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Ductile Iron Pipe Research Association

Technical Resources / *Calculators* /
Thrust Restraint Calculator

PROJECT DATA

TYPE OF FITTING
Tee

DIAMETER OF RUN (IN)
8

DIAMETER OF BRANCH (IN)
6

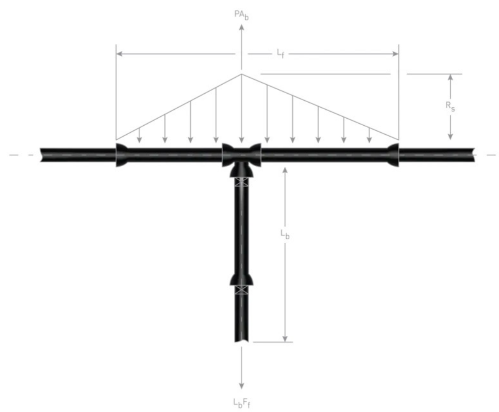
RUN LENGTH (FIRST JOINTS) (FT)
36

LAYING CONDITION
Type 5

SOIL DESIGNATION
Good Sand & Grave

DEPTH OF COVER (FT)
3.5

DESIGN PRESSURE (PSI)
90



TEE

UNIT FRICTIONAL FORCE (LBS/FT)	238
UNIT BEARING RESISTANCE (LBS/FT)	973

REQUIRED RESTRAINED LENGTH FOR EACH SIDE OF THE BEND

BARE L (FT)	0
POLYWRAPPED L (FT)	0

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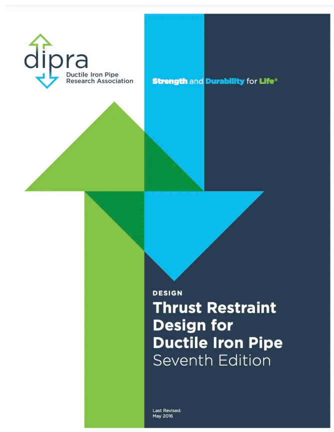
CALCULATE



This program is based on the equations and procedures found in the DIPRA brochure **Thrust Restraint Design for Ductile Iron Pipe**. Conservative assumptions, along with an explicit safety factor, have been employed to assure a conservative design with an adequate overall safety factor. For any given project, the ultimate responsibility for the proper use of this program rests with the user.

Thrust Restraint Design for Ductile Iron Pipe

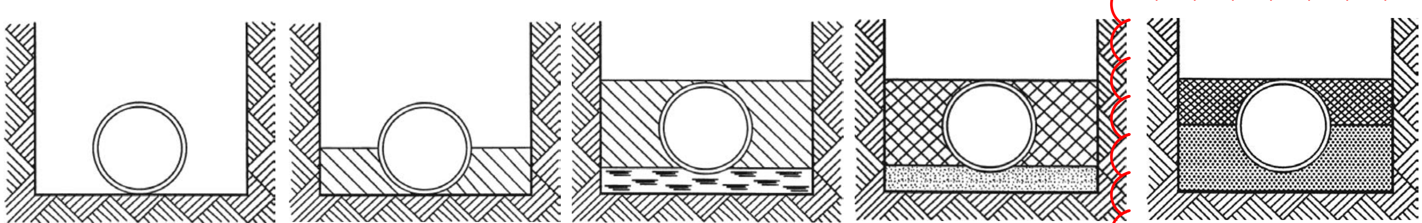
TABLE 2
Dimensions and Unit Weights of Pipe and Water

Nominal Pipe Size (in)	Pressure Class	Pipe Outside Diameter, D' (ft)	Cross-sectional Area of Pipe, A (in^2)	W_p (lbs/ft)	W_w (lbs/ft)	$W_p + W_w$* (lbs/ft)
3	350	0.33	12.3	10	4	14
4	350	0.40	18.1	12	6	18
6	350	0.58	37.3	18	13	31
8	350	0.75	64.3	24	24	48
10	350	0.93	96.7	30	37	67
12	350	1.10	136.8	39	53	92
14	250	1.28	183.8	47	72	119
16	250	1.45	237.7	57	94	151
18	250	1.63	298.6	66	119	185
20	250	1.80	366.4	78	147	225
24	200	2.15	522.7	93	212	305
30	150	2.67	804.2	123	329	452
36	150	3.19	1152.0	163	473	636
42	150	3.71	1555.2	206	642	848
48	150	4.23	2026.8	261	838	1099
54	150	4.80	2602.1	325	1078	1403
60	150	5.13	2981.2	371	1237	1608
64	150	5.47	3387.0	410	1407	1817

*Based on minimum pressure class pipe with standard cement-mortar lining. The difference in $W_p + W_w$ for other pipe pressure classes is not normally significant in relation to these calculations and these values may be used conservatively regardless of pipe pressure class. However, the designer may use actual pipe weights for optimum design if desired.

FIGURE 9

Standard ANSI/AWWA C150/A21.50 Laying Conditions for Ductile Iron Pipe



Type 1*
Flat-bottom trench.† Loose backfill.

Type 2
Flat-bottom trench.† Backfill lightly consolidated to centerline of pipe.

Type 3
Pipe bedded in 4-inch minimum loose soil.‡ Backfill lightly consolidated to top of pipe.

Type 4
Pipe bedded in sand, gravel, or crushed stone to depth of 1/8 pipe diameter, 4-inch minimum. Backfill compacted to top of pipe. (Approximately 80% Standard Proctor, AASHTO T-99.)§ (See Table 1 for notes.)

Type 5
Pipe bedded to its centerline in compacted granular material,** 4-inch minimum under pipe. Compacted granular or select‡ material to top of pipe. (Approximately 90% Standard Proctor, AASHTO T-99.)§

* For 14-inch and larger pipe, consideration should be given to the use of laying conditions other than Type 1.
† "Flat-bottom" is defined as "undisturbed earth."
‡ "Loose soil" or "select material" is defined as "native soil excavated from the trench, free of rocks, foreign material, and frozen earth."
†† AASHTO T-99 "Standard Method of Test for the Moisture-Density Relations of Soils Using a 5.5 lb (2.5 kg) Rammer and a 12 in. (305 mm) Drop." Available from the American Association of State Highway and Transportation Officials.
** Granular materials are defined per the AASHTO Soil Classification System (ASTM D3282) or the Unified Soil Classification System (ASTM D2487), with the exception that gravel bedding/backfill adjacent to the pipe is limited to 2" maximum particle size per ANSI/AWWA C600.

Tees (Figure 11)

$$PA_b = L_bF_f + 1/2R_sL_r$$

Employing a safety factor and solving for L_b,

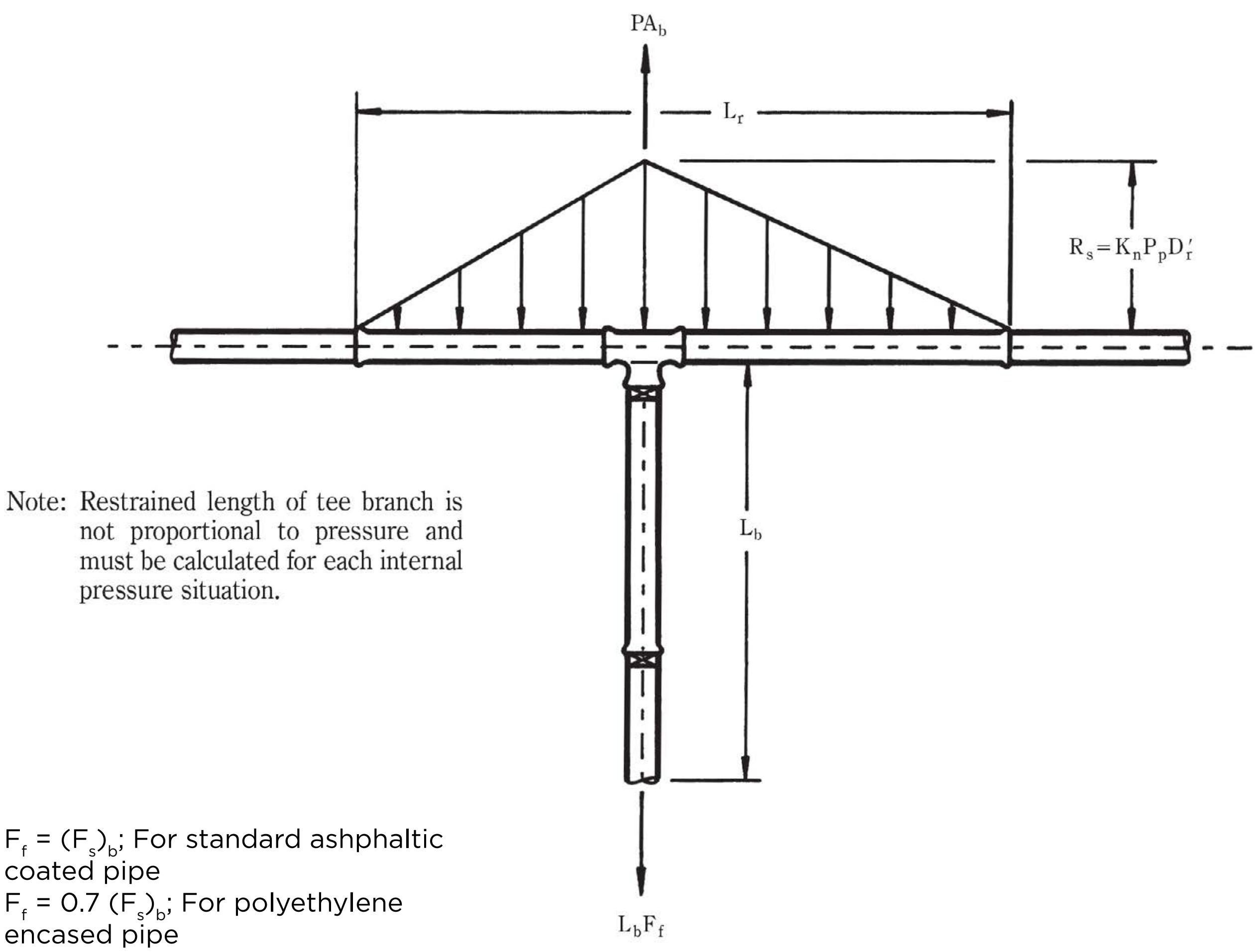
$$L_b = \left[\frac{S_f\,PA_b - 1/2R_sL_r}{F_f}\right] \quad (9)$$

$$R_s = K_nP_pD'_r$$

A_b = Cross sectional area of branch (in²)
L_b = Length of branch (ft) to be restrained
L_r = Total length between first joints on either side of tee on the run (ft)
D'_r = Diameter of run (ft)
F_f = $(F_s)_b$; For standard asphaltic coated pipe
F_f = 0.7 $(F_s)_b$; For polyethylene encased pipe
$(F_s)_b$ = Unit frictional force (lbs/ft) on branch
= $\pi D'C + (2W_e + W_p + W_w)\tan\delta$
(used for tee branches, dead end conditions and reducers)
S_f = Safety factor (Usually 1.5)

FIGURE 11

Tees



F_f = $(F_s)_b$; For standard ashphaltic coated pipe
F_f = 0.7 $(F_s)_b$; For polyethylene encased pipe

Nomenclature

A = Cross-sectional area of pipe ($inch^2$) = 36π D′ 2 (See Table 2)

A_p = Surface area of pipe exterior (ft^2/ft)

b = Thrust block width (ft)

C = Pipe cohesion (lbs/ft^2)

C_s = Soil cohesion (lbs/ft^2) (See Table 3)

D′ = Outside diameter of pipe (ft) (See Table 2)

f_c = Ratio of pipe cohesion to soil cohesion (See Table 3)

F_f = Unit frictional resistance (lbs/ft)

F_s = Unit frictional force assuming 1/2 the pipe circumference bears against the soil (lbs/ft)

$(F_s)_b$ = Unit frictional force assuming the entire pipe circumference contacts the soil (lbs/ft)

f_φ = Ratio of pipe friction angle to soil friction angle (See Table 3)

h = Thrust block height (ft)

H = Depth of cover to top of pipe (ft)

H_c = Depth of cover to pipe centerline (ft)

H_t = Depth to bottom of thrust block (ft)

K_n = Trench condition modifier (See Table 3)

L = Minimum required restrained pipe length (ft)

N_φ = tan2 (45° + φ/2)

P = Design pressure (psi)

P_p = Passive soil pressure (lbs/ft^2)

R_s = Unit bearing resistance (lbs/ft)

S_b = Horizontal bearing strength of soil (lbs/ft^2) (See Table 1)

T = Resultant thrust force (lbs)

γ = Backfill soil density (lbs/ft^3) (See Table 3)

W = Unit normal force on pipe = 2 W_e + W_p + W_w (lbs/ft)

W_e = Earth prism load (lbs/ft) = γHD′

W_m = Density of thrust block material (lbs/ft^3)

W_p = Unit weight of pipe (lbs/ft) (See Table 2)

W_w = Unit weight of water (lbs/ft) (See Table 2)

Ø = Bend angle (degrees)

δ = Pipe friction angle (degrees)

φ = Soil internal friction angle (degrees) (See Table 3)

S_f = Safety factor (usually 1. 5)

V_g = Volume of thrust block (ft^3)

References

1. Carlsen, R.J., "Thrust Restraint for Underground Piping Systems." *Cast Iron Pipe News*, Fall 1975.
2. Conner, R.C. "Thrust Restraint of Buried Ductile Iron Pipe," Proceedings of Pipeline Infrastructure Conference, Boston, Massachusetts, June 6-7, 1988. Published by *ASCE*, New York, NY, 1988, p. 218.
3. Reference U.S. Pipe & Foundry Company research (Unpublished).
4. Potyondy, J.G., M. Eng., *Skin Friction Between Various Soils and Construction Materials*.
5. ASTM D 2487—Classification of Soils for Engineering Purposes.