The methods just described for the design of the two elementary systems are fundamental and apply to the design of all hot water heating systems. In every system, however large and complicated, the pipe system must be such that the *ph* forcing the water from the boiler to any one radiator is equal to the *fh* in that radiator's circuit when the radiator is receiving its proper quantity of hot water and the system is functioning at a steady rate.

Two-Pipe Gravity Circulation System

Example 3. In the system shown in Fig. 10, water leaving the boiler may flow to any one of the three radiators. If the system is designed correctly, each radiator will receive its proper share of the hot water. Since Radiator 3 has the largest load and is also farthest from the boiler, it is the least favorably located with reference to circulation, and its circuit should be designed first. If the pipes leading to it are large enough, it will be easy to secure sufficient circulation for the other two radiators.

The system is to function with a 40 F flow-return temperature difference. The *ph* for each radiator is 7 x 175 (Fig. 4), or 1225 milinches; the *fh* for each radiator circuit must, therefore, also be 1225 milinches.

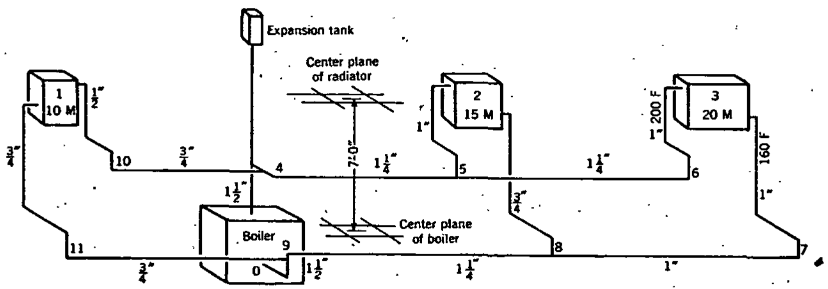

FIG. 10. TWO-PIPE GRAVITY CIRCULATION SYSTEM

Solution. In order to design a radiator circuit accurately and systematically, the circuit should be divided into sections. The division points of sections must be where the pipe sizes change or may change, and where the volume of water flowing in the pipe changes. The data relating to the several sections may be recorded as shown in Table 5.

Data recorded in Table 5 show that Circuit 3 consists of 70.4 ft of pipe and 21.5 elbow equivalents. Assuming that the average size of the pipe will be 1¼ in., the 21.5 elbow equivalents may be replaced by 21.5 x 2.6 (25/12 x 1.25 x 1.0), or 56 ft of pipe, which would make the total equivalent length of the circuit 70.4 plus 56 or 126.4 ft of pipe, and the average *fh*, 1225/126.4, or about 10 milinches per foot. For this unit *fh* and a temperature difference of 40 F (see Fig. 3), a 1 in. pipe will convey 18 Mbh, a 1¼ in. pipe, 37 Mbh, and a 1½ in. pipe, 56 Mbh. The pipe sizes for the several sections of Circuit 3 may be selected as indicated in Table 5. Having selected the pipe sizes, the unit friction heads may be found from Fig. 3 and the total friction head calculated and recorded as shown in Table 5. If the grand total, in the present case 1192 milinches, differs materially from the available *ph*, 1225 milinches, one or more of the pipe sizes must be changed and the calculation repeated until the total *fh* is practically equal to the available *ph* of 1225 milinches.

It is not necessary, in the design of hot water heating systems, to be extremely careful to have the *fh* exactly equal to the available *ph*, 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 *fh* is 1192 milinches, or about 3 per cent less than the calculated available *ph*; the water would, therefore, circulate a little faster than contemplated and the return temperature would be a little higher than 160 F. This would

immediately lower the available *ph* and the *ph* and *fh* would come into balance at a value higher than 1192 and lower than 1225.

Since it is generally not necessary to make extremely refined calculations, Table 1 may often be used instead of the chart of Fig. 3 to determine pipe sizes. For example, in the present case, Table 1 shows that for an *fh* of 10 milinches a 1½ in. pipe would convey 28 Mbh with a temperature difference of 20 F or 56 Mbh with a temperature difference of 40 F. Since the 1½ in. pipe in Fig. 10 is to convey only 45 Mbh with a temperature difference of 40 F, or only 22.5 with a temperature difference of 20 F, it is evident from the table that the *fh* 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 *fh* would be estimated to be about 6.5, which would be sufficiently accurate for the present calculation.

TABLE 5. TABULATED DATA FOR EXAMPLE 3

Circuit No. 3. Available ph 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 ph 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						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 ph 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						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

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 5, so that the total *fh* of Circuit 2 will be practically equal to the total *fh* of Circuit 3.

Having completed the design of Circuit 2, it is necessary to design Circuit 1, as shown in Table 5, so that its total *fh* will be approximately equal to the total *fh* of the other two circuits since all three circuits have equal pressure heads.

Two-Pipe Forced Circulation System

Example 4. In the design of a system for Fig. 11, as in the design of Example 2, there are three unknowns—pressure 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