of 1 ft of 1 in. pipe is found from Fig. 4 to be about 46 milinches at 20 Mbh, and the corresponding velocity 9 in. per second. (Note that all values in Fig. 4 are based on a temperature difference of 20 deg).

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. 4.

To find the friction 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 friction of the circuit will be 45 x 46, or 2070 milinches, and if 1¼ in. pipe is used, the friction 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 deg.

If the circuit is of 1 in. pipe, the circulation will take place with a temperature difference greater than 20 deg, and if the circuit is of 1¼ in. pipe, the circulation will take place with a temperature difference smaller than 20 deg. 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 deg.

From Fig. 5, the head available for producing circulation would be 175 milinches per foot or 1750 for the system for a temperature drop from 200 to 160 F. The friction of the

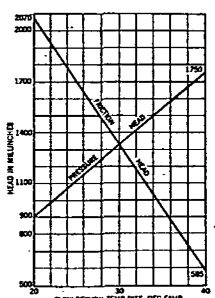


FIG. 10. DETERMINATION OF REQUIRED TEMPERATURE DIFFERENCE

system may be found from Fig. 4; the chart of this figure is based on a temperature difference of 20 deg; if the temperature difference were 40 deg, 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 read 13 milinches per foot. Note that the velocity would then be only about 5 in. per second. The total friction would then be 45 x 13 or 585 milinches. Since the head would be 1750, circulation would take place with a temperature difference less than 40 deg. The required temperature difference may be determined by constructing the diagram of Fig. 10, from which it appears that the temperature difference with which the 1 in. pipe circuit would function is about 30 deg. 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. 9, according to one of the outlined procedures. The procedure may be as follows: Assume the head developed by the circulating pump and the pipe size and find the flow-return temperature difference; or, assume the head developed by the pump and the flow-return temperature difference and find the pipe size; or, assume the pipe size and the flow-return temperature difference and find the head which the circulating pump must develop.

*Solution.* Assume that the circulating pump will develop a head 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. 8, and the available head will be 24,000/45, or 533 milinches per foot. In Fig. 4, 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 deg. 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 deg. 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 head, 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 head will be 22 milinches per foot, or 220 for the circuit (Fig. 5, 200 to 195). Since this is only 1 per cent of the pump head (24,000 milinches), it may be neglected in the calculation, as was done previously. However, there are cases in which the gravity head is so large compared with the pump head, 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 head forcing the water from the boiler to any one radiator is equal to the friction in that radiator's circuit when the

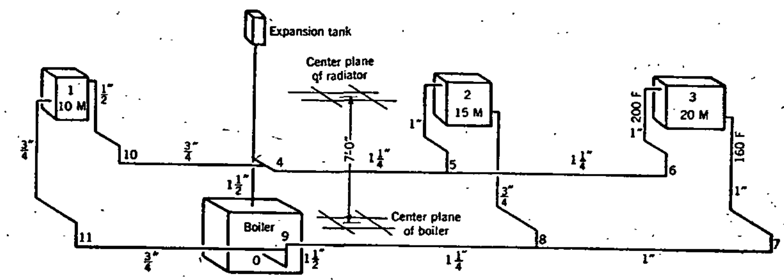


FIG. 11. TWO-PIPE GRAVITY CIRCULATION SYSTEM

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. 11, 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 deg flow-return temperature difference. The head for each radiator is 7 x 175 (Fig. 5), or 1225 milinches; the friction for each radiator circuit must, therefore, also be 1225 milinches.

*Solution.* In order to design a radiator circuit accurately and systematically, the circuit should be divided into sections. The division points of sections must be where the pipe sizes change or may change, and where the volume of water flowing in the pipe changes. The data relating to the several sections may be recorded as shown in Table 6.

Data recorded in Table 6 show that Circuit 3 consists of 70.4 ft of pipe and 21.5 elbow equivalents. Assuming that the average size of the pipe will be 1¼ in., the 21.5 elbow equivalents may be replaced by 21.5 x 2.6 (25/12 x 1.25 x 1.0), or 56 ft of pipe, which would make the total equivalent length of the circuit 70.4 plus 56 or 126.4 ft of pipe, and the average friction 1225/126.4, or about 10 milinches per foot. For this unit friction and a temperature difference of 40 deg (see Fig. 4), a 1 in. pipe will convey 18 Mbh, a 1¼ in. pipe, 37 Mbh, and a 1½ in. pipe, 56 Mbh. The pipe sizes for the several sections of Circuit 3 may be selected as indicated in Table 6. Having selected the pipe