sizes, the unit friction may be found from Fig. 4 and the total friction calculated and recorded as shown in Table 6. If the grand total, in the present case 1192 milinches, differs materially from the available head, 1225 milinches, one or more of the pipe sizes must be changed and the calculation repeated until the total friction is practically equal to the available head of 1225 milinches.

It is not necessary, in the design of hot water heating systems, to be extremely careful to have the friction exactly equal to the available head, because a hot water heating system has the ability to adjust itself to varying conditions of considerable magnitude. For example, in the present case, the calculated friction is 1192 milinches, or about 3 per cent less than the calculated available head; the water would, therefore, circulate a little faster than contemplated and the return temperature would be a little higher than 160 F.

TABLE 6. TABULATED DATA FOR EXAMPLE 3

Circuit No. 3. Available head 1225 milinches

Section	Load Mbh	Pipe Length Ft	Elbows No.	Pipe Size In.	Equivalent Length, Ft	Unit Friction Milinches per Ft	Total Friction, Milinches
0-4	45	3.5	2.5	1½	11.3	6.3	71
4-5	35	10.0	2.0	1¼	15.2	9.2	140
5-6	20	12.0	0.0	1¼	12.0	3.4	41
6-3	20	6.5	5.5	1	17.5	13	228
3-7	20	9.5	5.5	1	20.5	13	267
7-8	20	12.8	1.0	1	14.9	13	194
8-9	35	13.8	2.5	1¼	20.3	9.2	187
9-0	45	2.3	2.5	1½	10.1	6.3	64
Total		70.4	21.5		121.8		1192

Circuit No. 2. Available head 1225 milinches

0-4	45						71
4-5	35						140
5-2	15	6.2	6	1	18.7	7.5	140
2-8	15	9.5	7	¾	20.4	24.0	490
8-9	35						187
9-0	45						64
Total							1092

Circuit No. 1. Available head 1225 milinches

0-4	45						71
4-10	10	9.0	1.5	¾	11.3	11	124
10-1	10	5.0	5.5	½	10.7	46	434
1-11	10	9.5	5.5	¾	18.1	11	199
11-9	10	11.5	2.5	¾	15.4	11	169
9-0	45						64
Total							1067

This would immediately lower the head available for circulation and the balance with the friction would occur at some point between 1192 and 1225 milinches.

Since it is generally not necessary to make extremely refined calculations, Table 1 may often be used instead of the chart of Fig. 4 to determine pipe sizes. For example, in the present case, Table 1 shows that for a friction of 10 milinches a 1½ in. pipe would convey 28 Mbh with a temperature difference of 20 deg or 56 Mbh with a temperature difference of 40 deg. Since the 1½ in. pipe in Fig. 10 is to convey only 45 Mbh with a temperature difference of 40 deg, or only 22.5 with a temperature difference of 20 deg, it is evident from the table that the friction will be between 6 and 8 milinches. For 6 milinches the heat conveyed is 21.2 and for 8 milinches, it is 24.8; for 22.5 Mbh, the friction would be estimated to be about 6.5, which would be sufficiently accurate for the present calculation.

Having completed the design of Circuit 3, it is simple to design Circuit 2 because it has four sections in common with Circuit 3 and it is only necessary to design Sections 5-2 and 2-8, as shown in Table 6, so that the total friction of Circuit 2 will be practically equal to the total friction of Circuit 3.

Having completed the design of Circuit 2, it is necessary to design Circuit 1, as shown in Table 6, so that its total friction will be approximately equal to the total friction of the other two circuits since all three circuits have equal heads.

Two-Pipe Forced Circulation System

Example 4. In the design of a system for Fig. 12, as in the design of Example 2, there are three unknowns—head, pipe size, and flow-return temperature difference, any two of which may be assumed and the third found. In the design of a system for Fig. 9, the pressure head and the temperature difference were assumed and the pipe sizes found. In this case, the head is to be found.

Solution. In selecting the temperature difference and the pipe sizes, it should be borne in mind that the first cost of the radiation can be reduced by reducing the temperature difference and the first cost of the pipe can be reduced by increasing water velocity, but the friction is increased and, thus, the cost of pumping. The choice of temperature difference and pipe sizes which produce the greatest economy in first cost and in cost of operation can be determined after having made two or three trial designs. For the first design, 20 deg will be selected as the temperature difference and the pipe

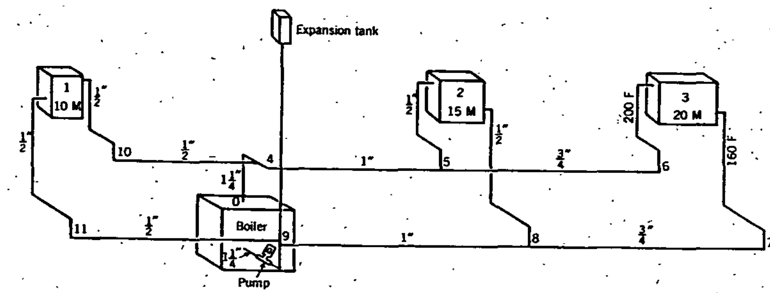

FIG. 12. TWO-PIPE FORCED CIRCULATION SYSTEM

sizes will be chosen as shown in Fig. 12. A calculation similar to that of Table 7 will show that the friction of Circuits 1, 2, and 3 will be, respectively, about 9000, 15,300, and 14,300 milinches. To increase the friction of Circuit 1 from 9000 to 15,000 milinches would require the insertion in the circuit of a section of ⅜ in. pipe, or an orifice resistor, or a regulating valve. However, this would cause unnecessary expense. The system will function well with the pipe system shown in Fig. 12. If the circulator maintains a head of 15,300 milinches, the velocity in Circuit 1 will increase until the friction of the circuit is also 15,300 milinches; *i.e.*, its friction will be increased from the calculated 9000 to the required 15,300, or 6300 milinches.

As calculated, the three radiators are to dissipate 10, 15, and 20 Mbh, respectively, with a temperature difference of 20 deg. Consequently, water must flow through these three radiators at the rates of 1, 1.5, and 2 gpm, respectively. When water flows through a ½ in. pipe at the rate of 1 gpm, the velocity in the pipe is (Fig. 4) about 13 in. per second and the unit friction is 165 milinches. The equivalent length of sections 4-10, 10-1, 1-11, and 11-9 of this circuit is 50 ft, and its total friction is 8250. In order that the friction may be increased 6300 milinches, the unit friction must be increased 126 milinches; consequently, the velocity in the ½ in. pipe (Fig. 4) must be increased from 13 to 16 in. per second. Hence, when the friction of Circuit 1 has been increased to 15,300, water will flow through Radiator 1 at the rate of 16 ÷ 13, or 1.23 gpm. This increase in volume of water will increase the load on the circulating pump in the proportion of 450 to 473 and will increase the heat dissipation of Radiator 1 slightly (about 3 per cent) but otherwise will not affect the operation of the system.

One-Pipe Gravity Circulation System

Example 5. A one-pipe system is one in which the cooled water from the heating units is returned to the supply main. A two-pipe system as shown in Figs. 11 and 12 is one in which the cooled water returns to the boiler through a separate return main.