$$E = 0.04 \times 5000 = 200 \text{ gal.}$$
$$P_1 = 14.7 \text{ psia}$$
$$P_2 = 100 + 14.7 = 114.7 \text{ psia.}$$

Substituting these values in Equation 3,

$$V = \frac{200}{\dfrac{14.7}{14.7 + 0.434\,(70)} - \dfrac{14.7}{114.7}} = \frac{200}{0.327 - 0.128} = 1000 \text{ gal.}$$

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

One story buildings: $x = 0.10\ V$ Three story buildings: $x = 0.17\ V$

Two story buildings: $x = 0.13\ V$ Four story buildings: $x = 0.23\ V$

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.

Table 6. Required *ASME* Size of Closed Expansion Tank

Sq Ft of Equivalent Direct Radiation Installed	Gallon Tank	Sq Ft of Equivalent Direct Radiation Installed	Gallon Tank
Up to 350	18	Up to 1400	40
Up to 450	21	Up to 1600	2—30
Up to 650	24	Up to 1800	2—30
Up to 900	30	Up to 2000	2—35
Up to 1100	35	Up to 2400	2—40

For systems with more than 2400 sq ft of installed equivalent direct water radiation, the required capacity of the cushion tank shall be increased on the basis of one gallon tank capacity per 33 sq ft of additional equivalent direct radiation.

It is common practice to use multiple tank installations on large systems in lieu of one tank, the required capacity of which would be beyond commercially available sizes.

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.

In smaller installations, gage fittings on the tank are usually omitted in order to prevent air loss from the tank. Occasional inspection of the tank or the necessity of adding water to the system will then indicate whether air should be added to the tank.

The *ASME* Low Pressure Heating Boiler Code 1946, in paragraph H-92, specifies that provision must be made for draining a closed expansion

tank without emptying the system. The Code also specifies the minimum sizes of closed expansion tanks based upon the equivalent direct radiation installed. (See Table 6.)

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 7. For a rough selection of size, however, it is sometimes assumed that 50 percent 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 tank.

INSTALLATION DETAILS

Items that should be considered in the design of piping for a hot water 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. When piping must be run around an obstacle such as a beam, it is advisable to drop the piping below the beam. If looped over the beam, it becomes necessary to provide for venting of air from the high point of the pipe.

Table 7. Volume of Water in Standard Pipe

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

When changing the size of horizontal runs of pipe, eccentric fittings should be used to keep the tops of the pipes in line to permit free passage of air along the pipe.

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 for balanced water distribution. This may be done by change of pipe size or change in piping detail.

The connections from the boiler to the mains should be short and direct, to reduce the friction, and should allow for expansion.

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 at either 45 or 90 deg from the horizontal plane.

Supply connections are usually made at the bottom of radiators so that circulation will not be stopped by accumulation of air, as would be the case with a top supply