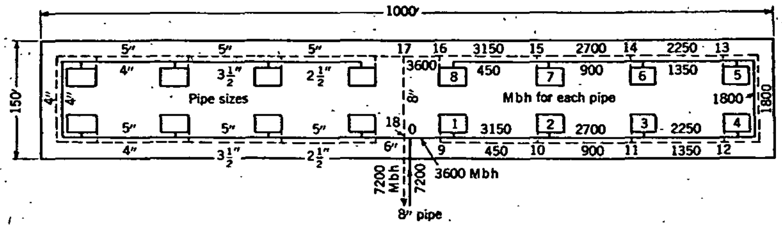

FIG. 15. TWO-PIPE REVERSED RETURN SYSTEM

and as a result less than 6 gpm will flow in the main between the points A and B, and the friction 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 friction from A to B assumed to be 4 x 86, or 344 milinches. The head 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 head 344 ÷ 32, or about 11 milinches per foot. With this head, a $\frac{3}{4}$ in. pipe will convey about 5 Mbh (Fig. 4), 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 deg 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 friction 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 $1\frac{1}{4}$ 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 friction for 1 gpm and a $\frac{3}{4}$ 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 4), and the equivalent length of the main circuit equal to 5.7 ft.

The friction 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 friction 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 deg, 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 deg.

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.

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

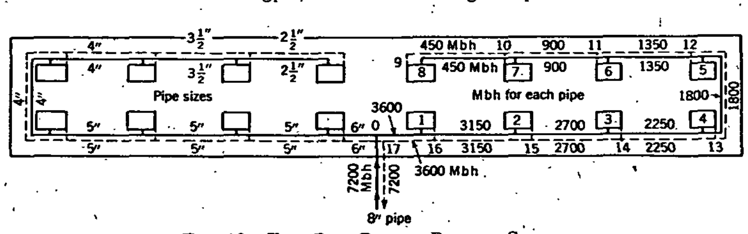

FIG. 16. TWO-PIPE DIRECT RETURN SYSTEM

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 deg instead of 30 deg, 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 deg, 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.

By decreasing the main from $1\frac{1}{4}$ to 1 in. between radiator branches while the flow is decreased from 6 to 5 gpm, the friction 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 friction 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 the water flowing through the radiator farthest from the boiler, as illustrated in Fig. 15. In a direct return system the radiators are connected so that all water returns to the boiler along the most direct path after it has passed through its radiator, as illustrated in Fig. 16.

Example 7. In Fig. 15, sixteen air conditioning units, each demanding 450 Mbh, are to be supplied with water from a central plant. The system is divided into two equal parts as shown. Each part supplies eight units and has, therefore, eight circuits. The total length of each of the eight circuits is about 1170 ft.

Solution. If the total friction is to be about 15 ft, the unit friction must be about 150 milinches per foot. With this preliminary estimate, pipe sizes may be selected from Fig. 4 and recorded with corresponding calculations as shown in Table 7 for Circuit 8, from which it appears that the friction of this circuit is 188,570 milinches, or 15.7 ft.

In order that each of the eight air conditioning units may receive an equal supply of water, the friction of each of the remaining circuits must also be 15.7 ft. Since all pipe sizes have been selected as shown in Example 6, any adjustments that may be necessary must be made in the connections from the main through the air conditioning unit and back to the main. For Circuit 8 the friction through the air conditioning unit was assumed to be 20,000 milinches. For Circuit 4, for example, a tabular calculation like that for Circuit 8 shows that the friction for Section 4-12 must be 19,700 milinches in order that the total friction may be 15.7.

This is practically equal to the 20,000 milinches assumed for Circuit 8 and this shows how simple it is to secure well-balanced circuits in a reversed return system.

Example 8. The direct return, forced circulation system shown in Fig. 16 is similar to Fig. 15, except that the water passing through Unit 1 returns directly to the boiler and the total length of this circuit is about 130 ft, whereas, the total length of Circuit 8 is about 1990 ft, or about 15 times as long.

Solution. The design must begin with Circuit 8. The calculations for this circuit if tabulated as shown for Circuit 8 of Fig. 15 will show that the total friction is 318,200 milinches, or 26.5 ft, as compared with 15.7 ft for the reversed return system.

In order that each of the eight units will receive its correct share of the water, the friction of each of the other seven circuits must also be 26.5 ft. For Circuit 1, for example, the total friction for Section 0-1 and 16-17 is 15,600 milinches; hence, the friction in Section 1-16 (through the air conditioning unit) must be 302,600 milinches, or 25.15 ft to prevent Unit 1 having an advantage over Unit 8.

Comparing the reversed return system of Fig. 15 with the direct return system of Fig. 16 it appears that the head against which the pump must deliver the 720 gpm is 15.7 ft as compared with 26.5 ft for the direct return and that the installation of the reversed return would require 130 ft of 8 in. pipe not necessary for the direct return system. The friction in the lines joining the pump to the pipe system shown in Figs. 15 and 16 is not included in this calculation.