in Figs. 1 and 2. With the reversed return system, the water has to travel approximately the same distance from and back to the boiler for any one radiator as for any other radiator, and therefore, the friction and temperature losses to all radiators should be nearly the same.

In some cases the reversed return system involves no more piping than the direct return system. In the case of large buildings, it might be advisable to zone the piping.

Mechanical Circulators

Circulating pumps are usually of the centrifugal type. The capacity of the pump is figured from the Mbh (symbol representing 1000 Btu per hour) required for heating and the drop in temperature selected. For example, for 100 Mbh and 20 F drop a pump having a capacity of 5000 lb water per hour or 10 gpm. The resistance head is based on the system as designed. In large systems the economical size of pump may be determined by comparing the cost of power for operation, with the annual charges on the capital cost of the piping system, as larger pipe sizes mean less pump power. Velocities through piping in excess of 4 fps are likely to cause disturbing noises in buildings other than factories. In large

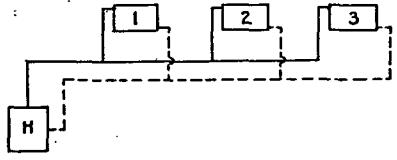


FIG. 1. A DIRECT RETURN SYSTEM

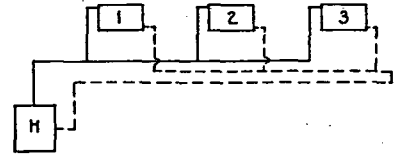


FIG. 2. A REVERSED RETURN SYSTEM

systems the pumps are run continuously while in small ones they are run either continuously or intermittently depending on the type of automatic temperature control selected. Small circulating pumps are usually driven by direct-connected electric motors. Under certain conditions a valved by-pass should be provided and the piping so designed that in case of breakdown of the pump or failure of electric current there will be sufficient gravity circulation to keep the building reasonably warm. In large buildings or groups of buildings, it is often advisable to have two pumps, each of about 70 per cent of the total capacity to take care of breakdown service. During mild weather, variations in water temperature may be utilized to balance the required heat loss. In the larger systems steam turbines are sometimes used to drive the pumps, the exhaust steam being used for heating the water, and in such buildings as hospitals this is usually the most economical method.

As the average pump used for water circulation is not over 60 per cent efficient, the cost of power on a large job should be figured and comparisons made between the savings made in capital cost of piping and the annual cost of power.

FORCED CIRCULATION PIPE SIZES

The pressure heads available in forced circulation systems are much greater 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 pipe sizes of a heating system are reduced, the necessary increase in the velocity of the water increases the friction losses and thus the cost of operation and the initial cost of the circulating equipment. The increased velocity of a forced circulation system offers a number of advantages, such as a much shorter heating-up period and a more flexible control of hot water circulation. This improved performance merits the small increase in operating cost necessary to circulate the water mechanically. The velocities required should be determined by calculation for the particular system under consideration.

Since forced circulation velocities are higher than those in gravity 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 is easier to design a satisfactory forced circulation system than a satisfactory gravity circulation system.

In forced hot water systems, it is customary to use a temperature drop of 20 or 30 F between the water entering and leaving the boiler or other heater. The head against which the system is to operate must then be decided. This varies from 2 to 5 ft for small systems and may rise to 100 ft on large jobs with a group of buildings. For iron pipe, the sizes can be figured using Fig. 3 and Tables 1 and 3. For copper tubing Tables 2 and 3 are to be used. In systems designed with reversed returns, it will generally be found that very little adjustment is necessary to secure even distribution to all radiators. However, orifices may be used to control the flow and the capacities are given in Table 5. In large buildings provision should be made for quickly draining radiators in case of breakage, and it is often advisable to install a lock shield valve on one end of each radiator and a hand controlled valve on the other. In case of breakage the two valves can be closed and the radiator removed without effecting the rest of the system. The lock shield valve can also be used for balancing the water circulation.

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

Example 1. From the plan of Fig. 4 note that the longest circuit consists of 151 ft of iron pipe; 1 boiler; 1 radiator; 1 radiator valve; 1 stop cock; 10 ells and 3 tees; and the shortest circuit consists of 127 ft of pipe; 4 tees; 1 boiler; 1 radiator; 1 radiator valve; 1 stop cock; and 6 ells. Design the piping for this system.

Solution. The friction in the various fittings can be expressed in terms of the friction in a 90-deg elbow from the values given in Table 3. The longest circuit consists of 151 ft of pipe and 44 elbow equivalents. The short circuit consists of 127 ft of pipe and 39 elbow equivalents.

The friction head in one elbow is approximately equal to the friction produced by the same sized pipe 25 diameters in length. Assume that the average pipe size for this system is 1 in. The equivalent length of the longest circuit will be 151 ft plus 100 ft or 251 ft of pipe. The equivalent length of the short circuit will be 217 ft.

Having determined the equivalent length of the circuits, the next step is to assume the rate at which the water is to be circulated in the system. The water may flow through the system so that it will cool any reasonable number of degrees. For the most economical average system a 20 F drop seems to be a satisfactory rate. This entails a slower water flow from the pumping equipment with a reasonable relationship between pipe