With the system designed as a gravity flow system, the total drop in temperature through the system was 25 deg.; the total heat output was 54,000 B.t.u., the quantity of water circulating through the system was $\frac{54,000}{25}$, or 2,160 lb. per hour. The heater pressure head was 0.4 in. The corresponding power was $\frac{2,160 \times 0.4}{12}$, or 72 ft. pounds per hour; or $\frac{1}{27,500}$ hp. Similarly, the power developed by the six-radiator pressure heads may be found to be about $\frac{1}{200,000}$ hp.

After having changed the system from gravity to forced circulation, much more power will be supplied by the pump than was supplied by the gravity pressure heads. Consequently, more water can be circulated through the system, thereby reducing the temperature drop through the system and as a result, smaller radiators and pipes may be used, thereby further increasing the velocity of the water and the power necessary to circulate it.

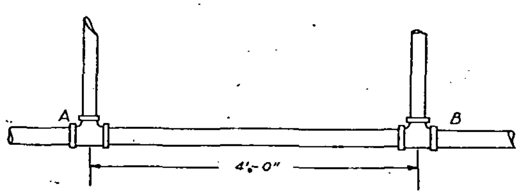

FIG. 9. RADIATOR CONNECTIONS FOR A ONE-PIPE SYSTEM ILLUSTRATING THE INFLUENCE OF THE PRESSURE DROP IN THE MAIN UPON THE CIRCULATION THROUGH THE RADIATOR

Let it be assumed that the total temperature drop is to be 5 deg. instead of 25 deg., and that the main shall be 1½ in. instead of 3 in. In this case the quantity of water circulating through the system will be $\frac{54,000}{5}$, or 10,800 lb. per hour, and the friction head will be 440 mil-inches per foot of pipe and about 1,850 mil-inches per elbow. The total friction head will be about 135 × 440, plus 10 × 1,850, or 6.49 ft. The velocity of the water in the main will be about 42 in. per second. The power required to produce the circulation will be about $\frac{1}{28}$ hp.

Assume that the radiator connections are to be reduced from 1¼ in. to 1 in., and that the distance along the main between radiator connections is 4 ft. as shown in Fig. 9. The pressure head between the points *A* and *B* must be such that it will force 10,800 lb. of water per hour from *A* to *B*. A part of this water moves along the straight pipe from *A* to *B* and the remainder flows through the radiator. The flow through the radiator is caused partly by the pressure head from *A* to *B* and partly by the pressure head produced in the radiator risers; the latter is very small compared with the former and may be neglected, the resulting errors being on the

side of safety. Neglecting the radiator pressure head, the flow of water from *A* to *B* will be so that the friction head in the two possible paths will be equal to each other and equal to the pressure head from *A* to *B*. One path consists of a 1½ in. pipe, 4 ft. long; the other, of a 1 in. pipe, 7 ft. long and 16 elbow equivalents. By a few trial calculations it is found that the friction head from *A* to *B* is about 85 per cent of that calculated before, and that about 900 lb. per hour flow through the radiator. The cooling in the radiator must, therefore, be $\frac{9,000}{900}$, or 10 deg.

The average temperature of the water will be 200 deg. in the first radiator, and 196 deg. in the sixth. The sixth radiator will be 4 per cent larger than the first instead of 25 per cent as calculated for the gravity system.

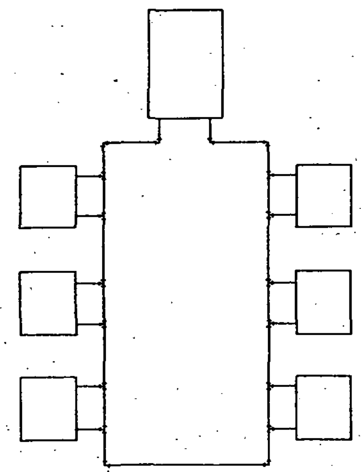

FIG. 10. ONE-PIPE FORCED CIRCULATION SYSTEM FOR SIX BUILDINGS

Relative Economy of Gravity and Forced Circulation

Comparing the economy of the gravity with the forced circulation system it may be concluded that it is more economical to use gravity circulation except when the increased cost produced by installing the pump and by operating, maintaining, and replacing it, when that becomes necessary, is less than the saving effected by using the smaller pipes and smaller radiators, made possible by the use of the pump.

There are some cases where gravity circulation cannot be used. For example: If in Fig. 11 the six rectangles represent six buildings instead of six radiators, each building requiring 500,000 B.t.u. to be supplied from the central plant, it will almost always be necessary to adopt forced circulation for such an installation. The heating main can be arranged as it could be to supply six radiators in a building, as a one-pipe system, Fig. 10; as a two-pipe reversed-returned system, Fig. 11, or as a two-pipe direct-return system, Fig. 12.