

also employ copper tubing extensively. For refrigeration use where tubing absolutely free from scale and dirt is required, bright annealed copper tubing that has been deoxidized is used. This tubing is available in a variety of sizes and wall thicknesses.

EXPANSION AND FLEXIBILITY

The increase in temperature of a pipe from room temperature to an operating steam or water temperature 100 F or more above room temperature results in an increase in length of the pipe for which provision must be made. The amount of linear expansion (or contraction in the

TABLE 4. NOMINAL WEIGHTS OF WELDED WROUGHT-IRON PIPE

NOMINAL PIPE SIZE (INCHES)	SCHED. 10	SCHED. 20	SCHEDULE 30		SCHEDULE 40		SCHEDULE 60	SCHEDULE 80
	Plain Ends	Plain Ends	Plain Ends	Threads and Couplings	Plain Ends	Threads and Couplings	Plain Ends	Plain Ends
1/8	-----	-----	-----	-----	0.25*	0.25*	-----	0.32*
1/4	-----	-----	-----	-----	0.43*	0.43*	-----	0.54*
3/8	-----	-----	-----	-----	0.57*	0.57*	-----	0.74*
1/2	-----	-----	-----	-----	0.86*	0.86*	-----	1.09*
3/4	-----	-----	-----	-----	1.14*	1.14*	-----	1.48*
1	-----	-----	-----	-----	1.68*	1.69*	-----	2.18*
1 1/4	-----	-----	-----	-----	2.28*	2.29*	-----	3.00*
1 1/2	-----	-----	-----	-----	2.72*	2.74*	-----	3.64*
2	-----	-----	-----	-----	3.66*	3.68*	-----	5.03*
2 1/2	-----	-----	-----	-----	5.80*	5.82*	-----	7.67*
3	-----	-----	-----	-----	7.58*	7.62*	-----	10.3*
3 1/2	-----	-----	-----	-----	9.11*	9.21*	-----	12.5*
4	-----	-----	-----	-----	10.8*	10.9*	-----	15.0*
5	-----	-----	-----	-----	14.7*	14.9*	-----	20.8*
6	-----	-----	-----	-----	19.0*	19.2*	-----	28.6*
8	-----	-----	24.7*	25.0*	28.6*	28.8*	-----	43.4*
10	-----	-----	34.3*	35.0*	40.5*	41.2*	54.8*	54.4
12	-----	-----	43.8*	45.0*	53.6	55.0	73.2	88.6
14 O. D.	36.0	44.8	53.6	-----	62.2	-----	87.6	104.0
16 O. D.	41.3	51.4	61.4	-----	81.2	-----	111.0	-----
18 O. D.	46.5	57.9	80.5	-----	103.0	-----	136.0	-----
20 O. D.	-----	77.0	103.0	-----	115.0	-----	-----	-----

Weights are given in pounds per linear foot and are for pipe with plain ends except for sizes which are commercially available with threads and couplings for which both weights are listed.

*Weights marked with an asterisk in Schedules 30 and 40 are identical with weights for standard-weight pipe in former lists; those in Schedules 60 and 80 are identical with weights for extra-strong pipe in former lists.

The Schedule Numbers indicate approximate values of the expression $1000 \times P/S$.

case of refrigeration lines) per unit length of material per degree change in temperature is termed the *coefficient of linear expansion* of that material, or commonly, the *coefficient of expansion*. This coefficient varies with the material.

The linear expansion of cast-iron, steel, wrought iron, and copper pipe, the materials most frequently used in heating and ventilating work, can be determined from Table 6.

The elongation values in Table 6 were computed from the following formula:

$$L_t = L_o \left[1 + a \left(\frac{t - 32}{1000} \right) + b \left(\frac{t - 32}{1000} \right)^2 \right] \quad (1)$$

where

L_t = length at temperature t degrees Fahrenheit, feet.

L_o = length at 32 F, feet.

t = final temperature, degrees Fahrenheit.

a and b are constants as given on the next page.

METAL	a	b
Cast-Iron.....	0.005441	0.001747
Steel.....	0.006212	0.001623
Wrought Iron.....	0.006503	0.001622
Copper.....	0.009278	0.001244

The three methods by which the elongation due to thermal expansion may be taken care of are:

1. Expansion joints.
2. Swivel joints.
3. Inherent flexibility of the pipe itself utilized through pipe bends, right-angle turns, or offsets in the line.

TABLE 5. STANDARD DIMENSIONS, WEIGHTS, AND DIAMETER AND WALL THICKNESS TOLERANCES FOR COPPER WATER TUBES*
(All Tolerances Plus and Minus)

NOMINAL SIZE, IN.	ACTUAL OUTSIDE DIAMETER, IN.	PERMISSIBLE VARIATION IN MEAN OUTSIDE DIAMETER, IN.		WALL THICKNESS, IN.						WEIGHT PER FT LB		
				Class K		Class L		Class M		Class K	Class L	Class M
				Nominal	Per- missible Variation	Nominal	Per- missible Variation	Nominal	Per- missible Variation			
3/8	0.500	0.0025	0.001	0.049	0.004	0.035	0.0035	0.025	0.0025	0.269	0.198	0.144
1/2	0.625	0.0025	0.001	0.049	0.004	0.040	0.0035	0.028	0.0025	0.344	0.285	0.203
3/4	0.875	0.003	0.001	0.065	0.0045	0.045	0.004	0.032	0.003	0.641	0.455	0.328
1	1.125	0.0035	0.0015	0.065	0.0045	0.050	0.004	0.035	0.0035	0.839	0.655	0.464
1 1/4	1.375	0.004	0.0015	0.065	0.0045	0.055	0.0045	0.042	0.0035	1.04	0.884	0.681
1 1/2	1.625	0.0045	0.002	0.072	0.005	0.060	0.0045	0.049	0.004	1.36	1.14	0.94
2	2.125	0.005	0.002	0.083	0.005	0.070	0.005	0.058	0.0045	2.06	1.75	1.46
2 1/2	2.625	0.005	0.002	0.095	0.005	0.080	0.005	0.065	0.0045	2.92	2.48	2.03
3	3.125	0.005	0.002	0.109	0.005	0.090	0.005	0.072	0.0045	4.00	3.33	2.68
3 1/2	3.625	0.005	0.002	0.120	0.005	0.100	0.005	0.083	0.005	5.12	4.29	3.58
4	4.125	0.005	0.002	0.134	0.006	0.110	0.005	0.095	0.005	6.51	5.38	4.66
5	5.125	0.005	0.002	0.160	0.006	0.125	0.006	0.109	0.005	9.67	7.61	6.65
6	6.125	0.005	0.002	0.192	0.006	0.140	0.006	0.122	0.005	13.87	10.20	8.91

*From Standard Specifications for Copper Water Tube of the American Society for Testing Materials, A.S.T.M. Designation B88-33.

Expansion joints of the slip-sleeve, diaphragm, or corrugated types made of copper, rubber, or other gasket material are all used for taking up expansion, but generally only for low pressures or where the inherent flexibility of the pipe cannot readily be used as in underground steam or hot water distribution lines.