

# Expansion Tank Design (Hydronic Hot Water)

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## 1.0 INTRODUCTION

An expansion tank is used in a hydronic hot water system to accomplish three main tasks, (1) accommodate thermal expansion of the hot water, (2) maintain positive pressure at all points in the system at all times and (3) maintain net positive suction head at the hydronic hot water pump(s). There are other techniques and equipment besides the expansion tank that help to accomplish these three purposes, but only the ways the expansion tank affects these three purposes will be discussed in this guide. In addition, the three expansion tank types will be discussed, along with their sizing equations. The three types of expansion tanks are (1) open, (2) closed and (3) diaphragm. Finally design elements related to expansion tanks will be discussed, which include locating the expansion tank, tank materials, tank manufacturers and ancillary devices.

### 1.1 UNITS

The primary units that are used in this calculator and guide are the United States Customary System Units (USCS). However, there will be another version provided in International System of Units (SI).

## 2.0 DISCLAIMER

In no event will Engineering Pro Guides be liable for any incidental, indirect, consequential, punitive or special damages of any kind, or any other damages whatsoever, including, without limitation, those resulting from loss of profit, loss of contracts, loss of reputation, goodwill, data, information, income, anticipated savings or business relationships, whether or not Engineering Pro Guides has been advised of the possibility of such damage, arising out of or in connection with the use of this document/software or any referenced documents and/or websites.

This book/software was created on the basis of helping engineers use the calculator and to understand the background knowledge behind the calculator.

## 3.0 OVERALL HYDRONIC HOT WATER SYSTEM

This guide covers the design and selection of a hydronic hot water expansion tank. The expansion tank is a part of an overall hot water system that often includes a hot water generator (fuel fired boiler), piping, valves/fittings, water treatment, hot water coils (air handling units and fan coil units) and hot water pump(s).

A hydronic system is a water system that is used to transport heat from one location to another. Typical hydronic systems include chilled water and hot water systems. This guide is on hot water systems, these systems have additional sub-systems based on the temperature of the system. Low temperature systems are defined as hot water systems less than 240 °F. Medium/High temperature systems are defined as hot water systems above 240 °F.

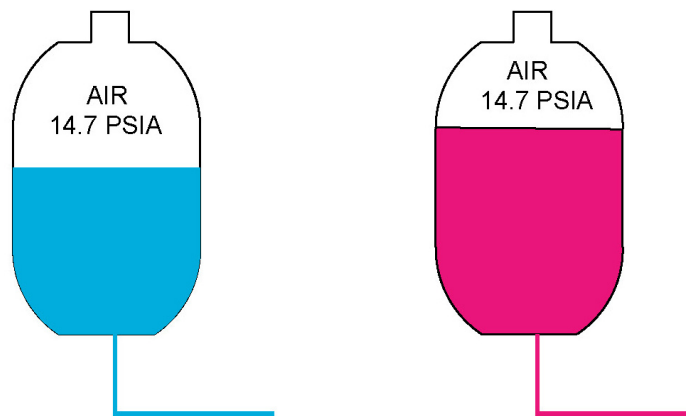
Hot Water System	Operating Conditions
Low Temperature	Temperatures less than 250 °F. Pressures less than 160 PSIG. Typically operates at a pressure much less than 160 PSIG, although high rise buildings may have pressures reaching 160 PSIG.
Medium Temperature	Temperatures between 250 °F and 350 °F. Pressures less than 160 PSIG, similarly to the low temperature hot water system.
High Temperature	Temperatures between 350 °F and 400 °F. Pressures more than 160 PSIG but less than 300 PSIG.

## 4.0 EXPANSION TANK TYPES

There are several types of expansion tanks provided by various manufacturers. However, there are only three main types for equation purposes. This section will take the major manufacturers and their expansion tank models and classify each model within one of the three expansion tank equations. The three main expansion tank sizing equations are (1) open tank, (2) closed tank with no bladder and (3) closed tank with bladder.

### 4.1 OPEN TANK

An open tank will most likely not be used in your HVAC system design, but it is shown here for completeness. An open tank consists of a large tank with an opening to the atmosphere. As temperature in the system builds, the fluid expands into the tank as shown in the figure below.



*Figure 1: The figure on the left shows the open expansion tank when the fluid temperature is cold. As the temperature rises, the fluid expands and begins to increase the volume within the expansion tank. This is shown as red in the figure to the right.*

The open tank is typically located at the top of the system.

The open tank is governed by the below equation. The  $(\frac{v_2}{v_1} - 1)$  term describes the percentage change in volume of the system volume. The  $3\alpha\Delta t$  term describes the percent change in piping volume due to the expansion of the piping. This term is subtracted from the percent change in volume term because the pipe expansion will help to offset the expansion in liquid volume.

$$V_T = 2 * V_S * [(\frac{v_2}{v_1} - 1) - 3\alpha\Delta t]$$

Please see section 3.4 for description of the variables and units.

## 4.2 CLOSED TANK WITH NO BLADDER

The closed expansion tank with no bladder does not have any openings to the atmosphere. It is simply a closed tank with a connection to the hydronic hot water system. The closed tank has extra space that is filled with air, when the temperature in the system is cold. As the temperature within the hydronic hot water system rises, the volume expands and fills the empty space within the tank.



*Figure 2: A closed tank with no bladder has free space when the hydronic hot water system is cold. As the temperature within the system rises, the water expands into the free space within the tank.*

The equation that governs the closed tank is shown below. This equation follows the same basic format as the open tank, except that the constant “2” is replaced with the  $(\frac{P_a}{P_1}) - (\frac{P_a}{P_2})$  term. This term describes the change in pressure that can be accommodated at the expansion tank. In the open tank, no pressure change can be accommodated. The open tank will fill as the liquid expands, but once the tank volume is filled, any additional volume will overflow the tank and no pressure change will be experienced. The closed tank on the other hand can accommodate an increase in volume and pressure. As the liquid expands the volume in the tank increases. Then, once the volume is filled, the closed tank will no longer increase in volume but will increase in pressure. This way the expansion tank can accommodate more liquid expansion with a lesser volume.

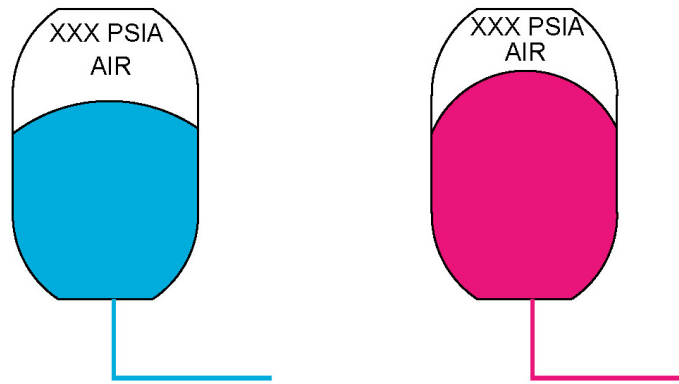
$$V_T = V_S * \frac{[(\frac{v_2}{v_1}) - 1] - 3\alpha\Delta t}{(\frac{P_a}{P_1}) - (\frac{P_a}{P_2})}$$

Please see section 3.4 for description of the variables and units.

### 4.3 CLOSED TANK WITH BLADDER/DIAPHRAGM

A closed tank with a bladder or diaphragm is the most common expansion tank. This expansion tank is similar to a closed tank, except within the tank there is a bladder or diaphragm that separates the water and the air. As the hydronic hot water volume expands the water pushes against the bladder or diaphragm. The bladder or diaphragm serves as a barrier between the air and the water to limit the air that can be entrained into the water.

The bladder or diaphragm also allows the air within the bladder or diaphragm to be pre-charged or pressurized. The importance of pressurizing the air is that it determines the pressure that the hydronic hot water must achieve before the expansion tank accepts volume. For example, the closed tank has a pressure of 14.7 psia. As the hydronic hot water pressure increases above 14.7 psia, the hydronic hot water will flow into the expansion tank. On the other hand, say the bladder/diaphragm is pressurized to 25 psig, then hydronic hot water will only enter the tank when the hydronic hot water exceeds 25 psig. This allows the closed tank with bladder or diaphragm to have a smaller volume because it does not need to accept volume at lower pressures.



*Figure 3: A closed tank with bladder consists of pre-charged air. As the temperature rises within the system, the volume expands and pushes up against the bladder or diaphragm. Hydronic hot water enters the system*

The basic equation for a bladder or diaphragm expansion tank with pre-charged air is shown below. The top term is the same as the closed expansion tank. The bottom term has replaced  $P_{atm}$  with  $P_{pre}$ , which is the pre-charged pressure.

$$V_T = V_S * \frac{\left[ \left( \frac{v_2}{v_1} \right) - 1 \right] - 3\alpha\Delta t}{\left( \frac{P_{pre}}{P_1} \right) - \left( \frac{P_{pre}}{P_2} \right)}$$

Most often,  $P_{pre}$  is selected to equal the minimum pressure in the system,  $P_1$ . This reduces the above equation to the below equation.

$$V_T = V_S * \frac{\left[\left(\frac{v_2}{v_1}\right) - 1\right] - 3\alpha\Delta t}{1 - (P_1/P_2)}$$

#### 4.4 DEFINITIONS OF EQUATION INPUTS

The following table lists all the variables used in the previous equations and provides descriptions and units for each variable based on USCS.

Variable	Description (units)
$V_T$	<i>expansion tank volume (gal)</i>
$V_S$	<i>system volume (gal)</i>
$v_1$	<i>specific volume at lower temperature <math>\left(\frac{ft^3}{lb}\right)</math></i>
$v_2$	<i>specific volume at higher temperature <math>\left(\frac{ft^3}{lb}\right)</math></i>
$\alpha$	<i>linear coefficient of thermal expansion <math>\left(\frac{in}{in\ ^\circ F}\right)</math></i>
$\Delta t$	<i>higher temperature – lower temperature (<math>^\circ F</math>)</i>
$P_1$	<i>pressure at lower temperature (psia)</i>
$P_2$	<i>pressure at higher temperature (psia)</i>

### 5.0 SIZING AN EXPANSION TANK

Once you select your expansion tank type, then you must determine the values to be used in the equation corresponding to the expansion type. Each of the variables will be discussed in this section, such that you can determine the values for each variable in a variety of situations.

#### 5.1 DETERMINING TEMPERATURE VALUES

The temperature values are used to determine the “delta T” and the specific volume values discussed in the next section. You must find the lowest and highest temperatures that will occur within the hydronic hot water system.

$$\Delta T = (T_2 - T_1); T_2 = \text{highest temperature } (^\circ F); T_1 = \text{lowest temperature } (^\circ F);$$

**Low Temperature:** The low temperature value is the temperature in the system that occurs when the hot water generator is off and the building is at its coldest. Thus the low temperature will depend on the location but should be in the range shown below.

- Low Temperature: 32 °F to 70 °F

If the hydronic hot water system is a glycol mixture, then the lowest temperature may be different than what was previously shown. Adding glycol to hydronic hot water allows for lower temperatures, due to glycol’s lower freezing point.

High Temperature: The high temperature value is the temperature that occurs when the hot water pump(s) and hot water generator(s) are on. When the hydronic hot water system is on, the hydronic hot water can reach the maximum hot water generator output temperature. . Low temperature hot water generators typically have a maximum temperature of 250 °F. Medium hot water generators can produce temperatures up to 350 °F and high temperature hot water generators can produce temperatures up to 400 °F.

- Supply Hydronic Hot Water: 250 °F to 400 °F

## 5.2 DETERMINING SPECIFIC VOLUME VALUES

The specific volume values are determined from the liquid property data. The expansion tank calculator for hot water only includes specific volume values for water.

$$v_1 = \text{specific volume at lower temperature} \left( \frac{ft^3}{lb} \right); v_2 = \text{specific volume at higher temperature} \left( \frac{ft^3}{lb} \right)$$

The specific volume values can also be found in ASHRAE Fundamentals for water and in the references tab of the calculator.

## 5.3 DETERMINING PRESSURE VALUES

The expansion tank calculator requires you to input three pressures values, (1) minimum pressure, (2) maximum pressure and (3) pre-charge pressure. Each of these values will be discussed below, but first you must understand the difference between gauge pressure and absolute pressure and the terms, vapor pressure and point of no pressure change.

The gauge pressure is the pressure with the added pressure of the atmosphere removed. For example a gauge pressure of 0 psig is the pressure of 1 atmosphere or (14.7 psi). The term absolute pressure accounts for the pressure of the atmosphere.

$$P_1 = \text{pressure at lower temperature (psia)}; P_2 = \text{pressure at higher temperature (psia)};$$

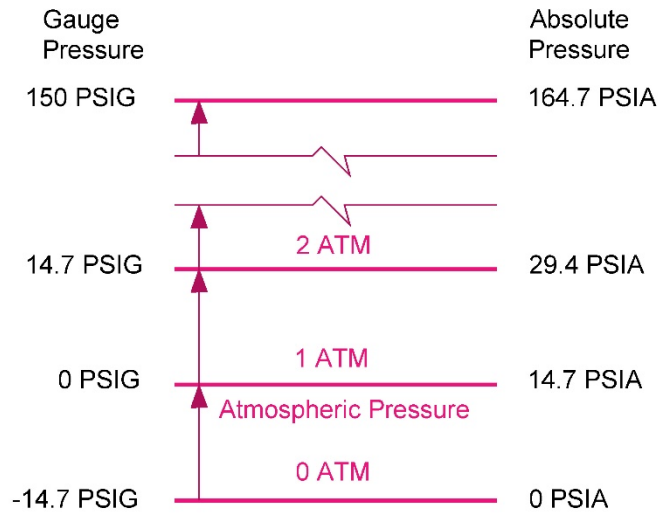


Figure 4: Remember to convert from gauge to absolute pressure before using the expansion tank equations.

### 5.3.1 VAPOR PRESSURE

The vapor or absolute pressure helps you to select the minimum pressure required in the system. The vapor pressure is a function of the water temperature. As the temperature increases, the vapor pressure also increases. For example, the vapor pressure of water at 85 F is roughly 1.4 feet of head and the vapor pressure of water at 200 F is roughly 26.6 feet of head. The vapor pressure is the minimum pressure required to keep water in its liquid form. For example, if the pressure of water at 200 F is changed to 20 feet of head, then the water will vaporize. The vapor pressure is automatically found based on the fluid type and fluid temperature.



Fluid Type	Temperature (°F)	Dynamic Viscosity (lbm/ft-s)	Density (lbm/ft <sup>3</sup> )	Vapor Pressure (psi)	Vapor Pressure (ft. head)
Water	32	1.20361E-03	62.41	0.0890	0.2056
Water	40	1.03804E-03	62.42	0.1220	0.2818
Water	50	8.77327E-04	62.41	0.1780	0.4112
Water	60	7.53134E-04	62.36	0.2560	0.5914
Water	70	6.54997E-04	62.30	0.3630	0.8385
Water	80	5.75970E-04	62.21	0.5070	1.1712
Water	90	5.11299E-04	62.11	0.6990	1.6147
Water	100	4.57638E-04	61.99	0.9510	2.1968
Water	110	4.12578E-04	61.86	1.2800	2.9568
Water	120	3.74344E-04	61.71	1.7000	3.9270
Water	130	3.41605E-04	61.55	2.2300	5.1513
Water	140	3.13344E-04	61.38	2.8900	6.6759
Water	150	2.88774E-04	61.19	3.7200	8.5932
Water	160	2.67275E-04	61.00	4.7500	10.9725
Water	170	2.48354E-04	60.79	6.0000	13.8600
Water	180	2.31615E-04	60.58	7.5200	17.3712
Water	190	2.16735E-04	60.35	9.3500	21.5985
Water	200	2.03449E-04	60.12	11.5000	26.5650
Water	210	1.91536E-04	59.88	14.1000	32.5710
Water	212	1.89302E-04	59.83	14.7000	33.9570

Figure 5: As temperature increases, the dynamic viscosity decreases and the vapor pressure increases.

### 5.3.2 POINT OF NO PRESSURE CHANGE

Often times you will hear that the expansion tank is the point at which the pressure in the system does not change. This is true, but the assumption is that the temperature does not change. The pressure at the expansion tank will not change, when the pump in the system is turned on or off, but the temperature remains the same. As you go through the next discussion points on the determination of the low/minimum and high/maximum pressure remember that the pressure at the expansion tank is a function of temperature and not the pump.

### 5.3.3 LOW/FILL/MINIMUM PRESSURE

The low pressure is the minimum pressure at the system to achieve the most demanding requirement of the following three constraints, (1) 10 psig at the highest point in the piping, (2) net positive suction head required at the hydronic hot water pump or (3) greater than vapor pressure of hot water at highest temperature at all points in the system.

(1) Elevation Constraint: The low or fill pressure is the pressure required at the fill point necessary to fill the entire piping system and achieve 10 psig at the highest point in the piping to stop air from entering the water/solution. When calculating this pressure, you must assume the pump(s) is off and the temperature of the fluid is at its highest. The fill point is typically used because the expansion tank is located at the fill point and have nearly the same pressures. If

the expansion tank is located away from the fill point, then you can use the elevation difference between the fill-point to find the minimum pressure at the expansion tank.

For example, assume the temperature of the fill water is 75 F and the water enters the system at an elevation of 10 feet above finished floor and the highest point in the system is 160 feet above finished floor. This will result in an elevation difference of 150 feet or 65.0 psig. Thus the fill pressure should be 75 psig. This example is illustrated in the first following figure.

(2) Net Positive Suction Head Constraint: Next, you should also check the net positive suction head required for the hydronic hot water pumps. The low or fill pressure must be large enough such that the net positive suction head required is met.

For example, assume the temperature of the fill water is 75 F and the water enters the system at an elevation of 10 feet above finished floor and the highest point in the system is only 30 feet above finished floor. This will result in an elevation difference of only 20 feet or 8.6 psig. Thus, according to the previous constraint the minimum pressure will be only 18.6 psig. However, if the hydronic hot water pump is located 10 feet above the fill point, then the pressure at the suction of the hydronic hot water pump will only be 14.3 psig. If the pump requires a net positive suction head of 20 psig, then the fill pressure determined from the elevation constraint will not meet the net positive suction head constraint. Thus the fill pressure must be increased to meet the net positive suction head constraint. This example is illustrated in the second following figure.

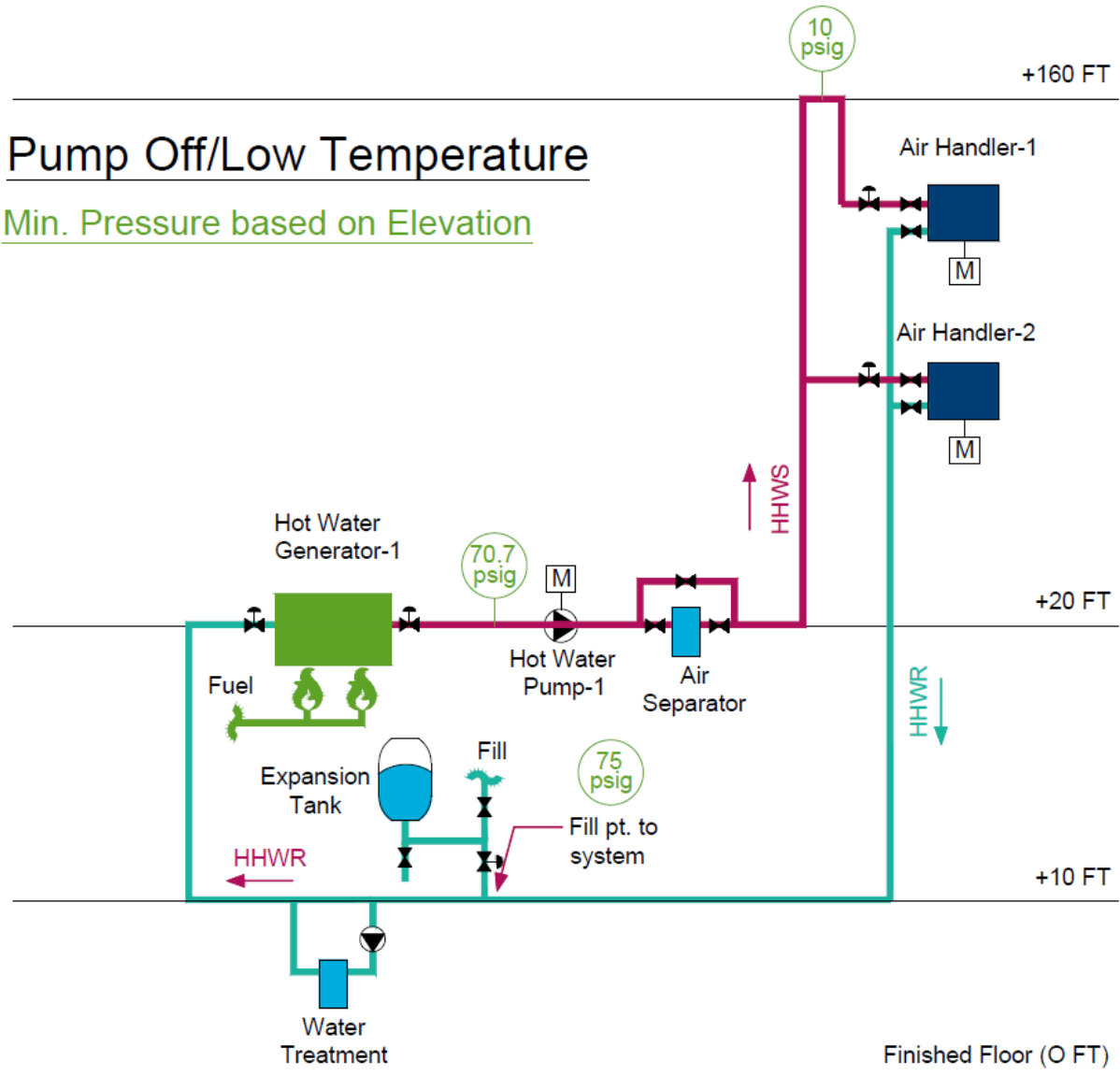


Figure 6: The minimum/fill pressure is determined to meet the 10 psig requirement at the highest point, as shown in green. The pressures at the lower elevations are then determined by converting ft. head to psig. This results in a fill pressure of 75 psig and a suction pressure at the hydronic hot water pump of 70.7 psig. You should also double check the net positive suction head required at the hydronic hot water pump is met, but in this example the suction pressure is very high and should be easily met. The pump is off, when determining the minimum pressure.

# Pump Off/Low Temperature

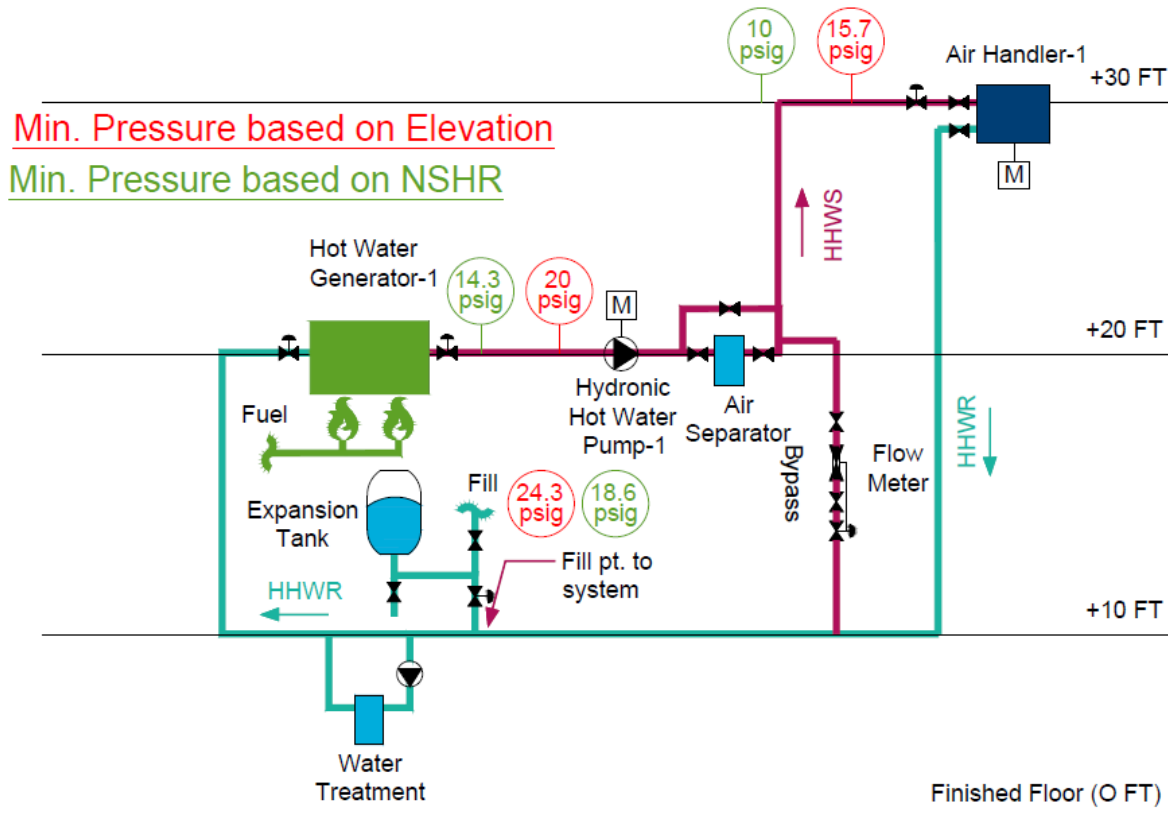


Figure 7: In this example figure, the green shows the minimum fill point pressure based on the 10 psig at the highest point. The red shows the fill point pressure based on a minimum 20 psig at the suction of the hydronic hot water pump. As you can see, the red produces the higher minimum fill point pressure and thus the higher minimum pressure at the expansion tank. Thus, for your equation you should use the higher minimum pressure value, based on the NPSHR. The pump is off when determining the minimum pressure.

**(3) Vapor Pressure Constraint:** The final constraint is typically the most stringent constraint for hydronic hot water systems due to the high temperatures. In this constraint, pressure throughout the entire system must remain higher than the vapor pressure of the fluid to prevent vaporization. If a pressure above the available pressure at the building is required, then the closed system is pressurized with a pressurization pump. This pump is different from the hydronic hot water pump which only circulates the fluid in the system. The pressurization pump pumps make-up water system into the closed hydronic hot water system at the desired pressure to achieve all three of the constraints.

In order to find the pressure required to meet the vapor pressure constraint you can simulate the pressures throughout the entire closed system under these two scenarios, Scenario A: Pump off, Maximum Temperature and Scenario B: Pump on, Maximum Temperature.

# Pump Off/High Temperature

## Fluid Information

Fluid Type:	Water
Temperature:	250.0 °F
Density:	58.8 lbs/ft <sup>3</sup>
Dynamic Viscosity:	0.000154 lbm/ft-s
Kinematic Viscosity:	2.626E-06 ft <sup>2</sup> /s
Absolute Pressure:	29.8 psia

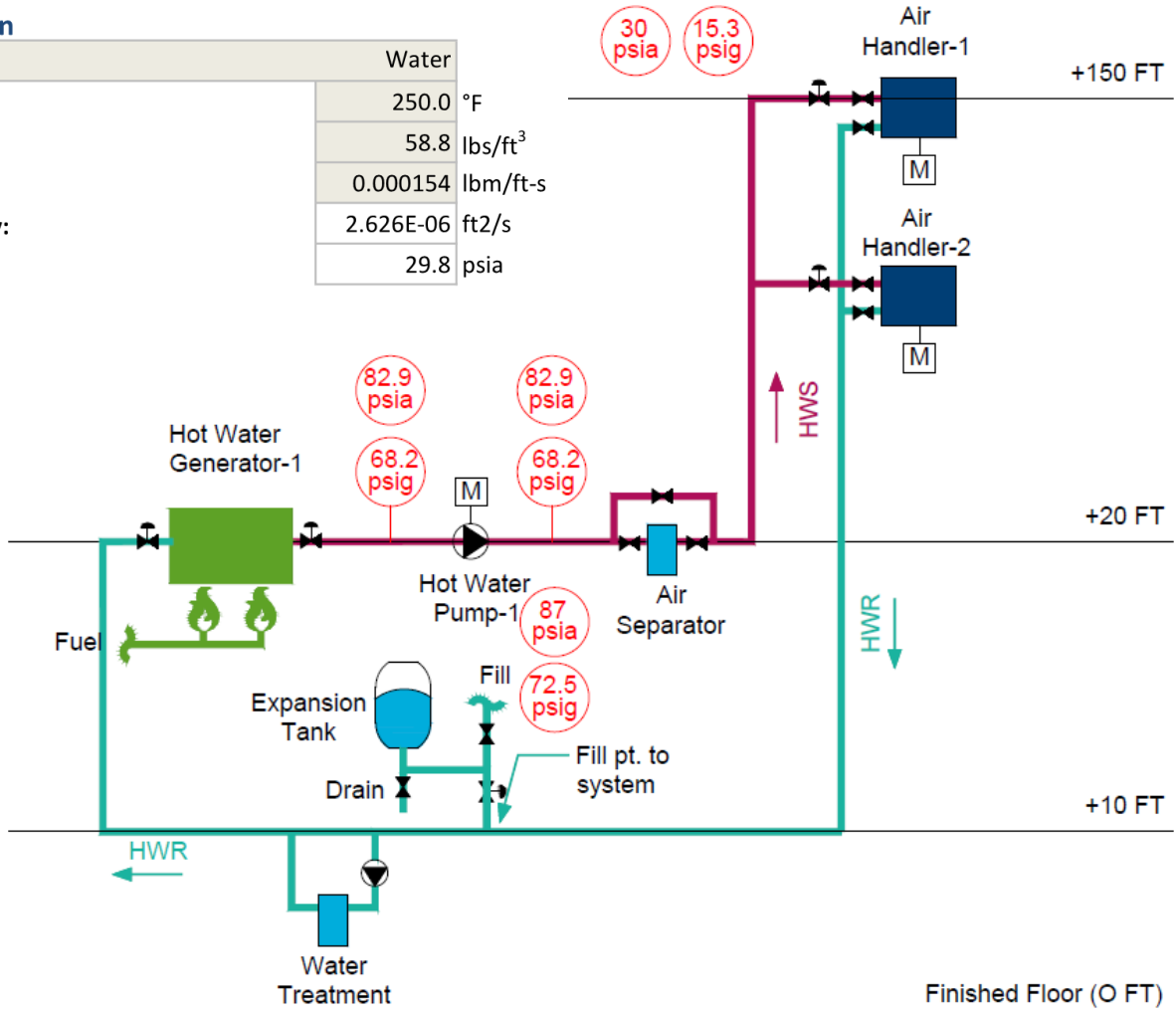


Figure 8: Scenario A: Pump off, Maximum Temperature of 250 °F. This figure shows an overall closed circuit, hydronic, (250 °F) hot water system. At the highest point, the lowest hot water pressure will be 30 psia, which is above the vapor pressure of 29.8 psia. This results in a pressure of 87 psia at the expansion tank. Pressures are shown in absolute and gauge pressure for an easy comparison to the vapor pressure. If you are following along with the foot head to psi conversions, you will also notice that the conversion is no longer 1 psi to 2.31 ft of head. This is because the density of the water is less now, so a higher water column is needed to provide the same pressure as before. At this temperature the conversion is 1 psi to 2.44 ft of head.

The next figure simulates Scenario B: Pump on, Maximum Temperature of 250 F. When the pump is turned on the pressure at the expansion tank will remain the same and all other pressures will be extrapolated from this point. The pump is assumed to provide 20 psia of pressure.

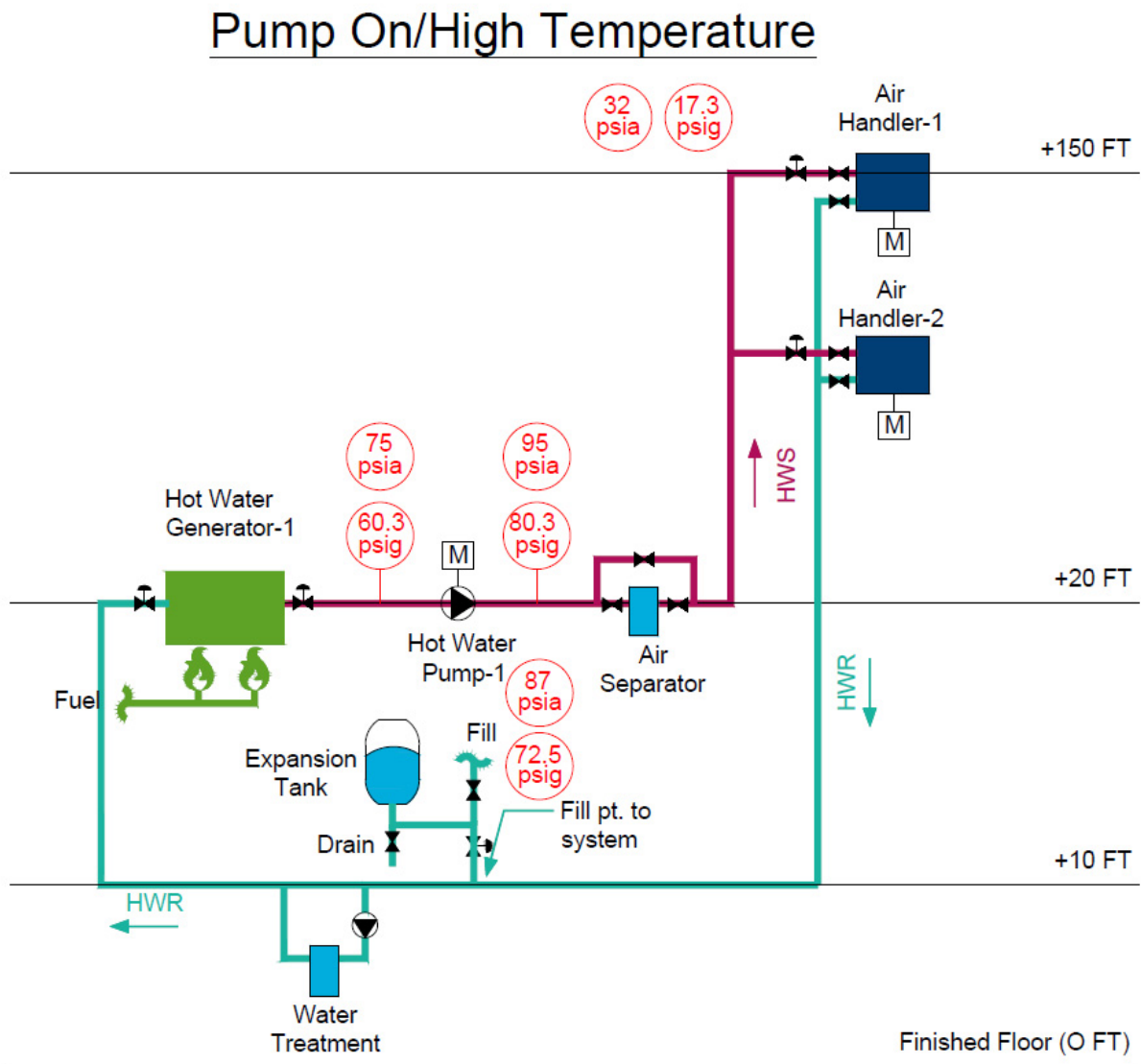


Figure 9: Scenario B: Pump on, Maximum Temperature of 250 °F. This figure shows the same system as the previous figure, except the pump is turned on. Since the pump is running, there will be friction losses between the expansion tank and the pump suction. This results in a pressure of 75 psia at the pump suction. The pump provides 20 psia of pressure so the discharge pressure will be 95 psia. The pressure at the top of the system is higher with the pump on because the pump provides additional pressure, thus the pressure is 32 psia at the top of the system. The drop between the top of the system and the expansion tank is larger, because there will be additional losses due to friction, since the fluid is moving.

The next figure summarizes the three criteria for determining minimum pressure for a different scenario. In this figure the maximum temperature is 250 °F, which corresponds to a vapor pressure of around 30 psia (15.3 psig). The highest point in the system is located at 30 feet above finished floor and 10 psig is required at this point to meet the elevation criteria. The required net positive suction head at the pump is 20 psig.

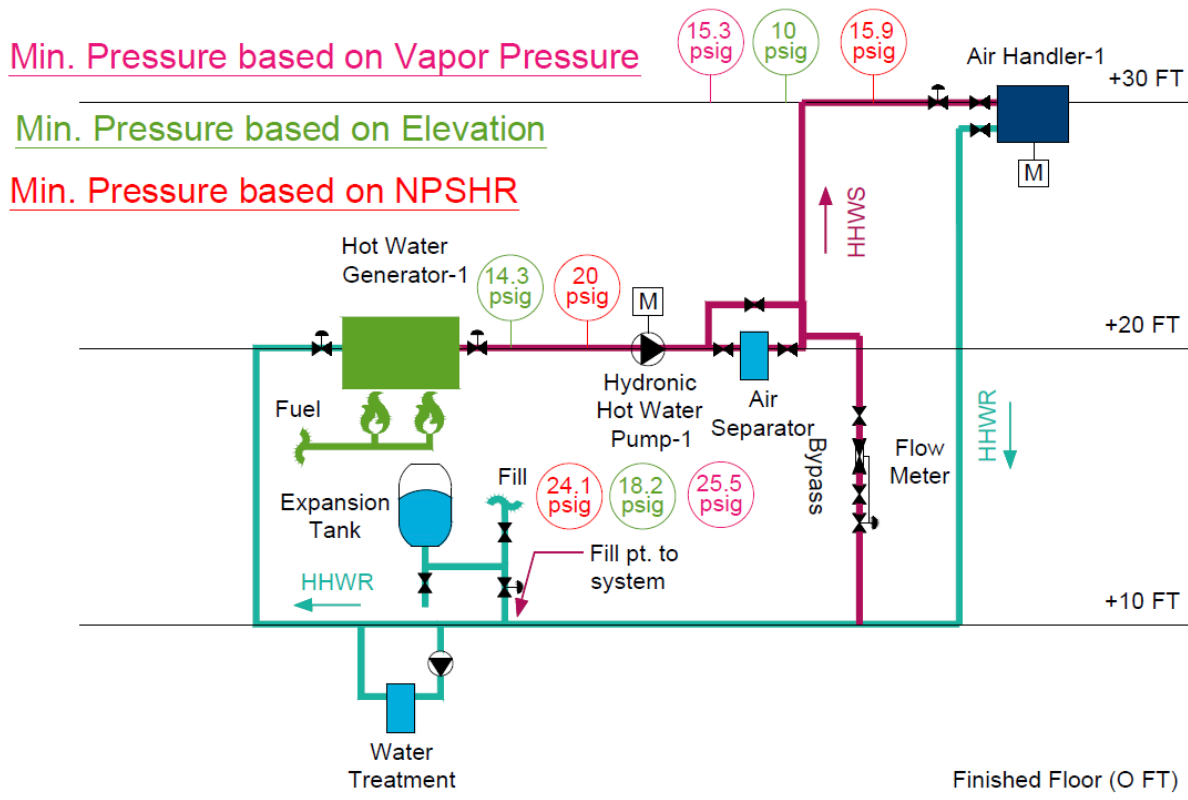


Figure 10: In this figure, the minimum pressure for all three constraints are shown. The minimum pressure to achieve 10 psig at the highest point is shown in green. The minimum pressure to achieve 20 psig (NPSHR) at the suction of the hot water pump is shown in red. The minimum pressure to achieve a vapor pressure of 30 psia (15.3 psig) at the highest point is shown in magenta. The minimum pressure that should be used in the calculator is 25.5 psig in red at the expansion tank. This is the highest minimum pressure.

### 5.3.4 HIGH PRESSURE

The high pressure value is the highest pressure that can occur at the expansion tank such that no pressure relief valves or equipment failure occurs due to high pressure. The scenario that you must check is the pump on and the hydronic hot water is at its highest temperature.

## High Pressure/Pump On

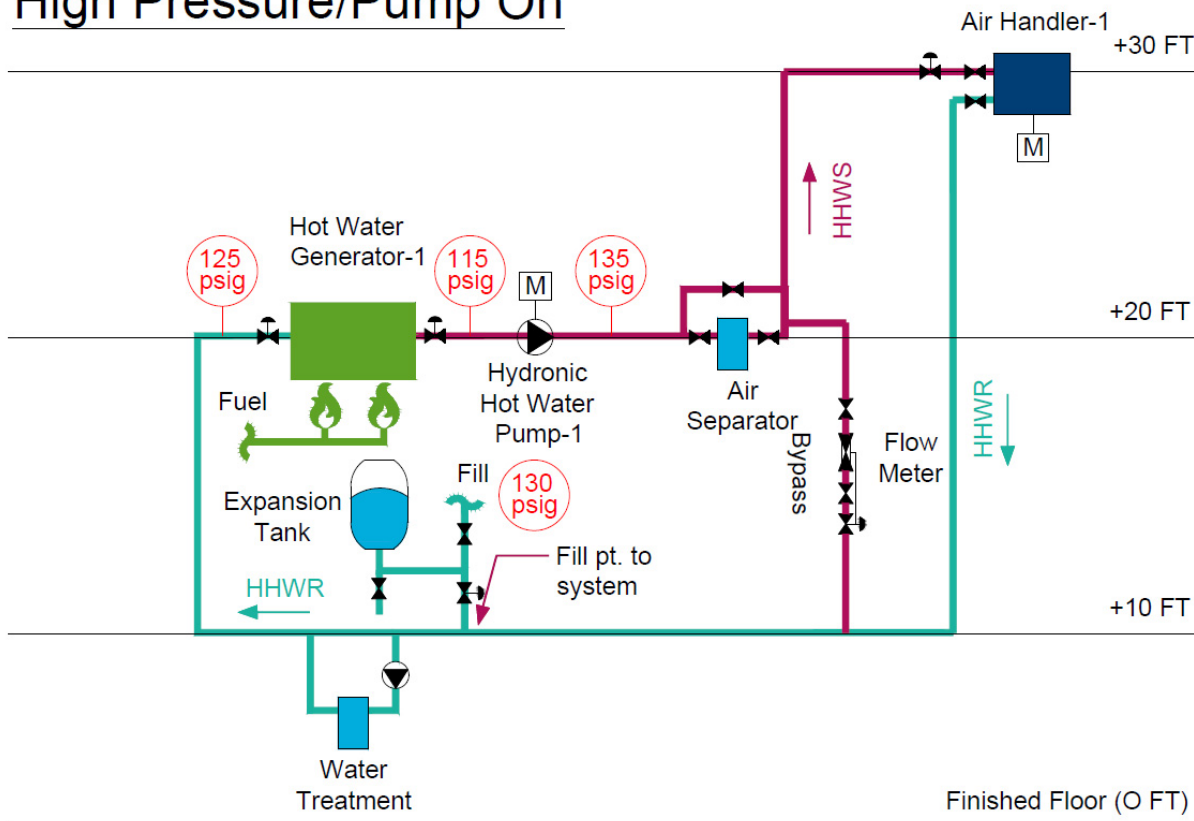


Figure 11: The high pressure at the expansion tank is determined by simulating the max pressure at the pressure relief valves and equipment and finding the maximum pressure value that ensures the pressure at all equipment and pressure relief valves are within their pressure limits. This figure tests the 125 psig maximum pressure at the hot water generator, with the pump on. This results in a maximum pressure at the expansion tank of 130 psig. The operating temperature of this system is 140 F.

You should always run the scenarios with the pump on and off, because the equipment must be within the pressure requirements, whether or not the pump is on or off. For example, in the previous scenario, the air separator will be subject to pressures at 135 psig. This fact would not have been found, if the pump was assumed to be off when testing for high pressures at the hot water generator. Since the air separator is at the same elevation, the air separator would be at the same pressure as the hot water generator when the pump is off.

### 5.4 LINEAR COEFFICIENT OF THERMAL EXPANSION

The following linear thermal coefficient of expansions can be used for your calculations. However, more accurate values can be achieved by using the data provided by the piping manufacturers.

$$\alpha_{steel} = 6.5 \times 10^{-6} \left( \frac{in}{in \cdot ^\circ F} \right); \alpha_{copper} = 9.5 \times 10^{-6} \left( \frac{in}{in \cdot ^\circ F} \right)$$



$$\alpha_{pvc} = 61.1 \times 10^{-6} \left( \frac{in}{in \text{ } ^\circ F} \right); \alpha_{polypropylene} = 18.0 \times 10^{-6} \left( \frac{in}{in \text{ } ^\circ F} \right)$$

If you have a mix of multiple pipe types, then you should use the lower coefficient of thermal expansion. This will result in a larger expansion tank. If you have a higher coefficient of thermal expansion then you will be taking advantage of the increased system volume that occurs when the piping expands. As the liquid heats up, the liquid expands, but the pipe also expands to accommodate some of the increased liquid volume. Thus, choosing the pipe material that expands the least will give the most conservative result.

## 6.0 EXPANSION TANK DESIGN ISSUES

This section focuses on the most common design issues encountered when designing an expansion tank for a hydronic hot water system. The issues include where to locate the tanks, what material to choose for the tank and what manufacturer to use for the tank.

### 6.1 LOCATING THE TANK

When locating the expansion tank you must check the pressures in the system, when the pump is on and off and when the system is cold or hot. The typical location for the expansion tank is on the suction line of the hydronic hot water pump, near or on the fill line. Another possible location that is used less often is at the highest point in the system. The best way to understand where to locate the tank is to understand the implications of locating the tank in these two locations.

#### 6.1.1 TANK LOCATED AT HWP SUCTION

When locating the tank at the HWP suction, near the lowest point in the system, the minimum and maximum pressures will be much higher than the tank at the highest point. This is because the lowest point will have the pressure from the elevation acting upon this point. In the following diagram, it is assumed that the minimum temperature is 60 F and the maximum temperature is 250 F. The maximum and minimum pressures are shown on the figures in green and red. In addition the total hydronic hot water volume is 2,100 gallons and the expansion tank is a diaphragm type tank.

The benefits of locating the tank at the HWP suction are that the expansion tank is typically easier to maintain near the pumps and hot water generators. The pumps and hot water generators are located at the ground floor in a mechanical room because it is too difficult to maintain equipment on the roof and too difficult to replace equipment on the roof.

As you may remember, the tank location is a point of constant pressure when the pump is turned on and off, assuming temperature remains constant. Thus, the tank is typically not located on the discharge side of the pump because this means that regardless of when the pump is turned on or off, the discharge of the pump will have the same pressure. Basically,

when the pump is turned on, the pressures throughout the hydronic hot water system are reduced as opposed to increased.

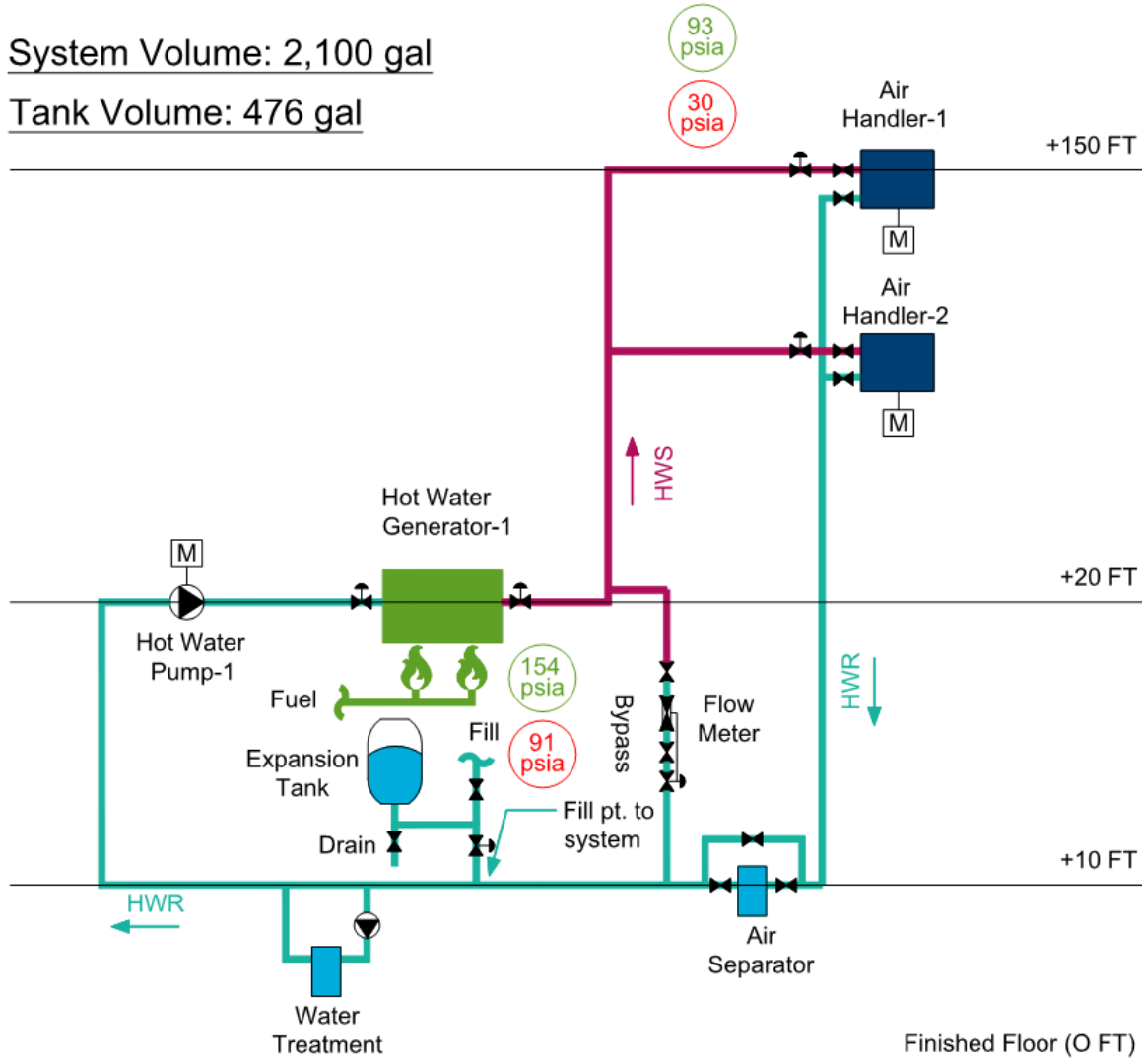


Figure 12: A tank located at the HWP suction will result in an expansion tank size of 476 gallons.

### 6.1.2 TANK LOCATED AT HIGHEST POINT

When the tank is located at the highest point, the maximum and minimum pressures will be lower. If all other variables are held equal and only the maximum and minimum pressures are changed, the expansion tank will need to be 304 gallons. As you can see, locating the tank at the higher point with the lower pressures will result in a smaller tank. The disadvantages are the maintenance issues with repairing and replacing a tank at the highest point in the hydronic hot water system.

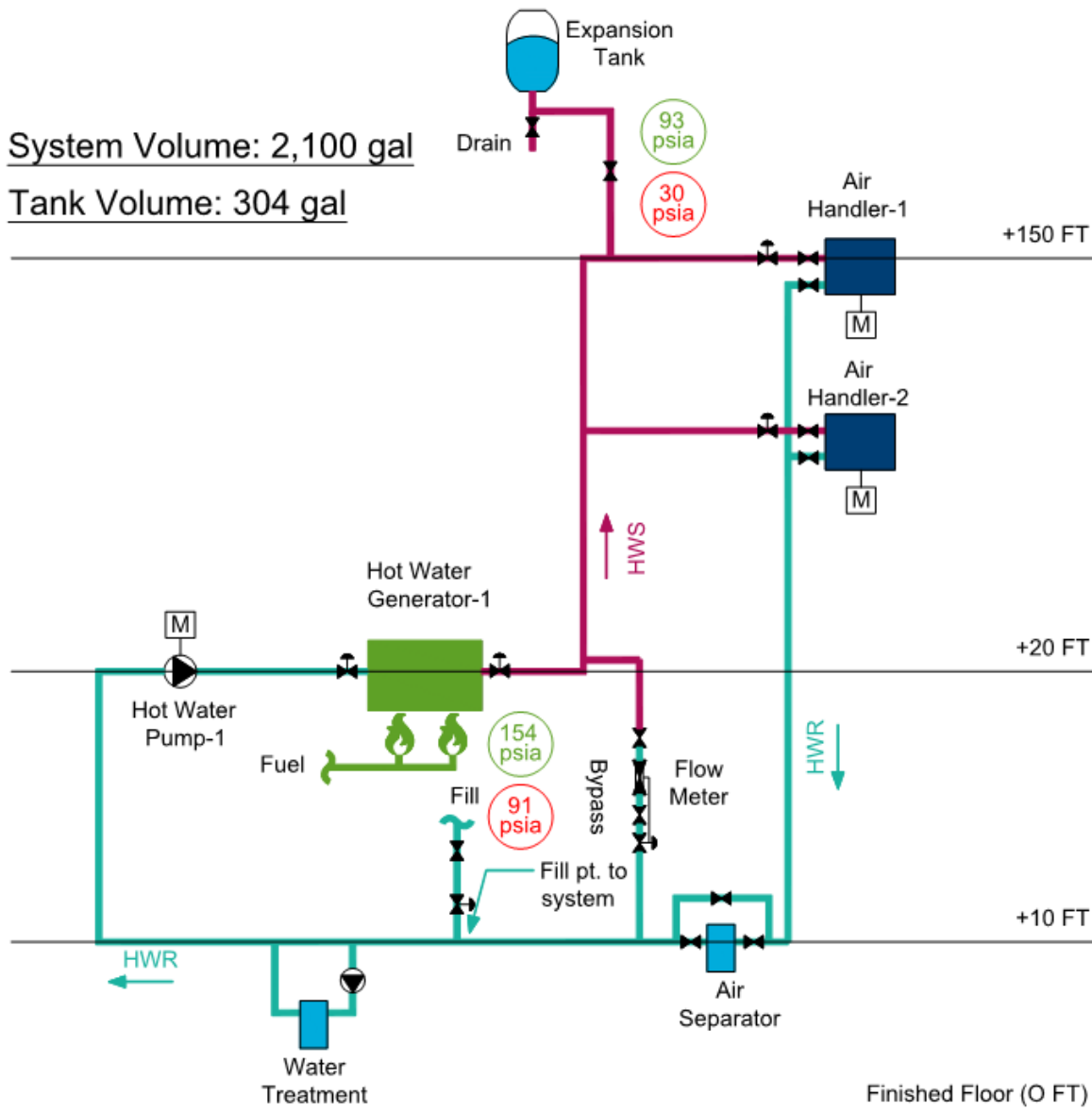


Figure 13: When all other variables are held constant, a tank located at lower pressures will result in a smaller expansion tank volume than a tank located at higher pressures. As you can see the pressure differential between maximum and minimum are nearly the same as the previous location, but the expansion tank volume is less.

## 6.2 TANK MATERIALS

When selecting an expansion tank, you must first select the type and then the size. Following these choices, you must next select the tank material.

**Shell:** The shell of an expansion tank should be ASME certified and should also be capable of withstanding the pressures within the system. Typically the shell is rated for 150 psig and most shells are steel.

Diaphragm/Bladder: The diaphragm/bladder should be suitable to withstand the corrosiveness of the air/water or glycol. Since the hydronic hot water is typically not used for potable water, the diaphragm/bladder does not need to be approved for handling potable water. The material of the diaphragm/bladder is typically a plastic like polypropylene or a rubber like butyl.

### 6.3 TANK MANUFACTURERS

Manufacturers that provide this type of expansion tank are shown in the table below. The last time this table was updated was in January 2018. Manufacturers may have changed the information below.

Manufacturer (Make)	Website
Amtrol	<a href="https://www.amtrol.com/product/therm-x-trol-expansion-tanks/">https://www.amtrol.com/product/therm-x-trol-expansion-tanks/</a>
Watts	
Flexcon	<a href="https://www.flexconind.com/products/category.html?newsid=62">https://www.flexconind.com/products/category.html?newsid=62</a>

### 6.4 ANCILLARY DEVICES

An expansion tank has the following typical ancillary devices that help to support the function of the expansion tank.

Shut-Off Valve: A shut off valve should be provided on the system connection between the hydronic hot water system and the expansion tank. The shut-off valve allows you to disconnect the expansion tank so it can be repaired or replaced.

Drain Valve: In order to repair the tank, the water must be drained from the expansion tank. Thus a drain valve should be provided on the tank or on the piping leading to the tank. The drain valve should be at the lowest point of the tank and should be in-between the shut off valve and the expansion tank.

Air Valve: The air valve is used to charge the bladder/diaphragm expansion tank types with compressed air.

Supports: The expansion tank should be supported by either hanging it from the ceiling or wall or floor supported. The expansion tank should not be supported by the piping.

## 7.0 EXPANSION TANK CALCULATOR

### 7.1 INPUTS

In this section you will input the temperature range and pressure range for the fluid. In addition, you must also specify the primary piping material.

## Inputs

Fluid

Temperature

Minimum Temperature:  °F

Maximum Temperature:  °F

Pressure

Minimum Pressure:  psig

Maximum Pressure:  psig

Pre-Charged Pressure:  psig

Piping

Primary Piping Material:

Pipe Linear Exp. Coefficient  in/in-°F

Figure 14: First, input the basic information of the hydronic hot water system which includes the minimum and maximum temperature of the fluid, minimum and maximum pressure of the fluid and the primary piping material. The primary piping material is the material with the smallest coefficient of thermal expansion. In addition, you should also input the pre-charge pressure if you are using a bladder/diaphragm tank.

## 7.2 PIPING INPUTS

In the piping section, you must input all hydronic hot water pipes into the table. All lengths of pipes must be encountered for in this section. The piping along with the equipment will determine the total system volume.

Pipe Section	Pipe Material	Material Type	Pipe Size	Pipe Length (ft)
A-B	Copper	Type_K	5/8 in	10
B-C	PP	DR_9	3/4 in	10
C-D	Steel	Sch_40	3-1/2 in	10

Figure 15: Next, you need to input all the piping information. Typically, you can sum up all the pipe lengths for a specific pipe material and pipe size and insert one row for all those sections. However, sometimes you may choose to break up the piping into pipe sections based on location. For example, “6” bypass” or “6” hot water generator”.

When you select the pipe material, the material type drop down will change to show the available material types under that material. For example, “Type K” and “Type L” are not available under “Steel”. Also, the combination of the pipe material and material type will also determine the available pipe sizes. Certain pipe material/type combinations do not have certain sizes available.

### 7.3 EQUIPMENT INPUTS

Next, you must input all equipment into the table and the volume of hydronic hot water within each piece of equipment. The hydronic hot water equipment volume along with the piping volume will determine the total system volume.

Equipment	Volume (gallons)
HW Gen-1	150.00
HW Gen-2	150.00
Air Handler-1	1,646.70
Air Handler-2	20.00
Air Handler-3	20.00
Air Handler-4	20.00

**Total Equipment Volume (gallons): 2,006.70**

*Figure 16: Do not forget to add the volume from the equipment. Equipment like hot water generators can hold a significant amount of liquid.*

### 7.4 EXPANSION TANK OUTPUTS

Using the total system volume and the fluid inputs, the calculator will automatically and instantly output the sizes of the three types of expansion tanks (1) open, (2) closed and (3) closed with diaphragm/bladder in the calculations below. At the top of the sheet, there is a drop down menu that you can use to choose your tank. Also you must insert your required safety factor. The safety factor is used to account for any piping changes that may occur during the construction of the system. There will also be slight variations in temperature and pressure during the actual operation of the system, so the safety factor should provide sufficient leeway to account for these differences between design and installation.

<b>Specific Volume @</b>	
<b>Minimum Temperature:</b>	1.604E-02 ft <sup>3</sup> /lb
<b>Maximum Temperature:</b>	1.700E-02 ft <sup>3</sup> /lb
<b>Total Piping Volume:</b>	93.3 gallons
<b>Total Equipment/Misc. Volume:</b>	2,006.7 gallons
<hr/>	
<b>Total CHW System Volume:</b>	2,100.0 gallons
<b>Initial Expansion Tank Size:</b>	202.8 gallons
<b>Safety Factor:</b>	1.5
<b>Bladder Expansion Tank</b>	<b>304.1 gallons</b>

Figure 17: Use the expansion tank outputs and the information gained from this guide to select an expansion tank for your system. The calculator will output the specific volume at the minimum/maximum temperatures and provide a summary of the total system volume (piping & equipment/misc.). The initial expansion tank size does not account for the safety factor. The last cell with the dark outline shows the size for your selected expansion tank type with your safety factor.