risers with 1-in. riser branches and 1-in. radiator tappings. Also select 1¼-in. return risers with 1¼-in. riser branches, and 1¼-in. radiator tappings. Similarly, for 18 Mbh, select 1¼-in. flow and return risers and riser branches, and 1¼-in. radiator tappings.

To develop a rule for determining radiator sizes, assume a system similar to that of Fig. 6, in which the total temperature drop is to be 35 F and which is equipped with 7 radiators, all radiators dissipating equal quantities of heat. The mean temperature of the water in the radiators will be reduced 5 F for each successive radiator. If the mean temperature of the water in the first radiator is 200 F, the mean temperature of the water in the seventh radiator will be 170 F, and, according to Table 3, Chapter 6, of the 1933 Guide, the heat dissipation of these two radiators will be to each other as 868 is to 617, or as 140 is to 100, and therefore if the last radiator is to dissipate as much heat as the first, its size must be 40 per cent larger.

Example 4. Design a two-pipe, direct return, gravity circulation system for the layout shown in Fig. 7. Assume that the main circuit from the boiler to the farthest flow riser and from the farthest return riser back to the boiler consists of 160 ft of pipe, 6 elbows, and 1 boiler.

Table 8. Maximum Capacities of Radiator Connections in *Mbh*, for One-Pipe and for Two-Pipe Direct Return Gravity Circulation Systems with a Temperature Drop of 35 F Through Each Radiator

Pipe Size		Equivalent Length of Pipe (Feet[a])	1st Floor	2nd, 3rd, and 4th Floors
Flow	Return		*Mbh*	*Mbh*
½	½	1.0	4.1	5.9
½	¾		5.2	7.5
¾	¾	1.5	7.0	10.5
¾	1		9.1	13.0
1	1	2.0	12.5	17.8
1	1¼		17.5	23.2
1¼	1¼	3.0	23.3	33.2

[a]Approximate length of pipe in feet equivalent to one elbow in friction head. This value varies with the velocity.

Solution. Replacing the boiler by 3 elbow equivalents and assuming that the largest size of the main will be about 3 in., the total equivalent length of the main will be 160 plus 45, or 205 ft. Assuming that the center of the boiler will be about 4 ft lower than the horizontal portion of the main, and that the temperature drop will be 35 F for the system, the pressure head caused by the difference in weight between the water in the flow and return risers joining the mains to the boiler will be about 0.6 in. of water, or about one-fortieth of the pressure head produced by the circulating pump selected for the system of Fig. 3.

Table 6 may be used to determine the size of the main as follows: Refer to Column 8 and note that for Sections *AB* and *IA*, which supply 105.6 Mbh, a 3-in. pipe is too large and a 2½-in. pipe is too small; hence, select 2½ in. for Section *AB* and 3 in. for Section *IA*. For Sections *BC* and *HI*, which supply 76.8 Mbh, a 2½-in. pipe is almost exactly the correct size and is selected for both sections.

For the forced circulation system of Fig. 5, the pressure head produced by the circulating pump is used to force the water through the mains and also through the risers. Gravity circulation systems have two distinct pressure heads. One is produced by the difference in weight of the water in the flow and return risers adjacent to the boiler, and is the boiler pressure head, which in this case is 0.6 in. The other pressure head is produced by the difference in weight of the water in the flow and return risers adjacent to the radiators, and is the radiator pressure head. If the temperature drop through the radiators is about 35 F, and if the story heights of the building are 9 ft and the distance from the center of the first floor radiator to the average level of the main is 3 ft, the

radiator pressure head of the first floor radiator is about 450 milinches and the pressure heads of the radiators on the upper floor are 1350 milinches greater than those on the next lower floors.

Tables 6 and 7 are based on the assumption that the boiler pressure head must be equal to the friction head in the mains, and that the several radiator pressure heads must be equal to the respective radiator and riser friction heads.

To design the radiator risers, use Table 7 and begin with the set nearest the boiler. The first floor risers must supply 28.8 Mbh. According to the table, 1¼-in. flow and return risers will supply 26.0 Mbh; if the return riser is increased to 1½ in., the capacity will be increased to 34.0 Mbh. This is considerably larger than necessary, and 1¼-in. flow and return risers are selected. However, it must be remembered that the riser branches, which are the connections from the flow and return mains to the flow and return risers, are to be one size larger than the risers.

The second floor risers must supply 19.2 Mbh. According to the table, the capacity of 1-in. flow and return risers is 20.0 Mbh, and that size is selected.

The third floor risers must supply 9.6 Mbh. If a ½-in. flow and a ¾-in. return riser are used, the capacity will be 8.0 Mbh; if both risers are ¾ in., the capacity will be 14.0 Mbh. The ¾-in. pipe is selected for both risers.

To design the radiator connections, use Table 8 and note that for the first floor radiator connections the capacity of a ¾-in. flow and 1-in. return is 9.1 Mbh, and that of a 1-in. flow and a 1-in. return is 12.5 Mbh. The former is more nearly the correct size, but since it is difficult to secure a good flow through first floor radiators, the 1-in. flow and return connection is selected. For the two upper floors, the capacity of a ¾-in. flow and return connection is 10.5 Mbh, and that size is used.

As explained in the design of the forced circulation system of Fig. 5, the two-pipe direct return system of Fig. 7 will not function correctly unless its four sets of risers are balanced among themselves. This necessary balancing is accomplished by adding resistances to all risers, except the one farthest from the boiler, equal to the excess boiler pressure heads available for those risers above the boiler pressure head available for the farthest riser. For example, the first set of risers is 60 ft nearer the boiler than the last set. Since the flow and return mains are designed for a friction head of 3 milinches per foot (See Table 6, Column 8), the boiler pressure head available for the first set of risers is 360 milinches in excess of that available for the fourth set. The velocity in the riser branch is 3 in. per second (See Table 7) and, therefore, according to Table 5, an 0.65-in. orifice in a 1¼-in. union should be used. This will provide a resistance of about 420 milinches. In the same manner it is found that for the second set of risers a resistance of 240 milinches is required and that an 0.70-in. orifice in a 1¼-in. union will provide a resistance of 285 milinches. For the third set of risers, a resistance of 120 milinches is required and an 0.60-in. orifice in a 1-in. union will provide sufficient resistance.

MECHANICAL CIRCULATION

Circulating pumps for hot water systems may be used to provide the motive head for forced circulation systems as already described, or to improve the operation of gravity-designed systems. Small specially-designed centrifugal pumps installed on a by-pass with the necessary gate or check valves near the point where the return main enters the heater may be employed. Specially-designed, electrically-driven, propeller-type circulating pumps or units may also be employed. The latter are usually installed directly in the return main and are available for all commercial pipe sizes used for hot water heating. The motor switch may be under manual control, automatic control using thermostatic elements,