Expansion Tank Concepts

For HVAC Project Engineers/Managers

Presented By WTF

(Institute of Higher Learning)

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ASHRAE Formula — No Concepts Here!

For closed tanks with air/water interface

$$V_t = V_s \frac{[(v_2/v_1) - 1] - 3\alpha\,\Delta t}{(P_a/P_1) - (P_a/P_2)}$$

For open tanks with air/water interface

$$V_t = 2V_s \left[\left(\frac{v_2}{v_1} - 1 \right) - 3\alpha\,\Delta t \right]$$

For diaphragm tanks

$$V_t = V_s \frac{[(v_2/v_1) - 1] - 3\alpha\Delta t}{1 - (P_1/P_2)}$$

where

V_t	=	volume of expansion tank, gal
V_s	=	volume of water in system, gal
t_1	=	lower temperature, °F
t_2	=	higher temperature, °F
P_a	=	atmospheric pressure, psia
P_1	=	pressure at lower temperature, psia
P_2	=	pressure at higher temperature, psia
v_1	=	specific volume of water at lower temperature, ft^3/lb
v_2	=	specific volume of water at higher temperature, ft^3/lb
α	=	linear coefficient of thermal expansion, in/in · °F
	=	6.5×10^{-6} in/in ·°F for steel
	=	9.5×10^{-6} in/in ·°F for copper
Δt	=	$(t_2 - t_1)$, °F

The Expansion Tank – What Does It Do?

4 Things: (Diaphragm/Bladder Tanks)

1. The obvious - it provides room for the expanded water volume and prevents the system pressure from getting to dangerous levels. You cannot compress water.

2. When properly designed, it maintains all parts of the piping loop above atmospheric pressure to avoid drawing air in.

3. It maintains the low pressure points of a system safely above the vapor flash point so that we are always pumping water and never steam. When properly designed and located, it also guarantees that the system pump always sees the NPSH required.

4. It provides a reference point for loop pressure calculations by providing a point of "no pressure change" for the system. (Like Ground in electrical circuit analysis.)
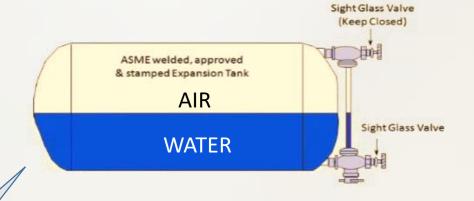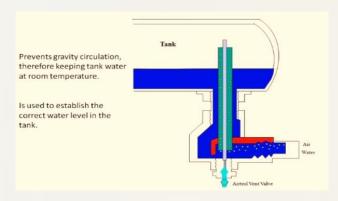
WHEN DO WE NEED AN EXPANSION TANK?

- How hot the system water needs to be before an expansion tank is required?

- WRONG QUESTION !

- Is the system "closed" or "open"?

- All CLOSED LOOP systems require expansion tanks. Even chilled water.

- In the WAC world, that means all loops except open cooling towers. (Some steam condensate loops are open systems, but we don't do much steam work.)

2 Types of Pressurized Tanks

AIR
WATER
Air
Bladder Tank

WATER AIR
Diaphragm Tank

Standard Compression Tank

Sight Glass Valve
(Keep Closed)

ASME welded, approved
& stamped Expansion Tank

AIR
WATER

Sight Glass Valve

Prevents gravity circulation,
therefore keeping tank water
at room temperature.

Is used to establish the
correct water level in the
tank.

Tank

Air
Water

Airtrol Vent Valve

A
B

Air
Control

Air
Elimination
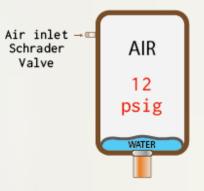
Air inlet →
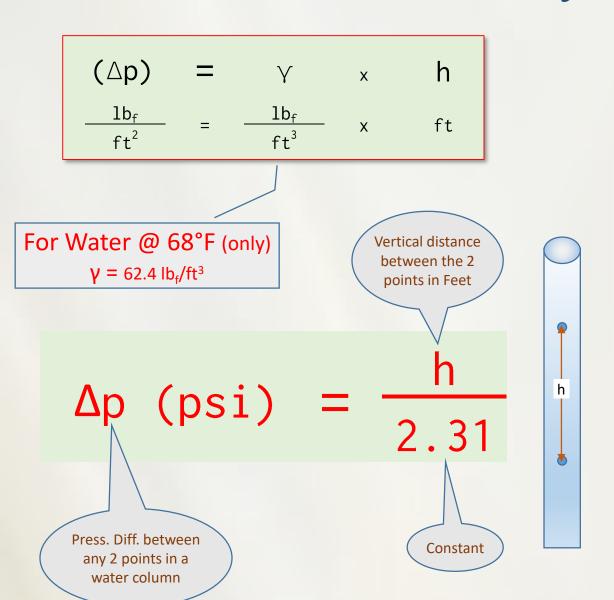Schrader
Valve

AIR
12
psig
WATER

The Expansion Tank – Location?

1. Always on the suction side of the pump. Preferably on the "Lowest Pressure Point" (LPP) of the system. (The top of the return riser in a multi-story building.)

2. If not located at the LPP due to practical reasons, then it is the designers job to set the Expansion Tank Pressure such that the remote LPP will be safely above the vapor flash point and above atmospheric pressure. Note that for flat systems the LPP can be inside the pump. You then check the NPSHR and set the Tank pressure accordingly.
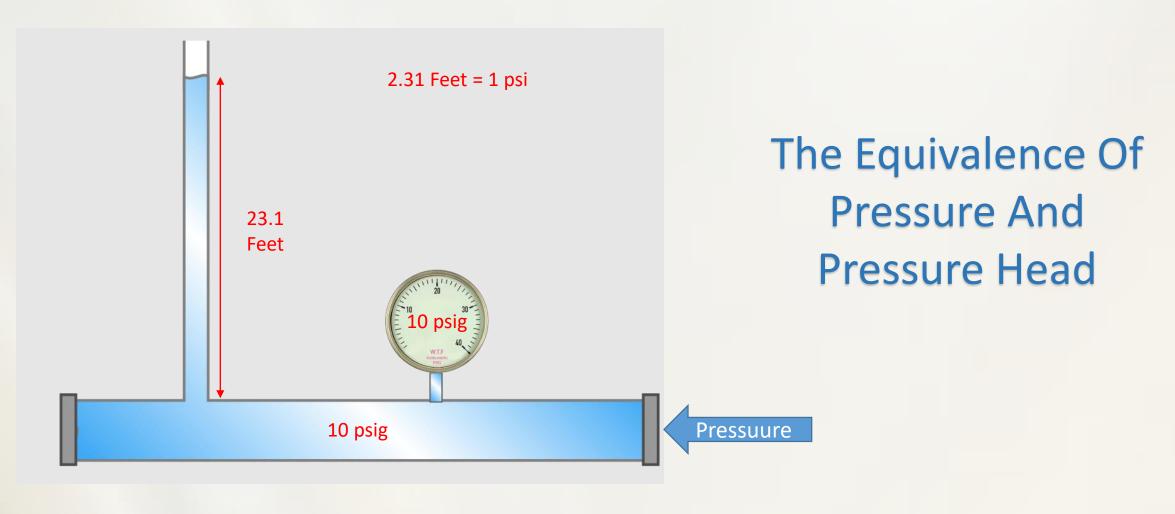
The Basic Hydrostatic Formula

$$(\Delta p) = \gamma \times h$$

$$\frac{lb_f}{ft^2} = \frac{lb_f}{ft^3} \times ft$$

For Water @ 68°F (only)

$\gamma = 62.4 \ lb_f/ft^3$

Vertical distance between the 2 points in Feet

$$\Delta p \ (psi) = \frac{h}{2.31}$$

h

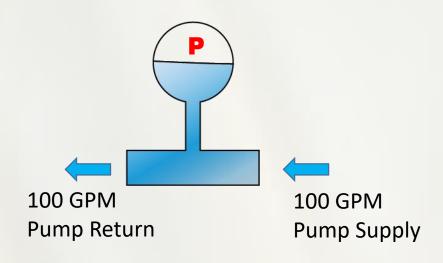Press. Diff. between any 2 points in a water column

Constant

- 2.31 comes from dividing 144/62.4

- You may choose to remember 0.433, the reciprocal of 2.31. Or both. Your choice.

- All it is saying is that: every 2.31 feet of a water column will exert 1 psi pressure at the base.

- You need to remember this Constant!

Note: For hydronic systems using glycol, or hot water, correct the gamma (γ) value by multiplying by the specific gravity of the glycol mixture.
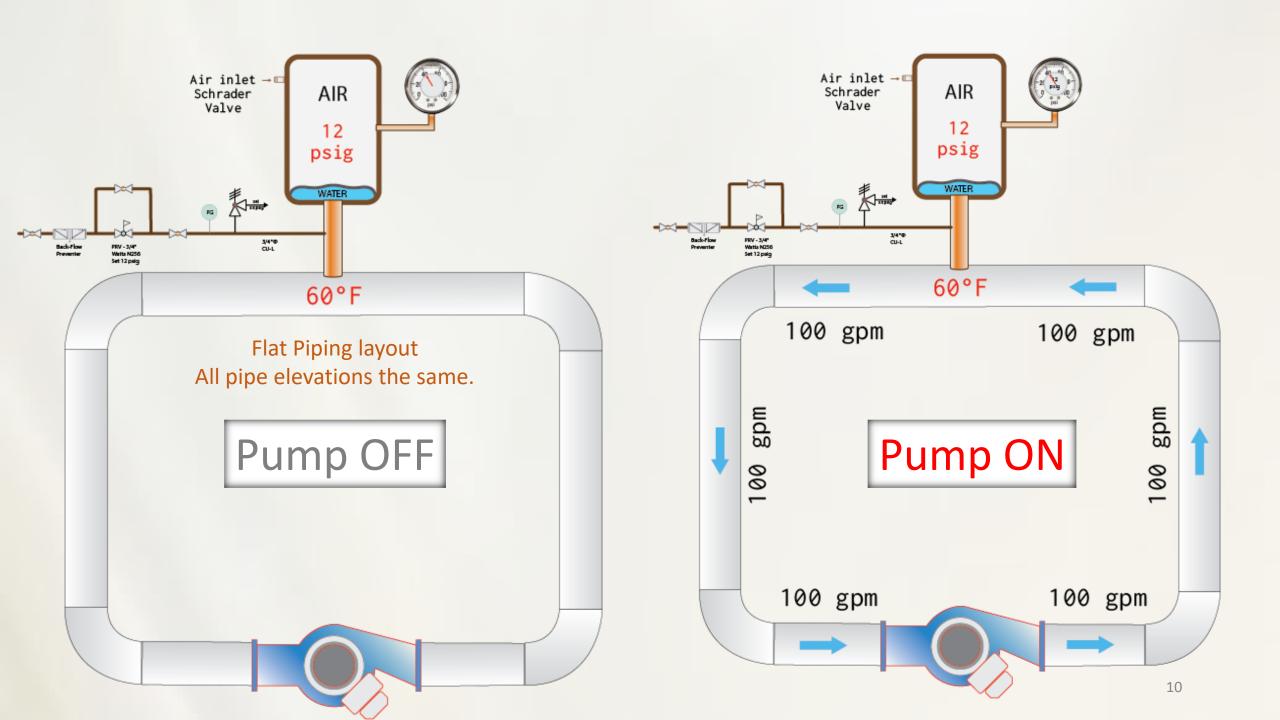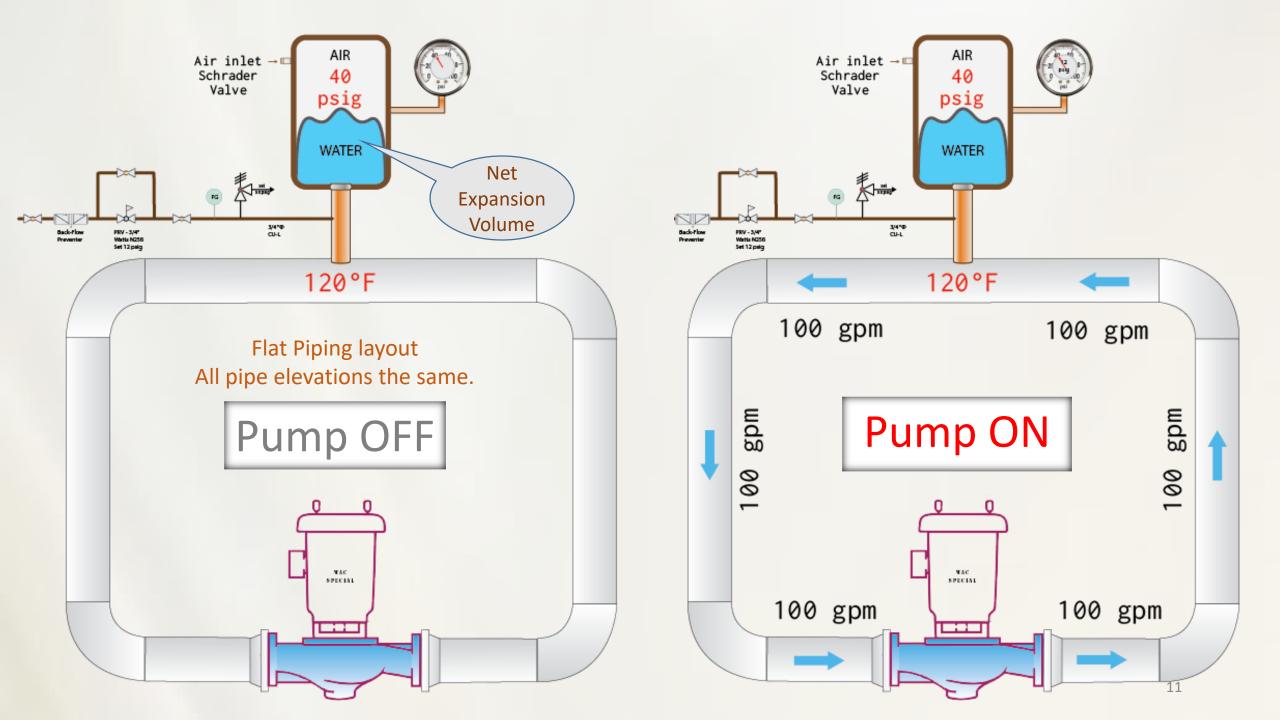
The Basic Hydrostatic Formula

2.31 Feet = 1 psi

23.1 Feet

20

10   30

10 psig

40

W.T.F
Instruments
PSIG

10 psig

Pressuure

The Equivalence Of Pressure And Pressure Head

THE EXPANSION TANK PRESSURE – TEE LAW

100 GPM
Pump Return

100 GPM
Pump Supply

- In pipe flow theory, the "Law" of the Tee states that the flow going into a Tee must equal flow leaving the Tee.

- Also for steady state flow, what leaves the pump must enter the pump.

- As the graphic on the left illustrates, the pump supply must match the pump return.

- The only way the pressure "P" can increase is if extra water is pushed up into the expansion tank.

- Since the pump cannot do that it cannot change the pressure "P" in the tank.

- Note that the water level in the tank WILL rise when the system water expands and the pressure "P" WILL go up.

Air inlet → Schrader Valve

AIR

12 psig

WATER

60°F

Back-Flow Preventer

PRV - 3/4" Watts N256 Set 12 psig

3/4"Ø CU-L

Flat Piping layout
All pipe elevations the same.

Pump OFF

Air inlet → Schrader Valve

AIR

12 psig

WATER

60°F

Back-Flow Preventer

PRV - 3/4" Watts N256 Set 12 psig

3/4"Ø CU-L

100 gpm   100 gpm

100 gpm   100 gpm

100 gpm   100 gpm
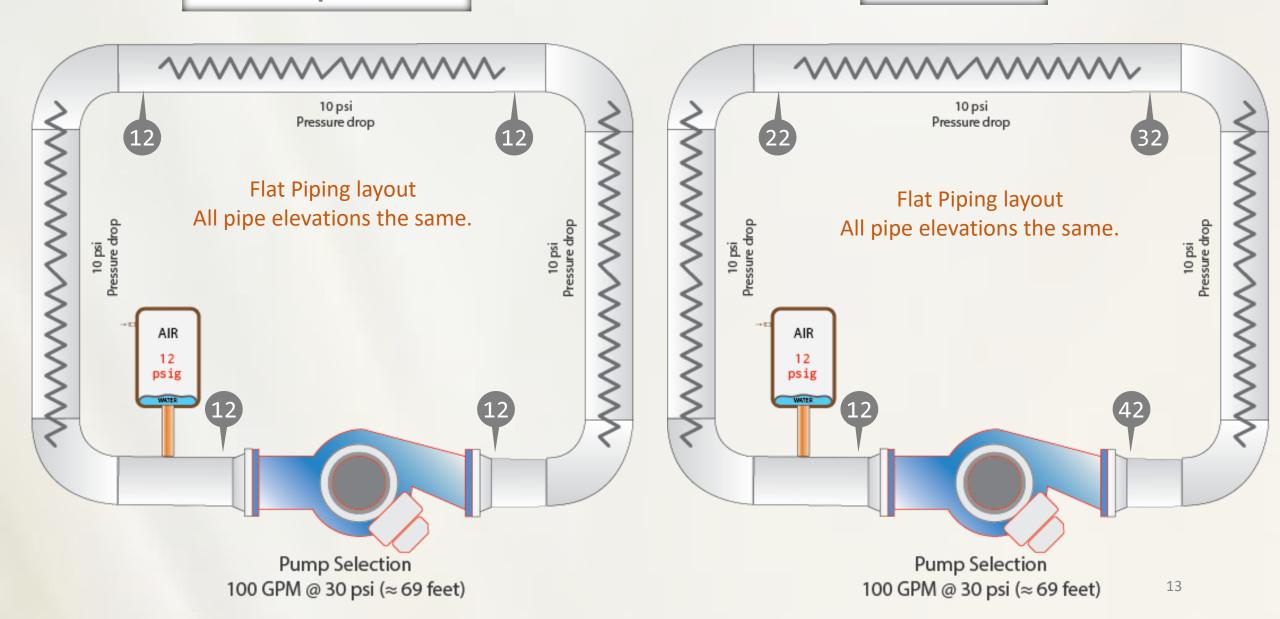
Pump ON

Takeaway For The Last 2 Slides

- The point where the expansion tank ties into the system is a point of "no pressure change" from the pump ON/OFF point of view. In other words, `switching` the pump ON/OFF cannot change that pressure.

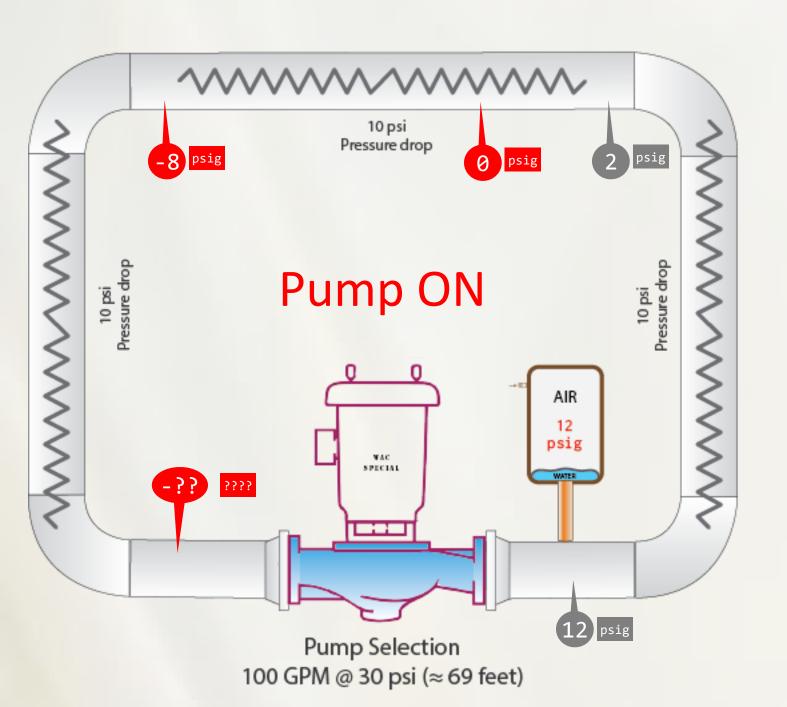- HOWEVER, the pressure does change when the system temperature changes and water goes in (or out) of the tank.

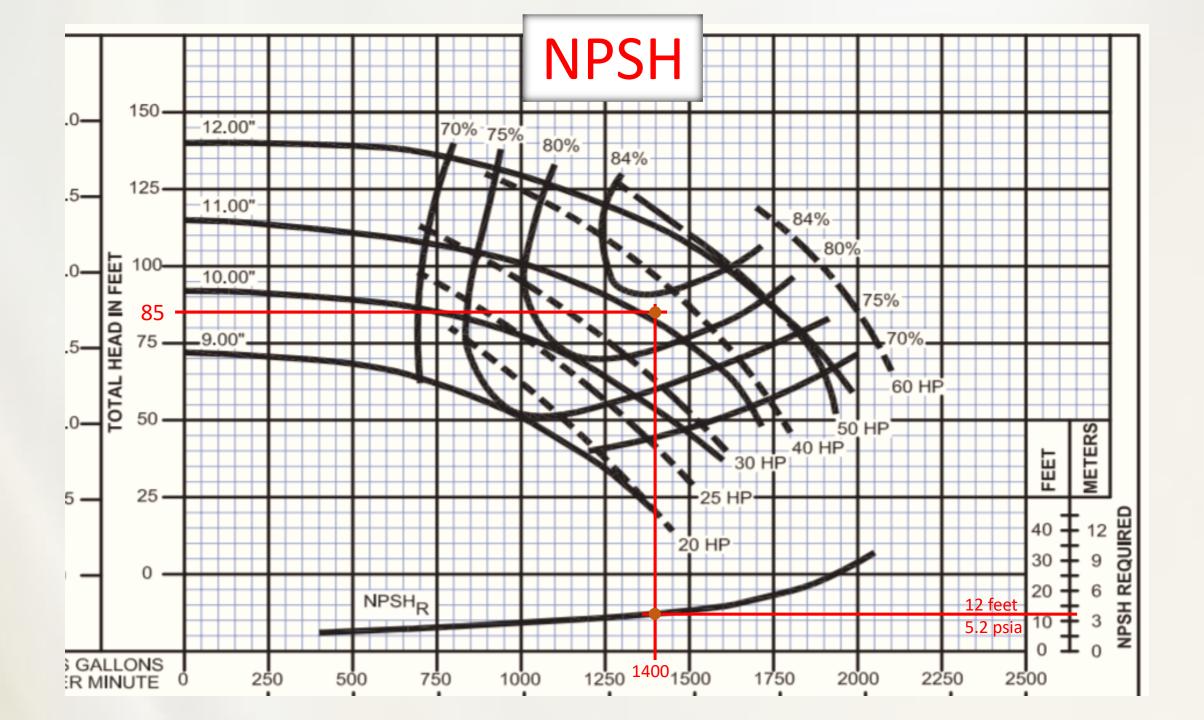# What The Next 2 Slides Will Show

- Because of the above system property – very bad things can happen if you install the expansion on the DISCHARGE side of the pump. The expansion tank always goes on the SUCTION side of the pump.
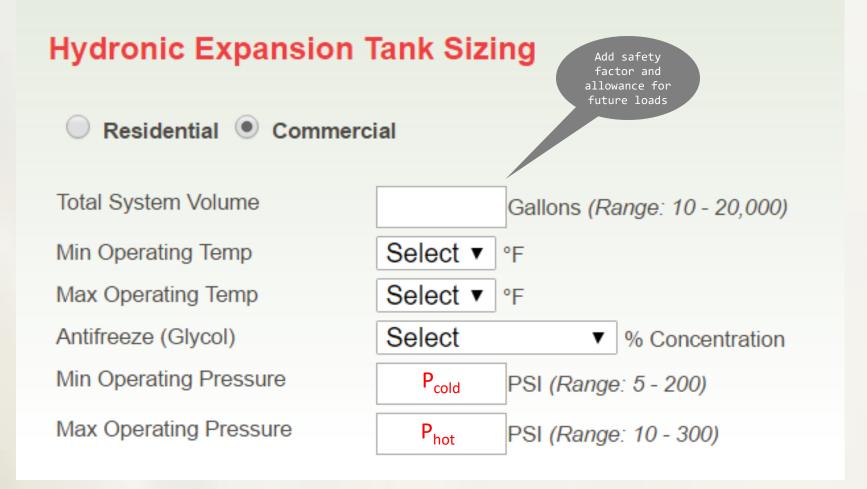
Pump ON

-8 psig · 10 psi Pressure drop · 0 psig · 2 psig

10 psi Pressure drop · 10 psi Pressure drop

AIR 12 psig WATER

WAC SPECIAL

-?? ????

12 psig

Pump Selection
100 GPM @ 30 psi (≈ 69 feet)

Hydronic Expansion Tank Sizing

Add safety factor and allowance for future loads

○ **Residential**   ● **Commercial**

Total System Volume [   ] Gallons *(Range: 10 - 20,000)*

Min Operating Temp [Select ▾] °F

Max Operating Temp [Select ▾] °F

Antifreeze (Glycol) [Select ▾] % Concentration

Min Operating Pressure [P_{cold}] PSI *(Range: 5 - 200)*

Max Operating Pressure [P_{hot}] PSI *(Range: 10 - 300)*

WTF Suggested Min Temps:
HW	50°F
CHW	45°F
CDW	50°F

Note: Min temp is not the fill water temp for the system. It is the coldest temp possible during operation or standby/off.
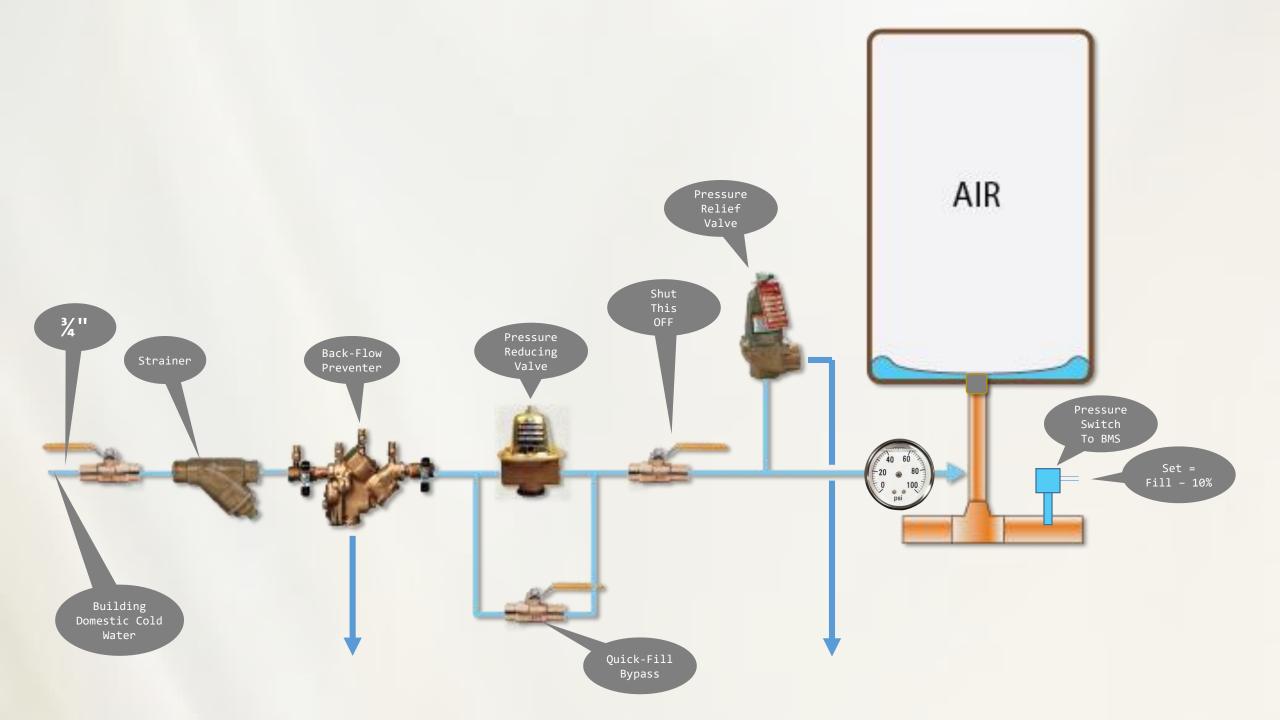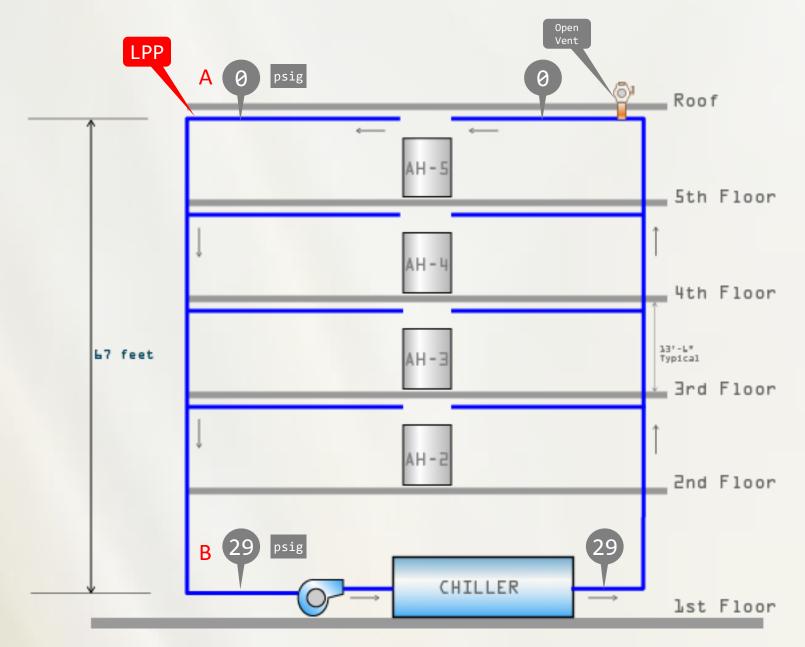
WTF Suggested Max Temps:
HW	210°F
CHW	100°F
CDW	120°F

So specifying P_{cold} and P_{hot} correctly is the goal for this discussion.

Also called [min, max], [initial, final], [fill, xxx]

Pump OFF – Hydrostatic Pressures

- If expansion volume was our only concern we could locate the expansion tank anywhere in the loop and it would do the job.

- But as we have seen, keeping the LPP safely positive and above any vapor pressure issues is also a key concern.

- We know that the tank should be on the pump suction.

- Either point A or B can be used. But you have to make sure that the LPP does not drop below 5 psig. (Not a system requirement – just good practice.)

- Notes:

- Try to keep CHW, HW, CDW pressures under 100 psig in the system.

- If not - be very careful and check all equipment, accessories and instruments for their pressure ratings.

- Always try to incorporate a second safety relief valve. Pump discharge header is usually a good location.

Standard Relief Valve on Copper Finned Tube Boilers

Options

OPTION	HEAT EXCHANGER	PRESSURE RELIEF VALVE			
	A-3	A-10	A-11	A-12	A-14
	CUPRO-NICKEL	30 PSIG	45 PSIG	60 PSIG	75 PSIG
MODEL	ALL	H	H	H	H
503A/504A	$342	$34			
753A/754A	$490				
1003A/1104A	$693		$35		
1253A/1504A	$858				$70
1503A	$985	$650		Standard	
1753A/2004A	$1,201	See Note 1	Size 2003	on	
2003A	$1,373		See Note 1	H units	
2503	$2,250	$248			
3003	$2,579		N/A		N/A
3503	$2,908	$608			
4003	$3,236				
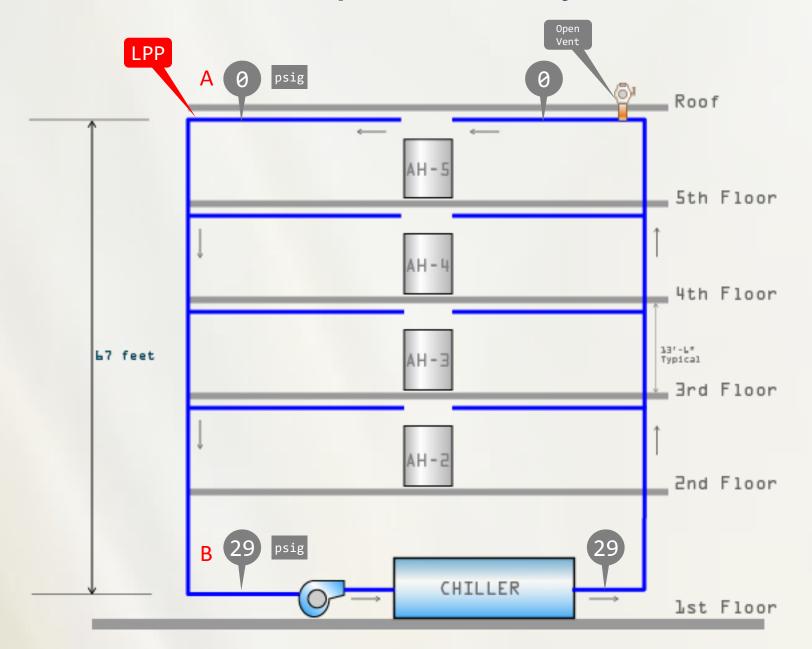
RayPak
Higher Relief Settings
Available as add Option
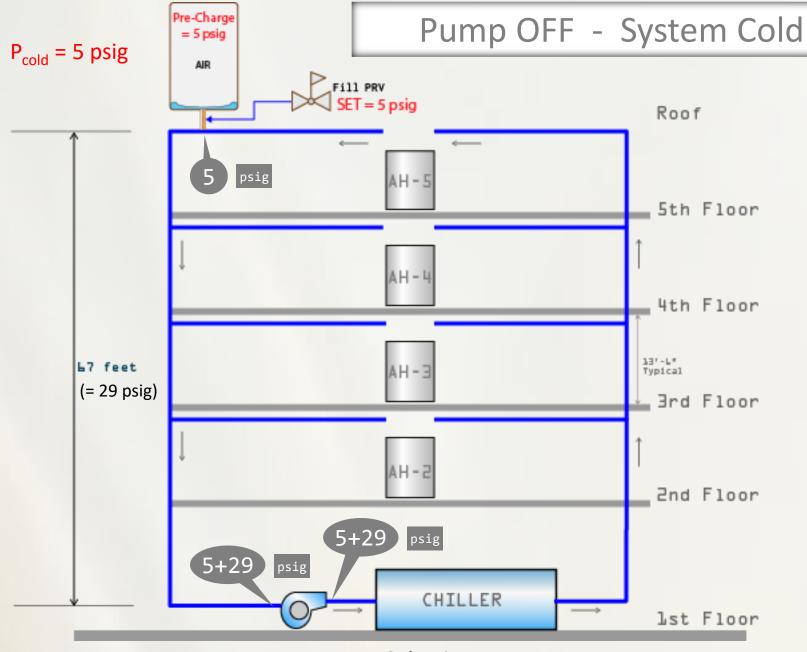
Tag Name: 600 ton Centrifugal

Chiller

Chiller Model **19XRV5252446LBH64**
Starter / VFD .... **VFD - Unit Mounted (STD Tier)**
Refrigerant Type **R-134a**
Isolation Valve .... **Installed**
Operation Type .... **Cooling**

Cooler

Size **52**
Waterbox Type .... **Nozzle-in-Head, 150 psi**
Passes **2**
Nozzle Arrangement . **D (Nozzles on Compressor End)**
Tubing .... **Super E3 (SUPE3), .025 in, Copper**
Fluid Type .... **Fresh Water**
Fouling Factor (hr-sqft-F)/BTU **0.00010**

Compressor

Size **446**

Weights

Total Rigging
Total Operati
Refrigerant W

Condenser

Size
Waterbox Ty
Passes
Nozzle Arran
Tubing
Fluid Type
Fouling Facto

Motor

Size
Line Voltage/

Flow Controls

Float Valve S
Flasc Orifice

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Pump OFF – Hydrostatic Pressures

- The smallest tank size for a given range of P_{cold} and P_{hot} will be when the tank is located at the LPP.

- Other concerns may dictate placing the tank in the equipment room on first floor. Like fill water availability, maintenance access, and floor space.

- But then you need to make sure that the LPP does not drop below 5 psig (roughly) by selecting the tank initial pressure high enough.

- We will do an example of tank sizing at location B.

Pump OFF - System Cold

P_{cold} = 5 psig

Pre-Charge = 5 psig

AIR

Fill PRV
SET = 5 psig

Roof

5 psig

AH-5

5th Floor

AH-4

4th Floor

67 feet
(= 29 psig)

AH-3

13'-L"
Typical

3rd Floor

AH-2

2nd Floor

5+29 psig

5+29 psig

CHILLER

1st Floor

Pump Selection
1,000 gpm @ 90 feet TDH (39 psi)

- By placing the expansion tank at the LPP we have eliminated any chance of system pressures going negative or vapor flashing

- We need to check what is happening to the pressures below and see if there are any problems when the pump starts in this "cold" state and also a couple of slides down, in the "warm" state

- Note, right now the pump is OFF and the system is "cold". Maybe the chiller just recently cycled off.

- Let us work with this P_{cold} value of 5 psig and see how pressures look.

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Pump ON - System Cold

- With pump running, there is always a pressure drop in the direction of water flow.

- Let us assume that there is a 4 psi head loss due to friction between A and B

- Point A pressure cannot change

- Point B pressure is now

    = 5 + 29 – 4 = 30 psig

- Point C (with pump running)

    = Point B + 39 = 69 psig

- Note that (unless the piping runs further below the 1st floor) this is also the highest pressure point in the system

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Pump OFF - System WARM

P_{hot} = 25 psig

25 psig AIR

WATER

Fill PRV SET = 5 psig

Roof

25 psig

AH-5

5th Floor

AH-4

4th Floor

67 feet
(= 29 psig)

AH-3

13'-6" Typical

3rd Floor

AH-2

2nd Floor

25+29 psig

25+29 psig

CHILLER

1st Floor

Pump Selection
1,000 gpm @ 90 feet TDH (39 psi)

- Hot summer weekend. The chiller pump has been OFF. Say water temp rises to 100°F

- Water expands and the expanded volume starts moving in the expansion tank – that is what the tank is there for

- Just roughly eye-balling the graphic, if the air is compressed to half its original volume, then $P_1V_1 = P_2V_2$ tells us that pressure will roughly double. Ignoring the formula, this makes sense intuitively. But remember these are Absolute Pressures. So 5 psig is 20 psia and double of that is 40 psia which is 25 psig.

- With the pump OFF, the pump suction and discharge gages are reading 54 psig

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Pump ON - System Warm

P_{hot} = 25 psig

- Warm start Monday morning

- Let us assume that there is a 4 psi head loss due to friction between A and B

- Point A pressure cannot change

- Point B pressure is now

    = 25 + 29 − 4 = 50 psig

- Point C (with pump running)

    = Point B + 39 = 89 psig

- Still OK, but getting high, so probably don't want any higher P_{hot} even if it reduces tank size.

- Note again that the pump is indifferent ("cannot see") to the system static pressure

For closed tanks with air/water interface

$$V_t = V_s \frac{[(v_2/v_1)-1]-3\alpha\,\Delta t}{(P_a/P_1)-(P_a/P_2)}$$

$$V_t = 2V_s\left[\left(\frac{v_2}{v_1}-1\right)-3\alpha\,\Delta t\right]$$

$$V_t = V_s \frac{[(v_2/v_1)-1]-3\alpha\Delta t}{1-(P_1/P_2)}$$

$$\text{Tank Size} = \frac{\text{Net Expansion Volume}}{1 - \dfrac{P_{cold}}{P_{hot}}}$$

Suppose in our CHW example, the total system volume is 2,000 gpm. Ball park net expansion rule of thumb:
1% for CHW and 4% for HW

$$\text{Tank Size} = \frac{2{,}000 \text{ gallons x } 0.01}{1 - \dfrac{20}{40}}$$

5 psig

25 psig

K_2 = specific volume of water at higher temperature, ft3/lb

$$\text{Tank Size} = 40 \text{ gallons}$$

$\Delta t = (t_2 - t_1)$, °F

The benefit of doing it this way is the visual awareness of what is going on. Supposing we want to reduce the size by setting a higher P_{hot}. Say 65 psig or 80 psia. It is immediately obvious then the tank size will then be 27 gallons.
But then you have to check to see what is happening to the bottom floor pressures.

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THE END