boiler, so that the air liberated from the water in the boiler will enter the expansion tank.

In a forced circulating hot water heating system, the pipe to the open expansion tank should be connected on the suction side of the circulating pump, so that the pressure head on the suction side of the pump will remain practically constant.

A closed expansion tank is sealed against free venting to the atmosphere. The tank may be above the highest radiator or heat transmitter, or may be below the lowest one. The minimum contents of a closed expansion tank must be such that the expansion of the water due to increase in temperature will be cushioned against a reservoir of compressed air above the water level in the expansion tank. The tank must provide space not only for the change in water volume, but also for variations in air volume within the tank due to changes in air pressure. If the closed expansion tank is below the heat transmitters, the tank should be larger than if it is above them, and the higher the building, under such circumstances, the larger should be the air capacity within the tank in excess of that required merely for increase in water volume due to temperature increase.

The size of a basement-located closed expansion tank should be at least equal to the following:

One story buildings: $x = 0.10\ V$
Two story buildings: $x = 0.13\ V$
Three story buildings: $x = 0.17\ V$
Six story buildings: $x = 0.28\ V$

where

x = expansion tank size in gallons.
V = water volume in heating system in gallons.

This condition favors, especially in tall buildings, the placing of the closed expansion tank above the highest heat transmitter.

Any closed expansion tank located above the heat transmitters of a hot water heating system should be connected by a direct pipe with the flow main leaving the boiler, in order to enable the air to pass easily to the expansion tank. In a closed hot water heating system the water under pressure tends to absorb air at a rate increasing with pressure increase and decreasing with temperature increase.

Means must be provided to adjust and to observe the proportion of air within any closed expansion tank. This involves the provision of an air inlet valve, a water gage and a relief valve. A source of supply of compressed air for renewing the air cushion is highly desirable, especially in large, high pressure hot water heating systems where it is inconvenient, if not impracticable, to drain down the water in the system so as to permit introduction of atmospheric pressure air.

For every hot water heating system the designer should calculate the volume of water contained in the radiators, piping system, boiler, etc., in order to select the proper size of expansion tank. The water content of the piping can be obtained from Table 5. For a rough selection of size, however, it is sometimes assumed that 50 per cent of the volume of water is contained in the radiators, and that the water content per square foot of radiator heating surface is 0.2 gal for column radiators and 0.13 gal for tube type radiators.

Another rough method for determining the size of an expansion tank

to be located above the highest radiator is to divide the square feet of radiation by the factor 40 to obtain the required capacity in gallons of the expansion tank.

INSTALLATION DETAILS

Items that should be considered in the design of this type of system are:

All piping must be so pitched that all air in the system can be vented either through an open expansion tank, radiators or automatic relief valves.

All piping must be arranged so that the entire system can be drained. Sections of piping individually valved shall have corresponding drain valves.

In large buildings, the piping may be zoned according to exposure of building, usage of building, or method of control.

All piping must be installed so that it is free to expand and contract with changes of temperature without producing undue stresses in the pipes or connections. For this purpose it is generally sufficient to allow for a variation in length of 1 in. for 100 ft of pipe.

The pipe system should be designed so that each circuit has its correct friction head for balanced water distribution. This may be done by change of pipe size or change in piping detail.

Table 5. Volume of Water in Standard Pipe

Pipe Size, In.	Lineal Ft of Pipe Containing 1 Gal
½	63.1
¾	36.1
1	22.2
1¼	12.8
1½	9.47
2	5.75
2½	4.02
3	2.60
4	1.52
5	0.96
6	0.67

The connections from the boiler to the mains should be short and direct, to reduce the friction head and allow for expansion. It is frequently possible to avoid an elbow and to reduce the length of the pipe by running the pipe in a diagonal direction, either in a horizontal or in a vertical plane.

The mains and branches should pitch up and away from the heater, generally not less than 1 in. in 10 ft.

The connections from mains to branches and to risers should be such that circulation through the risers will start in the right direction. Hence, in a one-pipe system the flow connection must be nearer the heater than the return connection. In a correctly-designed two-pipe system, the pressure in the flow main is higher than that in the return main, and a slight variation in the distances of the flow and return connections from the heater is not material; but it is generally best to have the two connections about equally distant from the heater.

Generally connections to risers or radiators are taken out of the top of mains either 45 or 90 deg. In some cases it may be advisable to take the flow connection off the top of the main and the return connection from the side.

With forced circulation and high velocities, it is advisable to let the water enter at the top of the radiator and leave at the bottom of the opposite end. With gravity circulation the flow connection may be either at the top or at the bottom of the radiator. With short radiators both flow and return may be at same end, but top and bottom.

Unless used as heating surface, all piping, both flow and return, should be insulated.

EXAMPLES OF PIPING DESIGN

The following graded series of examples of the design of hot water piping systems will illustrate the fundamental principles and methods. The differences between reversed return and direct return systems are