line.

$D = \sqrt{(5.5)^2 + (3)^2 + (14.75)^2}$

$= \sqrt{30.25 + 9 + 217.56} = 16.025'$

$= 16'\text{-}0\tfrac{5}{16}"$

$\text{Tan } Ø = \dfrac{\sqrt{(5.5)^2 + (3)^2}}{14.75} = \dfrac{\sqrt{30.25 + 9}}{14.75}$

$= \dfrac{\sqrt{39.25}}{14.75} = \dfrac{6.265}{14.75} = 0.42474$

Ø = 23°+ and a one-sixteenth bend may be used.

$L = D - (E + S)$

$= 16'\text{-}0\tfrac{5}{16}" - (5\tfrac{1}{2}" + 13\tfrac{1}{2}")$

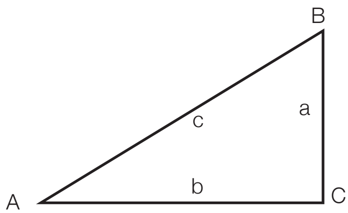
$= 14'\text{-}5\tfrac{5}{16}"$

For center-to-socket dimensions of Fastite fittings see Section 7. For center-to-face dimensions of flange fittings see Section 9.

Allowance in flange joint (usually 1/8" for gasket) and in mechanical joint (usually 1/4") should be taken into account in determination of required pipe length. Likewise, extension of restrained joints subjected to axial thrust load in installation and/or service should be considered as well.

Mathematical Formulas

Solution of Right Triangle



$a^2 + b^2 = c^2$

$\text{Sin A} = \frac{a}{c}$

$\text{Cos A} = \frac{b}{c}$

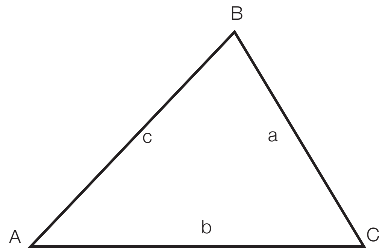
$\text{Tan A} = \frac{a}{b}$

$\text{Cot A} = \frac{b}{a}$

$\text{Sec A} = \frac{c}{b}$

$\text{Csc A} = \frac{c}{a}$

Solution of Oblique Triangle



$A + B + C = 180°$

Law of Sines

$\frac{a}{\text{Sin A}} = \frac{b}{\text{Sin B}} = \frac{c}{\text{Sin C}}$

Law of Cosines:

$c^2 = a^2 + b^2 - 2ab \text{ Cos C}$

Law of Tangents

$\frac{a + b}{a - b} = \frac{\text{Tan } 1/2 (A+B)}{\text{Tan } 1/2 (A-B)}$

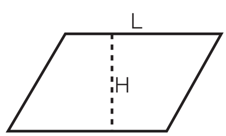
Plane Figures

A = Area

C = Circumference

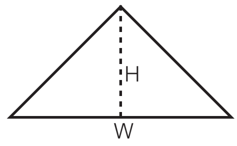
$\pi = 3.1415926536$

Parallelogram



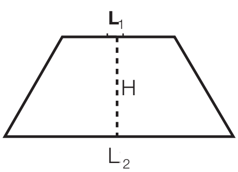
$A = H \times L$

Triangle



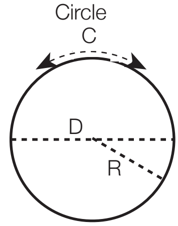
$A = 1/2\ WH$

Trapezoid



$A = 1/2\ H(L_1 + L_2)$

Circle

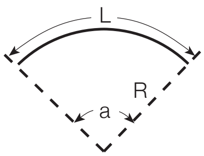


$C = \pi D$

$A = 1/4\ \pi D^2$

Mathematical Formulas - Continued

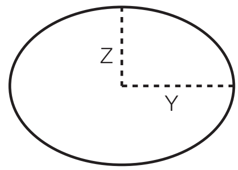
Segment of a Circle



$A = \pi R^2 \text{ x } a \div 360$

$L = 2\pi R \text{ x } a \div 360$

Ellipse



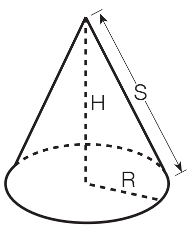
$A = \pi ZY$

$C = 2\pi\sqrt{1/2(Z^2 + Y^2)}$ (approximate formula)

Solid Figures

A = Surface Area V = Volume

Cone

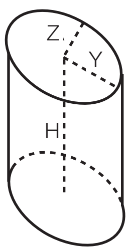


$A = \pi R\,(S + R)$

$A_l = \pi RS$ (Lateral Area)

$V = \frac{\pi}{3} R^2 H$

Elliptical Tank

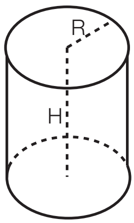


$A = 2\pi ZY + 2\pi H\sqrt{1/2(Z^2 + Y^2)}$

$V = \pi ZYH$

$A_l = 2\pi H\sqrt{1/2(Z^2 + Y^2)}$ (Lateral Area)

Cylinder

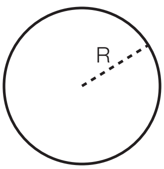


$A = 2\pi R\,(H + R)$

$A_1 = 2\pi RH$ (Lateral Area)

$V = \pi R^2 H$

Sphere

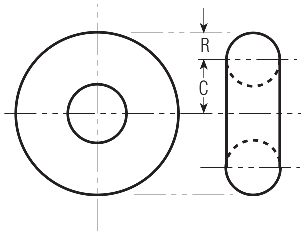


$A = 4\pi R^2$

$V = \frac{4}{3}\pi R^3$

Mathematical Formulas—Continued

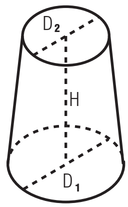
Torus



$A = 4\pi^2 CR$

$V = 2\pi^2 CR^2$

Frustum of Cone



$V = \frac{1}{12}\pi H\,[(D_1^2+D_2^2)+(D_1 X D_2)]$

AMERICAN's STANDARD COLOR CODES

AMERICAN routinely paints different colored marks on certain products to help differentiate them and facilitate identification.

Painted daub(s) on face of bell

Pink	Coal Tar Epoxy lining
Red	Full-length pipe cut shorter than nominal as allowed by AWWA Standards

Painted face of bell

White	Special deflection Fastite bells

Painted band immediately behind bell

Blue	Pipe with taps, welded-on bosses or outlets. (Blue circle also painted around the tap, boss, or outlet.)
Green	Pipe gauged full length for field cutting

Notes:

- Products to be furnished with special coatings, primers, etc., on the O.D. will not have color codings.
- Color codings are subject to change without notice. Contact AMERICAN for current codings.
- If special color codes are required to meet specific project requirements, the above colors should be avoided if at all possible.
- Other markings in addition to color codes may be painted or stencilled on products.

Decimal of an Inch and of a Foot

Table No. 17-14

Fractions of Inch or Foot		Inch Equivalents to Foot Fractions	Fractions of Inch or Foot		Inch Equivalents to Foot Fractions	Fractions of Inch or Foot		Inch Equivalents to Foot Fractions	Fractions of Inch or Foot		Inch Equivalents to Foot Fractions
	.0052	1/16		.2552	3 1/16		.5052	6 1/16		.7552	9 1/16
	.0104	1/8		.2604	3 1/8		.5104	6 1/8		.7604	9 1/8
1/64	.015625	3/16	17/64	.265625	3 3/16	33/64	.515625	6 3/16	49/64	.765625	9 3/16
	.0208	1/4		.2708	3 1/4		.5208	6 1/4		.7708	9 1/4
	.0260	5/16		.2760	3 5/16		.5260	6 5/16		.7760	9 5/16
1/32	.03125	3/8	9/32	.28125	3 3/8	17/32	.53125	6 3/8	25/32	.78125	9 3/8
	.0365	7/16		.2865	3 7/16		.5365	6 7/16		.7865	9 7/16
	.0417	1/2		.2917	3 1/2		.5417	6 1/2		.7917	9 1/2
3/64	.046875	9/16	19/64	.296875	3 9/16	35/64	.546875	6 9/16	51/64	.796875	9 9/16
	.0521	5/8		.3021	3 5/8		.5521	6 5/8		.8021	9 5/8
	.0573	11/16		.3073	3 11/16		.5573	6 11/16		.8073	9 11/16
1/16	.0625	3/4	5/16	.3125	3 3/4	9/16	.5625	6 3/4	13/16	.8125	9 3/4
	.0677	13/16		.3177	3 13/16		.5677	6 13/16		.8177	9 13/16
	.0729	7/8		.3229	3 7/8		.5729	6 7/8		.8229	9 7/8
5/64	.078125	15/16	21/64	.328125	3 15/16	37/64	.578125	6 15/16	53/64	.828125	9 15/16
	.0833	1		.3333	4		.5833	7		.8333	10
	.0885	1 1/16		.3385	4 1/16		.5885	7 1/16		.8385	10 1/16
3/32	.09375	1 1/8	11/32	.34375	4 1/8	19/32	.59375	7 1/8	27/32	.84375	10 1/8
	.0990	1 3/16		.3490	4 3/16		.5990	7 3/16		.8490	10 3/16
	.1042	1 1/4		.3542	4 1/4		.6042	7 1/4		.8542	10 1/4
7/64	.109375	1 5/16	23/64	.359375	4 5/16	39/64	.609375	7 5/16	55/64	.859375	10 5/16
	.1146	1 3/8		.3646	4 3/8		.6146	7 3/8		.8646	10 3/8
	.1198	1 7/16		.3698	4 7/16		.6198	7 7/16		.8698	10 7/16
1/8	.1250	1 1/2	3/8	.3750	4 1/2	5/8	.6250	7 1/2	7/8	.8750	10 1/2
	.1302	1 9/16		.3802	4 9/16		.6302	7 9/16		.8802	10 9/16
	.1354	1 5/8		.3854	4 5/8		.6354	7 5/8		.8854	10 5/8
9/64	.140625	1 11/16	25/64	.390625	4 11/16	41/64	.640625	7 11/16	57/64	.890625	10 11/16
	.1458	1 3/4		.3958	4 3/4		.6458	7 3/4		.8958	10 3/4
	.1510	1 13/16		.4010	4 13/16		.6510	7 13/16		.9010	10 13/16
5/32	.15625	1 7/8	13/32	.40625	4 7/8	21/32	.65625	7 7/8	29/32	.90625	10 7/8
	.1615	1 15/16		.4115	4 15/16		.6615	7 15/16		.9115	10 15/16
	.1667	2		.4167	5		.6667	8		.9167	11
11/64	.171875	2 1/16	27/64	.421875	5 1/16	43/64	.671875	8 1/16	59/64	.921875	11 1/16
	.1771	2 1/8		.4271	5 1/8		.6771	8 1/8		.9271	11 1/8
	.1823	2 3/16		.4323	5 3/16		.6823	8 3/16		.9323	11 3/16
3/16	.1875	2 1/4	7/16	.4375	5 1/4	11/16	.6875	8 1/4	15/16	.9375	11 1/4
	.1927	2 5/16		.4427	5 5/16		.6927	8 5/16		.9427	11 5/16
	.1979	2 3/8		.4479	5 3/8		.6979	8 3/8		.9479	11 3/8
13/64	.203125	2 7/16	29/64	.453125	5 7/16	45/64	.703125	8 7/16	61/64	.953125	11 7/16
	.2083	2 1/2		.4583	5 1/2		.7083	8 1/2		.9583	11 1/2
	.2135	2 9/16		.4635	5 9/16		.7135	8 9/16		.9635	11 9/16
7/32	.21875	2 5/8	15/32	.46875	5 5/8	23/32	.71875	8 5/8	31/32	.96875	11 5/8
	.2240	2 11/16		.4740	5 11/16		.7240	8 11/16		.9740	11 11/16
	.2292	2 3/4		.4792	5 3/4		.7292	8 3/4		.9792	11 3/4
15/64	.234375	2 13/16	31/64	.484375	5 13/16	47/64	.734375	8 13/16	63/64	.984375	11 13/16
	.2396	2 7/8		.4896	5 7/8		.7396	8 7/8		.9896	11 7/8
	.2448	2 15/16		.4948	5 15/16		.7448	8 15/16		.9948	11 15/16
1/4	.2500	3	1/2	.5000	6	3/4	.7500	9	1	1.0000	12

Equivalents and Conversion Factors English

The word gallon, used in any conversion factor, designates the U.S. gallon. Likewise, the word ton designates a short ton, 2,000 pounds.

The figures 10^{-1}, 10^{-2}, 10^{-3}, etc., denote 0.1, 0.01, 0.001, etc., respectively.

The figures 10^{1}, 10^{2}, 10^{3}, etc., denote 10, 100, 1000, etc., respectively.

"Parts Per Million," (designated as p.p.m.), is always by weight. As used in the sanitary field, p.p.m. represents the number of pounds of dry solids contained in one million pounds of water. In this field, one part per million may be expressed as 8.345 pounds of dry solids to one million U.S. gallons of water.

Conversion factors are based on water at a temperature of 4°C unless otherwise noted.

Table No. 17-15

Multiply	By	To Obtain
Acres	43,560	Square feet
Acre-feet	43,560	Cubic feet
Acre-feet	325,851	Gallons
Atmospheres	29.92	Inches of mercury
Atmospheres	33.90	Feet of water
Atmospheres	14.70	Lbs/sq. inch
Barrels cement	376	Pounds-cement
Bags or sacks-cement	94	Pounds-cement
B.T.U.	778.17	Foot-lbs
B.T.U.	3.9301×10^{-4}	Horsepower-hrs.
B.T.U.	2.9306×10^{-4}	Kilowatt-hrs.
B.T.U./min.	12.970	Foot-lbs/sec.
B.T.U./min.	0.023581	Horsepower
B.T.U./min.	0.017584	Kilowatts
Cubic feet	7.48052	Gallons
Cubic feet	1728	Cubic inches
Cubic feet	0.03704	Cubic yards
Cubic feet/second	0.646317	Million gals./day
Cubic feet/second	448.831	Gallons/min.
Cubic inches	5.787×10^{-4}	Cubic feet
Cubic inches	4.329×10^{-3}	Gallons
Cubic yards	27	Cubic feet
Cubic yards	46,656	Cubic inches
Cubic yards	202.0	Gallons
Drams	27.34375	Grains
Drams	0.0625	Ounces
Fathoms	6	Feet
Feet of water	0.8826	Inches of mercury
Feet of water (at 62°F)	0.4330	Lbs/sq. inch
Feet of water	62.427	Lbs/sq. feet
Feet of water	0.02950	Atmospheres
Foot-pounds	1.285×10^{-3}	B.T.U.
Foot-pounds	5.0505×10^{-7}	Horsepower-hrs.
Foot-pounds	3.766×10^{-7}	Kilowatt-hrs.
Foot-pounds/min.	3.0303×10^{-5}	Horsepower
Foot-pounds/min.	2.260×10^{-5}	Kilowatts
Gallons	0.13368	Cubic feet
Gallons	231	Cubic inches
Gallons, Imperial	1.20095	U.S. gallons
Gallons, U.S.	0.83267	Imperial gallons
Gallons water (at 4°C)	8.3453	Pounds of water
Gallons water (at 62°F)	8.3355	Pounds of water
Gallons/min.	2.228×10^{-3}	Cubic feet/sec.
Gallons/min.	8.0208	Cu.ft./hr.
Grains (troy)	1	Grains (avoir.)

Equivalents and Conversion Factors
English

Table No. 17-15 - Continued

Multiply	By		To Obtain
Grains	0.06480		Grams
Grains/U.S. gal.	17.119		Parts/million
Grains/U.S. gal.	142.86		Lbs/million gal.
Grains/Imp. gal.	14.254		Parts/million
Hectares	2.471		Acres
Horsepower	42.407		B.T.U./min.
Horsepower	550		Foot-lbs/sec.
Horsepower	0.7457		Kilowatts
Horsepower (boiler)	33,520		B.T.U./hr.
Horsepower (boiler)	9.824		Kilowatts
Inches	1.0	x 10^{-3}	Mils
Inches of mercury	1.133		Feet of water
Inches of mercury	0.4912		Lbs/sq. inch
Inches of mercury	0.03342		Atmospheres
Inches of water	0.07355		Inches of mercury
Inches of water	0.03613		Lbs/sq. inch
Kilowatts	56.87		B.T.U./min.
Kilowatts	737.5		Foot-lbs/sec.
Kilowatts	1.341		Horsepower
Miles	5280		Feet
Miles/min.	88		Feet/sec.
Million gals./day	1.54723		Cubic ft./sec.
Miner's inches	1.5		Cubic ft./min.
Ounces	437.5		Grains
Ounces	0.9115		Ounces (troy)
Ounces (fluid)	1.805		Cubic inches
Parts/million	8.345		Lbs/million gal.
Parts/million	0.058415		Grains/U.S. gal.
Parts/million	0.07016		Grains/Imp. gal.
Pounds	16		Ounces
Pounds	7000		Grains
Pounds	1.21528		Pounds (troy)
Pounds of water	0.01602		Cubic feet
Pounds of water	27.68		Cubic inches
Pounds of water	0.1198		Gallons
Pounds/cubic foot	5.787	x 10-4	Lbs/cubic inch
Pounds/sq. foot	0.01602		Feet of water
Pounds/sq. inch	2.307		Feet of water
Pounds/sq. inch	2.0358		Inches of mercury
Pounds/sq. inch	0.06803		Atmospheres
Quires	25		Sheets
Reams	500		Sheets
Square feet	144		Square inches
Square feet	2.296	x 10-5	Acres
Square miles	640		Acres
Square miles	2.788	x 107	Square feet
Square yards	9		Square feet
Square yards	2.066	x 10-4	Acres
Tons (long)	2240		Pounds
Tons (long)	1.12		Tons (short)
Tons (short)	2000		Pounds
Tons of water/24 hrs.	0.16639		Gallons/min.
Watts	0.05686		B.T.U./min.
Watts	0.7375		Foot-pounds/sec.
Watts	1.341	x 10-3	Horsepower

Conversion Factors are based on water at a temperature of 4°C unless otherwise noted.

Equivalents and Conversion Factors
Metric

Table No. 17-16

Multiply	By	To Obtain
Acres	4047	Square meters
Acre-feet	1233.5	Cubic meters
Atmosphere	1.01325	Bars
Atmospheres	76.0	Centimeters of mercury
Bars	0.98692	Atmosphere
Bars	1.02×10^4	Kgs./sq.meter
Bars	14.50777	Pounds/sq. in.
Bars	10.20	Meters of water
B.T.U.	0.2520	Kilogram calories
B.T.U.	107.6	Kilogram meters
Centimeters	0.3937	Inches
Centimeters of mercury	0.01316	Atmospheres
Centimeters of mercury	0.4461	Feet of water
Centimeters of mercury	27.85	Pounds/sq. ft.
Centimeters of mercury	0.1934	Pounds/sq. in.
Centimeters/second	1.969	Feet/minute
Centimeters/second	0.03281	Feet/sec.
Centimeters/second	0.6	Meters/min.
Cubic centimeters	3.531×10^{-5}	Cubic feet
Cubic centimeters	6.102×10^{-2}	Cubic inches
Cubic centimeters	2.642×10^{-4}	Gallons
Cubic centimeters	10^{-6}	Cubic meters
Cubic centimeters	10^{-3}	Liters
Cubic feet	28.32	Liters
Cubic feet	2.832×10^4	Cubic centimeters
Cubic feet	0.02832	Cubic meters
Cubic inches	16.39	Cubic centimeters
Cubic inches	1.639×10^{-5}	Cubic meters
Cubic inches	1.639×10^{-2}	Liters
Cubic meters	35.31	Cubic feet
Cubic meters	1.308	Cubic yards
Cubic meters	264.2	Gallons
Cubic meters	10^3	Liters
Cubic yards	0.7646	Cubic meters
Cubic yards	764.6	Liters
Dram	1.771845	Grams
Feet	30.48	Centimeters
Feet	0.3048	Meters
Feet of water	304.8	Kgs./sq. meter
Feet/sec./sec.	0.3048	Meters/sec./sec.
Feet/sec.	30.48	Centimeters/sec.
Feet/sec.	18.29	Meters/minute
Foot-pounds	0.1383	Kilogram-meters
Gallons	3785	Cubic centimeters
Gallons	3.785×10^{-3}	Cubic meters
Gallons	3.785	Liters
Gallons/minute	0.06308	Liters/second
Gallons/minute	6.308×10^{-5}	Cubic meters/sec.
Grams	15.432	Grains
Grams	0.03527	Ounces
Grams	980.7	Dynes
Grams/sq. centimeter	0.9808×10^{-3}	Bars
Grams/liter	58.410	Grains/gal.
Grams/liter	8.344	Pounds/1000 gallons
Grams/liter	1000	Parts/million
Grams/cubic centimeter	1.000×10^3	Kilograms/cubic meter
Inches	2.540	Centimeters
Inches	25.4	Millimeters (mm)
Inches of mercury	345.3	Kgs./sq. meter

Equivalents and Conversion Factors Metric

Table No. 17-16—Continued

Multiply	By	To Obtain
Inches/second	2.540×10^{-2}	Meters/second
Inches/sec./sec.	2.540×10^{-2}	Meters/sec./sec.
Kilograms	2.2046	Pounds
Kilogram-calories/minute	51.47	Foot-pounds/sec.
Kilogram-calories/minute	0.06979	Kilowatts
Kilogram-calories/minute	0.09359	Horsepower
Kilograms/sq. meter	1.422×10^{-3}	Pounds/sq. inch
Kilometers	3281	Feet
Kilometers	0.6214	Miles
Kilometers/hour	0.9113	Feet/sec.
Kilometers/hour	27.78	Centimeters/sec.
Kilowatts	14.33	Kg.-calories/min.
Liters	0.2642	Gallons
Liters	61.02	Cubic inches
Liters	0.03531	Cubic feet
Meters	3.281	Feet
Meters	39.37	Inches
Meters	1.094	Yards
Meters of water	0.09803	Bars
Meters of water	1.422	Pounds/sq. inch
Miles	1.609	Kilometers
Miles/minute	1.609	Kilometers/minute
Milligrams/liter	1	Parts/million
Millimeters	0.03937	Inches
Newton/Cubic meter	6.365×10^{-3}	Pounds/cubic foot
Newtons/sq. millimeter	145.045	Pounds/sq.inch
Ounces	28.3495	Grams
Ounces (fluid)	29.58	Cubic centimeters
Pounds	453.5924	Grams
Pounds	4.448	Newtons
Pounds/cubic foot	0.01602	Grams/cubic centimeter
Pounds/cubic foot	16.02	Kilograms/cubic meter
Pounds/foot	1.488	Kilograms/meter
Pounds/inch	178.6	Grams/centimeter
Pounds/sq. inch	0.06893	Bars
Pounds/sq. foot	4.883	Kilograms/sq.meter
Pounds/sq. inch	2.30947	Feet of Water (at 62°F)
Pounds/sq. inch	703.1	Kilograms/sq.meter
Pounds/sq. inch	6.895	Kilopascals (kPa)
Pounds/sq. inch	6.895×10^{-3}	Megapascals (MPa)
Square centimeters	0.1550	Square inches
Square centimeters	1.076×10^{-3}	Square feet
Square feet	0.09290	Square meters
Square feet/second	9.290×10^{-2}	Square meters/sec.
Square inches	6.452	Square centimeters
Square kilometers	247.1	Acres
Square kilometers	1.076×10^{7}	Square feet
Square kilometers	1.196×10^{6}	Square yards
Square meters	10.76	Square feet
Square meters	1.196	Square yards
Square miles	2.590	Square kilometers
Square yards	0.8361	Square meters
Tons (long)	1016	Kilograms
Tons (metric)	10^{3}	Kilograms
Tons (metric)	2205	Pounds
Tons (short)	907.185	Kilograms
Watts	0.01433	Kilogram-calories/minute
Yards	0.9144	Meters

Conversion factors are based on water at a temperature of 4°C unless otherwise noted.

Engineering Data
Notes