the water flows through one radiator only during its circuit through the system, so that all radiators are supplied with water practically at the same temperature as that in the boiler. In a one-pipe system, the water flows through more than one radiator during its circuit. In that case, the 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 is more than that for a two-pipe system for the same service. This increase in heating surface is objectionable, and one-pipe systems should be installed only when special reasons make them desirable.

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

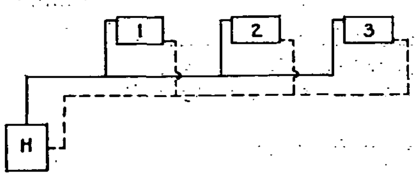

FIG. 1. A DIRECT RETURN SYSTEM

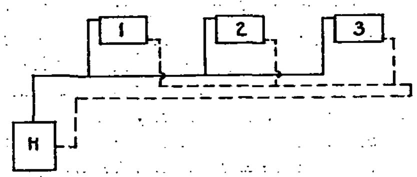

FIG. 2. AN INDIRECT RETURN SYSTEM

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 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 exactly 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.

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 and smaller radiators may be selected, and the first cost of the installation reduced. As the pipes of a heating system are reduced in size, the velocity of the water and the cost of operating the circulating pump are increased. 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

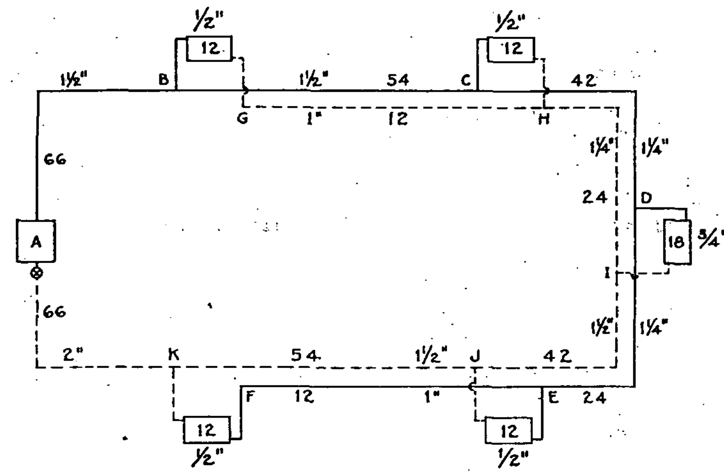

FIG. 3. A FORCED CIRCULATION INDIRECT RETURN SYSTEM[a]

[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 and not square feet.

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 potential in a forced circulation system than in a gravity circulation system, and consequently, it is easier to design and to construct a satisfactory forced circulation system than a satisfactory gravity circulation system. For this reason it is best to begin the study of pipe sizes for hot water heating systems with that of forced circulation.

FORCED CIRCULATION SYSTEM

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.