shown, and the methods of balancing the several radiators or circuits are illustrated. A simple gravity system is shown in Fig. 7 and an elementary forced circulation system is diagrammed in Fig. 8.

Elementary Gravity System

Example 1. A simple gravity-circulation system is illustrated in Fig. 7 with one radiator that is giving off heat at the rate of 20,000 Btu per hour or 20 Mbh. The boiler imparts heat to the water at the same rate, and the water circulates at a uniform velocity. The thermal or gravity *pressure head* which produces the circulation is equal to the friction head which resists the circulation. The circuit consists of 1 boiler, 1 radiator, 2 ells, 1 radiator valve and a total of 24 ft of pipe.

Solution. With the average water temperatures of 200 and 180 F in the supply and return risers, respectively, the pressure head will be 90 milinches per foot of water column. This pressure head may be found from Fig. 4. Since the center of the radiator is 10 ft above the center of the boiler, the total pressure head of the circuit is 10 x 90, or 900 milinches, or 0.9 inches of 190 F water. The friction head of the circuit must then also be 900 milinches. The friction head of 1 ft of 1 in. pipe is found from Fig. 3 to be about 46 milinches at 20 Mbh, and the corresponding velocity 9 in. per second. (Note that all values in Fig. 3 are based on a temperature difference of 20 F.)

Similarly, if a 1¼ in. pipe were to be used, the friction head would be about 12 milinches per foot and the corresponding velocity about 5 in. per second, from Fig. 3.

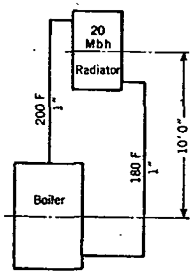

Fig. 7. Gravity System

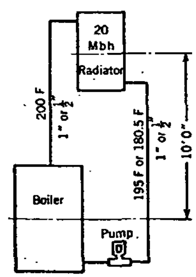

Fig. 8. Forced Circulation System

To find the friction head in the elbows, boiler, radiator and valve, Table 3 is used, and the entire circuit is found to be equal to 10 elbow-equivalents plus 24 ft of pipe. Each elbow-equivalent is equal to a pipe length of 25 times the nominal diameter. Then the equivalent lengths of straight pipe are 45 ft of 1 in. pipe or 50 ft of 1¼ in. pipe.

Hence, if 1 in. pipe is used, the *fh* (friction head) of the circuit will be 45 x 46, or 2070 milinches, and if 1¼ in. pipe is used, the *fh* will be 50 x 12, or 600 milinches. A 1 in. pipe would, therefore, be too small and a 1¼ in. pipe too large to permit the desired circulation with a flow-return temperature difference of 20 F.

If the circuit is of 1 in. pipe, the circulation will take place with a temperature difference greater than 20 F, and if the circuit is of 1¼ in. pipe, the circulation will take place with a temperature difference smaller than 20 F. To find, for example, the temperature difference at which a circuit of 1 in. pipe would transmit the required 20 Mbh, assume the difference to be 40 F. The *ph* (pressure head) would be (Fig. 4, from 200 to 160) 175 milinches per foot, or 1750 for the system. The *fh* for the system may be found from Fig. 3; the chart of this figure is based on a temperature difference of 20 F; if the temperature difference were 40 F, the heat conveyed would be twice that shown in the chart. Hence, find 10 Mbh on the lower scale, proceed vertically upward to the intersection with the 1 in. line, and from there to the left scale and read 13 milinches per foot. Note that the velocity would then be only about 5 in. per second. The total *fh* would then be 45 x 13 or 585 milinches. Since the *ph* would be 1750, circulation would take place with a temperature difference less than 40 F. The required temperature difference may be determined by constructing the diagram of Fig. 9, from which it appears that the temperature difference with which the 1 in. pipe circuit would function is about 30 F. Hence, if the flow riser temperature is 200, the return riser temperature will be 170, and the average water temperature in the radiator, about 185 F.

Elementary Forced Circulation System

Example 2. Design a system for the piping arrangement shown in Fig. 8, according to one of the outlined procedures. The *ph* developed by the circulating pump and the pipe size may be assumed and the flow-return temperature difference found; or, the *ph* developed by the pump and the flow-return temperature difference may be assumed and the pipe size found; or the pipe size and the flow-return temperature difference may be assumed and the *ph* found which the circulating pump must develop.

Solution. Assume that the circulating pump will develop a *ph* of 2 ft or 24,000 milinches and that a 1 in. pipe is to be used. The equivalent length of the circuit will then be 45 ft, as in Fig. 7, and the available *ph* will be 24,000/45, or 533 milinches per foot. In Fig. 3, find 533 on the left scale, move horizontally to the intersection with the 1 in. pipe line, and read about 77 Mbh delivered by the pipe (with a velocity of about 35 in. per second) for a temperature difference of 20 F. Since the circuit is to deliver only 20 Mbh, the temperature difference will be 20 divided by 77 and multiplied by 20, or 5.2 F. Hence, if the flow riser temperature is 200, the return riser temperature will be about 195, and the average water temperature in the radiator, about 197.5 F.

If a ½ in. pipe were used instead of a 1 in., the equivalent length of circuit would be 35 ft instead of 45; the unit *ph*, 686 milinches instead of 533; the velocity, 27 in. per second instead of 35; the temperature difference, 19.5 instead of 5.2; and the average water temperature in the radiator, about 190.5 instead of 197.5 F.

If the 1 in. pipe is used for the circuit, the gravity *ph* will be 22 milinches per foot,

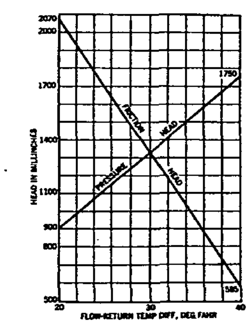

Fig. 9. Determination of Required Temperature Difference

or 220 for the circuit (Fig. 4, 200 to 195). Since this is only 1 per cent of the pump *ph* (24,000 milinches), it may be neglected in the calculation, as was done previously. However, there are cases in which the gravity *ph* is so large compared with the pump *ph*, that it should be included in the calculation.

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.