first radiator receives the hottest water; the second radiator, somewhat cooler water; the third one, still cooler; and so on. As the temperature of the water supplied to a radiator is lowered, the size of the radiator must be increased and, consequently, the total heating surface for a one-pipe system must be greater than that for a two-pipe system for the same service.

Two-pipe systems may be divided into two classes, ***direct return*** systems (Fig. 1), and ***reversed return*** systems (Fig. 2). In a direct return system the water returns to the heater by a direct route after it has passed through its radiator and, as a result, the paths through the three radiators shown in Fig. 1 are of unequal lengths, the path through the first radiator being the shortest and that through the third radiator, the longest. In a reversed return system, the water returns to the heater by an indirect route after it has passed through the radiators, so that the paths leading through the three radiators shown in Fig. 2 are practically of equal length.

The reversed return system has an advantage over the direct return system in that it is more likely to function satisfactorily even though the

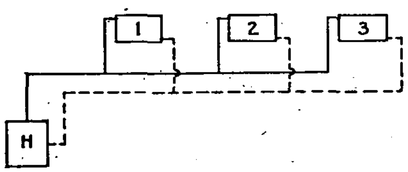

FIG. 1. A DIRECT RETURN SYSTEM

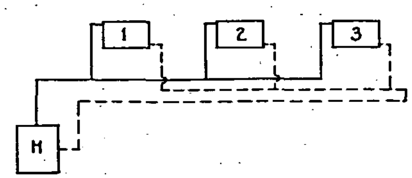

FIG. 2. A REVERSED RETURN SYSTEM

pipe system is not accurately designed. For example, if in Fig. 2 all pipes are of one size, each of the three radiators will receive approximately the same quantity of hot water because the three paths are practically of equal length, whereas in Fig. 1, if all pipes are of the same size, Radiator 1 will receive more water than the others because the path through it is shorter than those through the other radiators. As a result, Radiator 1 will be filled with water at a higher average temperature than the remaining two radiators, and will therefore dissipate more heat. To prevent this unequal distribution of heat it is necessary to throttle the paths through Radiators 1 and 2 so that the friction heads of the three paths are equal when each radiator receives its proper quantity of water.

A comparison of Fig. 1 and Fig. 2 may suggest that a reversed return system requires considerably longer mains than a direct return system. This is not always the case. For example, note the reversed return system of Fig. 3.

SELECTING PIPE SIZES

The pressure heads available in forced circulation systems are much larger than those in gravity circulation systems, consequently, higher velocities may be used in designing the system, with the result that smaller pipes may be selected and the first cost of the installation reduced. As the pipes of a heating system are reduced in size, the necessary increase in

the velocity of the water increases the cost of operating the circulating pump. There is an optimum velocity of the water in a heating system for which the sum of the cost of the system and the cost of its operation is a minimum. This velocity should be determined by calculation for the particular system under consideration.

Since the velocities in forced circulation systems are higher than those in gravity circulation systems, and since the friction heads in a heating system vary almost as the squares of the velocities, a given error in the calculation or assumption of a velocity is less important in a forced circulation system than in a gravity circulation system and, consequently, it

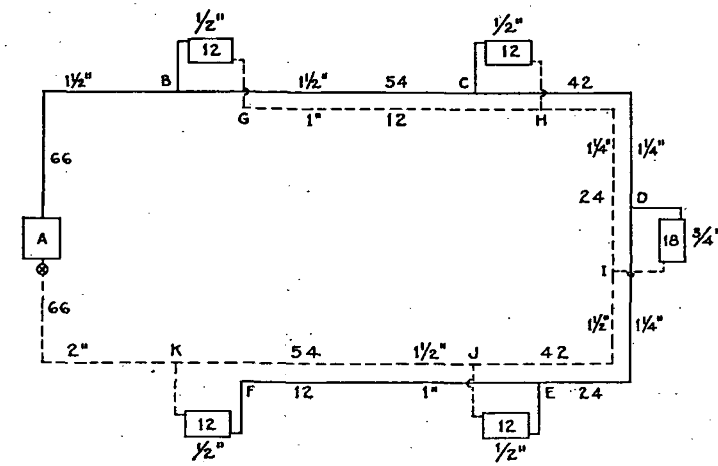

FIG. 3. A FORCED CIRCULATION REVERSED RETURN SYSTEM[a]

[a]This system could be divided into two branches. This would permit the use of smaller pipes and would produce only slight changes in the total length of the pipe. It is shown as a single system here simply to illustrate the method of determining pipe sizes by means of pipe size tables. Note that the numbers on the radiators indicate thousands of Btu per hour (Mbh) and not square feet.

is easier to design a satisfactory forced circulation system than a satisfactory gravity circulation system.

FORCED CIRCULATION

The following examples will illustrate the procedure to be followed in designing forced circulation systems:

Example 1. Assume that the paths through the five radiators shown in Fig. 3 consist each of 150 ft of mains, 5 ft of radiator connections, 1 boiler, 1 radiator, 1 radiator valve, 10 ells, and 2 tees. Design the piping for this system.

Solution. The friction heads in the boiler, radiator, valve, and tee may be expressed in terms of the friction head in one elbow according to the values given in Table 1. Having done this, each of the five circuits is taken as 155 ft of pipe and about 24 elbow equivalents. The friction head of one elbow is approximately equivalent to that in a pipe having a length equal to 25 diameters. Assuming that the average pipe size in this case will be about 1¼ in., one elbow equivalent may be placed equal to about 3 ft of pipe and the total length of the circuit equivalent to about 227 ft of pipe.

Having determined the equivalent pipe length, assume the rate at which the water is