of 150 milinches per foot, or 600 milinches for 4 ft. If the first floor radiators are located 3 ft above the mains, second floor radiators 12 ft above the mains, third floor 21 ft, and fourth floor 30 ft, the heads are 450, 1800, 3150, and 4500 milinches, respectively.

In *forced circulation* systems flow is produced mechanically by means of a pump driven by electricity, steam, or other source of energy. As

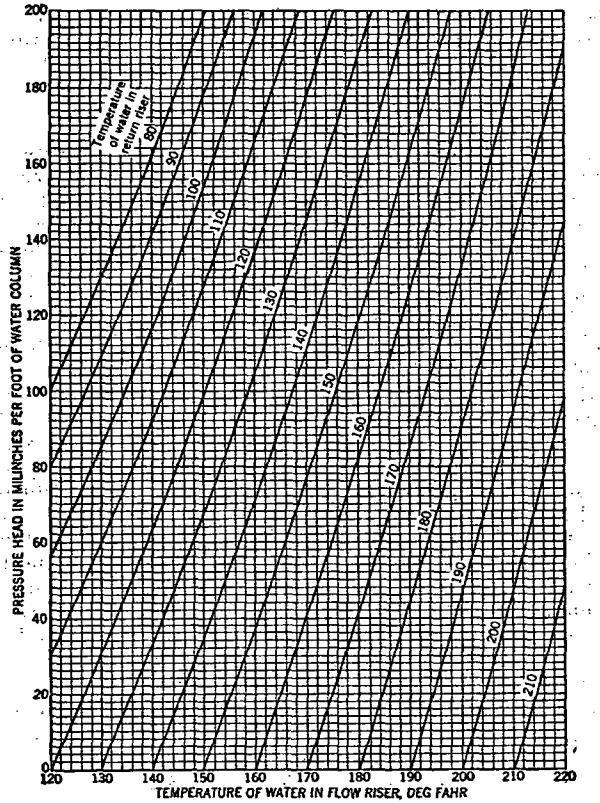

FIG. 1. HEADS RESULTING FROM TEMPERATURE DIFFERENCE (GRAVITY SYSTEMS)

forced circulation velocities are higher than those in gravity systems, and as the friction in a heating system varies almost as the square of the velocity, a given error in the calculation or assumption of the velocity is less important in a forced circulation system than in a gravity circulation system, and, consequently, it is easier to design a satisfactory forced circulation system than a satisfactory gravity circulation system.

FRICTION LOSS

Values of friction loss due to flow of water in the various parts of a heating system must be known in order to design either gravity or forced circulation systems. The friction loss of fittings is customarily expressed in equiv-

TABLE 1. IRON AND COPPER ELBOW EQUIVALENTS[a]

Fitting	Iron Pipe	Copper Tubing	Fitting	Iron Pipe	Copper Tubing
Elbow, 90-deg	1.0	1.0	Angle radiator valve	2.0	3.0
Elbow, 45-deg	0.7	0.7	Radiator or convector	3.0	4.0
Elbow, 90-deg long turn	0.5	0.5	Boiler or heater	3.0	4.0
Elbow, welded, 90-deg	0.5	0.5			
Reduced coupling	0.4	0.4	Tee, per cent flowing through branch:		
Open return bend	1.0	1.0	100	1.8	1.2
Open gate valve	0.5	0.7	50	4.0	4.0
Open globe valve	12.0	17.0	25	16.0	20.0

[a] The friction in one 90 deg standard elbow is approximately equal to the friction of a length of straight pipe of the same nominal size and 25 diam long. Hence, one elbow equivalent in feet of pipe equals 25 diam (in inches) divided by 12.

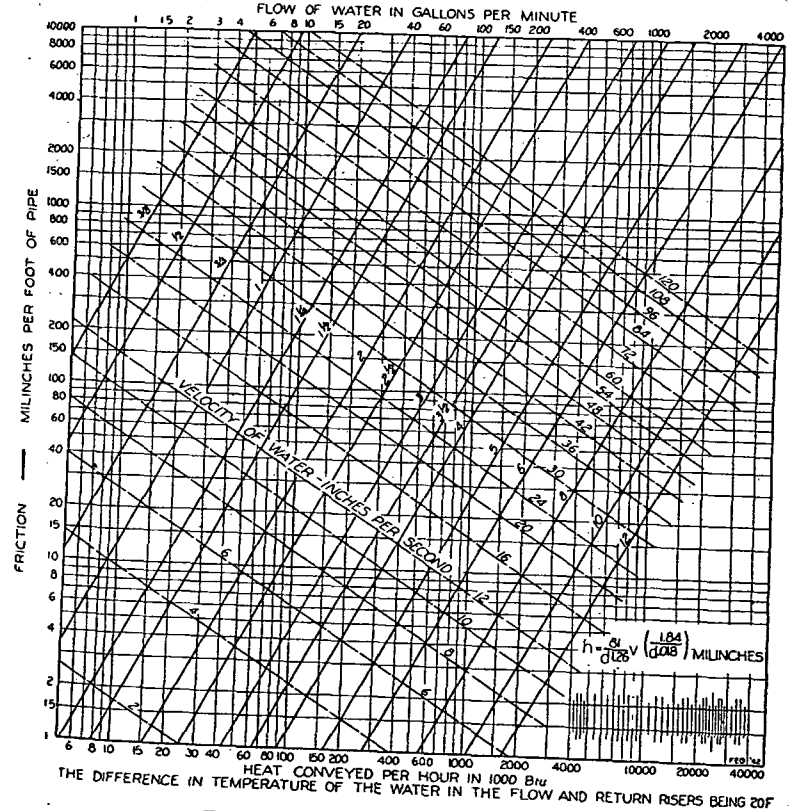

FIG. 2. FRICTION IN BLACK IRON PIPES

Lower scale of chart is based on 20 deg temperature difference between flow and return risers. To find friction when temperature drop is other than 20 deg, multiply the actual heat conveyed by $\left(\frac{20}{\text{actual temp. drop}}\right)$ and read the corresponding friction.