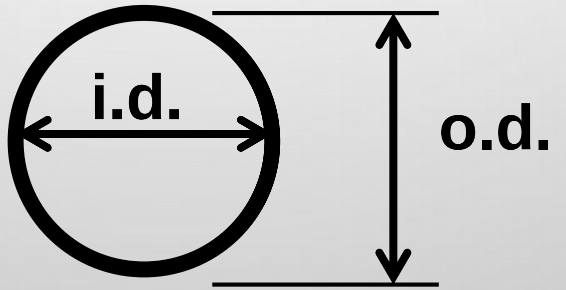
HYDRONICS SYSTEM COMPONENTS

HYDRONIC HEATING SYSTEMS - PIPING

- Piping materials
  - Copper
    - Corrosion resistant
    - Easily installed and joined
    - Lightweight
    - Two types
      - K (thicker wall) - green line
      - L – blue line
    - Fittings are based on blue line copper

HYDRONIC HEATING SYSTEMS - PIPING

- Copper pipe sizes:
  - Refrigeration – measure by outside diameter (o.D.)
  - Plumbing – measure by inside diameter (i.D.)



HYDRONIC HEATING SYSTEMS - PIPING

- Steel (galvanized, black iron)
  - Corrosion resistance – moderate
  - Water treatment and lack of air (oxygen) will reduce corrosion
  - Subject to external corrosion
  - If connected to copper components galvanic corrosion can occur – dielectric fittings can eliminate this.

HYDRONIC HEATING SYSTEMS - PIPING

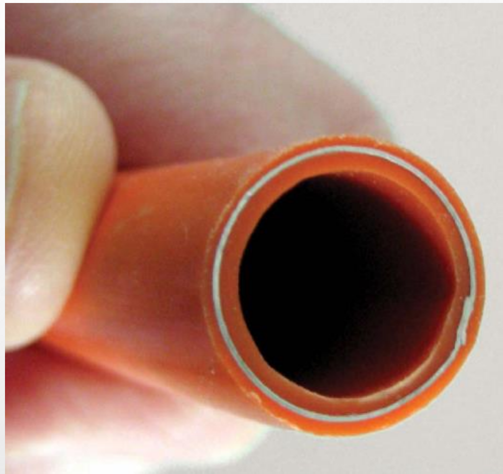
- Plastic – PEX (cross linked polyethylene)
  - Continuous roll up to 1,000 ft.
  - Pressure/temperature rating change

Temperature (°F)	Pressure Rating for water
73.4	160 psi
180	100 psi
200	80 psi

  - Manufacturers certified fittings
  - May be repaired by bringing it to its amorphous state
  - In-floor radiant heating systems

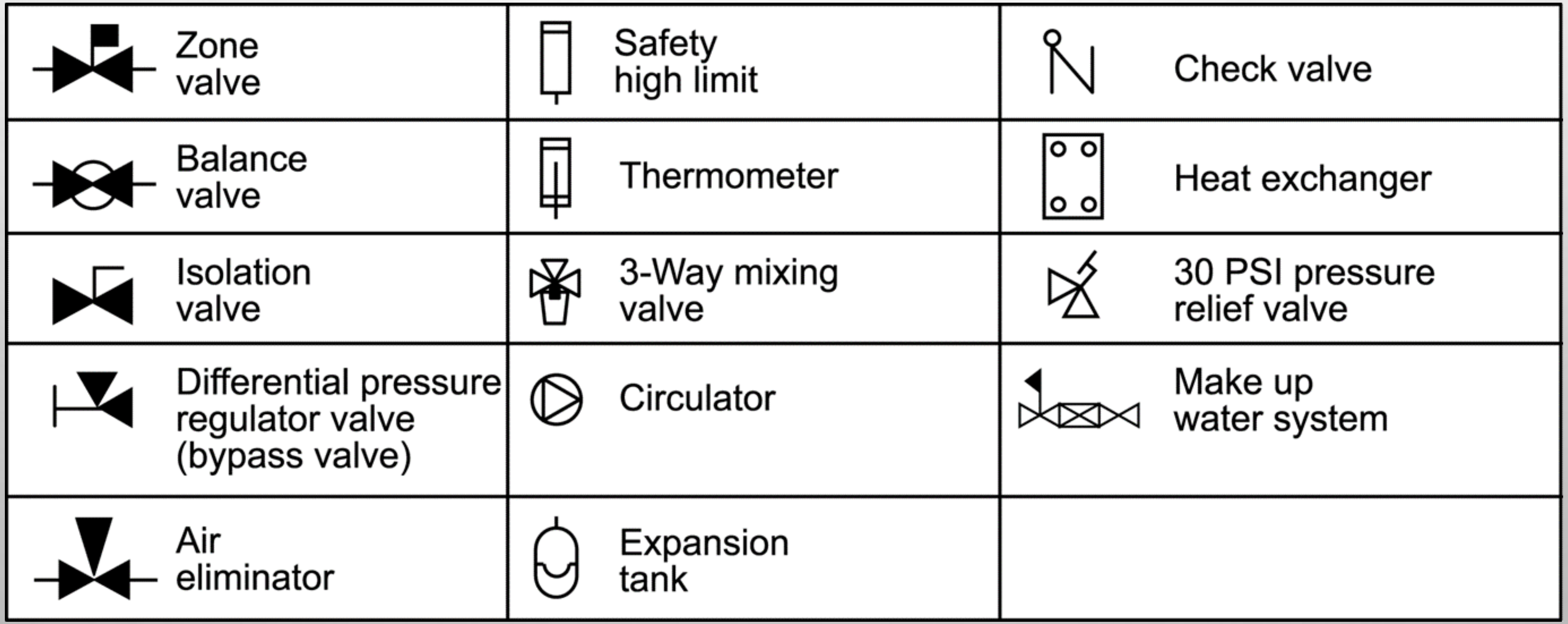
HYDRONIC HEATING SYSTEMS - PIPING

- PEX-AL-PEX
  - Inner and outer layers are PEX.
  - Middle layer is longitudinally welded aluminum.
  - Temperature/pressure rating slightly higher than PEX.
  - Aluminum significantly reduces expansion movement.
  - Maintains its shape when bent.



OTHER COMBINATION SYSTEMS

- Below are common symbols used in hydronic system illustrations that need to be understood

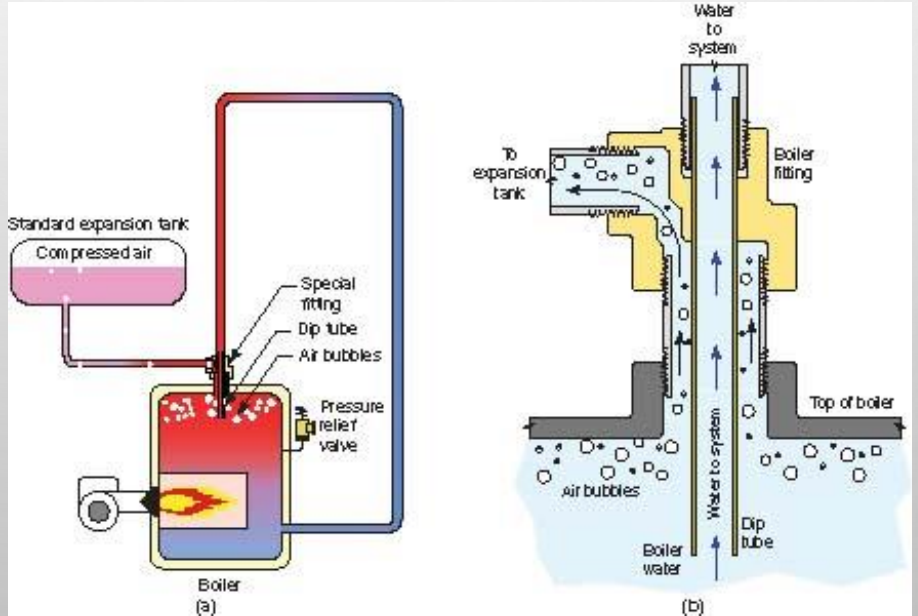


OPEN EXPANSION VS. CLOSED EXPANSION

- When a liquid is heated, it expands volumetrically and when it cools, it decreases volumetrically.
- Boiler systems need to accommodate this volume change as the temperature continually goes up and down.
- Sizing of these expansion tanks is important.
- Open expansion tanks were open to atmosphere and allowed for the expansion/contraction of boiler water. The system design meant that these tanks were installed at the highest point of the system.
  - These tanks had sight glasses to help monitor the air/water levels.
  - Theses tanks were often used on gravity systems.

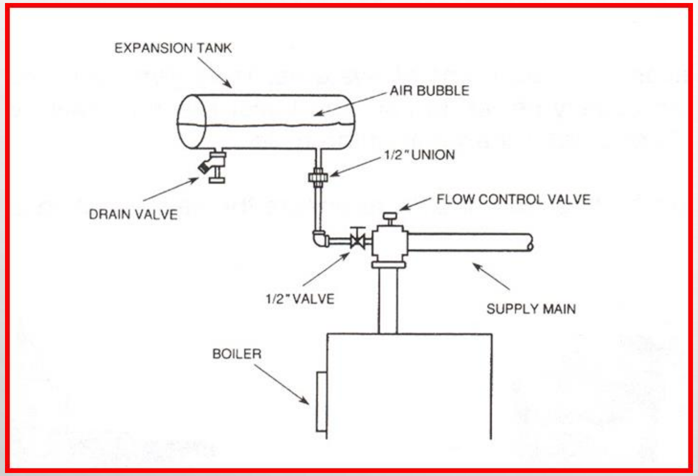
AIR CUSHION EXPANSION TANKS

- A closed tank is not open to atmosphere.
- No separation between the air and the boiler water.
- When system cools it absorbs air which can be taken throughout the system.
- Air removal devices must be selected and installed to return this air to the tank.



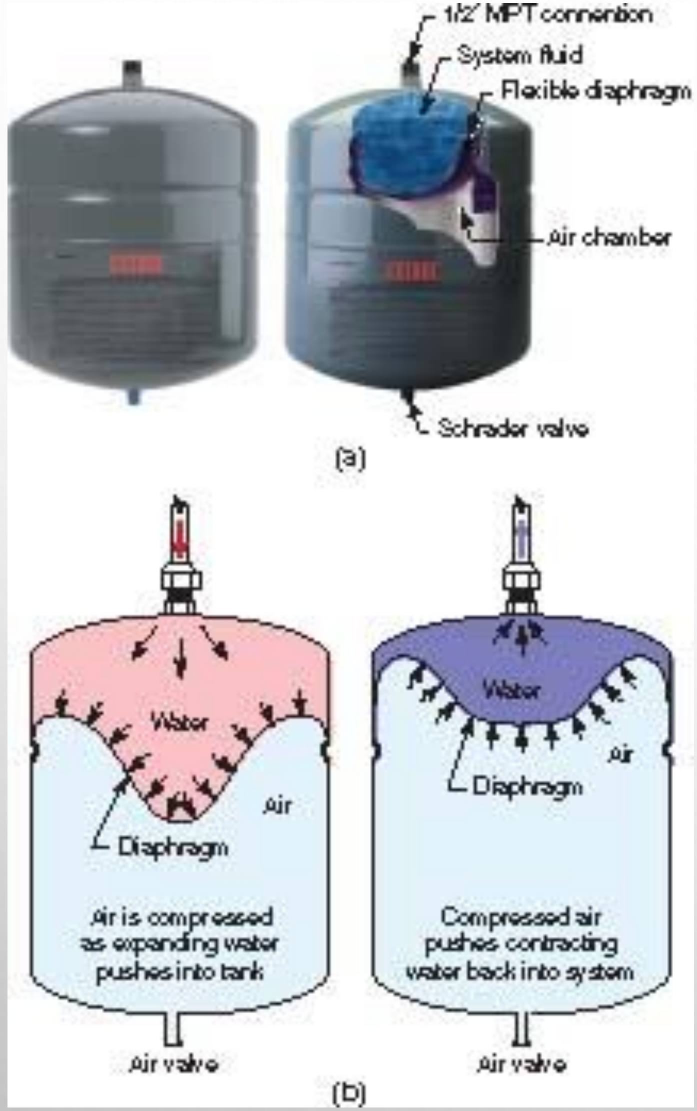
AIR CUSHION EXPANSION TANKS

- SIZING IS VERY IMPORTANT…



BLADDER OR DIAPHRAGM EXP. TANK

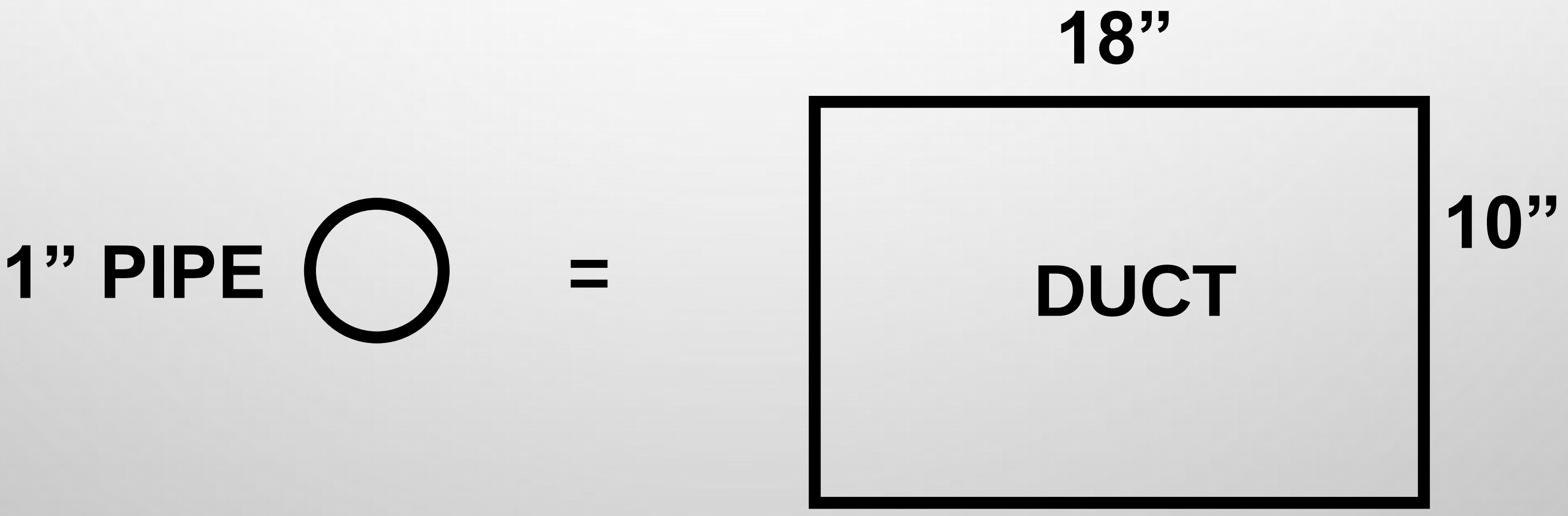
- Most common used today.
- Pre-charged with air prior to being put into the system (low pressure hydronic systems typically12-18 psi depending on the inlet pressure of the system).
- Uses an elastomeric membrane to separate the air and water (usually butyl rubber).
- Ensure tank (rubber) is chemically resistant to any chemicals used in the system.
- Typical ratings are 60psi and 240°F.


1/2" MPT connection
System fluid
Flexible diaphragm
Air chamber
Schrader valve
(a)
Water
Air
Diaphragm
Air is compressed as expanding water pushes into tank
Water
Air
Diaphragm
Compressed air pushes contracting water back into system
Air valve
Air valve
(b)


(a)
(b)

HYDRONIC SYSTEMS – PIPE SIZING

- Water vs Air – equivalent heat movement



HYDRONIC SYSTEMS – PIPE SIZING

- Hydronic piping and tubing need to be sized in order to avoid:
  - Noise - undersized piping resonates noise and vibration as water flows through it.
  - Erosion - the interior wall of pipes and fittings can literally erode and pit way if water flow is too fierce within.
  - Economy - oversized piping is not an operational problem but does cost more to purchase and install.

DELTA T - ΔT

- Design delta T - is the design temperature difference between the temperature of the water leaving from and returning in a system.
- The design water temperature drop through the system provides the basis for determining zone and system gpm requirements and affects the pipe size and pump size required.
- By the definition of a Btu, if one pound of water drops one °F as it circulates through the system, then one Btu is given off.
- A U.S. Gallon of water weights approximately 8.3 lb. So it will give off 8.3 Btu's if it drops one degree F as it is circulated through the system.

UNIVERSAL HYDRONIC FORMULA

- Use to calculate sensible water heating and cooling
- Btu/h = US GPM x delta T x 500
- The 500 comes from the fact that 1 US gallon weighs 8.33 lbs. If that one gallon has a 1°F ΔT as it circulates (GPM) through an hour it will reject/accept 500 Btu/h.
  - Btu = m x s.h. X ΔT = 8.33 x 1 x 1 = 8.33 Btu/min since water is circulating in gpm.
  - Btu/h = 8.33 x 60 = 499.8 Btu/h (round to 500 Btu/h) for every 1°F temp. change when circulating water at 1 usgpm.
- **Note:** if imperial gallons are being calculated, the number changes from 500 to 600 since an imperial gallon weighs 10 lbs. Per gallon
  - Btu = M x s.H. X ΔT = 10 x 1 x 1 = 10 btu/min
  - Btu/h = 10 x 60 = 600 btu/h for every 1°F temp. Change when circulating water at 1 usgpm.

GLYCOL

- The value of 500 Btu/h is for water only. Other fluids, such as a mixture of glycol and water have other values. Common values for propylene glycol include:

Propylene Glycol Concentration	Value for Hydronic Formula
0%	500
10%	490
20%	480
30%	467.5
40%	447.5
50%	425
60%	405.5

- E.G. How many Btu/h will a system using a 50% water/glycol mixture move if it is running at 25 usgpm and a 15°F temp. change?
  - Btu/h = usgpm x ΔT x 425 = 25 x 15 x 425 = 159,375 Btu/h

DELTA T - ΔT

- Using 500, the design water temperature drop multiplied by 500 is the Btu/h delivered by the system when one GPM is circulated throughout the system.
- For the range of design water temperature drops typically used in hot water systems, the Btu/h delivered per gpm circulated are:
  - 10°F drop = 10 x 500 = 5,000 Btu/h
  - 15°F drop = 15 x 500 = 7,500 Btu/h
  - 20°F drop = 20 x 500 = 10,000 Btu/h
- Now easy to calculate the gpm requirement:
  - If 120,000 Btu/h is needed to be removed and the system is operating with a 15°F, what is the required usgpm?
  - 120,000 ÷ 7,500 = 16 usgpm

DELTA T - ΔT

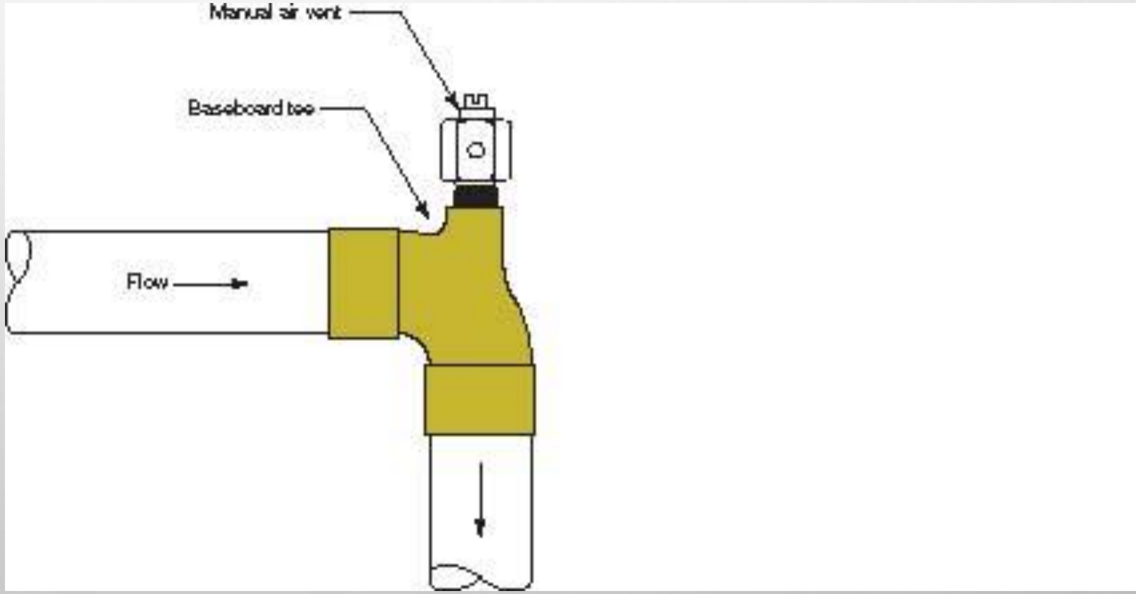
- The higher the design water temperature drop, the more Btuh are delivered per GPM and the less the amount of water that must be circulated to deliver a given amount of Btu's.
- The lower the flow rates, the smaller the pipe size required.
- So larger ΔT means smaller pipe (and pump) sizes, lower installation costs, and lower operating costs.

HYDRONIC SYSTEMS – FILLING AND BLEEDING

- Systems must have the air removed (purged) as the system is being filled or problems occur:
  - Air acts as an insulator reducing heat transfer
  - System will become noisy
  - Can develop air locks
- System filling and purging can be done by:
  - Gravity purging – allows air to escape from the high points in the system while filling, trough vents. If there are not enough vents it can take a long tome to accomplish.
  - Forced water purging – can be done by using high pressure water as the filling method which "chases" the air out of the system.

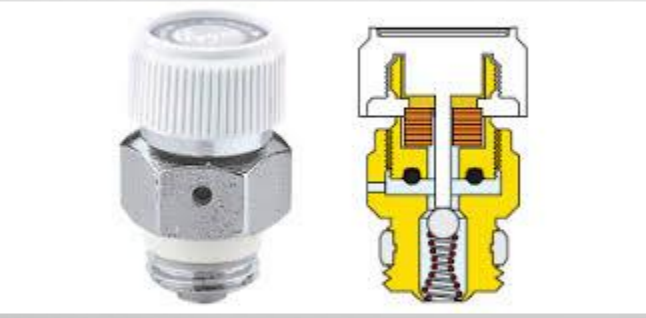
AIR ELIMINATION DEVICES

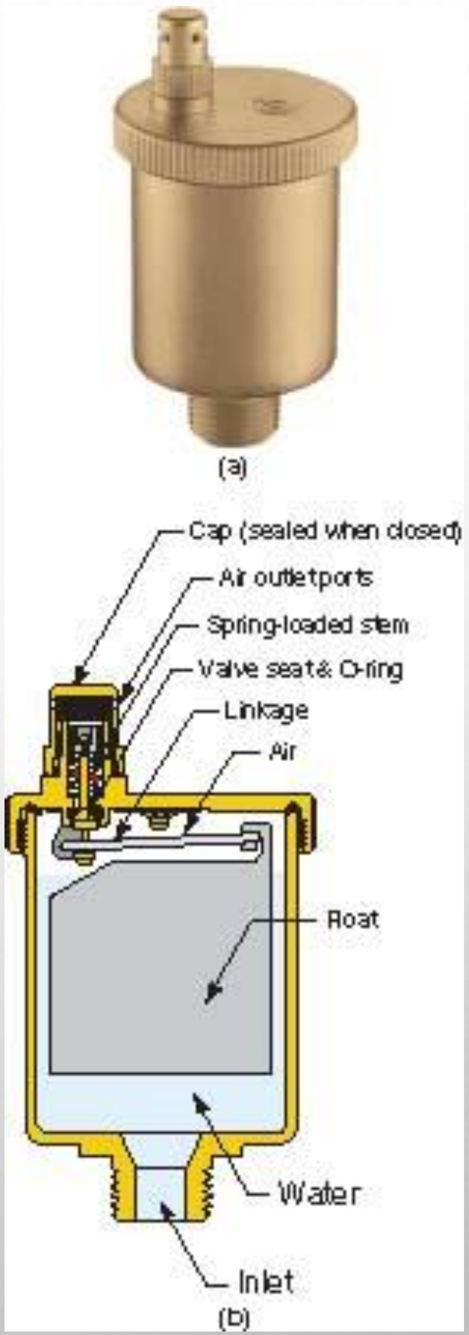
- 4 common devices are used for air elimination:
- #1 - Manual air vent (coin vents) must be opened and closed manually to purge.



AIR ELIMINATION DEVICES

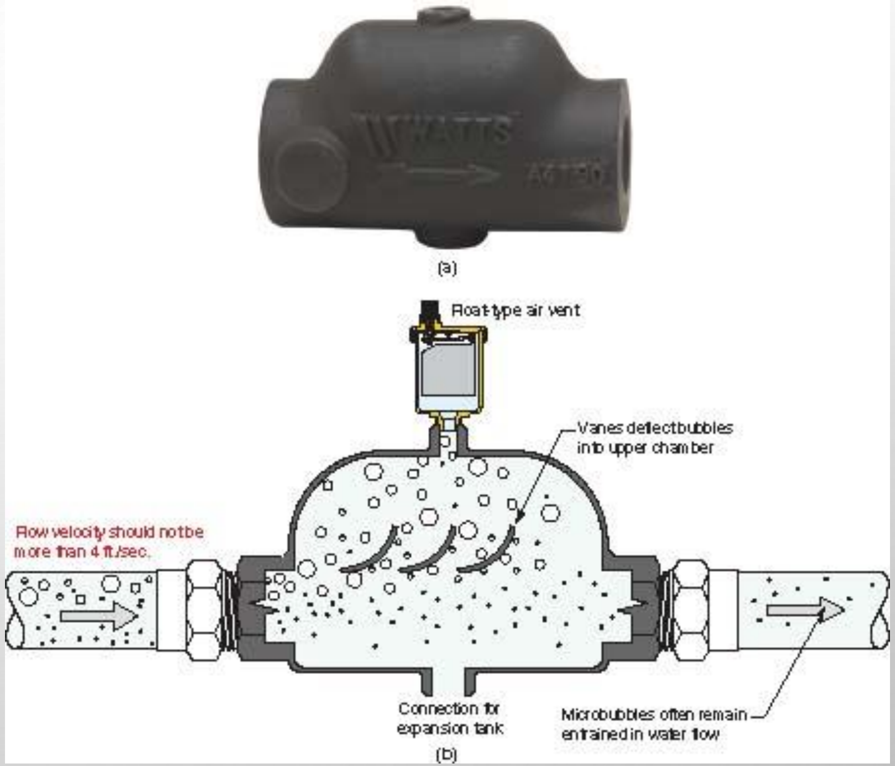
- #2 - Automatic air vents will automatically purge air when it enters the vent. 2 types: washer-type vent with a cellulose fiber disc, and float-type vent.





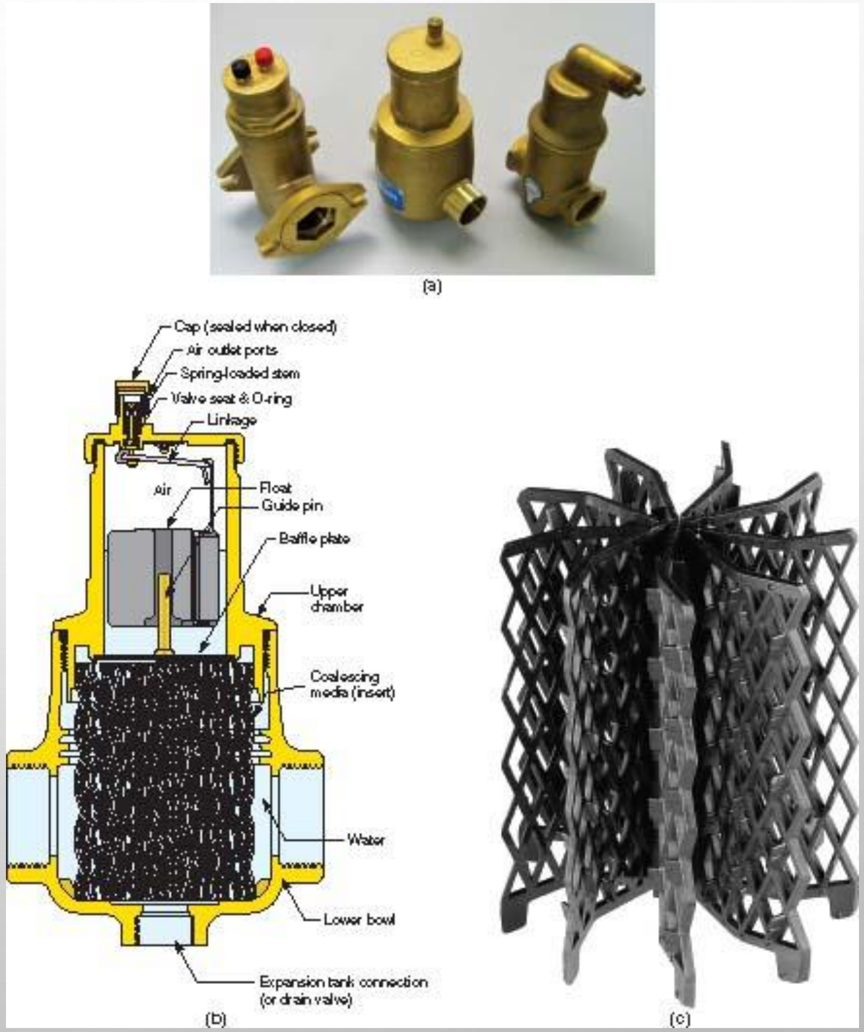
AIR ELIMINATION DEVICES

- #3 - Air purger/scoop has 2 paths in its chamber which separate air bobbles entrained in the heat transfer fluid.
  - Installed horizontally and as close to the boiler as possible on the supply side.



AIR ELIMINATION DEVICES

- #4 - Microbubblers contain small wires acting as a strainer and separate the microbubbles from the water.
  - Best from of air eliminator when properly maintained.
  - Important with glycol systems.



AIR PURGING METHODS

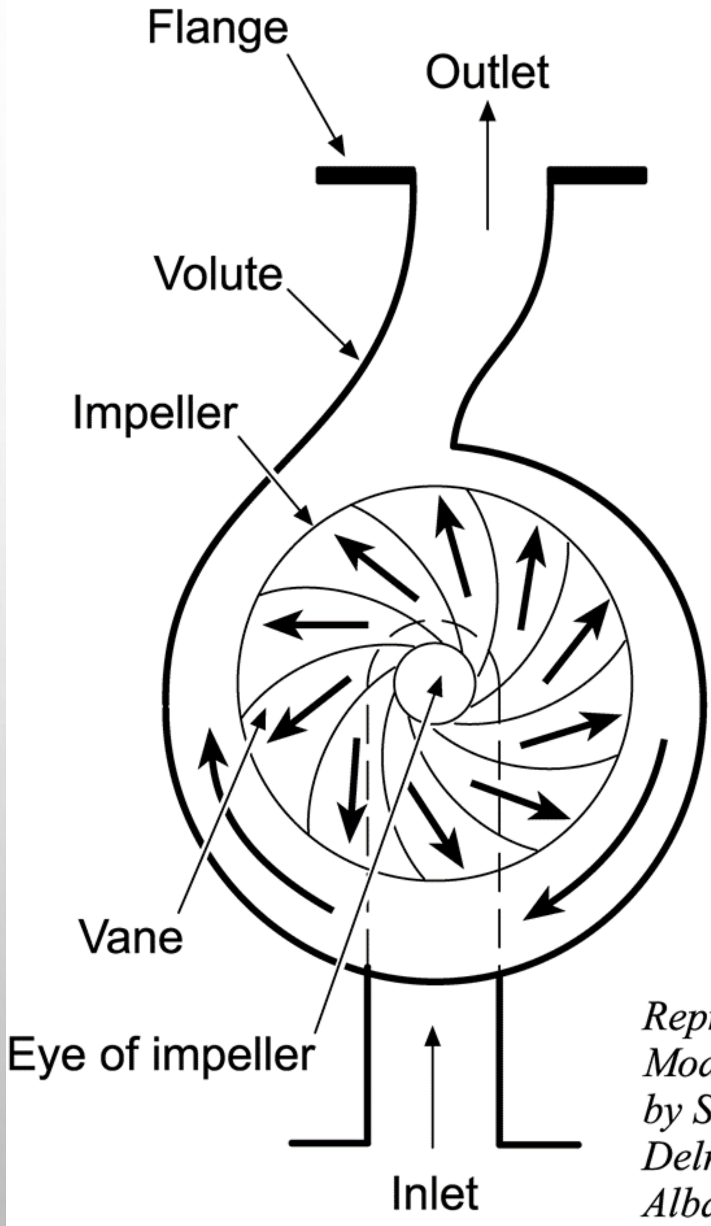
- Air must be purged from a system and the method depends on many variables:
  - Distribution system type.
  - Heat transfer fluid type.
  - Emitter types.
  - Material/piping/joining methods used.
  - Size of system and associated piping.
  - Manufacturer requirements and/or certified instructions.
  - Whether for an initial start-up or the system was drained for servicing.

SYSTEM WITH MANUAL BLEEDERS AT ALL RADS

1. Ensure the bleeder valves are closed.
2. Ensure expansion tank is empty of water.
3. Turn on the water supply.
4. Check all zones for hissing – possible open bleeder.
5. Open the fast fill valve while monitoring pressure.
6. Fill to the proper pressure.
7. Close the fast fill valve (keep flow through PRV open).
8. Make final check of system pressure.

CIRCULATOR PUMPS

- Centrifugal pumps are the most commonly used circulator pump moving fluid through a system.
- They are powered by an induction motor utilizing a spinning impellor to move fluid.
- Impellor factors:
  - Longer impellors produce more pressure
  - Wider impellers move more fluid
  - The larger the suction opening, the more fluid it can move
  - The faster the impeller turns, the more fluid it can move at a higher pressure



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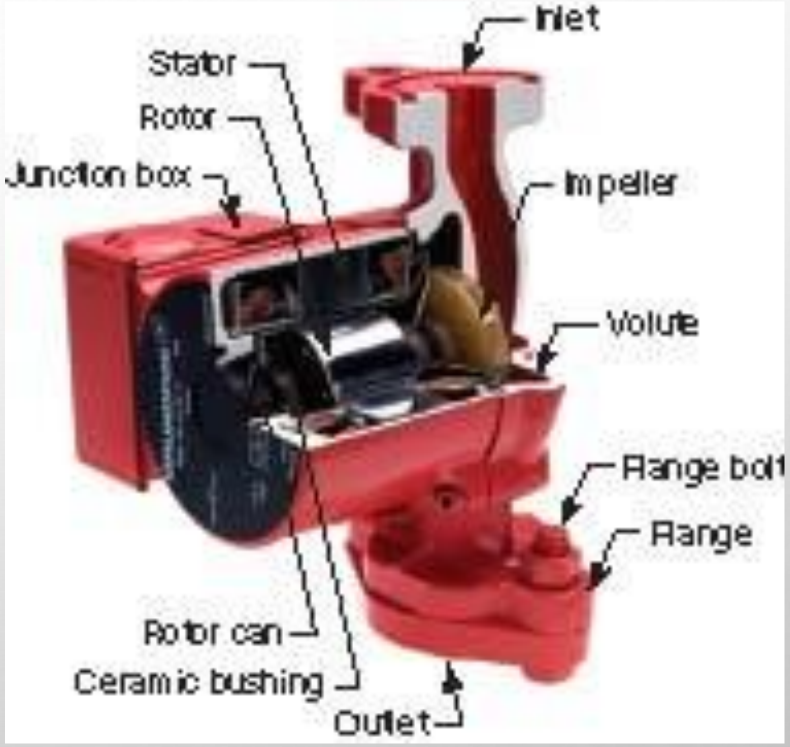
(a)


(b)

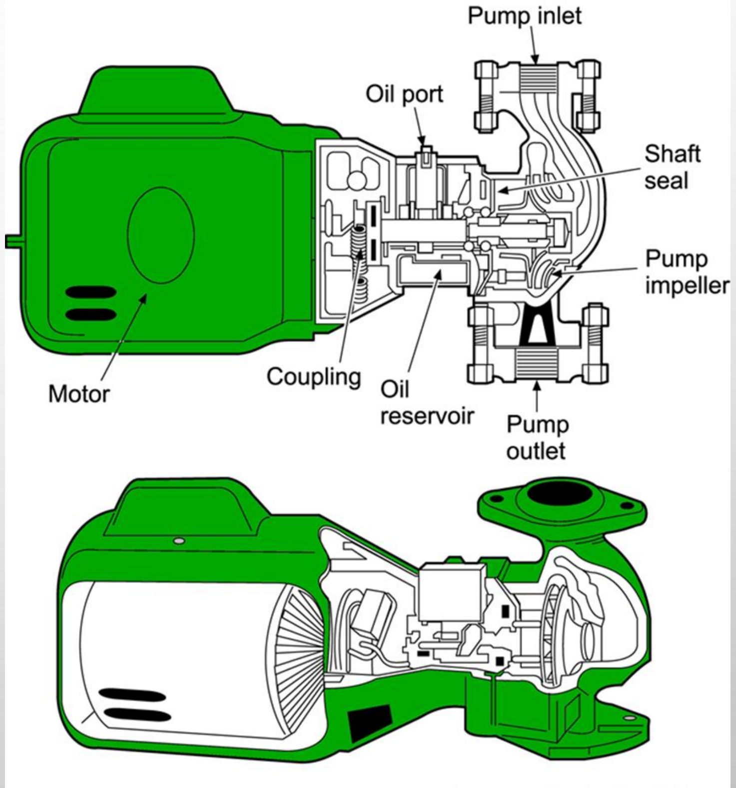
WET-ROTOR CIRCULATORS

- Wet-rotor circulators are now being used.
- Usually constructed of iron or bronze.
- The motor, shaft and impeller are in one unit, all filled with the system fluid.
- The fluid acts as a coolant for the motor and lubricant for the bearings.



THREE-PIECE CIRCULATORS

- Three piece circulators consist of: motor, pump body (impellor and housing), and coupling (bearing seal assembly).
- The three components are able to separate to allow for servicing without necessarily opening up the piping system.



Courtesy of ITT Bell and Gossett

INLINE AND END-SUCTION CIRCULATORS

- The wet-rotor and three-piece circulators are both inline suction pumps.
- End-suction circulators have their inlets and outlet ports located on a common center line.
- This creates a 90^{o} bend.

CIRCULATOR SELECTION AND SIZING

- Factors to consider when selecting a pump include:
    - The pump’s flow characteristics
    - Where the pump will be located in the system
    - Electrical requirements
    - Type of coupling and alignment
    - Type of motor
    - Maintenance requirements
    - Removal criteria
    - Safety considerations
    - Type of pump specified by the system design engineer
    - Suction and mounting configuration
    - Flow rate the pump can produce
    - The head the pump can develop
    - Environmental conditions

CIRCULATOR SELECTION

- Need to understand 2 basic principles:
  - System flow rate – can be calculated a couple of ways.
  - System resistance – calculated by adding all the resistance in the system from fittings, pipe, components etc.

SYSTEM FLOW RATE CALCULATION

- Universal hydronic formula
  - Btuh = US GPM x delta T x 500
  - Can be manipulated to read:

Imperial:

$$\text{Flow rate (US gpm)} = \frac{\text{System heat loss (Btu/h)}}{\text{Temperature drop (°F)} \times 500}$$

Metric:

$$\text{Flow rate (L/s)} = \frac{\text{System heat loss (kW)}}{\text{Temperature drop (°C)} \times 4.2}$$

SYSTEM FLOW RATE CALCULATION

- Example:
  - For a boiler with a 20^{0}F differential
  - 500 x 20 = 10,000 btu/h per gallon circulated
  - E.G. A boiler with a 250,000 output with a system differential of 20 ^{0}F requires a pump running at 25 US gpm. 250,000 / (500 x 20) = 25 US gpm

SYSTEM PRESSURE LOSS (RESISTANCE)

- The total pressure loss, or system resistance is the sum total of all resistances in the flow restricting elements of the system.
- The individual resistance of piping and components are listed in manufacturer's spec and manuals.

Table 8.5: Equivalent Lengths for ¾" I.D. Copper Tubing Fittings

Fitting	Equivalent Length in Feet
Gate or Ball Valve	0.5
Globe Valve	23.0
Angle Valve	12.0
Check Valve	6.0
Balance Valve	6.0
Standard Elbow	2.3
Long Radius Elbow	1.5
45° Elbow	1.0
Standard Tee (Straight Through)	1.5
Standard Tee (90° Turn)	5.0

Table 8.5: Equivalent Lengths for ¾" I.D. Copper Tubing Fittings	
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Standard Tee (Straight Through)	1.5
Standard Tee (90° Turn)	5.0

Example: A system with 125 ft of ¾ copper pipe also contains 20-90° elbows, a ball valve and a globe valve. What is the equivalent length?

A. 20 elbows x 2.3 = 46 ft.
1 ball valve = 0.5 ft
1 globe valve = 23 ft
125 ft of pipe = 125 ft
Equivalent length = 194.5 ft.

Calculating Head Pressure

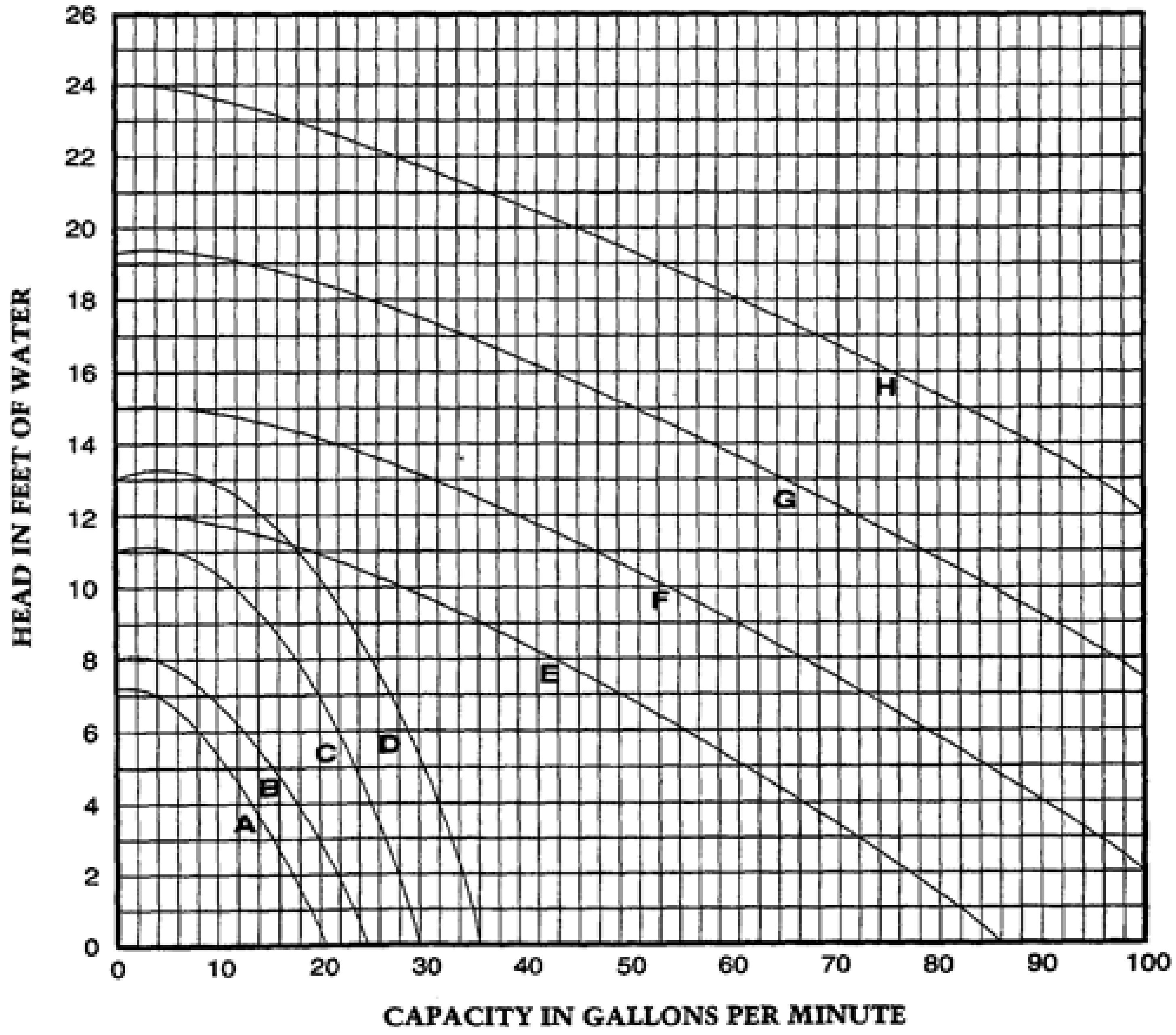
Table 8.6: Head Pressure per 100 Feet of Equivalent Length Of ¾" I.D. Tubing		
Flow Rate in U.S. GPH	Velocity in Feet per Second	Head Pressure In Feet per 100 Feet
1	0.74	0.56
1.5	1.11	1.20
2	1.47	1.84
2.5	1.84	2.79
3	2.21	3.73
3.5	2.58	4.95
4	2.94	6.16
5	3.67	9.12
6	4.41	12.57
7	5.14	16.51
8	5.88	20.91
9	6.61	25.77
10	7.35	31.08

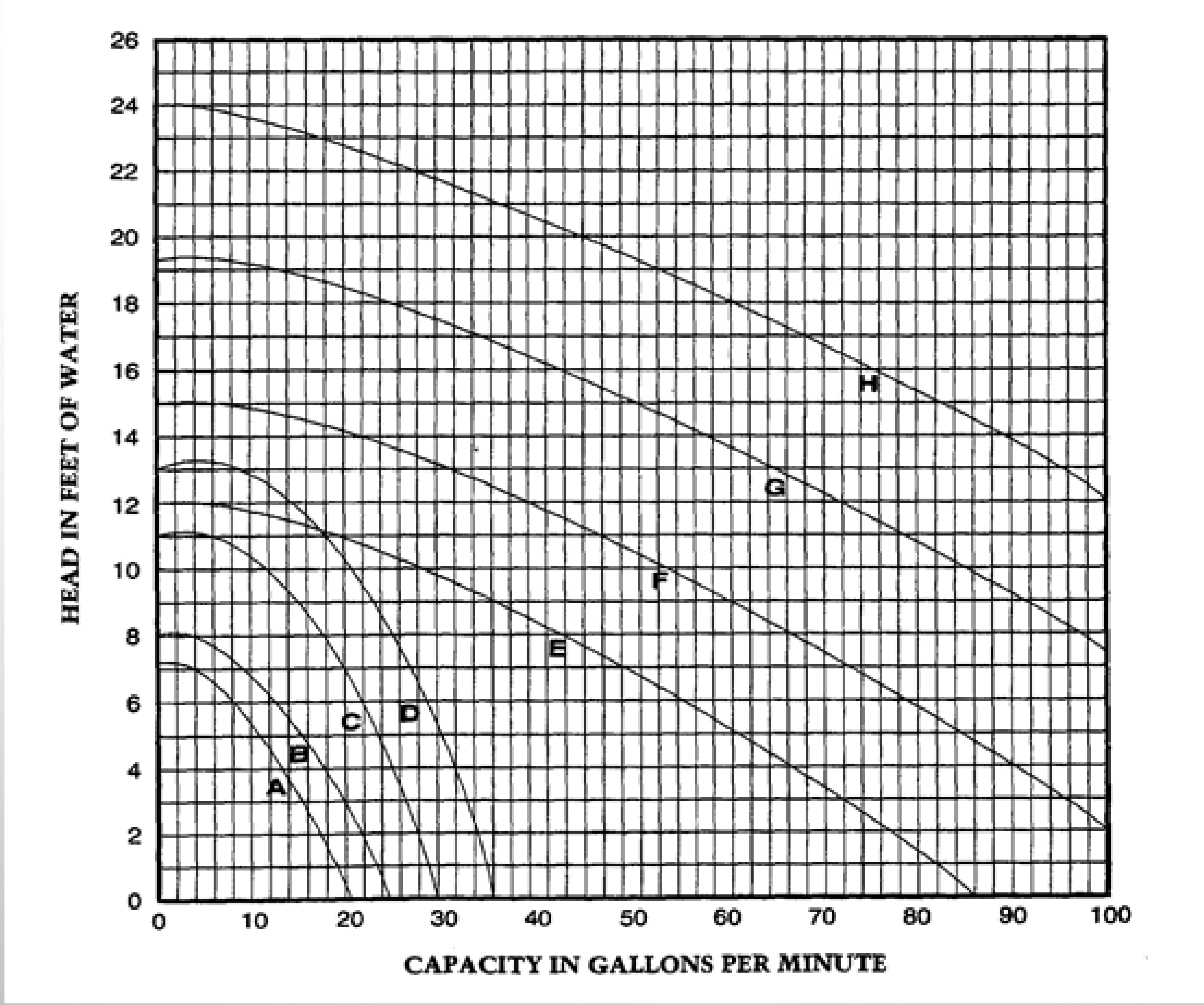
- From the last example, if the system requires 5 gpm what would the head pressure be using the 194.5 ft. of equivalent pipe length we calculated?

- 194.5 ÷ 100 = 1.945
- 1.954 x 9.12 = 17.78 ft. of head would be the resistance the pump would have to overcome.

PUMP CURVES

- Manufacturers use pump curves to help choose the proper pump:
  1. Determine the required flow rate – heat loss/gain.
  2. Determine the amount of head loss the pump is required to overcome.
  3. Plot these two values on the pump curve.
  4. The chosen circulator should have 10 to 20% extra head capacity as a system buffer.


HEAD IN FEET OF WATER
26
24
22
20
18
16
14
12
10
8
6
4
2
0
0
10
20
30
40
50
60
70
80
90
100
A
B
C
D
E
F
G
H
CAPACITY IN GALLONS PER MINUTE

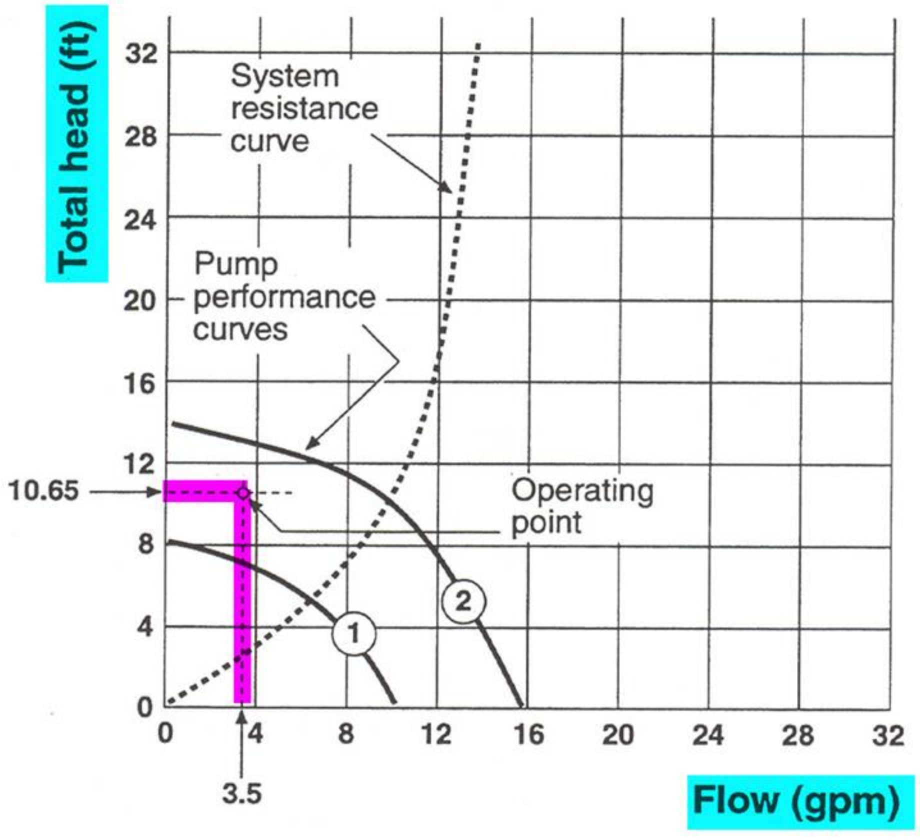


Find the intercept point of 5 gpm at 17.78 ft of head

Which pump would be required?

PUMP PERFORMANCE CURVE

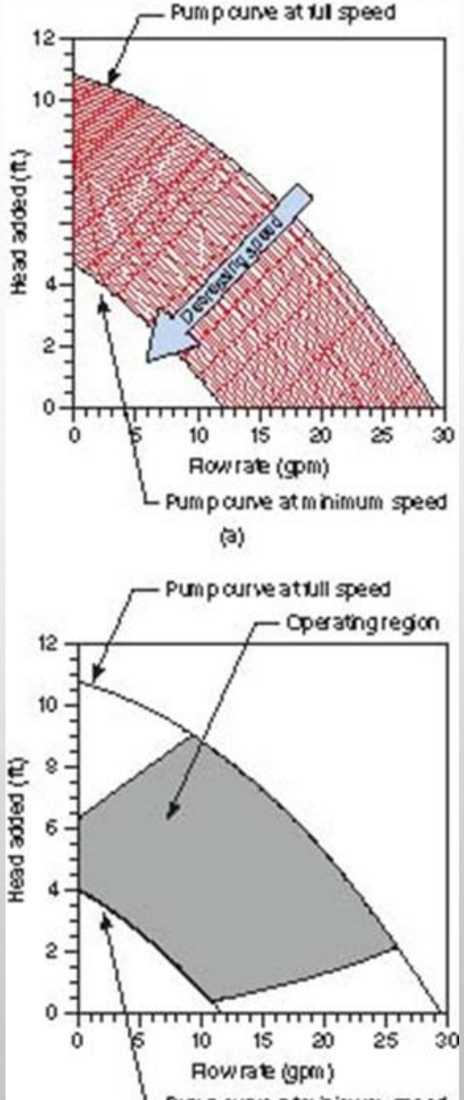
- E.G. If a system has a head loss of 10.65 and requires a flow rate of 3.5 gpm, the operating point is plotted as shown.
- Only pump 2 would be able to do the job



Pump performance curve

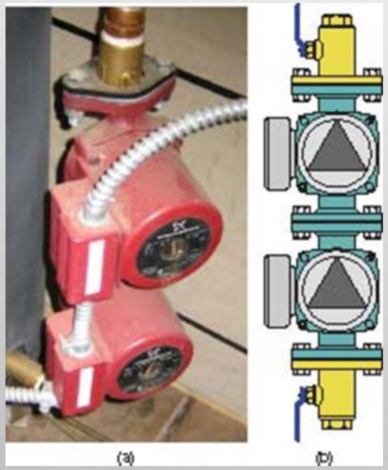
SMART CIRCULATORS

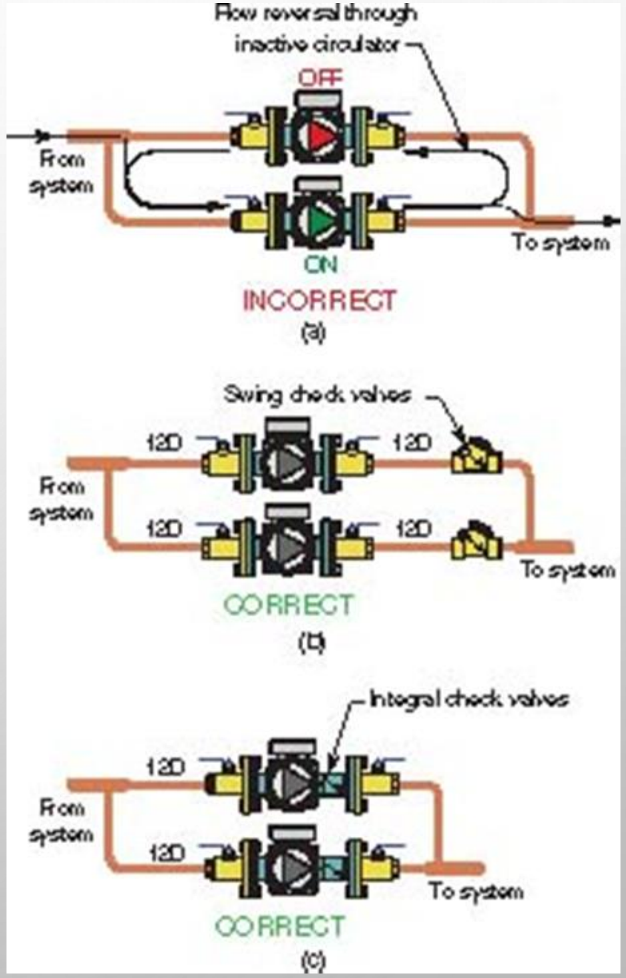
- These circulators can automatically vary their speed to adjust to different pressure changes in the distribution system
- They utilize ECM motor technology and microprocessor based speed control circuitry which allows it to operate according to a coded instruction set.
- This allows one pump to operate within a wide range of pump curves.
- When the circulator is commissioned, the circulator is set for the differential pressure desired when all zone valves are open. The circulator then automatically varies to maintain this set point. (A.K.A. Constant differential pressure control)



INCREASING FLOW AND PRESSURE

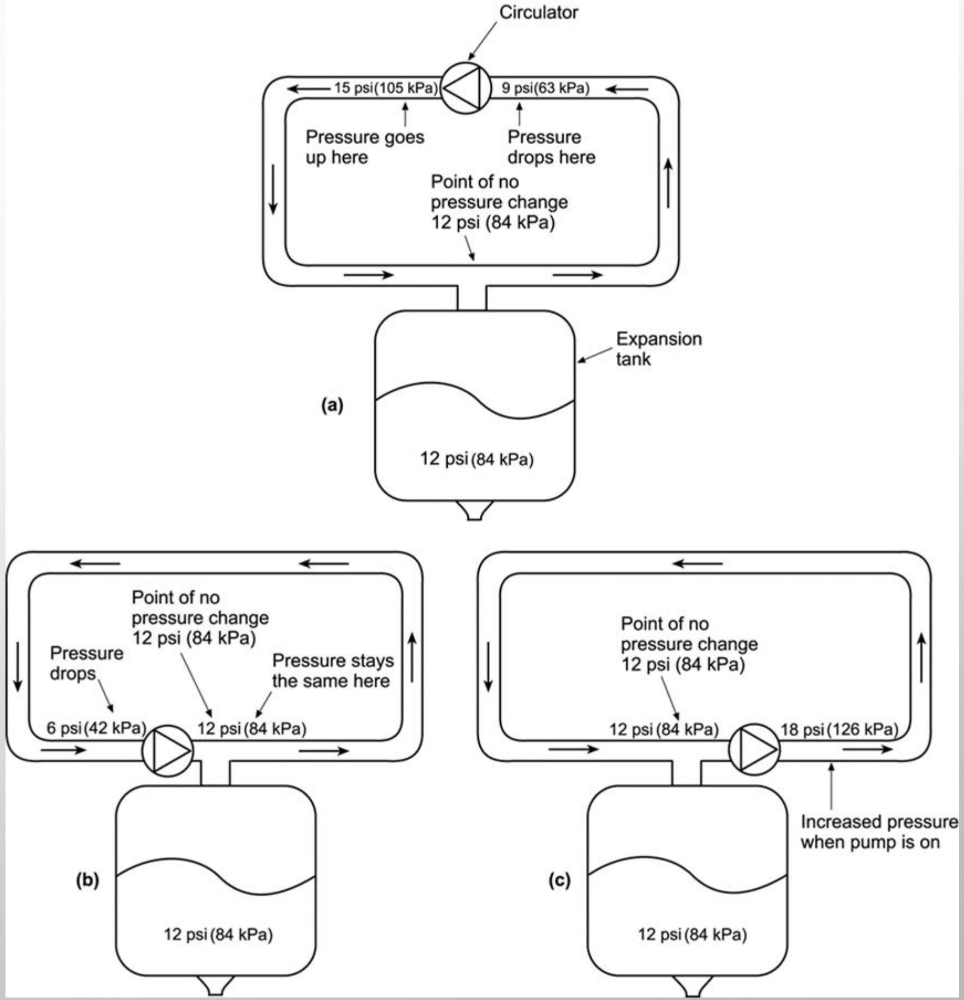
- Increasing flow and pressure can be accomplished by :
  - Putting 2 pumps in parallel (doubling the system flow rate)
  - Putting 2 pumps in series (doubling the system pressure)
  - Note: pumps must be the same size for both these hook-ups





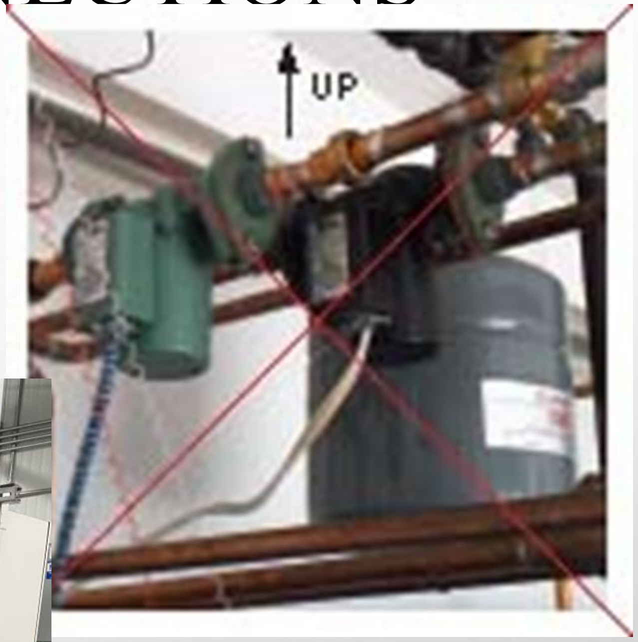
CIRCULATOR LOCATION

- The circulator location in relation to other components is important to consider
- Typically it is located with the inlet as close as practical to the point where the expansion tank connects allowing the circulator to pump system fluid away from the expansion tank and *the point of no pressure change*



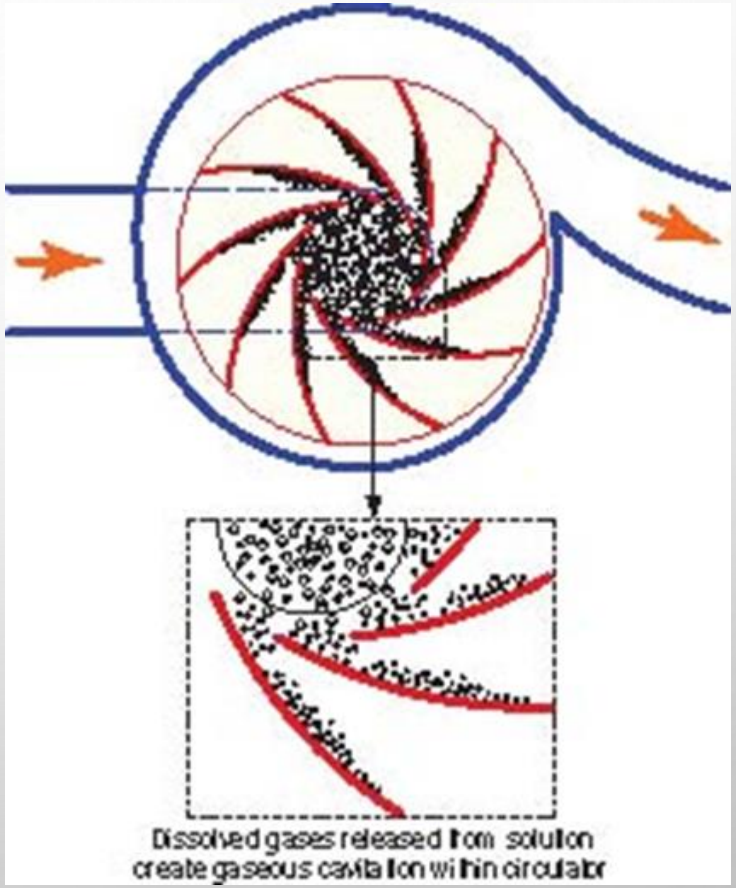
PUMP MOUNTING AND PIPING CONNECTIONS

- Most circulator pump are designed to have the mounting so the pump shaft is in the horizontal position due to the effects on the bearings
- The pump is also positioned in the correct direction of fluid flow all while maintaining a horizontal pump shaft
- The system piping should not be relied on to support the pump if it is not designed to do so.
- Large commercial circulators are designed with the proper bearings to allow for vertical motor shaft installation



PUMP CAVITATION

- The term "pump cavitation" refers to the problem of air molecules turbulating inside a pump cavity.
- At low pressure some water can flash into vapour (boil) and create bubbles.
- These bubbles are carried into the higher pressure area of the pump and then collapse.
- As these bubbles collapse the adjacent area is subjected to shock and erosion.
- Results in noise, erosion and vibration.



CAVITATION

- Pictures showing damage to a circulator’s impellor (a) and damage to a circulator’s volute (b).

(a)

(b)

GUIDELINES FOR AVOIDING CAVITATION

- Keep the static pressure in the system as high as practical.
- Keep the fluid temperature as low as possible.
- Always install the expansion tank connection near the inlet side of the circulator.
- Keep the circulator low in the system to maximize static pressure at its inlet
- Do not place any components with high flow resistance (especially flow-regulating valves) near the inlet of the circulator (place balancing valves downstream of the pump).
- Provide a straight length of pipe at least 12 pipe diameters long upstream of the circulator’s inlet.
- Install good de-areating devices in the system.

FLUIDS, FLOW, MIXING AND THE LAW OF THE TEE

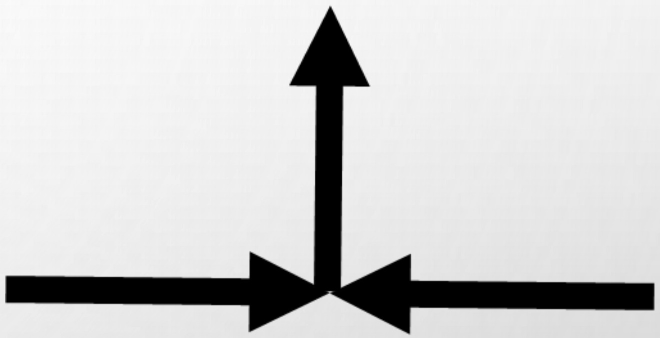
- Fluids:
  - A fluid is any substance that can flow.
  - The term fluids describes both liquids and gases, but not solids.
- Study of fluids:
  - Fluid mechanics is the scientific field of study that works with fluids.
  - Fluid dynamics is the field of study of fluids in motion. It is a sub category of fluid mechanics.
  - Both fields are important to HVACR.

FLOW

- Flow is the motion or movement of a gas or liquid.
- Flow is created by pressure differential.
  - A pressure differential is a difference in pressure between two parts or areas of the system.
- Fluids must flow if a pressure differential exists, and fluids will not flow if a pressure differential does not exist.
- The rate of fluid flow is dependent on the pressure differential.
  - A higher pressure differential will create a higher flow rate.
- Fluids are directed by ducts and pipes
- The flow of fluids will encounter resistance from friction, caused by the fluid rubbing on the boundaries of the path. This will cause pressure loss.
- Pressure loss will also be caused by dynamic loss, or turbulence.
- Therefore the pressure exerted on the fluid will slowly be consumed.

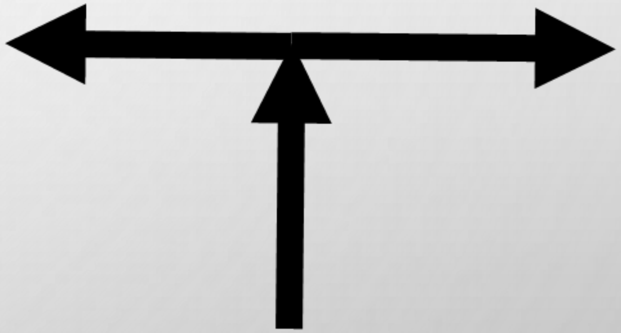
MIXING

- Mixing is when two or more substances are mixed together.
- Mixing can occur in tanks, vessels, pipes, ducts, valves etc.
- It is common for two fluid streams to be brought together and mixed.
  - Two different pipes containing water may join in a tee.
  - Two different ducts may bring air from two different locations – perhaps return air and outside air.
- A mixing tee or valve has two inlets and one outlet.



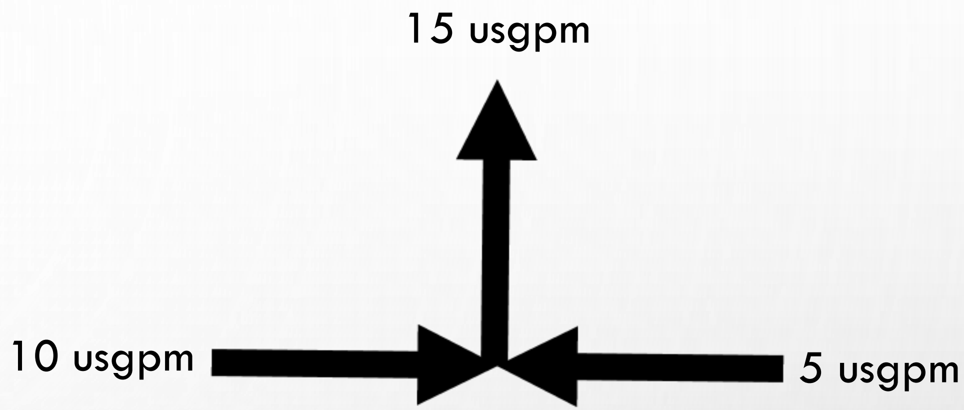
DIVERTING

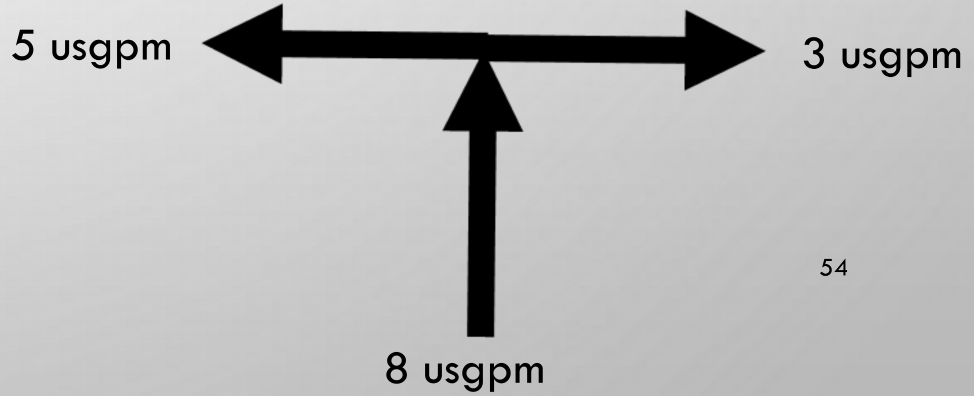
- Diverting is when a stream of fluid is broken into 2 or more paths, with some sent in one direction, and the remainder in another.
- Diverting often happens in pipe, ducts and valves
    - A pipe containing water may have the flow split into two directions.
    - A duct may split and take some air as return air to the air handler, and exhaust the remainder outdoors
- A diverting tee has one inlet and two outlets.



THE LAW OF THE TEE

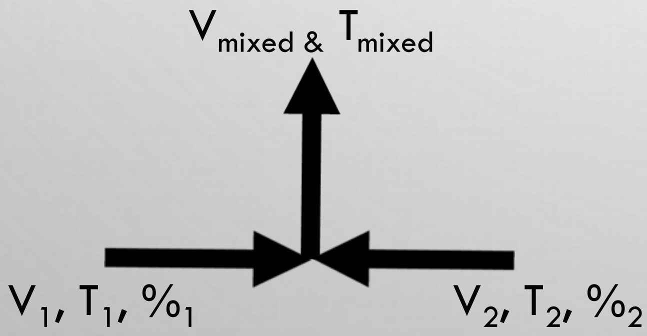
- The law of the tee is quite simple.
- The law states:
  - The total flow into a tee must match the flow out of the total tee.





MIXED FLUID FORMULAS

- These formulas are simplified, and are only accurate if:
  - The fluids being mixed are the same substance
  - The density of the fluid be very similar
    - Temperature must be similar
    - Pressure must be similar
    - The greater the variances the larger the error in the calculation, and the greater the need to use a complete formula to correct for density



To find the temperature of the mixed fluid when the input fluids temps and volumes are known:

Mixed fluid volume (V_{mixed})= $V_1 + V_2$

$$\%_1 = \frac{V_1}{V_{Total}} \qquad \%_2 = \frac{V_2}{V_{Total}}$$

Mixed fluid ^{O}T ($^{O}T_{mixed}$) = $(T_1 \text{ x } \%_1) + (T_2 \text{ x } \%_2)$

To find the proportional quantity of one of the inputs as a percentage of the output if the input volumes are unknown:

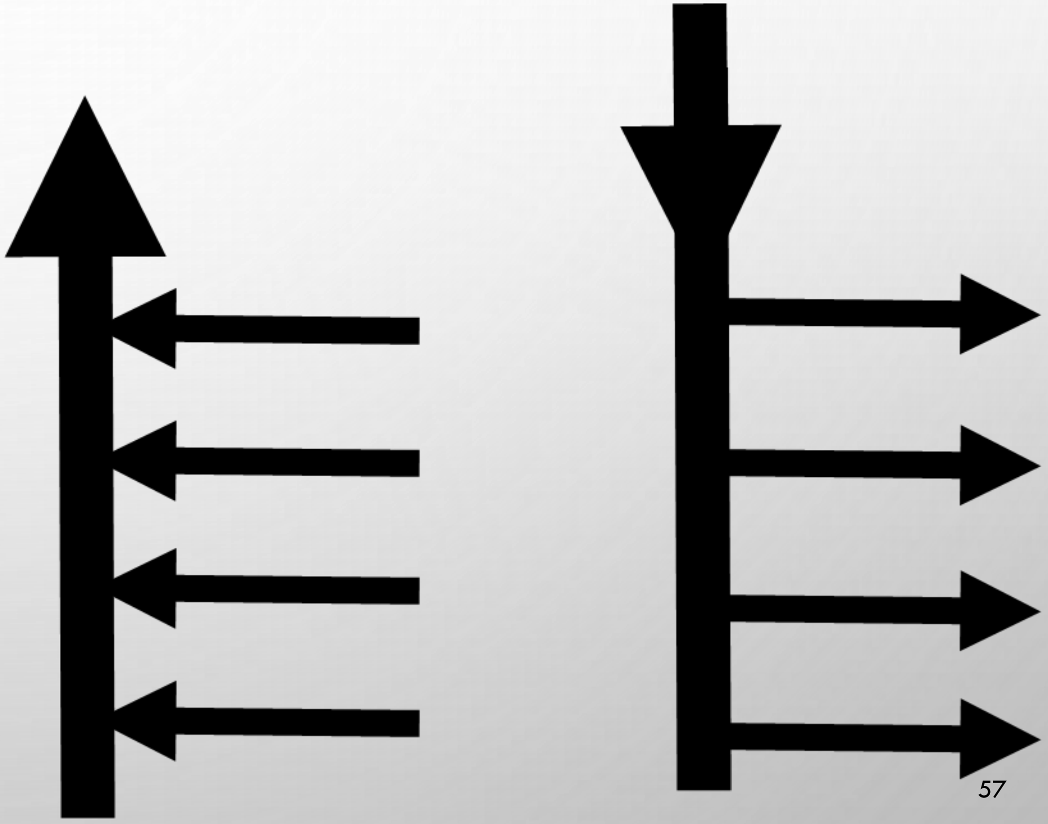
$$\%_1 = \frac{Difference\ between\ T_2\ and\ Tmixed}{Difference\ between\ T_2\ and\ T_1} \text{ x } 100$$

MIXED FORMULA EXAMPLES

- #1 – if you have a mixing tee and one branch has a flow of 7 gpm at 150°F and the second branch has a flow of 3 gpm at 110°F, what is the flow rate and temperature coming out of the tee?
- Volume = $V_1 + V_2 = 7 + 3 = 10$ gpm.
  - V_1 Makes up 70% of the total volume and V_2 is 30% of the total volume
- Mixed Temp = (T_1 x % of mixture) + (T_2 x % of mixture)
- = (150 x 70%) + (110 x 30%)
- = 105 + 33 = 138°F
- So mixing 7 gpm of 150°F water with 3 gpm of 110°F water will produce a flow rate of 10 gpm at 138°F

MANIFOLDS AND HEADERS

- A manifold or header is used to distribute or collect fluid to multiple places.
- Often the required flow rate is the same to each component, although it may also be different.
- A manifold will only work properly for single phase flow.
- A manifold is incapable of delivering equal quantities of mixed phase (two state) flow. Mixed phase flow would typically include both a liquid and a gas.
- A common form of manifold is a number of smaller pipes connecting to a larger pipe.



VALVES

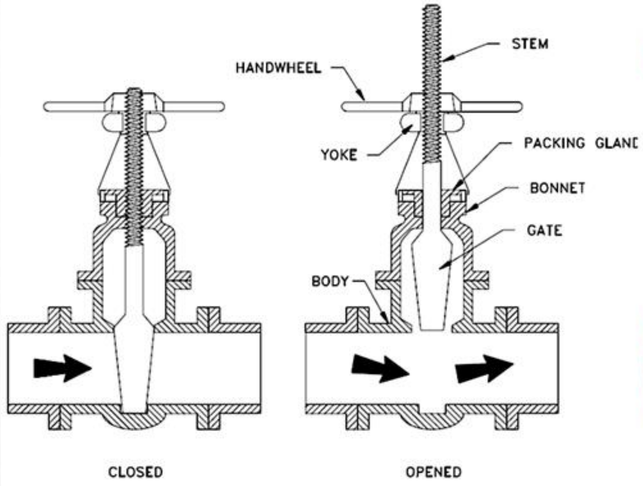
- Isolation valves:
  - Typically ball valves
  - Allows for repair/replacement of components
- Bypass feed valve/fast fill bypass:
  - Used to fill the boiler quickly and is piped in parallel with the PRV
  - Should be located on the straight through line

- Other common manual valves used for either component isolation or flow regulation.
  - Gate valves
  - Globe valve
  - Angle valve
  - Boiler drain

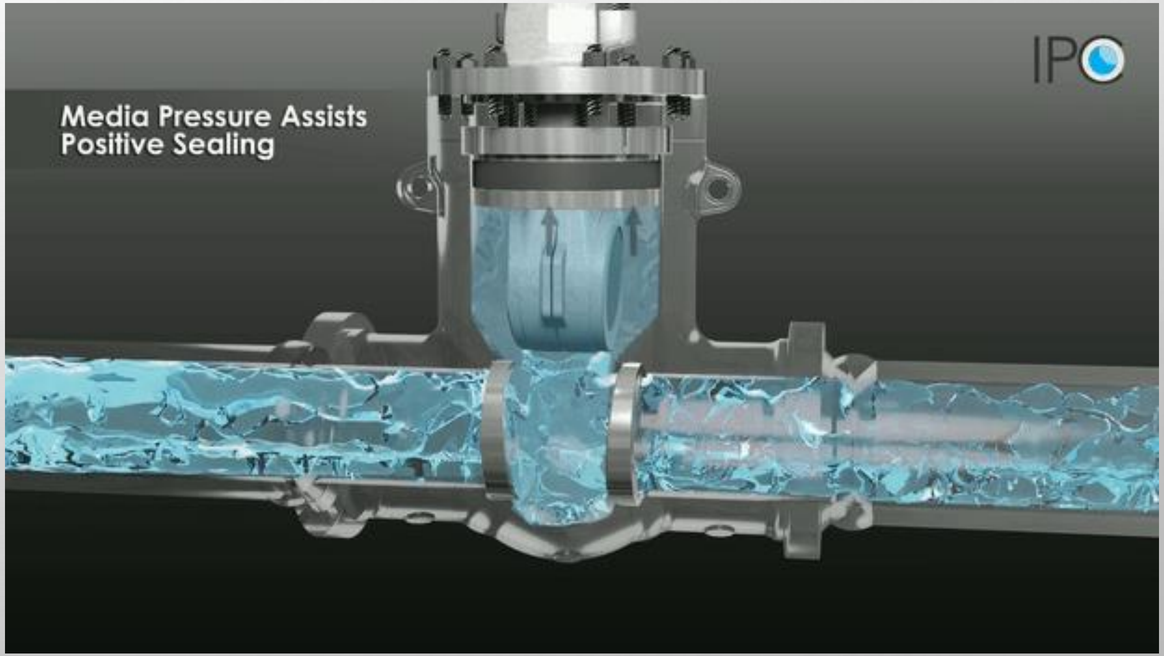
BALL VALVES

- Available in restricted or full bore.
- Designed for fully open or closed operation – not for throttling.
- Handle indicates the position of the ball.
- Soldered in the open or closed position?

GATE VALVES

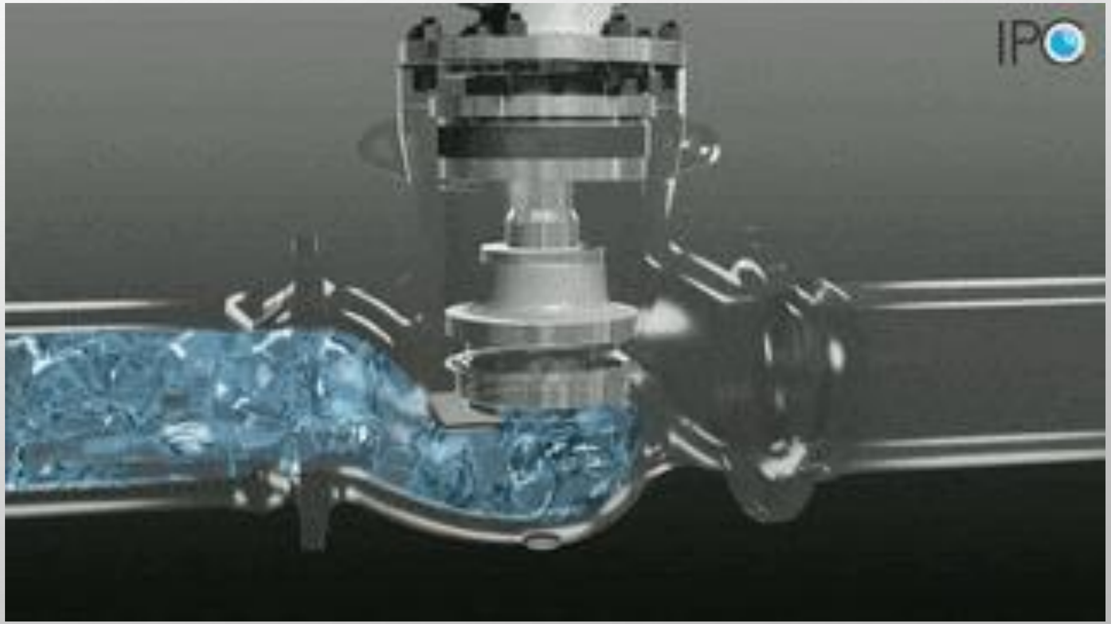


- Designed for fully open or closed operation – not for throttling.
- Soldered in the open or closed position?
- May be O,S, & Y…



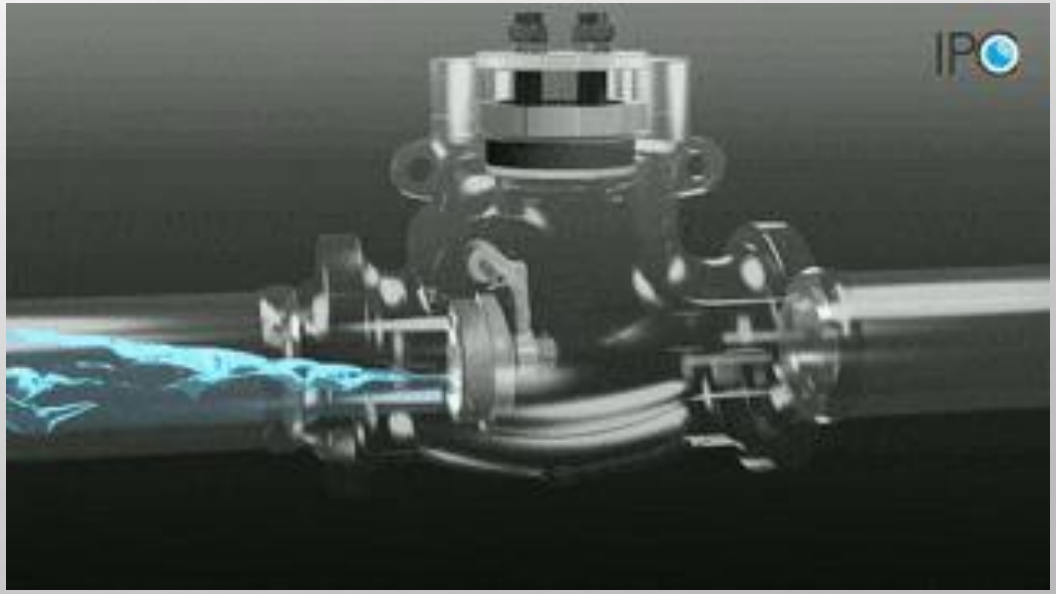
GLOBE VALVES

- Designed for throttling – has much more resistance to flow than ball or gate because of the interior design.
- Soldered in the open or closed position?

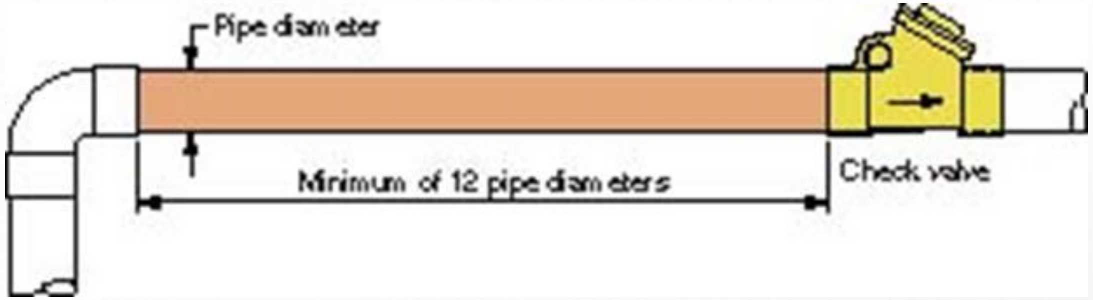


UNIDIRECTIONAL VALVES

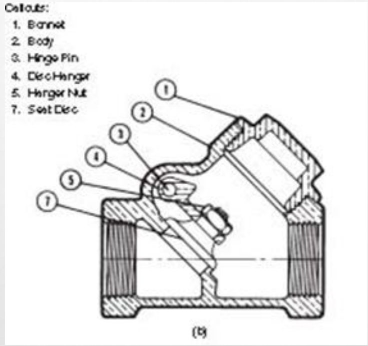
- SWING CHECK VALVES
- (FLOW) CHECK VALVES
  - ONE DIRECTION FLOW VALVE
- BACKFLOW PREVENTER

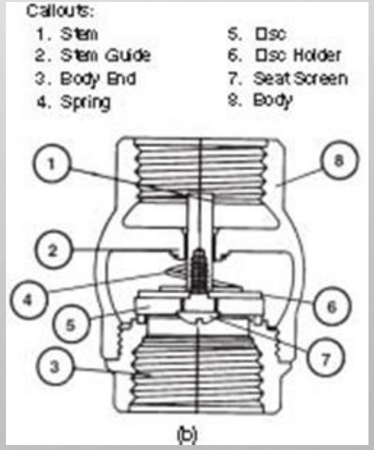


CHECK VALVES

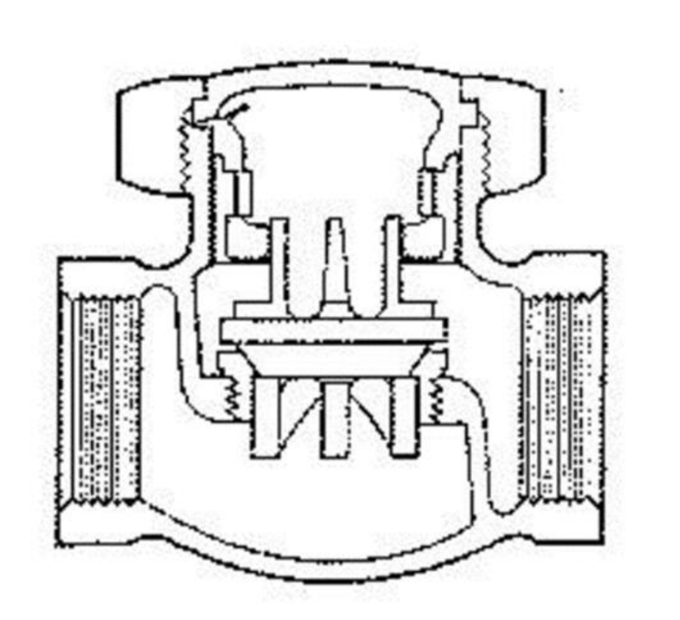


- 2 main types:
  - Swing-check valve
    - Install in horizontal piping or can cause water hammer
    - Install with a minimum of 12 pipe diameters of pipe upstream
  - Spring-loaded check valve
    - Install in any orientation
    - Spring operation creates more pressure drop compared to a swing-check





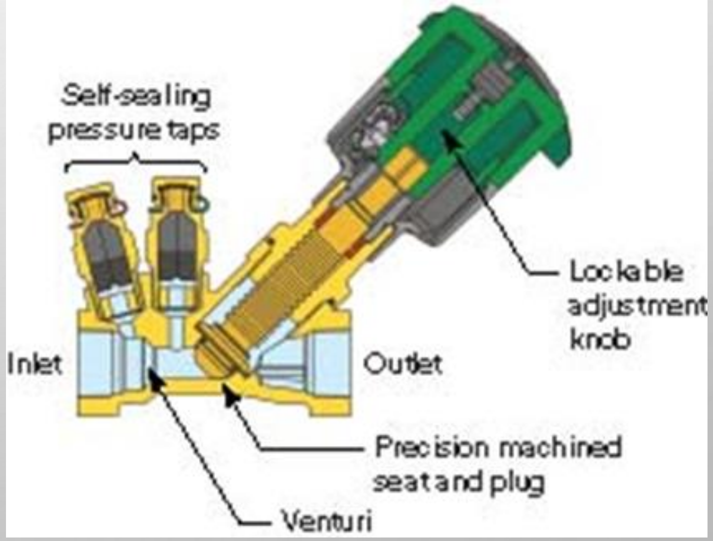
OTHER CHECK VALVES



- Lift check:
  - A lift check valve has greater resistance to flow than a swing check but is more suitable for rapid operation cycles
  - Available for horizontal and vertical applications
- Flow-check:
  - Specially for use in hydronic systems
  - Has a weighted internal plug that takes approx. 0.3 psi to lift it
  - Can prevent backflow as well as thermal migration when the circulator is off
  - Used when utilizing circulators instead of zone valves for zone control
  - Available with either two or three ports

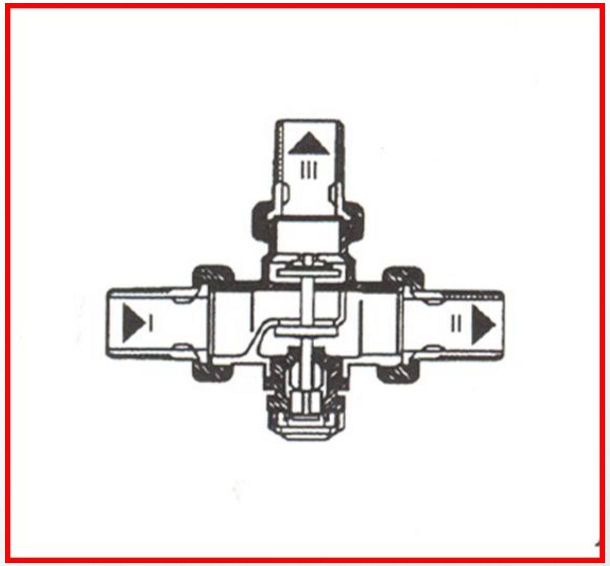
BALANCING VALVES

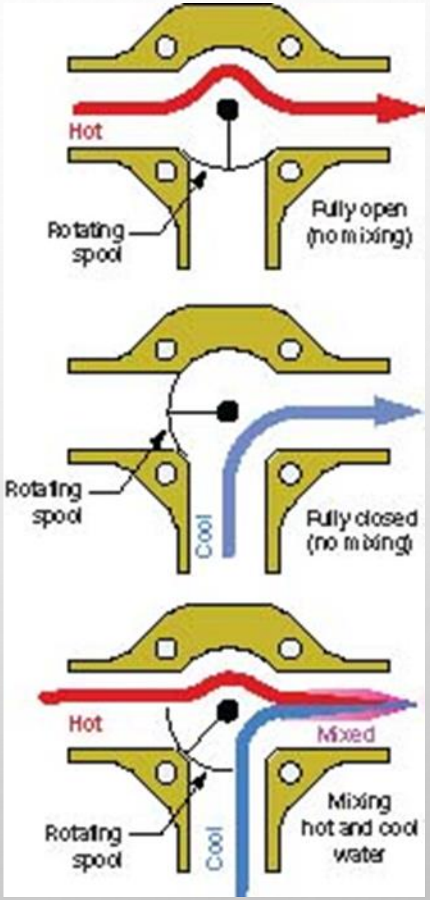
- Designed to throttle flow
- Testable in order to calculate actual flow during operation

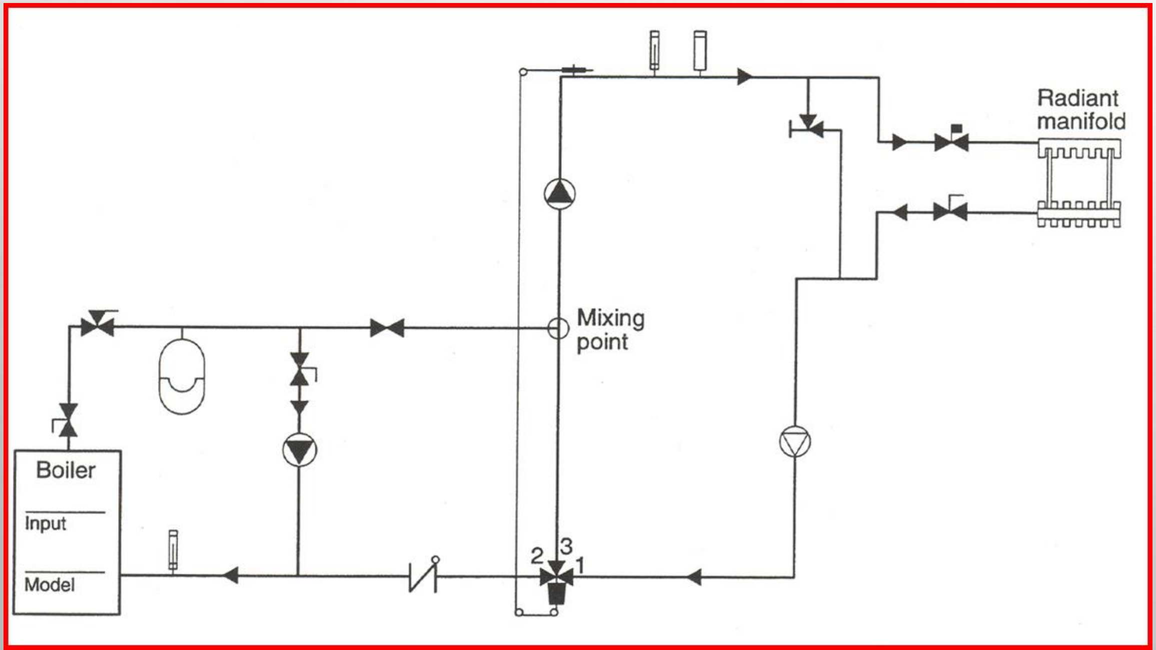


THREE-WAY DIVERTING VALVES

- One inlet, two outlets
- Will modulate flow to both outlet ports depending on the positioning of the two valve discs.

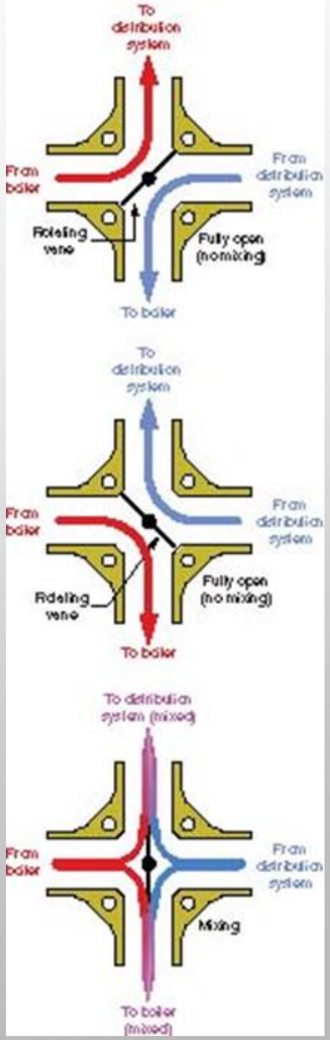






4-WAY MIXING VALVES

- Using a four-way mixing valve ensures full flow through the boiler and that the return water to the boiler is always properly tempered, regardless of the valve position.



FLOW SWITCH

- DESIGNED TO SENSE FLUID MOVEMENT.
  - AIR FLOW SWITCH
  - LIQUID FLOW SWITCH
  - PADDLES CAN BE TRIMMED TO FIT DIFFERENT PIPE SIZES.

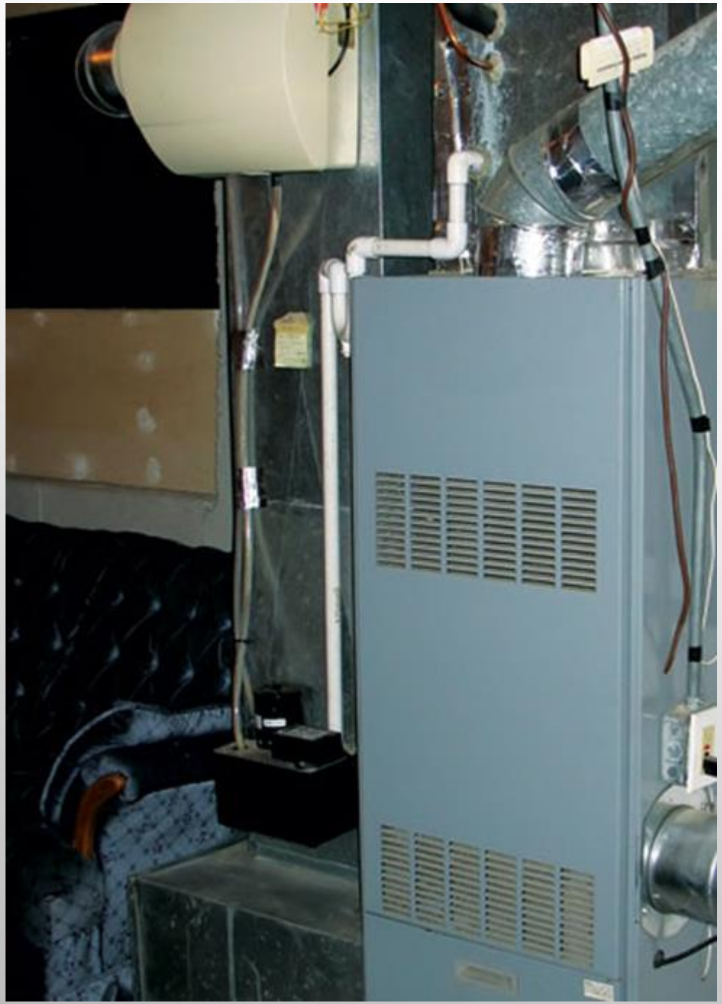
DRAINAGE, CONDENSATE, MELTWATER,

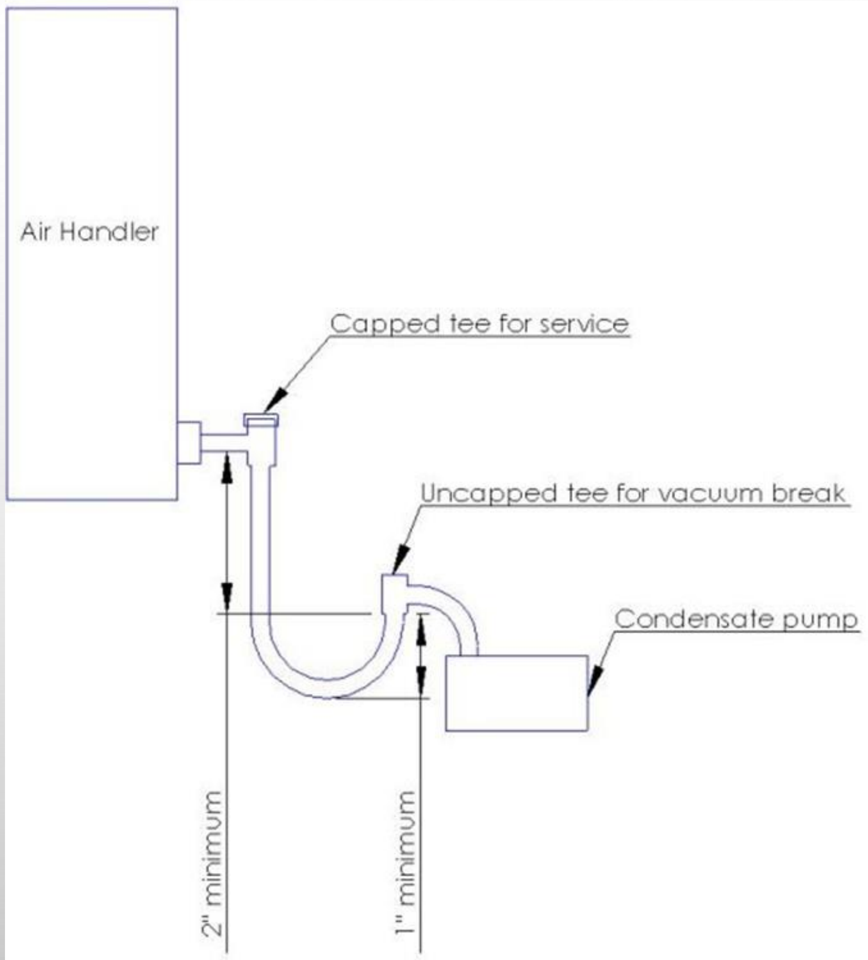
- The need for drains:
- The evaporator will lower the temperature of the return air to its dew point. At this point the moisture in the air begins to condense as liquid water on the cold surfaces of the evaporator which falls into the drain pan.
- The condensate must be drained away from the drain pan, typically to the sanitary sewer of the building.
- If not drained sufficiently the drain pan can overflow, damaging equipment and the space containing the equipment
- Systems with defrost will create meltwater, which must be handled similarly to condensate.
- Systems with once through condenser cooling water need to dispose of the water

CONDENSATE GENERATION

- An average humidity space will create ~3 pints per ton of air conditioning per hour. This about 1.5L or 3/8 of a US gallon per ton per hour.
- Higher or lower humidity in the return air and the rate of dehumidification will increase or decrease the rate of condensate generation.

BASIC CONDENSATE DRAINAGE





DRAIN PANS

- Drains pans may be plastic or metal.
- Most new equipment has corrosion free plastic drain pans.
- Some older style evaporators required the fabrication and installation of a sheet metal drain pan. The joints in the pan must be soldered. These drain pans are subject to corrosion.
- Drain pans must be sloped toward the outlet drain connection.
- Some equipment may have inherently sloped drain pans.
- Other equipment, and fabricated pans require they be installed with slope – at least 1/8" per foot, however ¼" per foot is better.
  - Some refrigeration unit coolers and evaporators require field sloping at installation.
- Always verify the equipment installation requirements!

DRAIN LINE MATERIALS

- Must be suitable to handle the condensate and meltwater.
- If condensate is from a high efficiency burner it will be acidic, and copper or brass or not suitable. They will be corroded by the acid.
- Material must meet fire and smoke rating for the building classification. A non-combustible building will require a minimum of a 25 or less fire rating and a plenum requires a 50 or less smoke rating.
- Plastics should generally be avoided on freezer drains, as it becomes brittle and can break easily. Copper is preferred.

Material	Fire 25	Smoke 50 Rating	Notes
White or Grey PVC	No	No	Available in small dimensions. Sized IPS. Common.
Cream CPVC	No	No	Available in small dimensions. Sized CTS. POE can dissolve.
Copper	Yes	Yes	Available in small dimensions. Sized CTS. Common.
Clear Vinyl Tubing	No	No	Available in small dimension. Sized CTS. Flexible, prone to kinking. Common.
ABS	No	No	Sized IPS
Steel Pipe / Iron Fittings (Black Iron)	Yes	Yes	Not permitted in plumbing drainage systems due to corrosion. Sized IPS
Galvanized Steel Pipe / Iron Fittings	Yes	Yes	Sized IPS
XFR (Ipex)	Yes	Yes	Sized IPS
X15 (Ipex)	Yes	No	Sized IPS
Stainless	Yes	Yes	Sized IPS. Premium. Costly
IPS = Iron Pipe Size CTS = Copper Tube Size			

DRAIN LINE SIZING

- The national building code of canada, and the ontario building code both require that the drain size be no smaller than the outlet size of the fixture or appliance.
- Most air conditioners have a ¾" npt outlet connection for the condensate drain, therefore these systems must have a ¾" nominal drain size.
- Code also requires that when two fixtures drain into a common drain line that the minimum drain line size be 1-1/4". This requirement is often not enforced for a combination high efficiency furnace and air conditioner.
- Lengthy, complicated or multi-equipment condensate drains will require consultation with a plumber and/or mechanical engineer or designer.

COMMON CONDENSATE DRAIN LINE SIZES

System Tonnage	Drain Line Size
Up to 20 tons*	¾”
21 to 40 tons	1”
41 to 90 tons	1-1/4”
91 to 125 tons	1-1/2”
126 to 250 tons	2”
**Many manufacturers change the condensate outlet connection size to 1”between 10-15 tons*	

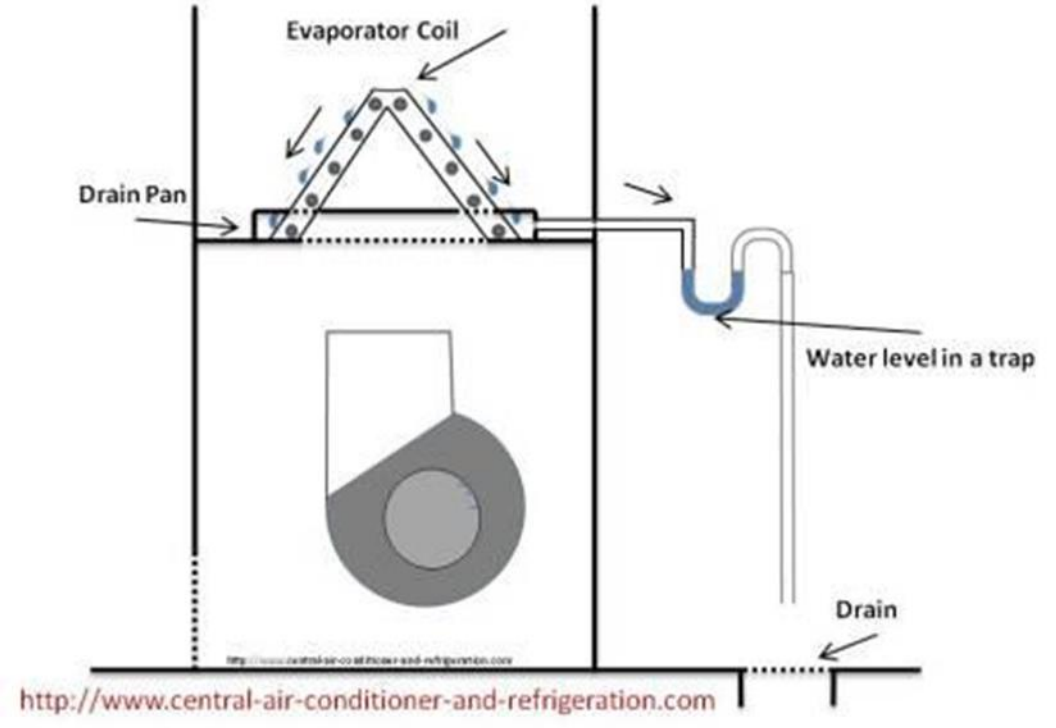
- These guidelines are specified in some non-Canadian codes and can serve as guidelines.
- Actual calculations of volume of condensate water and piping design should be completed for unusual systems

AIR PRESSURE

- The evaporator fan will expose the drain pan to either a positive or negative air pressure. If the evaporator is on the inlet side of the fan the pressure will be negative, if the evaporator is on the outlet side of the fan the pressure will be positive.
- If the drain line is at negative pressure, untreated air will be drawn in through the drain and the condensate will not be able to leave the drain pan. The drain pan will fill and eventually flood, if the run cycle is long enough
- If the drain pan is at a positive pressure, both condensate and supply air will be blown out of the drain pan, wasting energy. Equivalent to having a hole in the ductwork the size of the drain connection.
- The drain pan and drain line must drain freely, and a solution is needed to decouple the drain line from the air pressure at the drain pan and drain outlet connection

TRAPS

- A trap is used to decouple the drain pan from the drain line
- The trap has a deliberately created low point.
- The trap is primed or filled with water.
- The water blocks the flow of air, and decouples the drain line from the air pressure created by the evaporator fan
- The trap must be constructed properly and to the correct dimensions in order to function properly.

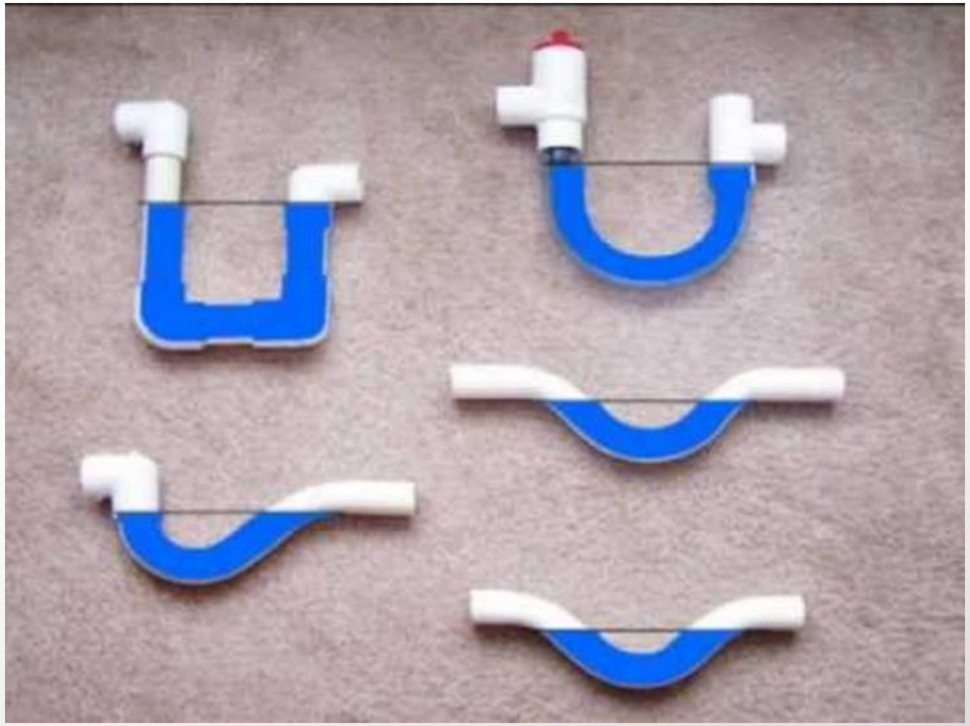


TRAP TYPES

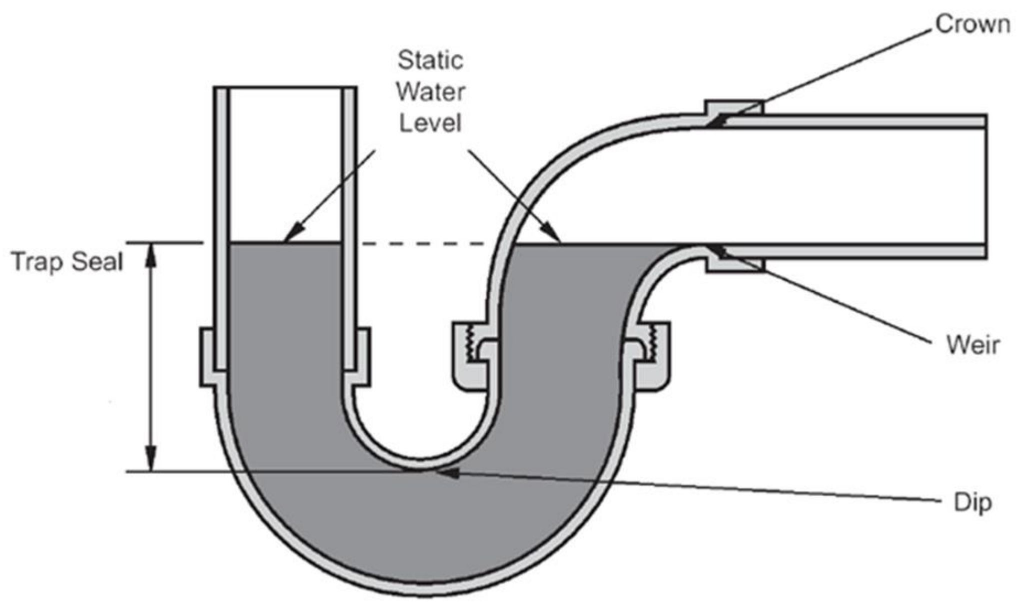
- Traps may be prefabricated or field fabricated from fittings
- The most common trap is a p-trap with the inlet on the vertical, and the outlet on the horizontal.
- An s-trap can also be used, with both the inlet and the outlet on the vertical.
- A less commonly used trap is the r-trap, or running trap, with the inlet and outlet on the horizontal. The design of this trap is typically not suitable to decouple the drain line from fan pressure, it merely serves as an off cycle liquid seal to block insects and odours from travelling through the drain line. It is not typically suitable.

TRAP TYPES

- P traps are entered on the vertical
- R traps are entered on the horizontal
- S traps are entered on the vertical and exited on the vertical.
- Note that s-traps are not legal under the plumbing code (7.2.3.1(4) – A bell trap or an s-trap shall not be installed in a drainage system). Neither are running traps unless it has a cleanout



Parts of a Trap



PARTS OF TRAPS

1. The trap seal is the vertical depth of liquid between the weir and the dip.
2. The weir is the level at which the liquid will spill over into the waste pipe.
3. The dip is the level below which there is no effective barrier against the emission of sewer gas.
4. The crown is the point above the weir.

TRAP DIMENSIONS

- The outlet must always be lower than the inlet of a trap.
- The dimensions of a trap for condensate are critical in 2 measurements.
  - The depth from the inlet to the outlet
  - The depth from the dip to the outlet
- The maximum pressure of the fan in the application, as well as whether the pressure on the trap will be positive or negative must be known to determine the trap sizing.
- Inches of water column (in. Wc., “Wc, in. Wg., “Wg) is the typical air pressure measurement, and the trap dimensions can be determined in inches.

NEGATIVE PRESSURE TRAP

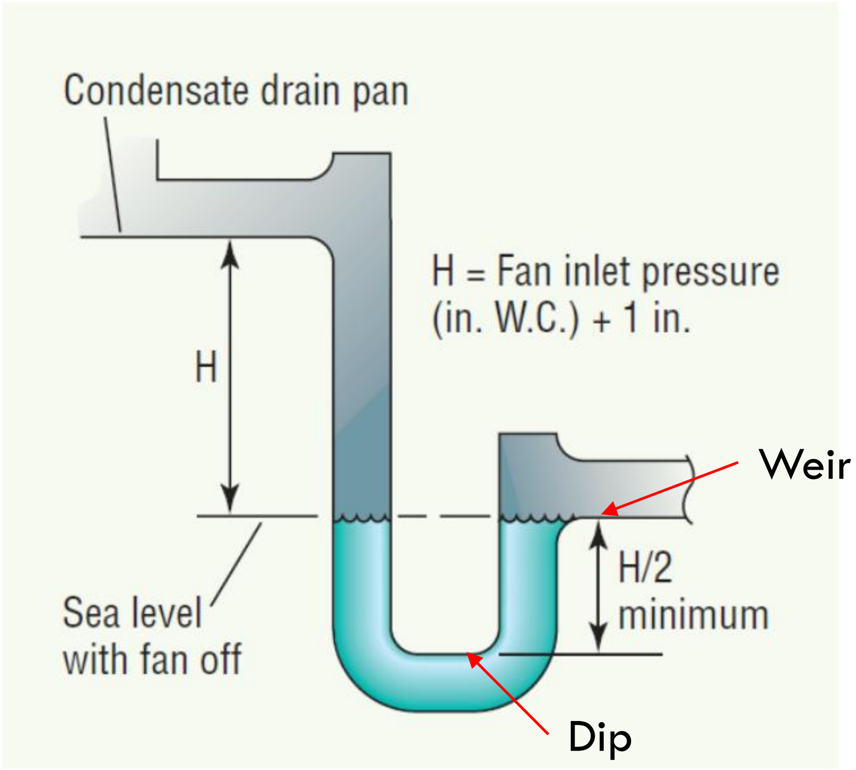


FIGURE 1. Trap for draw-thru unit, fan off.

- **INLET:**
- $\text{HEIGHT}_{\text{DROP}}$ FROM *__INLET__* TO *__WEIR (OUTLET)__* = *H*
- *H* MUST BE AT LEAST AS HIGH IN INCHES AS THE MAXIMUM NEGATIVE PRESSURE THE FAN CAN GENERATE IN IN.WC. *__PLUS__* A MARGIN OF ERROR. CONSIDER DIRTY FILTERS, ETC WHEN DETERMINING THIS VALUE.
  - THE EXTRA HEIGHT FOR THE MARGIN OF ERROR SHOULD BE 1" MINIMUM, UP TO 50% OF THE VALUE OF H, ESPECIALLY IF NOT CERTAIN OF THE NEGATIVE PRESSURE THE FAN WILL GENERATE.

- **OUTLET:**
- $\text{HEIGHT}_{\text{RISE}}$ FROM THE *__DIP__* TO THE WEIR (__*OUTLET)*__ = *H* ÷ 2
- IF THE $\text{HEIGHT}_{\text{RISE}}$ IS INCREASED, THEN THE $\text{HEIGHT}_{\text{DROP}}$ MUST INCREASE. ***THE RATIO OF HEIGHT MUST STAY THE SAME.***

NEGATIVE PRESSURE TRAP IN OPERATION

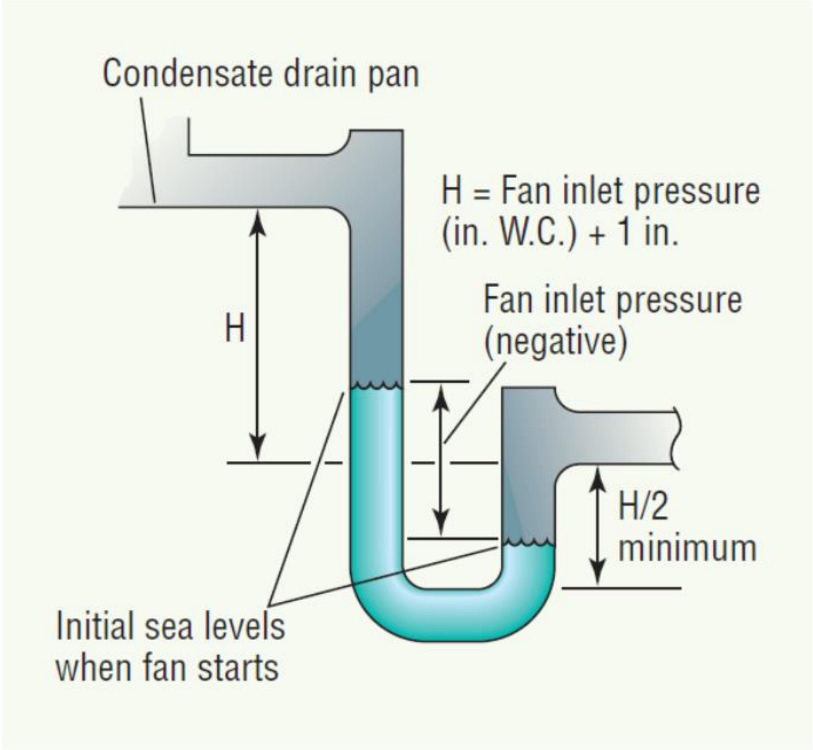


FIGURE 2. Trap for draw-thru unit, fan just started.

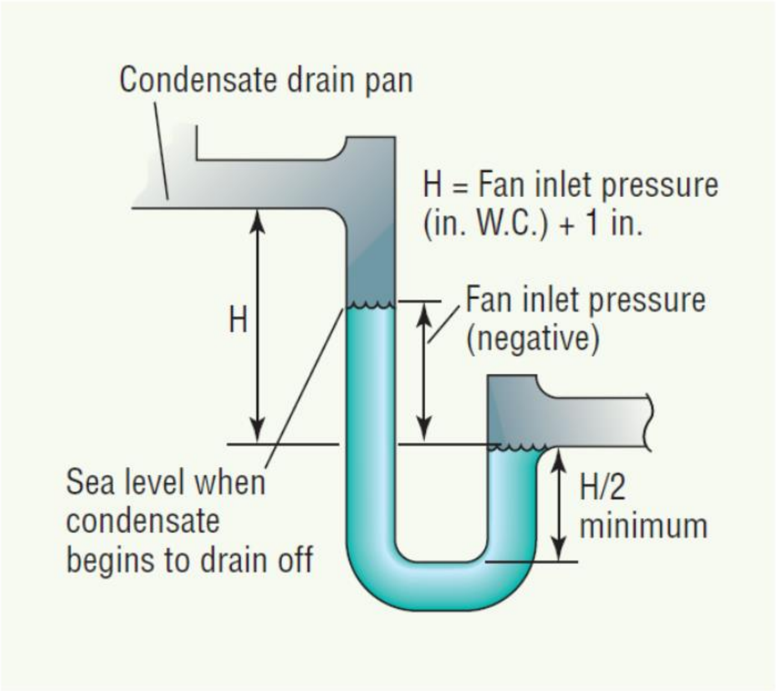


FIGURE 3. Trap for draw-thru unit, condensate beginning to drain away.

POSITIVE PRESSURE TRAP

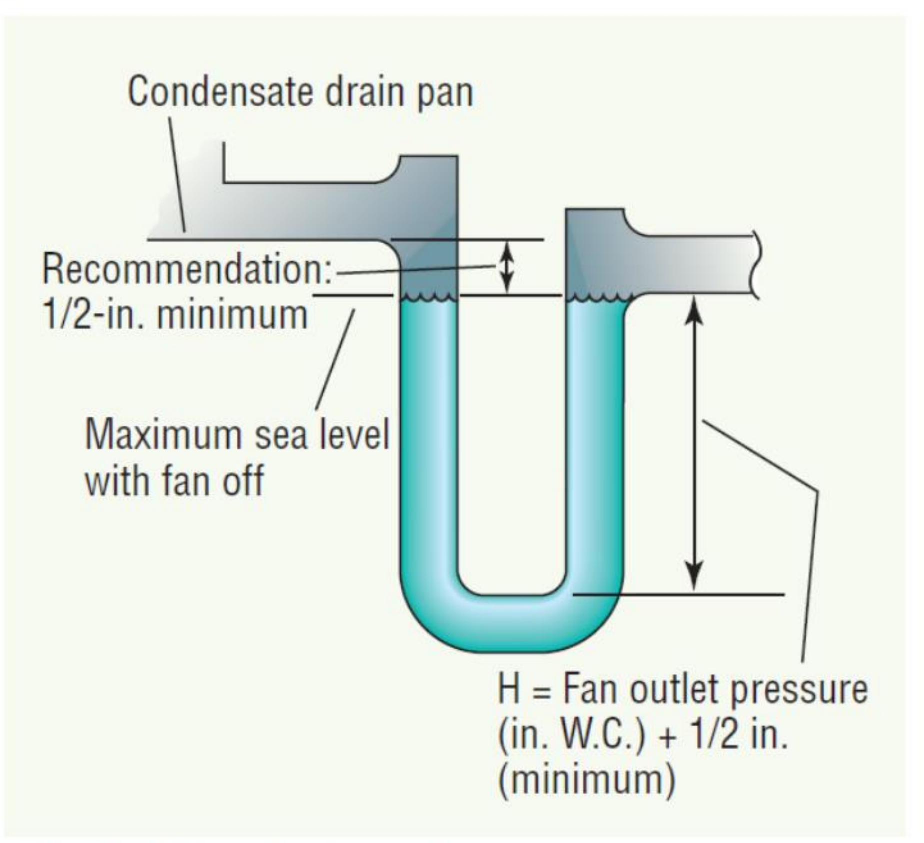


FIGURE 4. Trap for blow-thru unit, fan off.

- Height from inlet to outlet = H
- Height h must be at least as high in inches as the maximum positive pressure the fan can generate in in.Wc. *Plus* a margin of error.
- The extra height for the margin of error should be 1/2 minimum "(1" is better), up to 50% of the value of h, especially if not certain of the positive pressure the fan will generate.

POSITIVE PRESSURE TRAP IN OPERATION

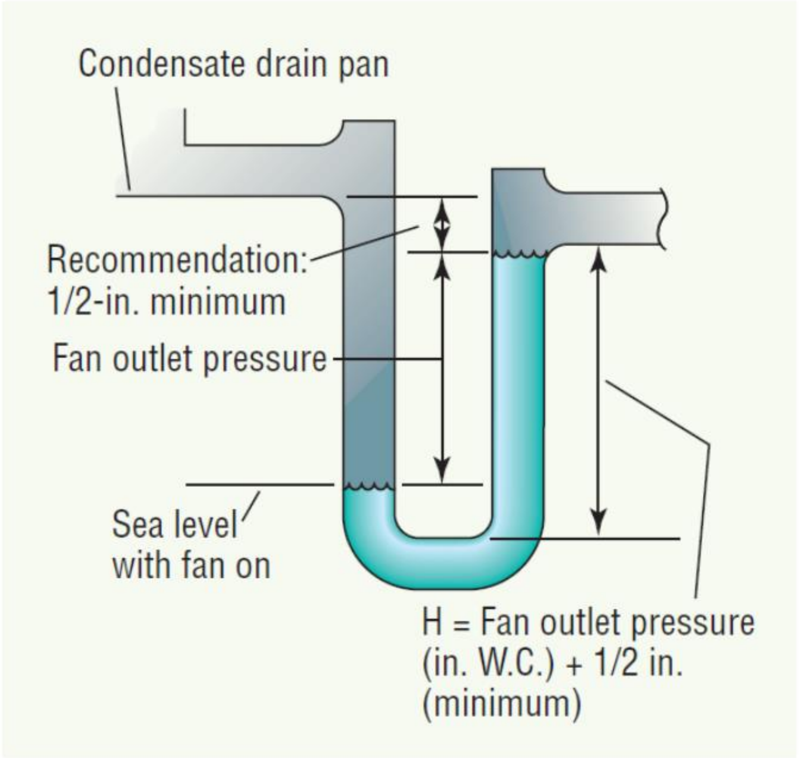
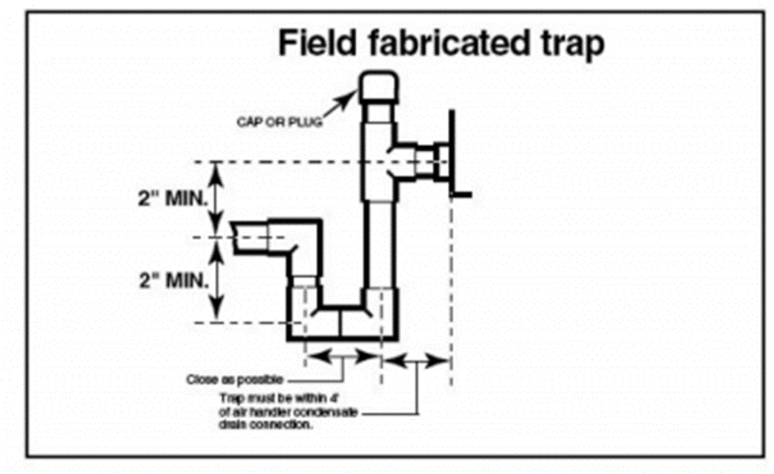


FIGURE 5. Trap for blow-thru unit, fan running and condensate beginning to drain away.

RESIDENTIAL EQUIPMENT TRAP SIZES

- A common size for the residential condensate traps is a 2” drop and 1” rise.
- This works with the indoor blower fans which are often limited to less than 1”wc of either positive or negative static pressure (typical furnace has 0.5” ESP)
- Equipment manufacturers may provide instructions for trap construction.
  - These dimensions will be specific to that equipment, based on the fan’s pressure capability.

SAMPLE MANUFACTURERS INSTRUCTIONS



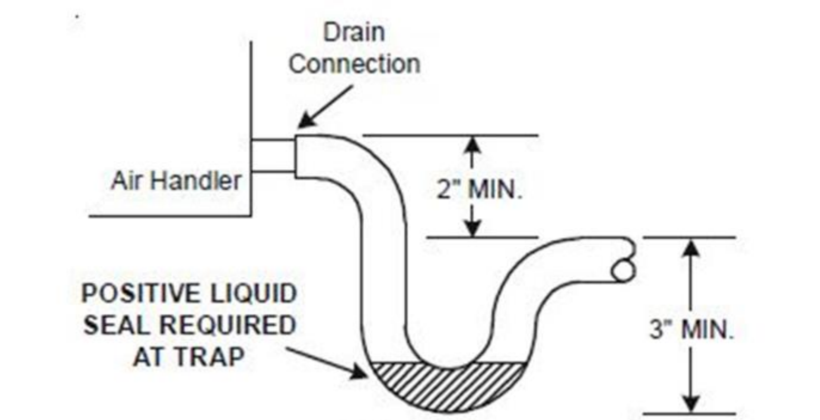
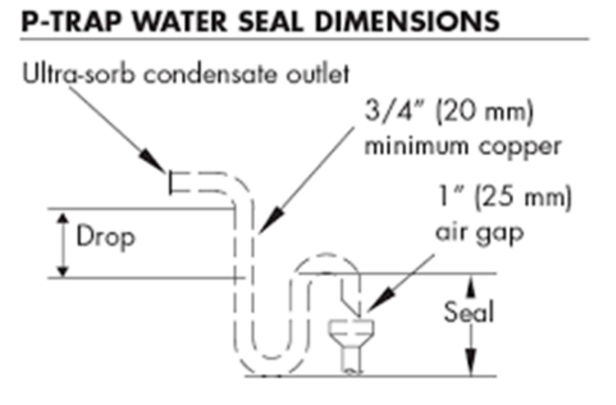
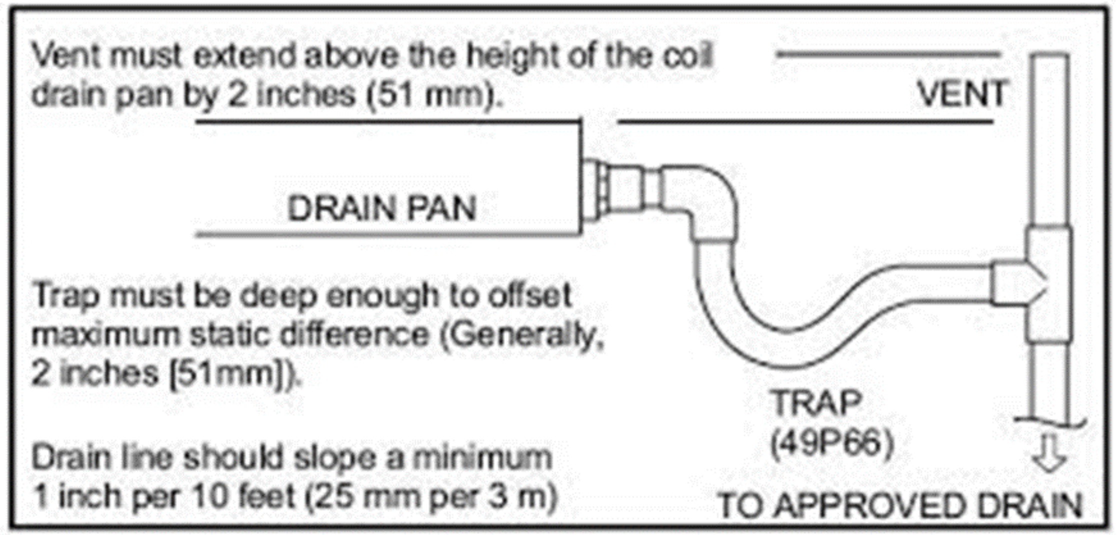


Figure 7





OEM TRAPS

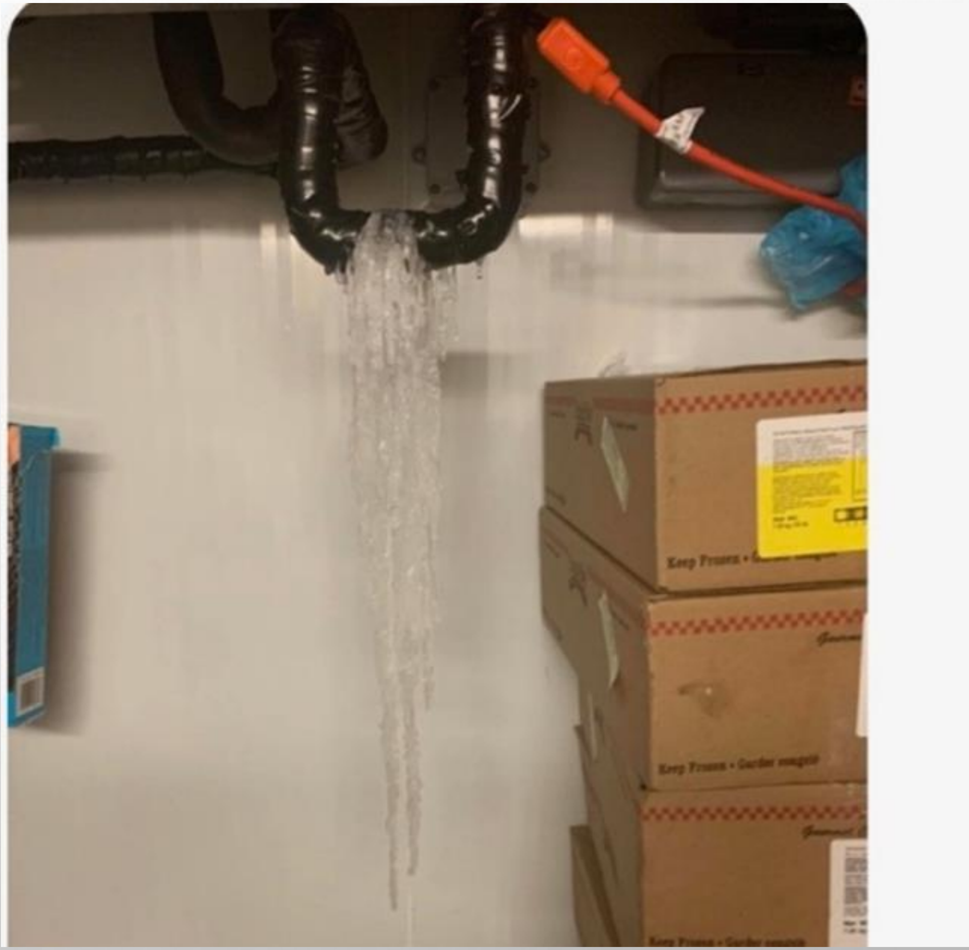
- It is common for equipment such as furnaces and blowers to have unique, OEM designed and supplied traps.
- The outlet connection may be designed for different types and sizes of material, verify the materials needed from the installation manual of shop drawing.
- It is common for high efficiency furnace traps to be sized for ½" or ¾" pvc, or ½" cpvc. These sizes are different as PVC is sized IPS and CPVC in small sizes is sized CTS.

DOUBLE TRAPPING

- A double trap in a line, that is two or more liquid seals, will create an air lock and impede or inhibit the flow of water.
- Never intentionally install two or more traps in a line.
- Avoid sags, dips, high points or other unwanted traps by installing piping with sufficient supports and maintain consistent slope.

FREEZER TRAPS

- Traps in a freezer should be located outside the freezer, where the trap cannot freeze.
- Even with heat tracing the water in a trap may freeze in some cases, and if the heat tracing fails the trap will almost definitely freeze and split piping due to the expansion of the water as it turns to ice.



HEATING OF DRAIN LINES

- Drain lines must be heat if the space they are in is below freezing.
- If heated the drain line must be insulated.
- Typically self regulating heat trace tape is used. The heat trace tape can be inserted inside the drain line or wrapped around the outside. If inserted the drain line size may need increased.
- Typically, heat trace tape cannot be wrapped over itself - it will overheat and fail.
- The drain fittings from the drain pan in a walk in should be wrapped.
- As a guideline, use 30 watt per foot heat trace in rooms below 0°F, and 20 watt per foot heat trace in rooms over 0°F.
- Energize heat trace at all times.

CLEAN OUTS

- Traps may collect dirt, debris and sludge. Eventually this can obstruct the trap.
- A clean out allows the traps to be cleaned and serviced
- Clean-outs must be sealed tightly to prevent a leak
- The quantity of dirt can be minimized with improved air filtration.
- Long drain lines may require multiple clean out locations.
- The application of bleach may prevent the growth of biologicals in the trap/drain.
- PVC clean-outs might be an unglued cap at the top of stand-pipe.

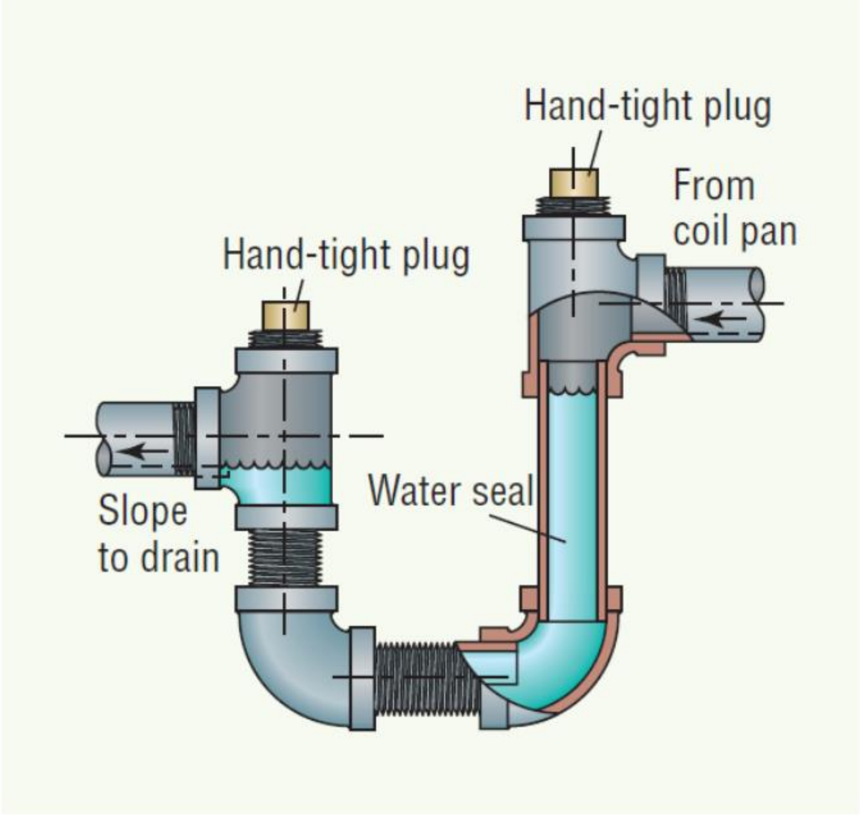
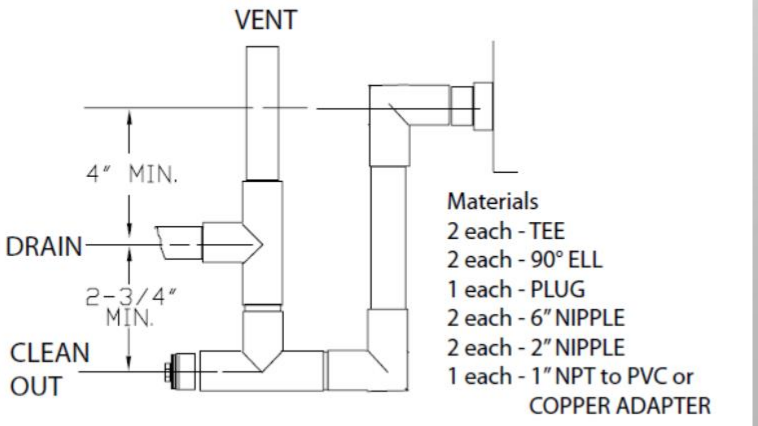


FIGURE 6. Recommended use of tees and plugs.

Figure 19. Typical drain trap assembly



VENT

- After the P trap, a vent may be required to prevent either pressure or suction (siphonage) from developing and preventing the condensate from draining
- The vent allows air to enter or exit the drain line and break any vacuum
- Vent must be left open to atmosphere. The vent line must extend above the level of the drain pan
- This vent line is downstream of the trap, therefore isolated from the drain pan and the air pressure created by the fan.
- The vent should be located before the drain line slopes downwards more than one pipe diameter.
- The longer the drain line, the more important the vent line.

CROWN VENTING

- Installing a vent at the crown of the trap is called crown venting.
- The plumbing code prohibits crown venting
  - A crown vent in a plumbing system is prone to clogging, and is therefore prohibited.
- If needed, rather then crown venting a vent should be installed within two pipe diameters of the weir.
- The pipe from the weir to the vent is called the trap arm.
- These requirements are often overlooked with the small traps and vents used on HVACR equipment. Crown vents are often installed.
  - The vent is almost universally open to the surrounding space, as the wastewater does not contain dangerous or smelly sewage. The problems that crown venting creates in plumbing systems are not found on these HVACR drains.

SLOPE

- Drain lines must be sloped to move water.
- Plumbing code calls for a minimum slope of ¼" per foot, also known as 2% or 1:50
- Due to dirt and debris that collects on the evaporator coils of refrigeration systems without air filters, a walk in cooler drain should be sloped at 1" per foot if possible.
- To prevent freezing up the drain, a walk in freezer drain should be sloped at 4" per foot if possible.

SUPPORT AND SAGGING

Horizontal Piping Support Requirements	
Type of Piping	Support Requirements
ABS and PVC DWV Pipe	Intervals not exceeding 1.2m(4’), at the ends of branches, at changes of direction or elevation, if the pipe is a fixture drain more than 1m in length in which case as close to the trap as possible
Copper Tube	3m(10’) for larger than 1” hard drawn, 2.5m(8’) for 1” and smaller hard drawn, 2.5m(8’) for all soft drawn
Galvanized Steel	2.5m(8’) for sizes less than 6”
Additional piping materials and sizes found in the plumbing code.	

Vertical Piping Support Requirements
Vertical piping shall be supported at its base and as the floor level of alternate storeys.
The maximum spacing of supports shall be 7.5m(25’)

PLUMBING CODE

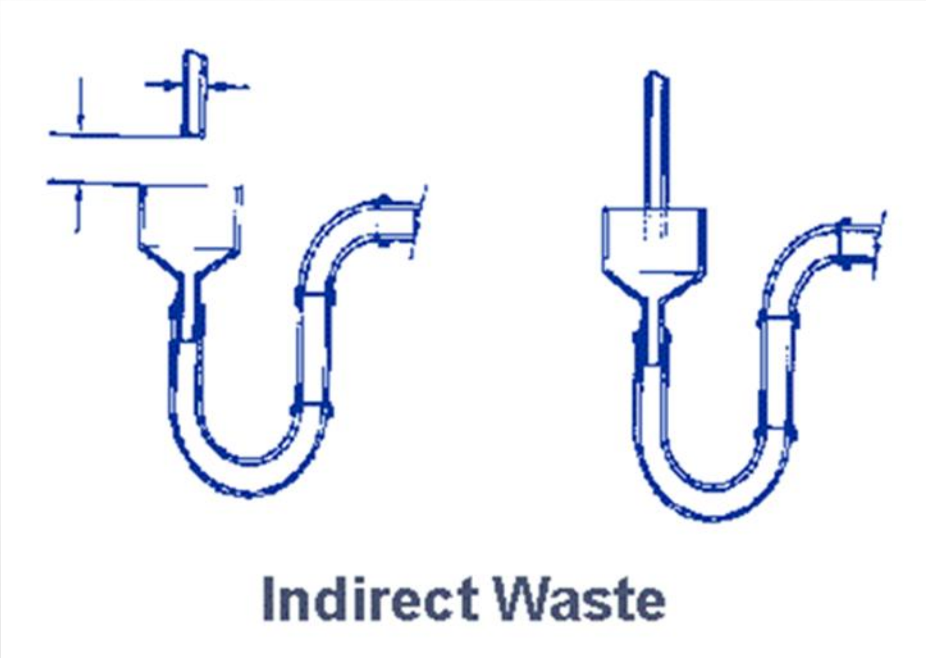
- The field of plumbing deals with the supply of potable (domestic) water, and the removal of sanitary waste.
- The field of plumbing is regulated by code contained in the national building code of Canada and the Ontario building code and this scope of work is done by plumbers.
  - Section 7 of the code
- The field of hydronics is separate. Plumbers, gasfitters and refrigeration mechanics all work in it. The scope of work is covered by pipefitter/steamfitter. There has been an effort to develop a dedicated hydronics trade.
- Items of note in the code for HVACR:
  - Clear water waste
  - Indirect vs direct connections
  - Trapping
  - Air break
  - Air gap
  - Walk in cooler drain

CLEAR WATER WASTE

- Clear water waste is safe and poses no risk to health.
  - Condensate from air conditioning and refrigeration equipment can be considered "clear water waste" according to code.
  - The water from a once through water cooled condenser can be considered clear water waste.
  - Bin meltwater from an ice machine bin can be considered clear water waste
- Clear water waste may be drained to a sanitary drain however it can be permissibly drained to sump pump pit or storm drain if draining to sanitary would require pumping
- Note: The acidic condensate from a high efficiency burner is not clear water waste.

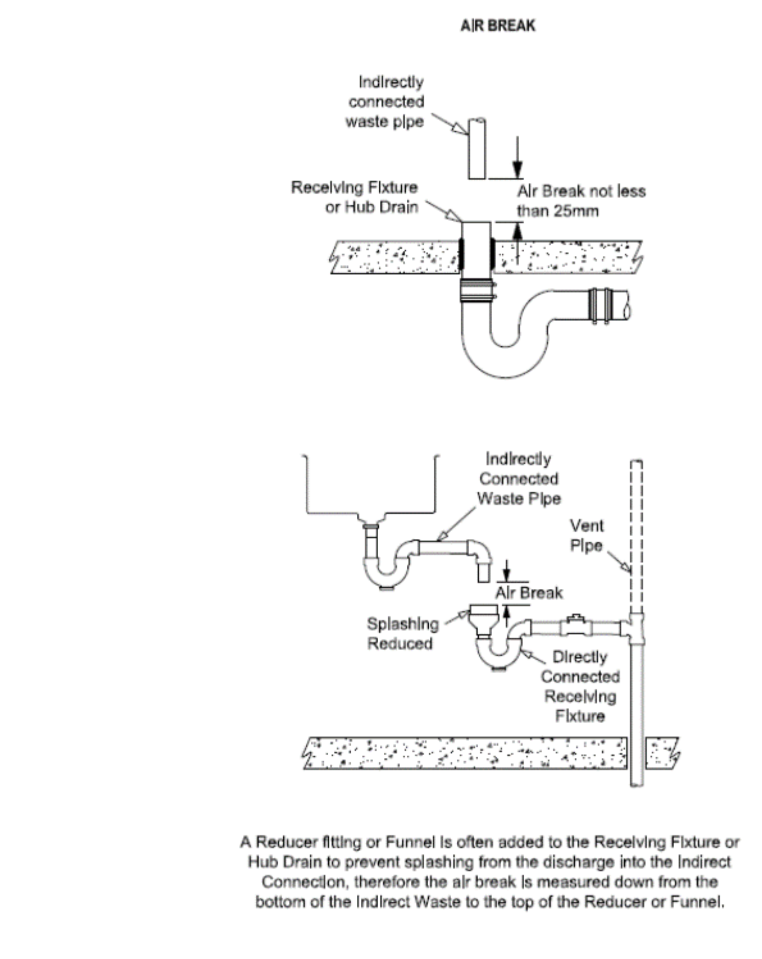
INDIRECT CONNECTIONS

- The requires certain types of drain connections to be made indirectly rather than directly.
- The indirect connection requires an air break between the drain from the appliance and flood level of the receiving fixture
- The air break must be a vertical distance of at least 25mm (1")
- The connection between HVACR equipment and sanitary sewers must be indirect.
- The air gap prevents a sewer backup from causing contact between sewage and the condensate drain

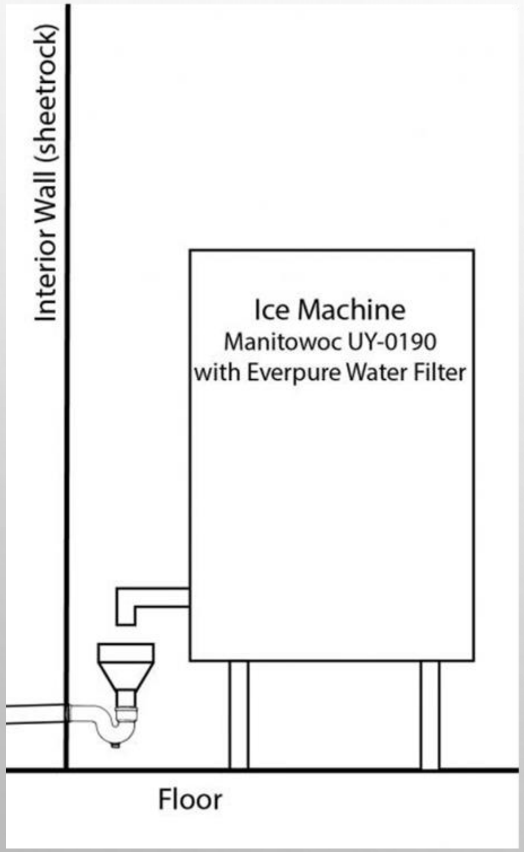


RECEIVING DEVICES

- Common receiving fixtures include;
  - A funnel type drain
  - A floor drain with a funnel
    - The flood level of the fixture is at the floor with this device. This should allow the insertion of the appliance drain outlet into the funnel, but at times it is prohibited by local plumbing inspectors
  - A laundry tub or similar
  - A sump pit
- A funnel assists in ensuring the drain water enters the receiving fixture without spilling. A reducing coupling is common used, with a 3” or 4” inlet.
- A funnel on a floor drains minimizing splashing



AIR BREAKS


Interior Wall (sheetrock)
Ice Machine
Manitowoc UY-0190
with Everpure Water Filter
Floor

SOLUTION TO SPLASHING AT AN AIR GAP

- In some cases the drain water may not drip into the funnel as desired.
- This can happen because the water follows the exterior of the pipe, and on a vertical drop tends to spiral down the pipe wall.
- When the spiralling water reaches the open end of the pipe, instead of dropping straight it is thrown sideways by inertia from the spiralling action, and some of the water may miss the funnel, no matter how the technician orientates the drain.
- One solution is to miter the outlet of the drain at a 45° angle, or to cut one more vertical slits in the pipe. Both of these interrupt the spiralling and assist the water to exist the vertical opening straight downwards.

SOME POSSIBLE REGULATIONS AND BYLAWS

- Ph of wastewater entering the sewer can not be lower than 5.5 or higher than 11 and the temperature can not be greater than 60°c
- Meeting these requirements may require condensate neutralizers for fossil fuel equipment, dilution drain water to dilute the ph or the temperature, or holding tanks that allow hot water to cool before drainage
- Many municipalities have adopted bylaws banning the use of once through water cooled condenser.
    - In some cases it is a total ban.
    - In other cases it is ban above a certain tonnage / capacity.

REFRIGERATION EQUIPMENT DRAINAGE

- As a summary:
- PVC can be used in a cooler but is not recommended for a freezer. Copper works well in both freezers and coolers.
- Install a union to allow the evaporator drain pan to be accessed and serviced.
- Drain pan heater must be energized during defrost.
- Slope drain line 1” per foot for cooler, 4” per foot for freezer.
- Locate trap outside of freezer.
- Heat trace and insulate drain lines in a freezer. Energize heat trace at all times.
- Floor drain must have indirect connection or a back-water valve.
- It is important to seal all penetrations of a walk in box.
- Follow all standard practices and requirements regarding drain line size, indirect connections, etc.

PRESSURIZED DRAINS

- Some drains from HVACR equipment are pressurized, such as once through water cooled condenser drains, and the sump drains on ice machines
- Pressurized drains must run independently to the nearest sanitary drain, they cannot be connected in common with any other drain, from the same unit or another.
- A pressurized drain from hvacr must terminate in an indirect connection, and the receiving fixture must be sized to receive the quantity of water required. Sanitary drains sized as per plumbing code will function acceptably.

SECONDARY DRAIN LINE

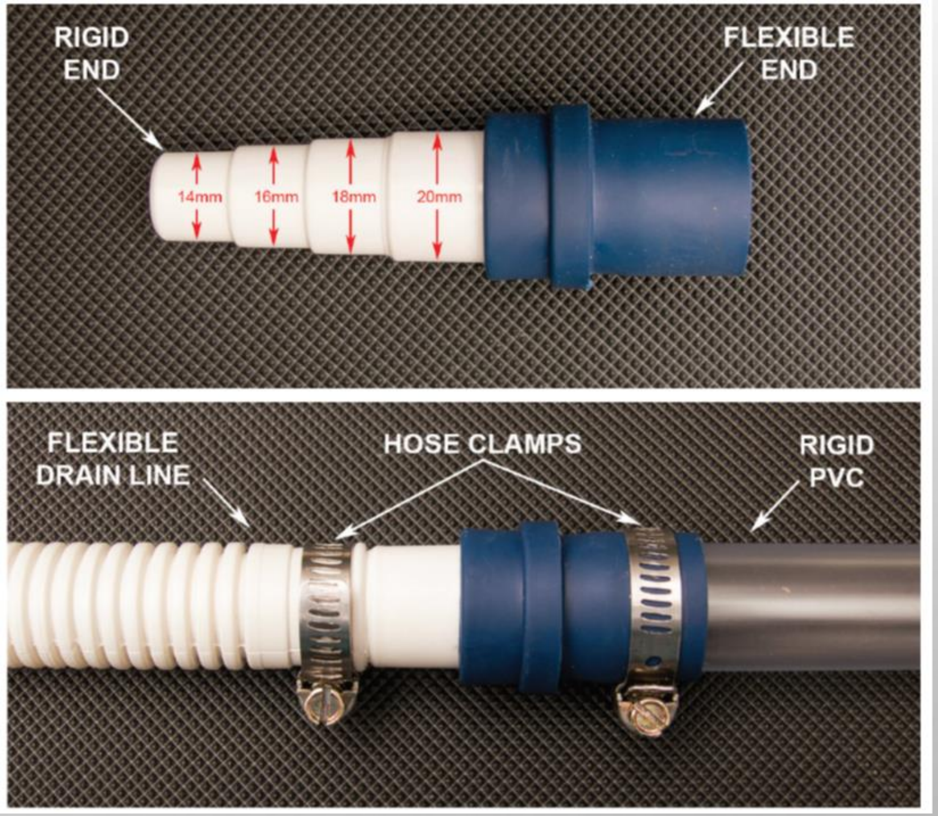
- Secondary drain connections are found on residential equipment.
- If the equipment is located above a finished space, such as in an attic, the secondary drain line should be connected to prevent a flood from causing significant property damage.
- It is located higher in the drain pan, and will only drain condensate if the primary drain is obstructed.
- The secondary drain line should be terminated in an obvious location so the occupant becomes aware of a problem.
- The secondary drain should not connected into the primary drain line, this defeats the purpose
- Commonly used in the US, required by code there. Many homes have no basements, attic installations are common

SECONDARY DRAIN PAN

- A secondary drain pan is an entire additional drain pan, typically located under an entire piece of equipment.
- Used for hot water tanks, attic mounted equipment, air handlers mounted above ceiling spaces, etc.
- The secondary drain pan may or may not have a drain line. If a drain line is used, it should be installed as a secondary drain line.
- Drain pan may be fabricated from sheet metal, or manufactured from plastic.
- A condensate overflow switch can be used to detect the presence of water in a secondary drain pan, or a high water level in a drain line or in the primary drain pan.
- The switch should interrupt the compressor, to prevent the generation of further condensate which would result in flooding.
  - Breaking the Y circuit may lead to short cycling the ac if the drain is only partially plugged. Breaking the R circuit can lead to freezing a building by preventing heating.
  - An audible or visible alarm should be connected.

MINISPLIT CONDENSATE

- Minisplit air conditioners have a flex tube type drain. The drain tube dimensions are typically metric.
- An adaptor fitting to connect the flexible outlet tube to standard drain materials may be required. If the drain connection will be concealed within a wall the connection must be secured properly to prevent it become dislodged or overflowing, leaking, etc. inside the wall.



CLEANING A DRAIN

- An HVACR drain line can be cleaned using a flexible brush or other tool. This is called rodding the line.
- Sucking dirt and muck out of a drain line with a shop vac works well.
- It is a common practice to use pressurized nitrogen or carbon dioxide (co_2) gas from a cylinder. One shot cartridges of CO_2 are available for specialized guns. One common brand name is a gallo gun.

PRECAUTIONS WHEN BLOWING OUT A DRAIN

- Before using pressurized gas, ensures every opening in the drain is found and sealed, otherwise dirty drain water will erupt from the opening in the line.
- Use caution when pressurizes lines. Poor glue or solder joints that have held during zero pressure drain service may blow apart when pressurized.
- Avoid pressurizing inaccessible lines concealed in walls, etc. The pressure may blow the line apart, and extensive damage may result if the leak is not noticed.
- If a concealed line must be blown out, always verify it drains properly before leaving the job.