

ing in establishing the factor c which influences the working pressure, is that after nominal use the pipe may not be as sturdy as it was at the time of manufacture. Note that the joint factor, c , is not included for plain end non-ferrous pipe as listed in Table 2.

In addition to IPS copper pipe, several varieties of copper tubing are in use with either flared or compression couplings or soldered joints. Dimensions of copper water tubing intended for plumbing, underground water service, fuel-oil lines, gas lines, etc., have been standardized by the U. S. Government and the *American Society for Testing Materials*. There are three standard wall-thickness schedules of copper water tubing classified in accordance with their principal uses as follows:

Type K—Designed for underground services and general plumbing service.

Type L—Designed for general plumbing purposes.

Type M—Designed for use with soldered fittings only.

TABLE 4. THERMAL EXPANSION OF PIPE IN INCHES PER 100 FT*

(For superheated steam and other fluids refer to temperature column)

SATURATED STEAM			ELONGATION IN INCHES PER 100 FT FROM -20 F UP				SATURATED STEAM		ELONGATION IN INCHES PER 100 FT FROM -20 F UP			
Vacu- um Inches of Hg	Pres- sure Psig	Temper- ature Fahren- heit Degrees	Cast-Iron Pipe	Steel Pipe	Wrought- Iron Pipe	Cop- per Pipe	Pres- sure Psig	Temper- ature Fahren- heit Degrees	Cast-Iron Pipe	Steel Pipe	Wrought- Iron Pipe	Cop- per Pipe
		-20	0	0	0	0	2.5	220	1.634	1.852	1.936	2.720
		0	0.127	0.145	0.152	0.204	10.3	240	1.780	2.020	2.110	2.960
		20	0.255	0.293	0.306	0.442	20.7	260	1.931	2.183	2.279	3.189
		40	0.390	0.430	0.465	0.655	34.5	280	2.085	2.350	2.465	3.422
29.39		60	0.518	0.593	0.620	0.888	52.3	300	2.233	2.519	2.630	3.665
28.89		80	0.649	0.725	0.780	1.100	74.9	320	2.395	2.690	2.800	3.900
27.99		100	0.787	0.898	0.939	1.338	103.3	340	2.543	2.862	2.988	4.145
26.48		120	0.926	1.055	1.110	1.570	138.3	360	2.700	3.029	3.175	4.380
24.04		140	1.051	1.209	1.265	1.794	180.9	380	2.859	3.211	3.350	4.628
20.27		160	1.200	1.368	1.427	2.008	232.4	400	3.008	3.375	3.521	4.870
14.63		180	1.345	1.528	1.597	2.255	293.7	420	3.182	3.566	3.720	5.118
6.45		200	1.495	1.691	1.778	2.500	366.1	440	3.345	3.740	3.900	5.358

* From *Piping Handbook*, by Walker and Crocker. This table gives the expansion from -20 F to the temperature in question. To obtain the amount of expansion between any two temperatures take the difference between the figures in the table for those temperatures. For example, if a steel pipe is installed at a temperature of 60 F and is to operate at 300 F, the expansion would be 2.519 - 0.593 = 1.926 in.

In general, Type K is used where corrosion conditions are severe, and Types L and M where such conditions may be considered normal as, for instance, in heating work. Types K and L are available in both hard and soft tempers; Type M is available only in hard temper. Where flexibility is essential as in hidden replacement work, or where as few joints as possible are desired as in fuel-oil lines, the soft temper is commonly used. In new or exposed work copper pipe of a hard temper is generally used. All three classes are extensively used with soldered fittings.

Standard dimensions, weights, and diameter and wall-thickness tolerances for these classes of copper tubing are obtainable from Table 2. Copper pipe is also available with dimensions of steel pipe.

In refrigeration lines, used in connection with air conditioning equipment,

copper tube is used 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 deg 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 case of refrigeration lines) per unit length of material per degree change in temperature is termed the *coefficient of linear expansion*, 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 4.

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.

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 to some extent in low-pressure steam and hot-water heating systems, and in hot-water supply lines. Since swivel joints permit the expansive movement of the pipe by turning of threaded joints, which may ultimately result in a leak, it is preferable to provide sufficient flexibility without resorting to swiveling in the threads.

Probably the most economical method of providing for expansion of piping in a long run is to take advantage of the directional changes which must necessarily occur in the piping, and proportion the offsets so that sufficient flexibility is secured. Ninety-degree bends with long, straight tangents in either a horizontal or a vertical plane are an excellent means for securing adequate flexibility with larger sizes of pipe. When flexibility cannot be obtained in this manner, it is necessary to make use of some type of expansion bend. The exact calculation of the size of expansion bends required to take up a given amount of thermal expansion is relatively complicated.¹ The following approximate method, however, has been found to give reasonably good results and is deemed to be sufficiently accurate for most heating installations.

Fig. 1 shows several types of expansion bends commonly used for taking up thermal expansion. The amount of pipe, L , required in each of these bends may be computed from Equation 1.

$$L = 6.16 \sqrt{\Delta d} \quad (1)$$

where

L = length of pipe, feet.

d = outside diameter of the pipe used, inches.

Δ = the amount of expansion to be taken up, inches.

This formula, based on the use of mild-steel pipe with wall thicknesses