Thermal Expansion Tanks

Roger Griffith
VP Legislation, ASPE
East Tennessee Chapter

When heated, water expands. We all know that. But when a hot water system has a backflow preventer or check valve on one end and closed fixtures on the other end, the heated water has nowhere to expand, and system pressures can rise quickly and unseat the pressure-relief valve. This relieves the pressure, but repeated pressure excursions and relief valve operation reduces the system integrity, results in leaking valves, and wastes energy. The 1997 Standard Building Code paragraph 607.3.2 requires that a device for controlling pressure be installed when system pressure can increase in this manner. A thermal expansion tank is the preferred method for controlling pressure excursions.

How do you size thermal expansion tanks? The easiest method is to go to the tables in a manufacturer's catalog. The tables give the expansion tank manufacturer's model number corresponding to the selected water heater volume and supply pressure. These tables are based on three important assumptions.

First, the tables are based on a maximum allowable line pressure (when the thermal expansion tank is at maximum capacity) of 150 psi, which is the pressure setting of the water heater relief valve. In other words, the thermal expansion tank, if sized by the tables, could allow the system pressure to reach 150 psi, which is the relieving point for the relief valves – the whole intent is to avoid this point in the first place. I prefer to size the thermal expansion tank for a maximum allowable pressure of 135 psi, which is 10% below the relief valve set point.

Second, the manufacturer's tables are based on a tank precharge pressure of 40 psi. This by the way is not founded upon good engineering principle but is the Department of Transportation shipping limitation. Thermal expansion tanks should be sized based on a precharge air pressure equal to the line pressure. This reduces the size of the tank, which is a good deal for the owner. Please note – if expansion tanks are sized based on a precharge air pressure equal to line pressure, your specification should direct the contractor to charge the tank to that pressure. According to the SPC paragraph 604.8, the maximum line pressure is 80 psi, unless main supply risers having higher pressures are used in conjunction with pressure reducing devices prior to the fixtures. So the precharge pressure will typically be somewhere between 40 psi and 80 psi. If you want to do a good job and size the expansion tanks for a precharge air pressure equal to the line pressure, don't go to the tables.

Third, most of the manufacturer's sizing tables are based on a temperature rise of 40^0F. Think about this for a moment. The water heater is typically sized based on a 100^0F temperature differential. Typically, we assume cold water entering at 40^0F and being heated and stored at 140^0F. If we are designing the water heater to raise the water temperature 100^0F, shouldn't we size the expansion tank to accommodate the expansion of water that is heated 100^0F? This is, of course, a worst case scenario (complete emptying of the tank and filling with 40^0F cold water) which is likely to happen only a few times a year, but relief valves often start leaking after only two or three operations. I believe designing an expansion tank based on a 40^0F temperature rise is less than conservative.

This all means that if we want to design thermal expansion tanks for a maximum allowable pressure less than 150 psi, a precharge air pressure greater than 40 psi, and a temperature differential greater than 40^0F, we can't use the tables. Also on large systems the tank sizes are larger than the values in the tables. So what do we do? We use those dreaded things called *equations*. Here is my simplified method for sizing expansion tanks. A much more detailed and sophisticated method is presented in the ASPE Data Book, Volume 4.

To select a thermal expansion tank, the total capacity and the acceptance volume have to be calculated. The total capacity is the air volume of the tank when it is empty (no water). The acceptance volume is the amount of water that the tank will accept. First determine the amount of water that will expand in your system that the expansion tank will have to accommodate. This calculation is based on the temperatures of the water and the volume of the heater.

(1) $$V_{ACC} = V_T \times (Vs_2/Vs_1 - 1)$$

where,

V_{ACC} = Acceptance Volume (gallons)
Vs_2 = Specific volume of water at heated temperature, (ft^3/lb)
Vs_1 = Specific volume of water at entering temperature, (ft^3/lb)
V_T = Water heater storage tank volume (gallons)

The specific volume of saturated water at various temperatures can be found in tables of thermodynamic properties, or there is a handy table in the ASPE Data Book. Here is a good number to remember. Water heated from 40^0F to 140^0F will expand 1.7%. For example, let's assume we have a 120 gallon water heater and the water is heated from 40^0F to 140^0F.

V_{ACC} = 120 (0.01629/0.01602 – 1) = 120 (.017) = 2.0 gallons

This is the amount of water that the thermal expansion tank should accept. I know that this is a simplified approach. We have ignored the hot water in the piping that will expand, and we have also ignored the fact that the heater tank and the hot water piping will expand, thus providing a small amount of expansion volume. It is my experience that when these things are factored in, the results are insignificantly small. When the calculations are completed, we select tanks that come in rather large size increments. By the way, that is why I don't bother correcting for altitude. We typically don't need to be that accurate. Since we are assuming a 100 degree temperature difference, we have some built-in conservatism.

The final step is to determine the total tank capacity. The equation comes from Boyle's law. I will not bother with the explanation, but just give you the formula.

(2) $$V_{ET} = V_{ACC} / (1- P_1/P_2)$$

where,

P_1 = Static water line pressure, (psia)
P_2 = Maximum desired tank pressure, (psia)
V_{ACC} = Acceptance volume, (gallons)
V_{ET} = Total volume of expansion tank, (gallons)

(*Note that the pressures are absolute pressures (psia). Add 14.7 to gauge pressure to convert to absolute pressure. Also, note that this equation assumes that the* ***air precharge pressure is equal to the line pressure****. This equation should* ***not*** *be used if the precharge pressure does not equal the line pressure.)*

If the expansion tank has a 150 psi allowable working pressure, I use 149.7 psia (135 + 14.7 = 149.7) for P_2, which is 10% below the set point of the relief valve. Using our example above, let's assume that the line pressure is 80 psi.

Total tank capacity = 2.0 / (1 – 94.7/149.7) = 5.44 gallons

Given a total tank capacity of 5.44 gallons and an acceptance capacity of 2 gallons, you can go to manufacturer's data and select a tank that meets your <u>specific</u> application.

If the precharge pressure does not equal the line pressure, equation (2) cannot be used. The appropriate equation for a precharge pressure that does not equal the line pressure is given below.

(3) $$V_T = V_{ACC} / [(P_1/P_2) – (P_1/P_3)]$$

where,

P_1 = Precharge pressure, (psia)
P_2 = Static water line pressure, (psia)
P_3 = Maximum desired tank pressure, (psia)
V_{ACC} = Acceptance volume, (gallons)
V_{ET} = Total volume of expansion tank, (gallons)

For the preceding example, if the expansion tank has a factory precharge of 40 psig and it is not increased to the line pressure of 80 psig, then the required total capacity of the expansion tank capacity increases from 5.4 gallons to 9.4 gallons.

Remember that in Tennessee, unfired pressure vessels larger than 5 cu. ft. must have an ASME stamp. This corresponds to approximately 37 gallons. If the tank you need is larger than this, it must be constructed in accordance with ASME Section VIII. Using multiple smaller tanks is also an option.

The location of the expansion tank is also important. The tank will perform its intended function if located in either the cold or hot water piping. The cold water side is the preferred location, because the water temperature is lower, which will extend the life of the tank.

This sizing method is for thermal expansion. If you are sizing tanks for a booster pump system, the procedure is a little different. I hope this information is helpful. As we start a new year, if we do our jobs well, we will not lift any valves or blow any gaskets!