Fig. 8, the pressure head and the temperature difference were assumed and the pipe sizes found. In this case, the pressure 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 pipe system and of the radiation is reduced by reducing the temperature difference and by reducing the pipe sizes, but the *ph* and the cost of pumping the water are increased. 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 F will be selected as the temperature difference and the pipe sizes will be chosen as shown in Fig. 11. A calculation similar to that of Table 6 will show that the *fh* of Circuits 1, 2, and 3 will be, respectively, about 9000, 15,300, and 14,300 milinches. To increase the *fh* 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. 11. If the circulator maintains a pressure head of 15,300 milinches, the velocity in Circuit 1 will increase until the *fh* of the circuit is also 15,300 milinches; i. e., its *fh* 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 F. Consequently, water must flow through these three radiators at the rates of 1, 1.5, and 2 gpm, respectively. When water flows through

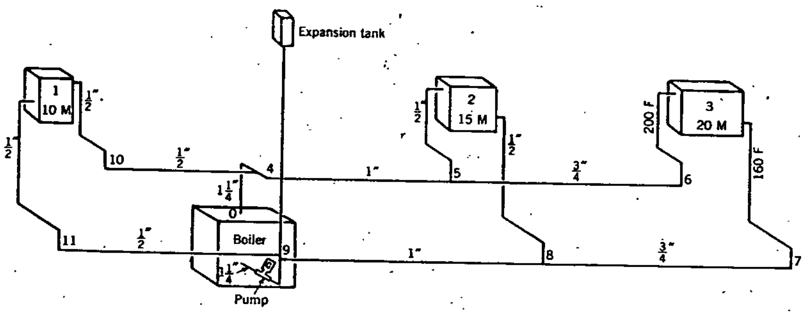

FIG. 11. TWO-PIPE FORCED CIRCULATION SYSTEM

a ½ in. pipe at the rate of 1 gpm, the velocity in the pipe is (Fig. 3) about 13 in. per second and the unit *fh* 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 *fh* is 8250. In order that the *fh* may be increased 6300 milinches, the unit *fh* must be increased 126 milinches; consequently, the velocity in the ½ in. pipe (Fig. 3) must be increased from 13 to 16 in. per second. Hence, when the *fh* 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 water flows through more than one radiator before it returns to the boiler to be reheated. A two-pipe system as shown in Figs. 10 and 11 is one in which the water returns to the boiler to be reheated after it has passed through one radiator. Many large heating systems contain some one-pipe and some two-pipe sections. The piping system shown in Fig. 12 functions with a flow-return temperature difference of 40 F.

Solution. Since the four radiators are each to deliver 15 Mbh, and since the water is to leave the boiler at 200 F and return at 160 F, Radiator 1 will receive 200 F water, Radiator 2, 190 F water, Radiator 3, 180 F water, and Radiator 4, 170 F water. Since the system is to supply 60 Mbh with a temperature difference of 40 F and since 1 lb of water liberates 1 Btu when cooled 1 F, it is necessary that water circulate through this

system at the rate of 60,000 ÷ 40, or 1,500 lb per hour, or 25 lb per minute. Assuming one gallon of water to weigh 8.33 lb, water must circulate in the system at the rate of 3 gpm. If the temperature difference were 20 F instead of 40, the circulation would be at the rate of 6 gpm. It is well to remember that, with a temperature difference of 20 F, water circulating at the rate of 1 gpm will convey heat at the rate of 10 Mbh. The chart of Fig. 3 shows the rate of circulation in gpm on the upper scale and the corresponding heat conveyance on the lower scale.

The system may be divided into 5 separate systems. Each of the four radiators with its flow and return lines constitutes an elementary heating system (similar to Example 1), and the flow main with its two risers is also a complete elementary system.

If the center of the boiler is 4 ft below the center of the flow main, and if the flow riser contains 200 F water and the return riser, 160 F water, the *ph* for the main circuit is (Fig. 4) 4 x 175, or 700 milinches. The circuit consists of 110 ft of pipe and 10 elbow equivalents; its equivalent length is about 150 ft if a 2 in. pipe is used as the main. The average *ph* will be 700 ÷ 150, or 4.7 milinches. According to Fig. 3 or Table 1 for a 4.7 milinch *fh*, a 2 in. pipe will convey about 70 Mbh. Since the pipe is to convey only 60 Mbh, it is slightly too large but should be used. The *fh* will, then, be 3.5 milinches instead of the permissible 4.7. The water will circulate with a temperature difference slightly less than 40 F, and the three last radiators would receive water slightly warmer than indicated in Fig. 12.

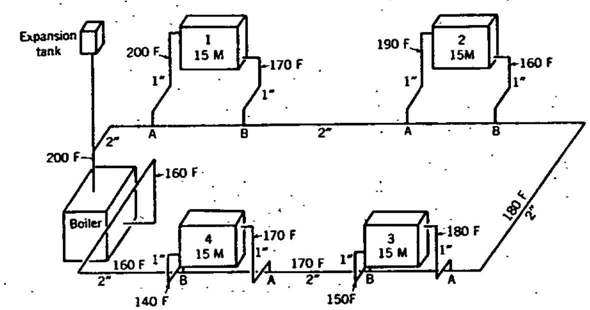

FIG. 12. ONE-PIPE GRAVITY CIRCULATION SYSTEM

As the water flows in the main and arrives at one of the four points marked *A*, the flow will be divided and a portion of the water will take the short path in the main to the point *B*, and the remainder will take the long path through the radiator to the point *B*. Since the two paths together offer less resistance to the flow than the one path alone, the unit *fh* will be less than 3.5 milinches between the points *A* and *B*. If the distance from *A* to *B* is 4 ft, and if, for example, the flow in the short path is 2 gpm, the *ph* forcing the water along the two paths is 4 x 1.6, or about 6 milinches. Since the *fh* of the long path is much greater than the *fh* of the short path, only a comparatively small portion of the water would take the long path. However, the gravity head of the radiator supplies an additional *ph* for the long path. If the center of the radiator is 4 ft above the main and if the radiator circuit is designed for a temperature difference of 30 F, the radiator *ph* will be about 4 x 120, or 480 milinches. In that case, the *ph* is 6 milinches for the short path and 486 milinches for the long path. The radiator circuit consists of 11 ft of pipe and about 14 elbow equivalents. If the circuit is of 1 in. pipe, its equivalent length is about 40 ft and the unit *fh* should be 486 ÷ 40, or 12 milinches. For this *fh* and 30 F temperature difference, a 1 in. pipe conveys about 15 Mbh (Fig. 3). A 1 in. pipe is, therefore, the correct size, and the water would flow through the radiator with a temperature difference of 30 F.

Since each of the four radiators delivers one fourth of the total heat, and since the total temperature difference is to be 40 F, the water would cool 10 F in every radiator if all the water passed through every radiator. Since the water cools about 30 F in flowing through the radiator only ⅓ of the water flows through the radiator and ⅔ flow through the main from point *A* to point *B*.

It follows from these calculations that, if the main is of 2 in. pipe and the radiator