Relieving Pressure Problems

Learn how to choose and size thermal expansion tanks to help save plumbing systems.

by James Fuller

Throughout the history of the American plumbing industry, safeguards have been established and implemented to ensure that end users have the highest quality drinking water. Consumers have come to expect safe potable water, and they rarely think of the necessary ongoing efforts to deliver it. The 1974 Safe Drinking Water Act, with subsequent revisions, has created a tremendous movement in safeguarding this quality by mandating that the ultimate protection belong at the municipal water authority level. A development of this protectionist requirement is the goal of eliminating all cross-connections between potable and nonpotable waters.

Many authorities implementing programs have experienced growing pains attributed to this requirement of cross-connection control. Water authorities embarking on newly implemented programs should learn from these experiences. Successful programs that have been executed include many stages of strategic planning. For instance, selection, installation, performance verification, and maintenance of the correct backflow preventer based on contamination potential are outlined with careful documentation. Emergency response plans are written, and emergency contamination drills are rehearsed. This forward-thinking preparation has resulted in saving lives, reducing property damage, and limiting the authority's liability when drinking water contamination occurs.

The Backflow Conundrum

As well-thought-out and comprehensive as these programs are, the water authority must not neglect the liability that may occur on the other side of the backflow preventer. The old adage that states "no good deed goes unpunished" is a good analogy of what happens when new safeguard programs are put in place. In Greek mythology, the dreaded Hydra was a serpent with a unique defense mechanism. When Hydra's menacing head was cut off, it sprouted two more in its place. An example of this happening in real life is the addition of backflow prevention valves in plumbing systems. The valve that protects against potential cross-connection contamination also can lead to major problems in a building's plumbing system.

Excessive water pressure buildup and increasing water hammer occurrence are just two examples of what has happened by cutting off Hydra's head. The excessive pressure buildup is caused by thermal expansion of the building's plumbing system water. Water expands when it is heated. This occurs several times each day as the water-heating equipment operates. This expanded water usually backs up into the water supply main, which absorbs the thermally expanded water. However, with a backflow preventer in place, water can't leave the building's plumbing system, and increased pressure results. Just how high the pressure rises depends on several factors.

The Pressure Problem

Water is incompressible. When heated and expanded, pressure will increase suddenly and rapidly to dangerous levels in a closed piping system. Figure 1 shows the elevation in pressure with increasing temperature in an average plumbing system. The pressure in the system will rise until a weak component in the plumbing system gives way and continually discharges water. This component is typically a faucet washer, although it could be a weak pipe, poor solder joint, or water closet valve.

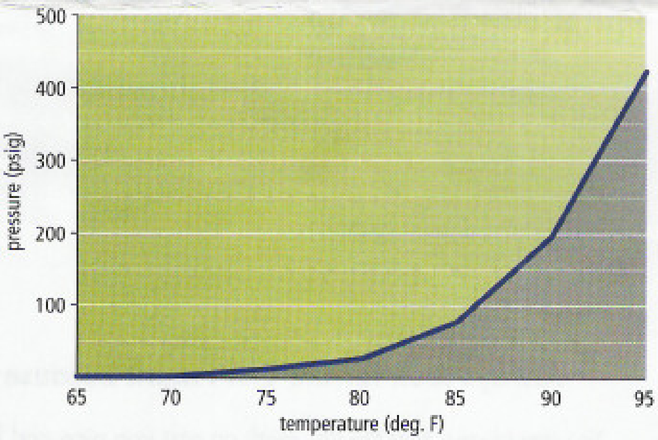

Figure 1 Increase in water pressure due to rise in temperature

Common Symtoms of Thermal Expansion

The most common symptoms that indicate a thermal expansion problem may exist include:

- The water heater relief valve operating to relieve excessive water pressure
- An excessive water pressure surge when a faucet is opened
- Increased frequency of faucet washer replacement
- Metallic expansion noises at the water heater
- Piping noises, cracking, or creaking with the water heater operating
- Premature failure of appliance solenoid valves and O-ring seals
- Severely reduced water heater life

- Flames periodically rolling out in gas-fired heaters
- Combustion products (flue gases) entering living spaces

Major United States water heater manufacturers and the American National Standards Institute (ANSI) have become extremely concerned with potential liabilities stemming from thermal expansion. For example, manufacturers send mailers that state: "Your water heater and plumbing system are no longer adequate or safe!" One major water heater manufacturer warns that failure to rectify a thermal expansion problem may result in "leaks within the system, failure of the water heater, water damage, sooting, flame roll out (possible when relighting the water heater), and even the spread of deadly carbon monoxide gas."

Water heater failure, as explained by another major water heater manufacturer, is caused by the sudden pressure-induced collapse of the center flue within a gas-fired water heater, resulting in the very serious possibility of carbon monoxide poisoning. For electric water heaters, severe deformation of the bottom dome results in the rapid reduction of heater life expectancy.

What To Do?

The solution to this potential liability problem must be accomplished in various stages. Stage 1 is inform and educate. The building owner must be informed of the conditions occurring within the plumbing system, the potential dangers, and the symptoms of the condition. Educate the building owner as to the acceptable solutions for properly controlling thermal expansion.

Stage 2 is repeat Stage 1. The success of any program depends on continually barraging the building owner with information on the installation and important maintenance requirements of the thermal expansion control equipment.

Thermal Expansion Control Devices

Building inspectors will accept approved and listed thermal expansion control tanks or devices as the means for controlling pressure in water systems. Some authorities still accept secondary relief valves, although this inexpensive quick fix is not considered acceptable by energy-conscious, water-conservation-minded authorities. A major dilemma occurs when new maintenance personnel are hired in a building that utilizes an auxiliary relief valve. An uninformed maintenance person may plug the relief valve or remove it, restoring the system to its non-controlled state. Manufacturers of such valves, such as secondary relief valves, also note that these are safety controls and cannot be used as an operating control to intermittently release water from the system. This is because any sediment collecting on the valve seat can cause continuous water-flow conditions, or worse, a totally blocked relief valve.

All national cross-connection control sections of the appropriate standards and plumbing codes, as well as many state public health codes, carry mandatory requirements for the provision of an approved thermal expansion control device. For example, Section 607.3 of the International Plumbing Code (IPC) and Section 2903.4 of the International Residential Code require the increased pressure caused by thermal expansion to be controlled. Also, IPC Section 504.4 prohibits using storage water heater relief valves as a means of controlling thermal expansion.

The preferred device is an approved thermal expansion tank. In fact, most relief valve manufacturers have acknowledged the advantages of the thermal expansion tank and have begun offering this alternative.

The thermal expansion tank acts like a "lung" on the piping system, accepting expanded water as the water heater functions. As water is used, it is pushed back into the piping system by the tank's compressed air cushion. Typically, expansion tanks utilize a flexible butyl diaphragm or bladder to separate a sealed compressible air cushion from the incoming expanded water. The air cushion is precharged to approximately 40 pounds per square inch gauge (psig) (based on Department of Transportation shipping limitations) and retained by the flexible bladder. The expanded water enters the bladder, which protects the tank's steel from the potentially corrosive fresh water. (See Figure 2.)

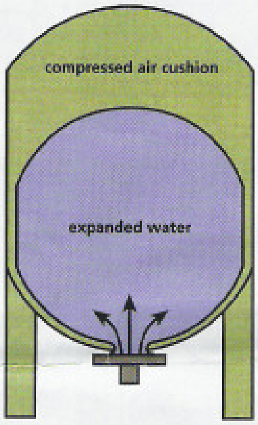

Figure 2 Expansion tank schematic

Sizing a Thermal Expansion Tank

The proper thermal expansion tank size is critical in limiting the pressure fluctuations in a piping system. Too small a tank leads to high pressure fluctuations; too large a tank reduces pressure fluctuations, but creates cost constraints that may prove prohibitive.

The critical size requirement for any thermal expansion tank is based on the physical properties of water and the subsequent required air cushion needed to absorb the water within a specific pressure range. The thermal expansion tank volume commonly is referred to as the tank acceptance volume. Many manufacturers provide both the acceptance volume and tank volume for each of their tanks.

The tank size is calculated by the following equation:

$$TX = \text{Expanded water}/(P1/P2 - P1/P3)$$

where

TX = Thermal expansion tank volume (gallons)
P1 = Precharge pressure (psia)
P2 = Static line pressure (psia)
P3 = Maximum allowable line pressure (psia)

The amount of expanded water depends on temperature rise and water heater volume. Industry practice is to protect against the potential condition of extreme temperature increase (40°F to 160°F) for the entire water heater volume. This extreme condition may occur only five to 10 times per year, compared to the thousands of smaller expanded water conditions occurring yearly, yet protection against this condition must be achieved. The typical air cushion precharge pressure for a thermal expansion tank is 40 psig (based on Department of Transportation shipping limitations), and the maximum line pressure is 135 psig (10 percent below safety temperature and pressure relief valve settings).

The equation then simplifies to:

TX = 0.0209 x Water heater volume/(54.7/P2 – 0.365)

A quick sizing table (see Table 1) can be used to aid water authority personnel, code officials, and plumbing contractors in sizing tanks based on the above equation. To use the table, simply find the water heater volume on the left-hand column and supply-line pressure along the top row. Trace down from the static pressure and over from the water heater volume until the two lines meet.

Table 1 Thermal expansion tank sizing chart (tank size in gallons)

water heater volume (gallons*)	supply pressure (psig) 40	50	60	70	80	90	100
50	1.6	2.2	2.8	3.7	4.9	6.6	9.3
100	3.3	4.4	5.7	7.4	10	13	19
150	4.9	6.5	8.5	11	15	20	28
200	6.6	8.7	11	15	20	27	37
300	9.9	13	17	22	29	40	56
400	13	17	23	30	39	53	75
500	16	22	28	37	49	66	93
750	25	33	43	56	74	100	140
1,000	33	44	57	74	98	133	187

* Include hot water recirculation line volume

The total critical volume, or acceptance volume (in gallons), required to absorb the thermally expanded water within the specified pressure range is displayed. For example, a 500-gallon water heater with 60-psig static line pressure requires a 28-gallon thermal expansion tank to control pressures. The installed tank can be verified by the authority having jurisdiction to meet or exceed this 28-gallon requirement.

Manufacturers typically create sizing tables reflecting exact model number requirements to satisfy this critical sizing. Utilizing a chart of this type ensures that the sizing is based on requirements similar to those previously discussed.

The figures in Table 1 indicate the tank size required without changing the factory precharge setting of 40 psig. The knowledgeable engineer and contractor will size the tank with the precharge air cushion pressure equal to the line pressure at the point the tank is installed in the system. This will allow a smaller tank to be used to handle the expanded water, while controlling the supply line pressures well below the maximum design pressure. (However, some expansion tank manufacturers require the precharge air pressure to be adjusted to the cold fill pressure of the system.) The governing equation reduces to:

TX = 0.0209 x Water heater volume/(1 – P2/149.7)

Using this equation for the above example results in a tank requirement of 20.9 gallons. This represents a 25 percent reduction in required tank size. Care should be taken to ensure that the tank is properly precharged at the jobsite.

The potential for public harm far outweighs the necessary effort to educate the building owner on newly implemented or ongoing cross-connection control policies and programs. The cause and effect of thermal expansion create even more potentially dangerous conditions and must be included in all educational information programs. Protection of life and property and the eradication of liabilities are all at stake when thermal expansion is neglected. **PSD**

JAMES FULLER is president of Wessels Co. in Greenwood, Indiana. Wessels Co. is a manufacturer of pre-pressurized bladder/diaphragm tanks. He can be reached at **jfuller@westank.com** or 317-888-9800. To comment on this article, e-mail **articles@psdmagazine.org**.