Under Pressure

Kennebec Valley Community College

INTRODUCTION

After having a leaking temperature and pressure relief valve replaced on her water heater, the customer calls the plumber the following day and leaves a message saying she paid $150.00 and the water heater is still leaking onto her floor.

The customer calls the plumber several more times but gets no call back.

The customer decides to call Houle's Plumbing and Heating for help.

ORGANIZATIONAL OVERVIEW

Houle’s Plumbing and Heating

Founded by Armand Houle in 1940, Houle's Plumbing, Heating and Air Conditioning has been providing services to the Greater Waterville area for over 70 years. Armand started out with one business philosophy: "if you do quality work, word of mouth will do the advertising for you". That philosophy has stood the test of time.

Houle's Plumbing Continued...

The one-man, one-truck business of the 1940s grew under the guidance of Armand's son Carroll to include one of the state's first bath showrooms, and expanded staff of 24 full-time professionals and 17 service vehicles.

Carroll's daughter Kimberly LaMarre, P.E. and son-in-law, Anthony LaMarre, P.E, joined the Company in 1995. Since Carroll's retirement in 2005, Anthony has taken over as President.

PROBLEM STATEMENT

After receiving the phone call, the president of Houle's Plumbing and Heating holds a meeting with his service department employees. President Anthony LaMarre would like the following to be resolved at the meeting:

To determine why the temperature and pressure valve is leaking.

PROBLEM DISCUSSION

Tony: Hey Casey and Steve, we have an opportunity to gain a customer. This customer that called me yesterday was very upset with the past plumber that came to her home.

Casey: What's the problem?

Tony: The temperature and pressure relief valve is leaking from the standpipe of the water heater onto the floor. The last plumber replaced the temperature and pressure relief valve.

Casey: But it is still leaking?

Tony: Right

Casey: Why did he replace the T&P?

Tony: Well, I think he just guessed. The T&P valve was leaking, therefore it must be defective.

Steve: So, I guess that wasn't the problem and there was nothing wrong with the T&P valve?

Tony: Right. So, I stopped by the customer's home this morning to get some more details about the plumbing system. Here is what I found out:

The temperature and pressure relief valve is indeed leaking from the standpipe onto the floor.

- there is a 120 gallon gas-fired water heater
- the incoming water pressure to the home is 98 psi and the incoming water temperature is 40 degrees Fahrenheit

The thermostat on the water heater is working properly and providing normal operating temperatures of about 120 degrees.

The customer said the only other work done on her home recently was when the water district replaced her old water meter with a new remote reading meter.

Tony: Okay guys, I have to go to another job. You guys figure it out and I will check back with you later.

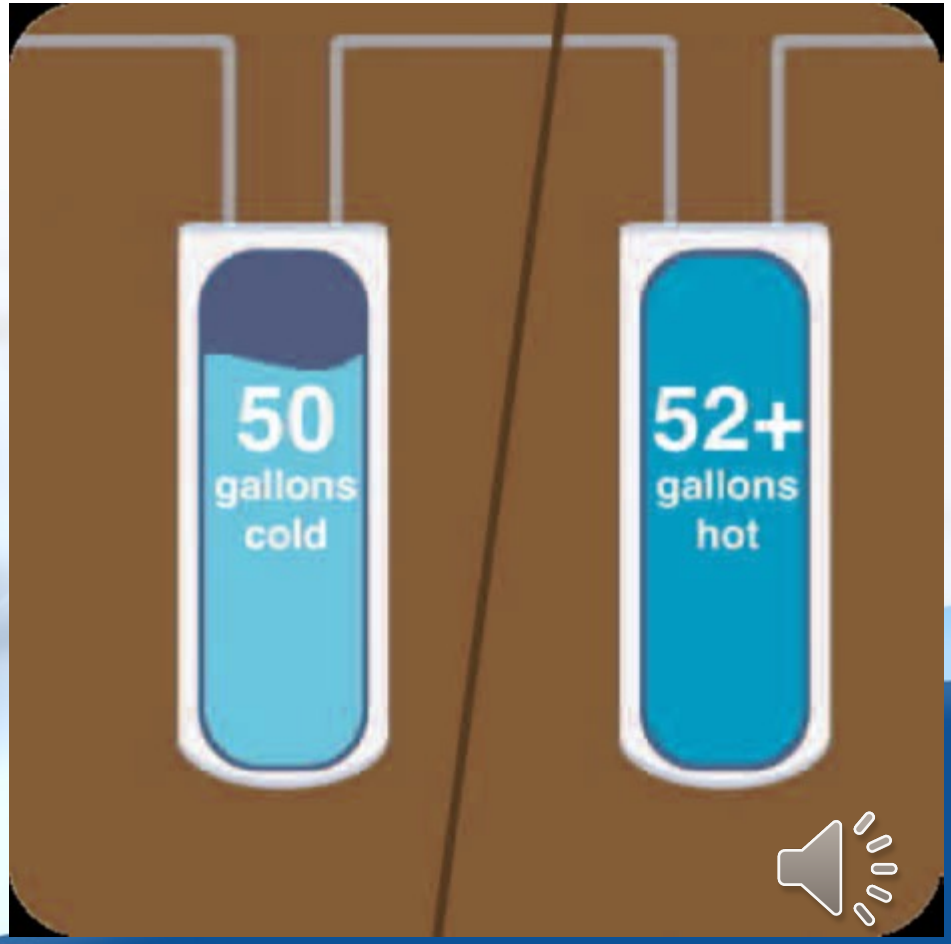
STOP

(Students should work on a plan to solve the situation. Once the students have come up with a solution, proceed to the following discussion slides.)

Thermal Expansion

Tony: Okay guys, what did you come up with?

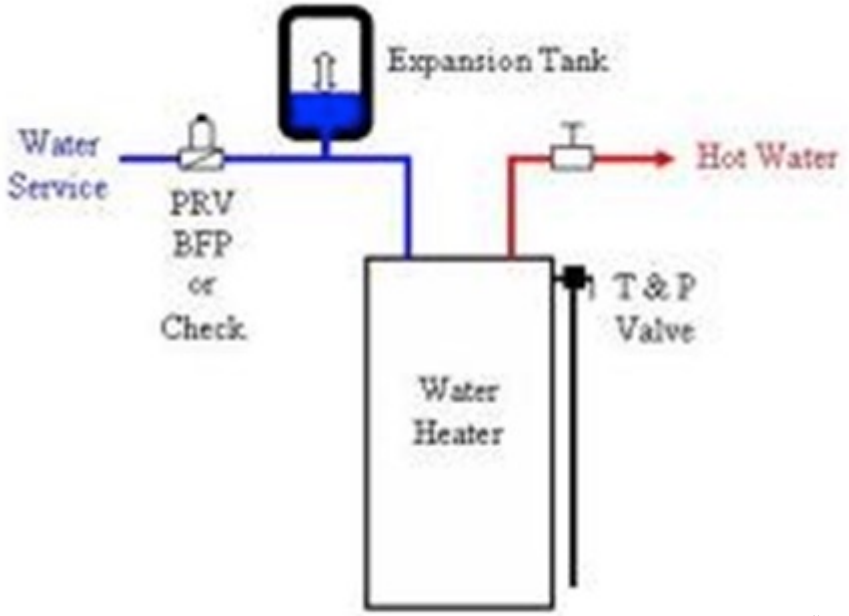
Casey: Well, we figured out that when water heats up, it's going to expand and increase in volume. This is called thermal expansion.



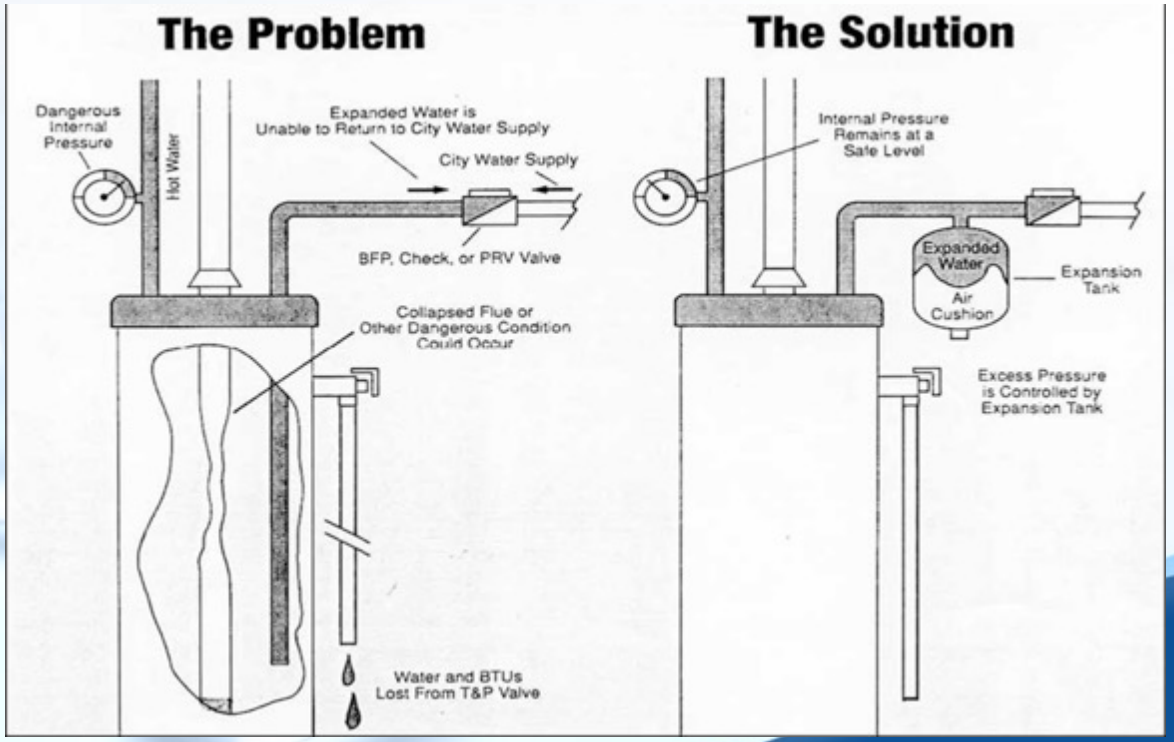
Steve: That additional volume needs a place to go. If the water is trapped or in a closed system, then the pressure is going to build up and cause the relief valve to leak.

Casey: When Kennebec Valley Water District recently replaced the water meter they probably installed a check valve with the new meter. This prevented the increase in water volume from expanding into the water main.

Steve: So, we determined that we need to install an expansion tank. When this small tank is added to the system, it will be a place for the additional volume to go into.



Casey: Based on our calculations, we have determined that we need a 5.5 gallon expansion tank.



Tony: Sounds good, make an appointment to install the expansion tank.

Casey: Will do.

(Casey and Steve go to fix the problem, and run into more problems, so they return to the shop.)

Casey: Hey Tony, while we were there, the customer requested that the plumbing code officer look at the job. She wanted to make sure it was fixed correctly.

Steve: The code officer said according to Section 608.2 in the Uniform Plumbing Code, the water system pressure can never exceed 80psi.

Steve: Right now the pressure is at 98 psi. The code officer said we need a pressure reducing valve to limit the incoming water pressure to 80 psi or less.

Casey: The code officer also said the expansion tank needs to be sized so the thermal expansion pressure does not exceed 80 psi as well.

Steve: We originally sized the expansion tank based on a maximum pressure of 135 psi.

Tony: Can we use the expansion tank that we installed to maintain a maximum pressure of 80 psi? Or, do we have to purchase another size?

Casey: I don't know. I will do some calculations to see if I can figure this out.

STOP

(Students should figure out the equations and work on the calculations.)

Student Resources

Under Pressure

Kennebec Valley Community College

- Uniform Plumbing Code
- Thermal expansion properties

To determine what size the expansion tank should be, you will need to use two formulas.

Here is the first one:

$$VACC = VT \times (Vs2/Vs1 - 1)$$

VACC = Acceptance Volume (gallons)
Vs2 = Specific volume of water at heated temperature, (ft3/lb)
Vs1 = Specific volume of water at entering temperature, (ft3/lb)
VT = Water heater storage tank volume (gallons)

Here is the second formula to determine the total tank capacity:

$$V_{ET} = V_{ACC} / (1 - P1/P2)$$

P1 = Static water line pressure, (psia)

P2 = Maximum desired tank pressure, (psia)

VACC = Acceptance volume, (gallons)

VET = Total volume of expansion tank, (gallons)

Instructor Resources

Under Pressure

Kennebec Valley Community College

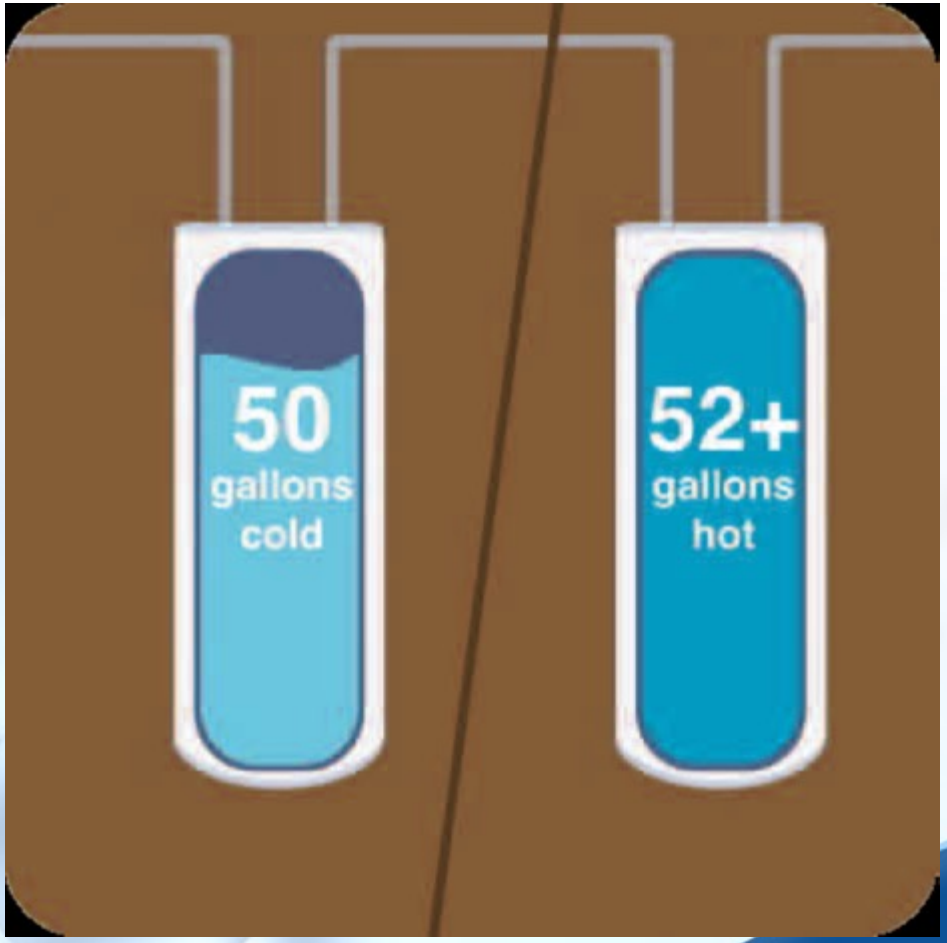
Mathematical Skills

- Interpreting Charts
- Basic Algebra skills
- Solving Rational Equations Algebraically

Plumbing Skills

- Basic understanding of potable water systems installation and sizing
- Knowledge of how water heaters operate
- Safety devices for water heaters
- Knowledge of pipe size, pipe materials fittings including required fittings
- Pipe hanger/supports and required spacing
- Referencing and interpreting charts

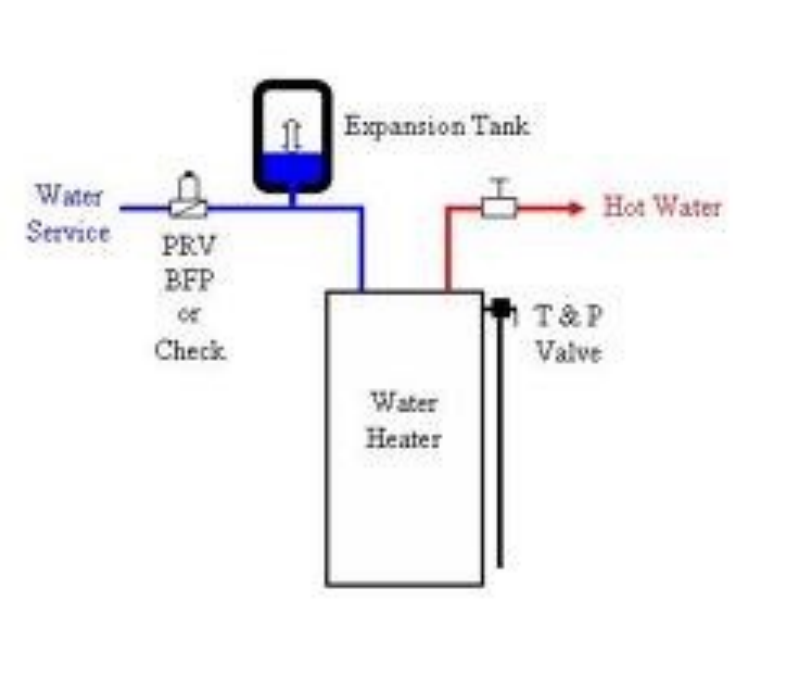
Thermal expansion occurs when water is heated.



In a closed system, the expansion of the heated water quickly increases the pressure inside the tank.

″Weeping″ of water through the water heater T&P Relief Valve could be an indication of excessive water pressure in the plumbing system.

When a water heating cycle ends, or when any fixture is opened within the system, the impact of thermal expansion is reduced, and water drains out of the expansion tank back into the system.



To select a thermal expansion tank, two things must be determined:

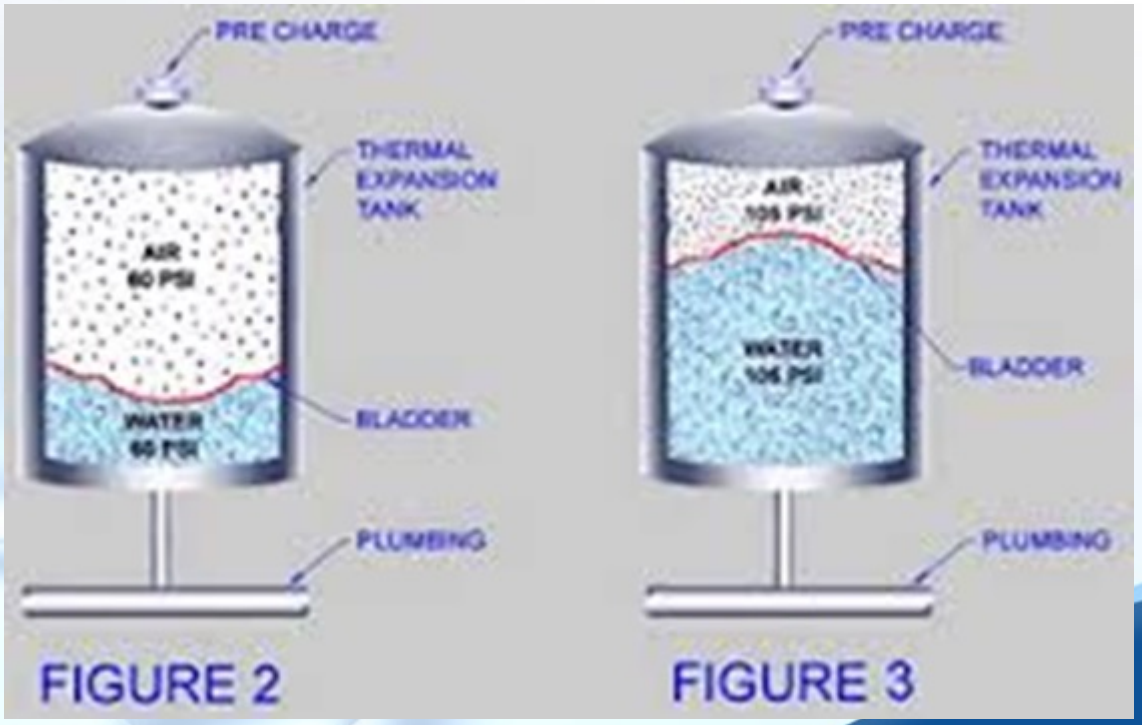
1. The total capacity has to be calculated.
2. The acceptance volume has to be calculated.

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.

If there is air already in the tank, as water enters it will compress the air in the tank until it equalizes in pressure.

As an example, a 2 gallon tank may only have an acceptance volume of 1 gallon against the compressed air volume.



To determine what size the expansion should be, you will need to use two formulas. Here is the first one:

$$VACC = VT \times (Vs2/Vs1 - 1)$$

VACC = Acceptance Volume (gallons)

Vs2 = Specific volume of water at heated temperature, (ft3/lb)

Vs1 = Specific volume of water at entering temperature, (ft3/lb)

VT = Water heater storage tank volume (gallons)

Use this chart of thermodynamic properties for the specific volume of water at various temperatures .

Temperature - t - ($^{\circ}F$)	Specific Volume - v - (ft^3/lb)	Weight Density - ρ - (lb/ft^3)	($lb/gallon$)
32	0.01602	62.41	8.344
40	0.01602	62.43	8.345
50	0.01602	62.41	8.343
60	0.01603	62.37	8.338
70	0.01605	62.31	8.329
80	0.01607	62.22	8.318
90	0.01610	62.12	8.304
100	0.01613	62.00	8.288
110	0.01617	61.86	8.270
120	0.01620	61.71	8.250
130	0.01625	61.55	8.228
140	0.01629	61.38	8.205
150	0.01634	61.19	8.180
160	0.01640	60.99	8.154
170	0.01645	60.79	8.126
180	0.01651	60.57	8.097
190	0.01657	60.34	8.067
200	0.01664	60.11	8.035
210	0.01670	59.86	8.002
212	0.01672	59.81	7.996
220	0.01678	59.61	7.969
240	0.01693	59.08	7.898
260	0.01709	58.52	7.823
280	0.01726	57.92	7.743
300	0.01745	57.31	7.661
350	0.01799	55.59	7.431
400	0.01864	53.65	7.172
450	0.01943	51.47	6.880
500	0.02043	48.95	6.543
550	0.02176	45.96	6.143
600	0.02364	42.30	5.655
650	0.02674	37.40	4.999
700	0.03662	27.30	3.651

For example, let's assume we have a 120 gallon water heater and the water is heated from 40F to 140F.

VACC = 120 (0.01629/0.01602 – 1) = 120 (.017) = 2.04 gallons

Just figuring the amount of expansion in the water heater tank with a temperature increase from 40 degrees to 140 degrees, the 120 gallons would expand by 2 gallons.

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.

These results are insignificantly small.

We don’t bother correcting for altitude either.

Here is the second formula that is needed to determine the total tank capacity.

$$VET = VACC / (1 - P1/P2)$$

P1 = Static water line pressure, (psia)

P2 = Maximum desired tank pressure, (psia)

VACC = Acceptance volume, (gallons)

VET = Total volume of expansion tank, (gallons)

For this example, 150 psi is the maximum desirable working pressure because at that point the relief valve would start leaking.

But we need a little cushion factor. So, we would use 90% of 150 psi, which would be 135psi.

Now the formula requires the pressures to be converted to absolute pressures (psia). To do this we add 14.7 psi to the 135psi which brings us back up to 149.7 psia. So the 149.7psia, which is our P2, is 10% below the set point of the relief valve.

For P1, the static pressure is the same as the incoming line pressure to the home. In this example will assume that the static pressure is 80 psi. Again we will need to convert 80 psi to absolute pressure by adding 14.7 psi to get 94.7psi as our number for P1.

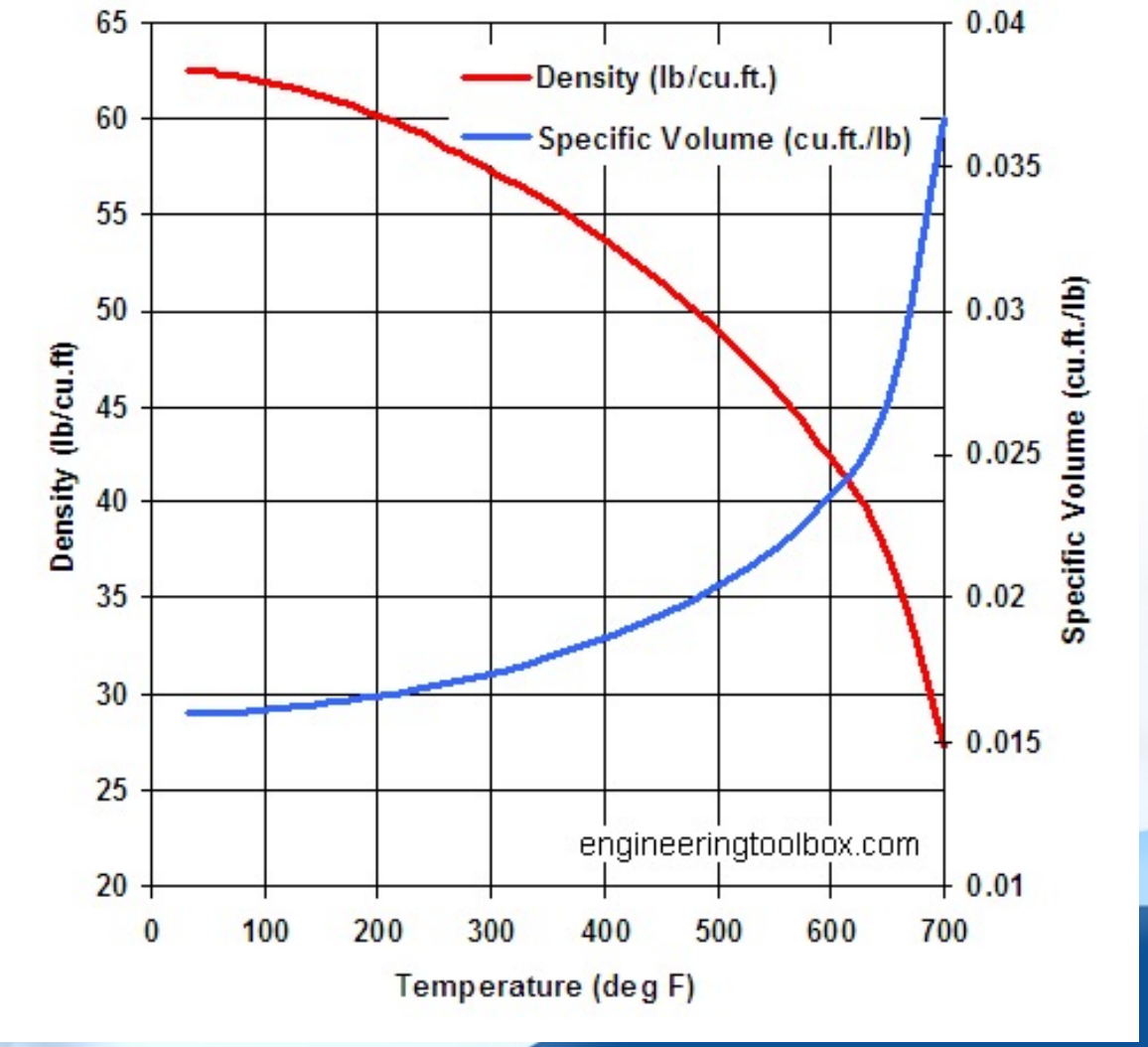
V_{ACC} = 2.04

P1 = 94.7

P2 = 149.7

Total tank capacity = 2.04 / (1 – 94.7/149.7)
= 5.44 gallons

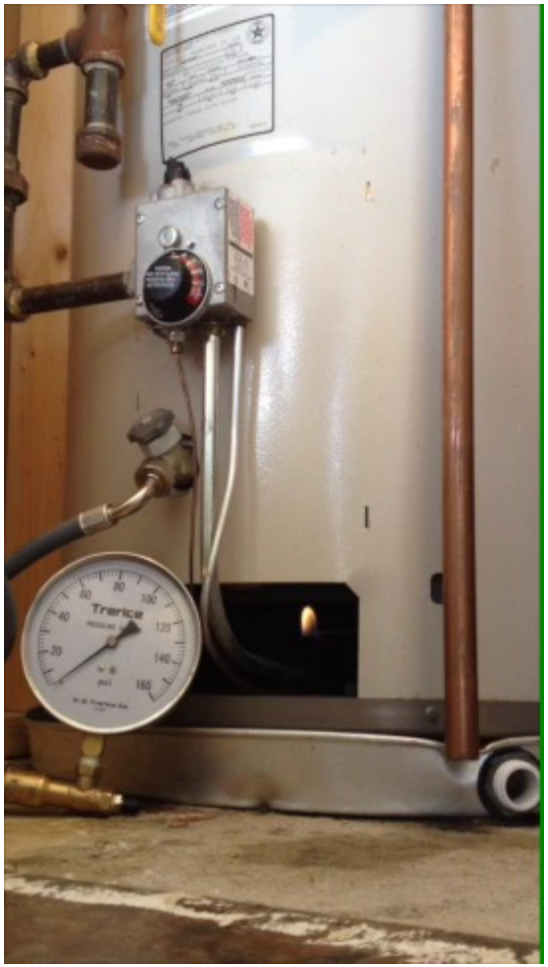
Alternatively, students could use a graphing calculator to determine the solution.



For second phase of the challenge, the students, after determining solution is an expansion tank, will have to fix the system so pressure never exceeds 80 psi as required by the Uniform Plumbing Code.

Solution will be to install a pressure reducing valve so incoming pressure is limited to 50 psi and size the expansion tank so system never exceeds 80 psi as water is heated.

The following slides present video clips showing the discovery of the problem.



Discovering and Investigating the Problem

Demonstrating the Problem

PROBLEM SOLUTION

The following slide is the math steps to show how to solve the problem.

$$\frac{2.04}{1-\left[\frac{x}{94.7}\right]} = 5.44$$

$$\left(1-\left[\frac{x}{94.7}\right]\right)\left(\frac{2.04}{1-\left[\frac{x}{94.7}\right]}\right) = \left(1-\left[\frac{x}{94.7}\right]\right)(5.44)$$

$$2.04 = 1(5.44) - \left[\frac{x}{94.7}\right](5.44)$$

$$2.04 = 5.44 - \frac{5.44x}{94.7}$$

$$2.04 = 5.44 - .057445618x$$

$$\begin{array}{r} -5.44 \\ \hline -3.4 \end{array} \qquad \begin{array}{r} -5.44 \\ \hline 0 \end{array}$$

$$\frac{-3.4}{-.057445618} = \frac{-.057445618x}{-.057445618}$$

$$59.19 \approx x$$

Remember, once you have the 59.19psia, you need to subtract the 14.7, (59.19-14.7 = 44.49). Now we have the accurate gauge pressure, which would be rounded to 44psi.

Tony: What did you guys figure out?

Casey: We determined that if we lower the incoming water pressure to 44psi, we can use the tank that we already installed.

Steve: So we installed a pressure reducing valve, and now it is code compliant and it is no longer leaking.

The End

This PBL Project was created and produced by Brad Harding, Jared Harvey and Toni Fredette, in collaboration with the New England Board of Higher Education