branches are of 1 in. pipe, water will circulate through the system at the rate of 3 gpm with a temperature difference somewhat less than 40 F and that, at the radiator connections, water will circulate through the radiators at the rate of 1 gpm and that, consequently, between radiator branch connections the *fh* is at a lower rate since only 2 gpm flow through in the main between those points.

One-Pipe Forced Circulation System

Example 6. The system shown in Fig. 12 as a gravity circulation system may be changed to a forced circulation system by inserting a circulating pump as shown in Fig. 13. The location of the expansion tank should then be changed as indicated.

Solution. To design this system the pipe sizes and the temperature difference may be assumed; for example, 1¼ in. pipe may be selected for the main and ¾ in. pipe for the radiator branches and risers, and 20 F as the flow-return temperature difference. Since the system is to deliver 60 Mbh with a temperature difference of 20 F, the pump must circulate 60 ÷ 10, or 6 gpm.

For this load, the unit *fh* for a 1¼ in. pipe is 86 milinches. The main circuit consists of 110 ft of pipe and 10 elbow equivalents and may be placed equal to 136 ft of 1¼ in. pipe.

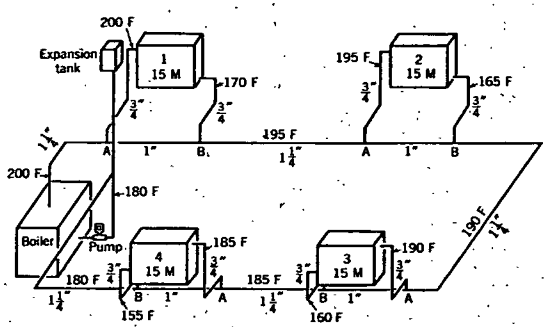

FIG. 13. ONE-PIPE FORCED CIRCULATION SYSTEM

The total *fh* for the main circuit is 136 x 86, or 11,696 milinches, or practically 1 ft for a flow of 6 gpm.

At the points *A*, a portion of the water will be diverted through the radiator circuit, and as a result less than 6 gpm will flow in the main between the points *A* and *B*, and the *fh* will be slightly less than 86 milinches per foot between these points. But the difference will be so small that it may be neglected and the total *fh* from *A* to *B* assumed to be 4 x 86, or 344 milinches. The *ph* forcing the water through the radiator circuit will then be 344 milinches. The radiator circuit consists of 11 ft of pipe and about 14 elbow equivalents and may be placed equal to 32 ft of pipe and the available *ph* 344 ÷ 32, or about 11 milinches per foot. With this *ph*, a ¾ in. pipe will convey about 5 Mbh (Fig. 3), or 0.5 gpm. Hence, only 5 ÷ 60, or about 8 per cent of the water, would flow through the radiator, if the radiator's gravity head is not considered. The water would, then, have to cool 60 F in order to deliver 15 Mbh, and the average radiator temperature would be 170 if the water entered at 200. This would require a large radiator and result in an unsatisfactory installation.

To secure a larger flow of water through the radiator it is necessary to increase the *fh* of the short path *A*-*B* in the main. This may be done by inserting special resistance tees at points *A* and *B*, or by inserting an orifice resistor between points *A* and *B*, or by reducing the 1¼ in. main between the points *A* and *B* to the next smaller size, *i.e.* 1 in.

The relative quantity of water flowing through the radiator may then be found by trial calculations. Assume, first, that 1 gpm will flow through the radiator and 5 gpm through the main. The *ph* for 1 gpm and a ¾ in. pipe is 40 milinches per foot, or 32 x 40, or 1280 for the radiator circuit.

The main circuit consists of 4 ft of 1 in. pipe and two reducing tees. The two reducing tees may be placed equal to 0.8 elbow equivalents (Table 3), and the equivalent length of the main circuit equal to 5.7 ft.

The *fh* for 5 gpm and a 1 in. pipe is 240 milinches per foot, or 5.7 x 240, or 1370 milinches for the main circuit. Since this is only slightly more than the calculated *fh* for the radiator circuit, it is evident that the flow through the radiator will be slightly more than 1 gpm, and it is not necessary to make a second trial calculation. The quantity of water flowing through the radiator can be varied by varying the distance between the points *A* and *B*, where the radiator branches join the main.

In order to deliver 15 Mbh to the radiator with a temperature difference of 20, it is necessary that 1.5 gpm flow through the radiator; since, in this case, the flow through the radiator is only 1 gpm, the temperature difference must be 30 F.

If the water enters the radiator at 190 F, the average water temperature will be 175 F. The quantity of water circulating through the radiator may be varied considerably without an appreciable effect on the quantity of heat dissipated by the radiator. This is evident from the following calculation.

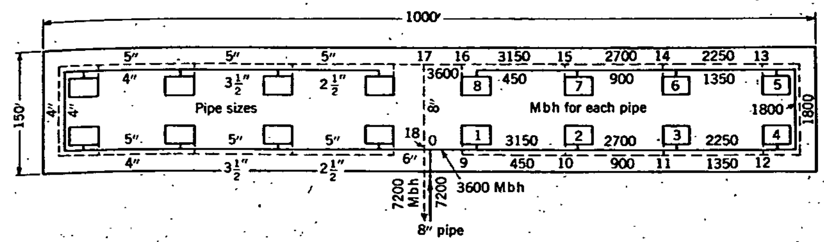

FIG. 14. TWO-PIPE REVERSED RETURN SYSTEM

Assume that Radiator 2 has been designed so that it will dissipate 15 Mbh when its flow of water is at the rate of 1 gpm, and when its average temperature is 175 F. Assume that the flow of water is increased 50 per cent—from 1 gpm to 1.5 gpm. The water will then flow through the radiator in two-thirds the time and will cool two-thirds as much; *i.e.*, it will cool 20 F instead of 30 F, and the average radiator temperature will be 180 F instead of 175 F. If the surrounding temperature is 70 F, the temperature differences, radiator and surroundings, will be 110 and 115 F, respectively. Consequently, the heat dissipation will be increased only about 6 per cent when the quantity of water flowing through the radiator is increased 50 per cent.

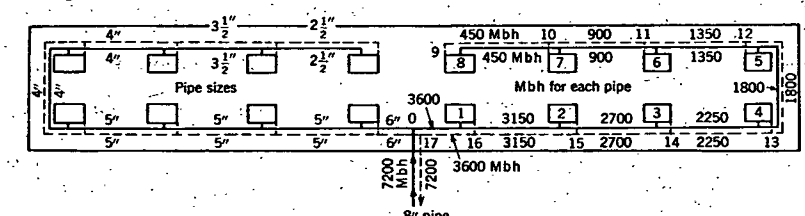

FIG. 15. TWO-PIPE DIRECT RETURN SYSTEM

By decreasing the main from 1¼ to 1 in. between radiator branches while the flow is decreased from 6 to 5 gpm, the *fh* in that section of the main is increased from 344 to 1370 milinches, or 926 milinches. Hence, for the four radiator sections the increase is 3704 milinches, and the total *fh* for the circuit will be 11,696 plus 3704, or 15.4 in. instead of 11.7 in. as first calculated. The pump must, therefore, circulate 6 gpm against a head of 1.3 ft.

Reversed and Direct Return Systems

In a reversed return system the radiators are connected so that all circuits are practically of equal length and so that the water flowing through the radiator nearest the boiler must travel practically as far as