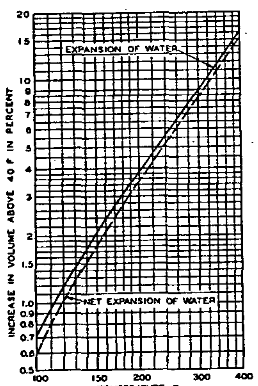
tures of 180 F or less because of system boiling and tank water evaporation problems. The tank should be at least 3 ft above the high point of the system and should be connected to the suction side of the pump to prevent subatmospheric system pressures caused by pump operation.[15] The system should have an internal overflow drain. Provision must be made to prevent water from freezing in the tank, the tank vent, and the pipe leading to the tank. These provisions are also required by the ASME code. The minimum tank volume should be equal to 6 percent of the total system water volume.

The *closed system* utilizes an airtight tank which provides a means of pressurizing the system for operation over a wide range of conditions. As the excess water due to thermal expansion moves into the expansion tank, it compresses the air trapped therein and increases the pressure on the system. If the tank, or the amount of air in it, is too small, the pressure on the system will exceed the maximum allowable, and cause the relief valve to waste water from the system. When the system cools, the pressure will drop to a value less than minimum, making the venting of air impossible or drawing air into the system if automatic air vent valves are located at a high point of the piping. If the tank is too large, it will cost more and require more space.

Determining Tank Size

The size of a closed expansion tank is determined by: volume of the water in the system; range of water temperatures normal to operation of the system; pressure of the air in the expansion tank when the fill water first enters the tank; relationship of the height of the boiler which usually, but not always, is the item in the system with the lowest working pressure; the expansion tank, and the high point of the system; head of the circulating pump; location of the circulating pump with respect to the expansion tank connection, and the boiler. The expansion tank size for a closed system may be determined from the following ASME formula. This formula should be used only for operating temperatures between 160 F and 280 F.



Note: Net expansion of water equals actual expansion of water less volumetric expansion of metal system.[17]

Fig. 16. . . . Expansion of Water Above 40 F

Table 5 . . . . Volume of Water in Standard Pipe and Tube

Nominal Pipe Size Inches	Standard Steel Pipe: Schedule No.	Standard Steel Pipe: Inside Dia Inches	Standard Steel Pipe: Gallons per Lin. Ft	Type L Copper Tube: Inside Dia Inches	Type L Copper Tube: Gallons per Lin. Ft
3/8	—	—	—	0.430	0.0075
1/2	40	0.622	0.0157	0.545	0.0121
5/8	—	—	—	0.666	0.0181
3/4	40	0.824	0.0277	0.785	0.0251
1	40	1.049	0.0449	1.025	0.0429
1 1/4	40	1.380	0.0779	1.265	0.0653
1 1/2	40	1.610	0.106	1.505	0.0924
2	40	2.067	0.174	1.985	0.161
2 1/2	40	2.469	0.249	2.465	0.248
3	40	3.068	0.384	2.945	0.354
3 1/2	40	3.548	0.514	3.425	0.479
4	40	4.026	0.661	3.905	0.622
5	40	5.047	1.04	4.875	0.970
6	40	6.065	1.50	5.845	1.39
8	30	8.071	2.66	7.725	2.43
10	30	10.136	4.19	9.625	3.78
12	30	12.090	5.96	11.565	5.46

$$V_t = \frac{(0.00041t - 0.0466)V_s}{\dfrac{P_a}{P_f} - \dfrac{P_a}{P_o}} \qquad (4)$$

where

V_t = minimum volume of the expansion tank, gallons.
V_s = system volume, gallons.
t = maximum average operating temperature, Fahrenheit.
P_a = pressure in the expansion tank when the water first enters, usually atmospheric pressure, feet of water, absolute.
P_f = initial fill or minimum pressure at tank, feet of water, absolute.
P_o = maximum operating pressure at tank, feet of water, absolute.

A widely used formula recommended for temperatures below 160 F is:

$$V_t = \frac{E}{\dfrac{P_a}{P_f} - \dfrac{P_a}{P_o}} \qquad (5)$$

where

E = net expansion of the water[16] in the system when heated from minimum temperatures to maximum temperature, gallons (See Fig. 16).

The volume of the water in a system should be determined from water capacities of heating units as given by manufacturers and the volume of pipe or tube from tables such as Table 5.

Effect of Pump Location

The required minimum pressure, P_f, and the maximum pressure in the expansion tank, P_o, may change for specific systems, depending on the effect of relative pump and tank location on system pressure changes caused by pump operation. Refer to diagrams *A*, *B*, *C*, and *D* of Fig. 17 and following discussion.

The degree of system pressure change caused by pump operation is established by the pump head. Whether the pump head will be added to, or subtracted from the system static pressure at the time of pump operation is determined by the relative pump and tank location. This is so because *the junction of the tank with the system is a point of no pressure change* regardless of whether or not the pump operates. Consequently, when the tank is located close to the pump suction, the pump suction pressure is unchanged when the pump starts and the pump head appears as an increase of pressure on the system. Conversely, when the tank is located close to the pump discharge, the pump discharge *pressure is unchanged when the pump starts and the pump* head appears as a decrease in pressure at the pump suction and on the system.

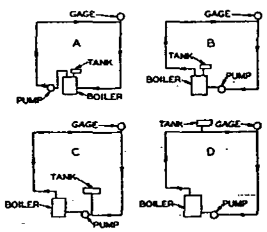


Fig. 17. . . . Effect of Pump Location and Expansion Tank Connection

When the pump discharges away from the boiler and expansion tank (*A*, Fig. 17) all pressure changes created by pump operation are additive. A gage located at any point in the system will show an increase in the pressure on starting the pump equal to the friction pressure drop between the gage and the boiler inlet (tank). Since the tank is located on the boiler, boiler pressures are unaffected by pump operation. The minimum pressure, P_f, required, is equal to height of the system above the expansion tank, plus any pressure required to assure positive air venting and prevent boiling; if the maximum water temperature exceeds 212 F. The maximum pressure, P_o, depends upon the pressure rating of that item of equipment having the lowest rated working pressure, usually the boiler or boiler relief valve, and the vertical distance between it and the expansion tank. This arrangement is recommended where high *head pumps are used.*

When the pump discharges into the boiler and expansion tank (*B*, Fig. 17), all pressure changes induced by pump operation are subtractive. A gage, located at any point in the system, will show a decrease in pressure on starting the pump equal to the pipe friction pressure drop between the gage and boiler outlet (tank). Assuming no friction loss between the discharge of the pump and the expansion tank, the minimum pressure, P_f, must be increased above that discussed for *A*, Fig. 17, by the head of the pump. The maximum pressure, P_o, is determined as described for *A*, Fig. 17. Arrangement *B* results in the largest size expansion tank, but is commonly used in residential and other small installations where water volumes, system heights, and pump heads are all low.

When the pump discharges into a boiler and the tank is connected to the pump suction line as in *C*, Fig. 17, the boiler is subjected to an increase in pressure equal to the pump head when the pump operates. The required minimum pressure, P_f, is as described for *A*, Fig. 17. The tank final operating pressure, P_o, equals the boiler working pressure, as discussed under *A*, Fig. 17, minus the pump head. With arrangement *C* the size of the expansion tank will be smaller than for arrangement *B*, but larger than for arrangement *A*.

Attic tanks are used for the purpose of tank size reduction. When used, as shown in *D*, Fig. 17, a gage located at any point between the tank and the discharge of the pump will show an increase in pressure when the pump operates, while any point between the tank and the suction line of the pump will show a decrease in pressure. This decrease in pressure on the suction side of the tank connection requires that a pressure equal to friction loss between the tank connection and the suction of the pump should be added to the vertical distance the tank is located below the high point of the system to obtain the minimum tank pressure, P_f. Since the pump is located between the expansion tank connection and the boiler, the maximum tank pressure, P_o, would be obtained as described under *C*, Fig. 17, except that pump effect on the boiler pressure is reduced by the friction *loss between the tank connection and the boiler. If the* pump were discharging from the boiler instead of into it, the pump operation would not affect P_o.

The following *Examples 4, 5*, and *6* illustrate the principles applying to sizing of closed expansion tanks.

The system used in the examples has: (1) a water volume of 1000 gal, (2) a high point of the system at the top of a return riser 25 ft from the top of the boiler directly above the boiler room, (3) a circulating pump having a 20-ft head, and a 30 psi boiler with an ASME rated relief valve as the item of equipment having the lowest pressure rating. The P_a is atmospheric pressure, 34 ft of water, absolute, in all examples. The design average water temperature is 200 F. Friction losses between the high point of the system and the boiler are assumed to be negligible.

Example 4: Determine the size of expansion tank required when connected as shown in *A*, Fig. 17.

Solution: Installation is as shown in *A*, Fig. 17, with the expansion tank at the same level as the relief valve. The net expansion of the water in the system is represented by the term $(0.00041\,t - 0.0466)V_s$ of Equation 4 and, hence, is

$$[(0.00041)(200) - 0.0466]\,(1000) = 35.4 \text{ gal.}$$

As stated, P_a is 34 ft of water, absolute. Referring to the discussion for *A*, Fig. 17, P_f, *the minimum pressure, is equal to the* height of the system above the expansion tank, 25 ft, plus 4 ft for positive venting, a total of 29 ft of water, gage, or 63 ft of water, absolute. P_o is equal to the relief valve setting, 30 psi × 2.31 ft of water, 69.3 ft of water, gage, or 103.3 ft of water, absolute.

Substituting in Equation 4:

$$V_t = \frac{35.4}{\dfrac{34}{63} - \dfrac{34}{103.3}} = 170 \text{ gal.}$$

Example 5: Determine the size of expansion tank required when connected as shown in *B*, Fig. 17.

Solution: All conditions remain the same, except that the expansion tank connection is at the discharge of the pump rather than at the suction. When the pump operates, the pressure at the top of the return riser is reduced by an amount equal to the head of the pump. Therefore, to maintain a positive pressure at the top of the system, the minimum pressure must be in-