perature results in an increase in length of the pipe for which provision must be made. The amount of linear expansion (or contraction in the 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,

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
⅛	.....	.....	.....	.....	0.25*	0.25*	.....	0.32*
¼	.....	.....	.....	.....	0.43*	0.43*	.....	0.54*
⅜	.....	.....	.....	.....	0.57*	0.57*	.....	0.74*
½	.....	.....	.....	.....	0.86*	0.86*	.....	1.09*
¾	.....	.....	.....	.....	1.14*	1.14*	.....	1.48*
1	.....	.....	.....	.....	1.68*	1.69*	.....	2.18*
1¼	.....	.....	.....	.....	2.28*	2.29*	.....	3.00*
1½	.....	.....	.....	.....	2.72*	2.74*	.....	3.64*
2	.....	.....	.....	.....	3.66*	3.68*	.....	5.03*
2½	.....	.....	.....	.....	5.80*	5.82*	.....	7.67*
3	.....	.....	.....	.....	7.58*	7.62*	.....	10.3*
3½	.....	.....	.....	.....	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 x P/S.

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 follows:

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				
		Annealed	Hard Drawn	Nominal	Permissible Variation	Nominal	Permissible Variation	Nominal	Permissible Variation	Class K	Class L	Class M
⅜	0.500	0.0025	0.001	0.049	0.004	0.035	0.0035	0.025	0.0025	0.269	0.198	0.144
½	0.625	0.0025	0.001	0.049	0.004	0.040	0.0035	0.028	0.0025	0.344	0.285	0.203
¾	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
1¼	1.375	0.004	0.0015	0.065	0.0045	0.055	0.0045	0.042	0.0035	1.04	0.884	0.681
1½	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
2½	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
3½	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.

Swivel joints are used extensively in low-pressure steam and hot water heating systems and in hot water supply lines. The swivel joints absorb the expansive movement of the pipe by the turning of threaded joints. In many cases the straight pipe in the offset of a swivel joint is sufficiently flexible to take up the expansion without developing enough thrust to produce swiveling in the threaded joint. This is preferable since con-