Commercial Heat Pump Piping Considerations

Single Pass vs. Multi Pass Conceptual Methods

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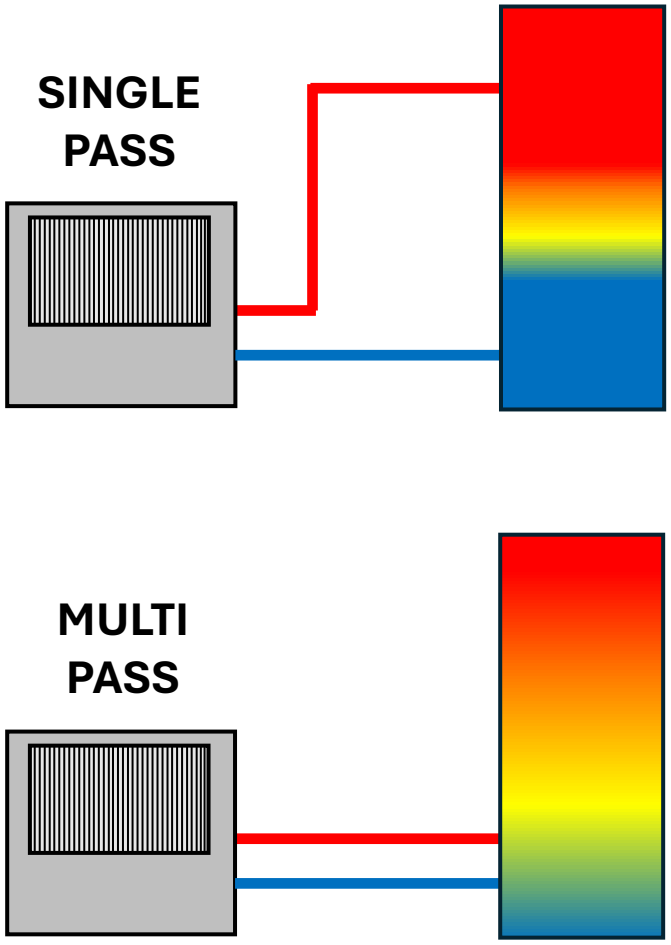
Two Ways to Heat Water with Commercial Heat Pumps



- Commonalities
  - Both use vapor compression cycle to move heat from air, achieving higher efficiencies
  - Their performance varies with changing air and water temperatures
  - Both have operating limitations based on temperatures
  - All heat pump systems utilize Lower Recovery Rates / Higher Storage Volumes as compared to gas or electric resistance systems
  - Both have domestic water pumps to circulate water to external storage tanks
- The difference?!
  - Heat is transferred to the water in different ways
  - THIS CHANGES HOW THEY INTEGRATE INTO SYSTEMS and will be explored in this presentation

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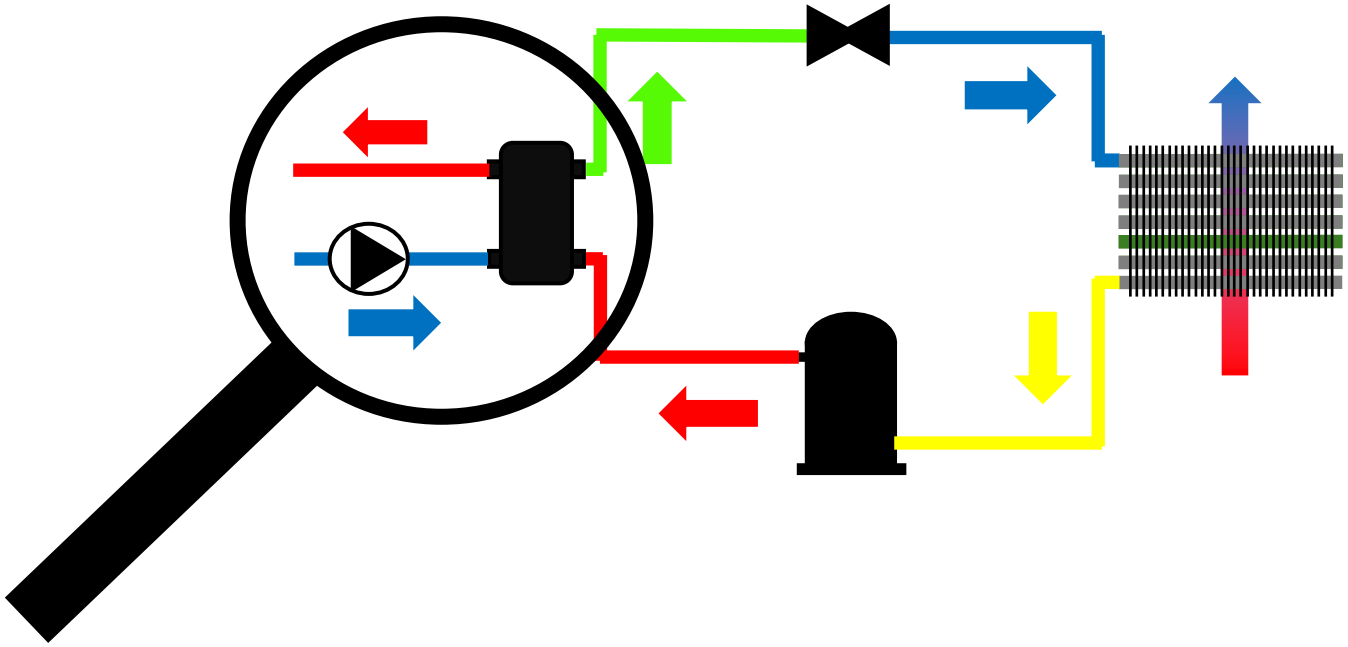
Focal Point – Water Side Heat Transfer Differences



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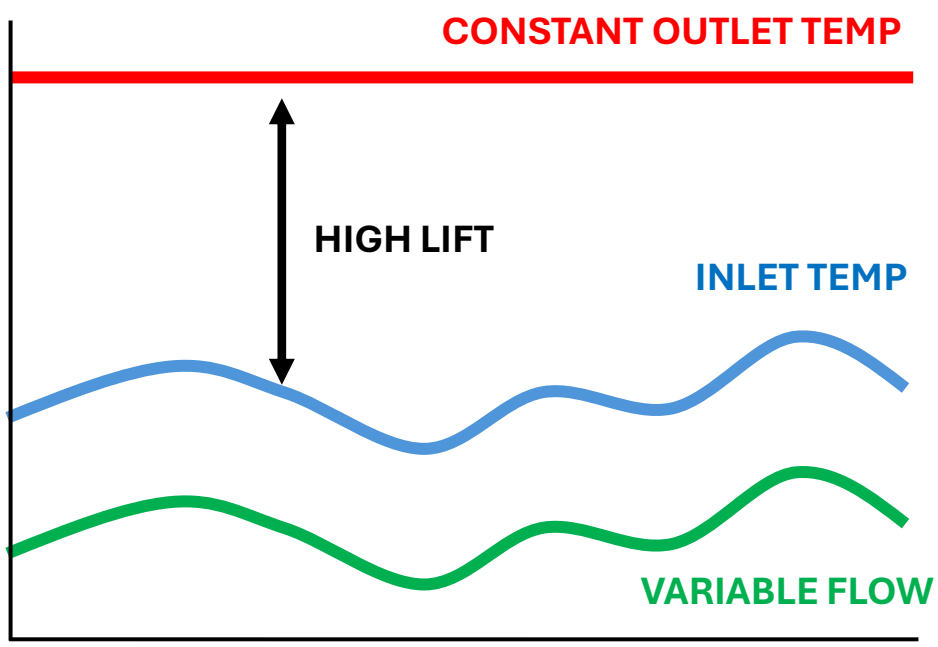
Single Pass Heating Characteristics



- **Key Characteristic: Has a high domestic water temperature lift matched to a steady output temperature. Aka "High Lift System"**
- This is achieved by varying the inlet flow rate to the heat pump to adjust the amount of heat transferred into the domestic water
- Flowrate adjusts based on incoming water temperature
  - Decreasing flow when colder water enters
  - Increasing flow with warmer water
- Can achieve high entering-to-leaving water temperature lifts
  - 100°F temperature rise in one pass through heat pump on natural refrigerant heat pumps, for example
  - Does this at lower flow rates
- Requires a minimum differential between entering and leaving water temperature (i.e. maximum entering water temperature for an output setpoint)
  - Typically, 15-20°F below setpoint

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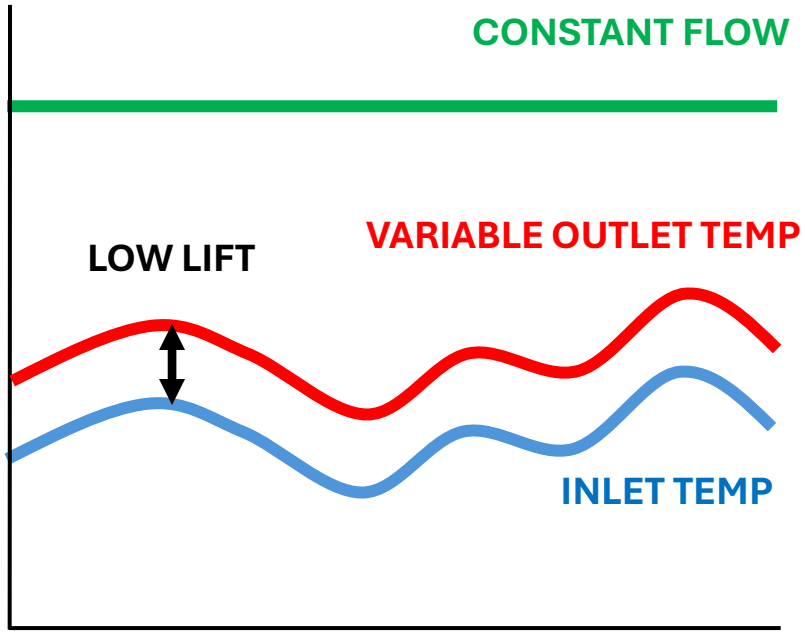
Multi Pass Heating Characteristics



- **Key Characteristic: Has a low domestic water temperature lift at a constant flow rate. Aka. “Low Lift System”**
- The flowrate is significantly higher for a multi pass system than single pass system (2 to 4 times)
- The outlet temperature varies according to the flow and incoming water temperature
  - Usually between 5 – 20°F higher than incoming water temperatures
- Multi pass heat pumps can handle varying incoming water temperatures, so long as there is adequate flow
- Final output temperature is limited on multi pass based on refrigerant pressure limits
- Flowrate dictates maximum inlet temperature

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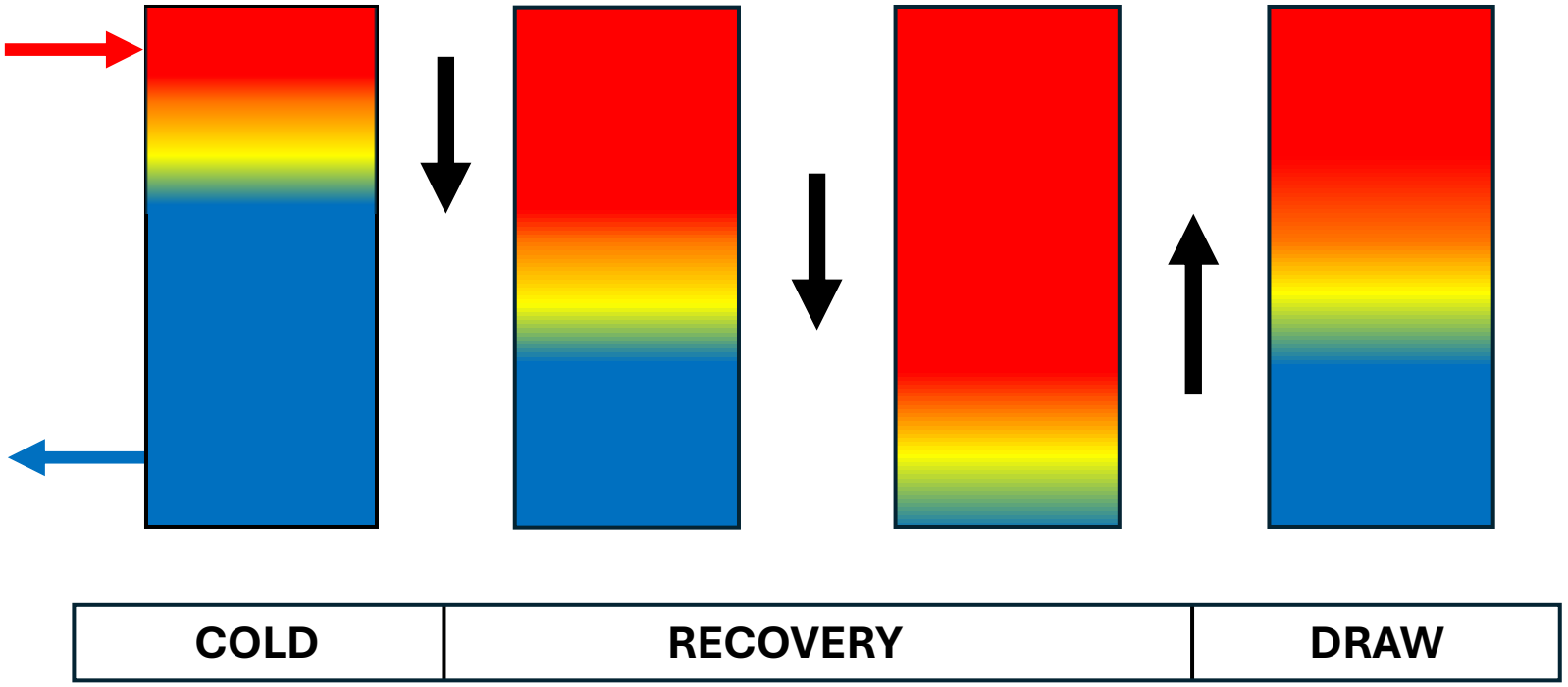
Single Pass vs. Multi Pass Storage

- It is important to understand storage methods and how they pair with the two heating methods

- Storage techniques have a direct impact to system performance

Single Pass (Stratified) Storage



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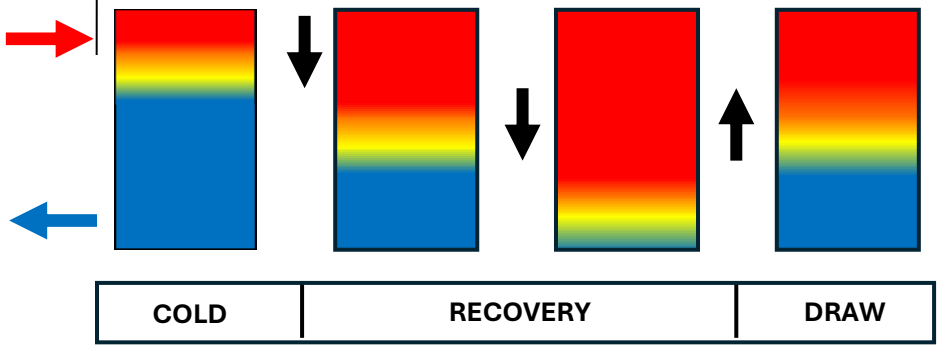
Single Pass (Stratified) Storage



- Stratified storage is used to maintain maximum separation between the heated and cold water
- Heating occurs from the top down
- This is different than gas or electric resistance heating and is piped much differently

- Single Pass heat pumps deliver “at temperature” hot water at the top of the tank
- Recovery and draw are from top of the storage tanks
  - A clear delineation between hot and cold water forms
  - The hot stays in tank top and the cold stays in tank bottom
- Less mixing keeps heat pump inlet water temperature colder through heating cycle, maximizing efficiency
- The heat pump is turned off *before* its maximum entering water temperature is exceeded
- Single pass storage allows for longer sustained output temperatures (via stratification) resulting in higher storage efficiency as compared to multi-pass

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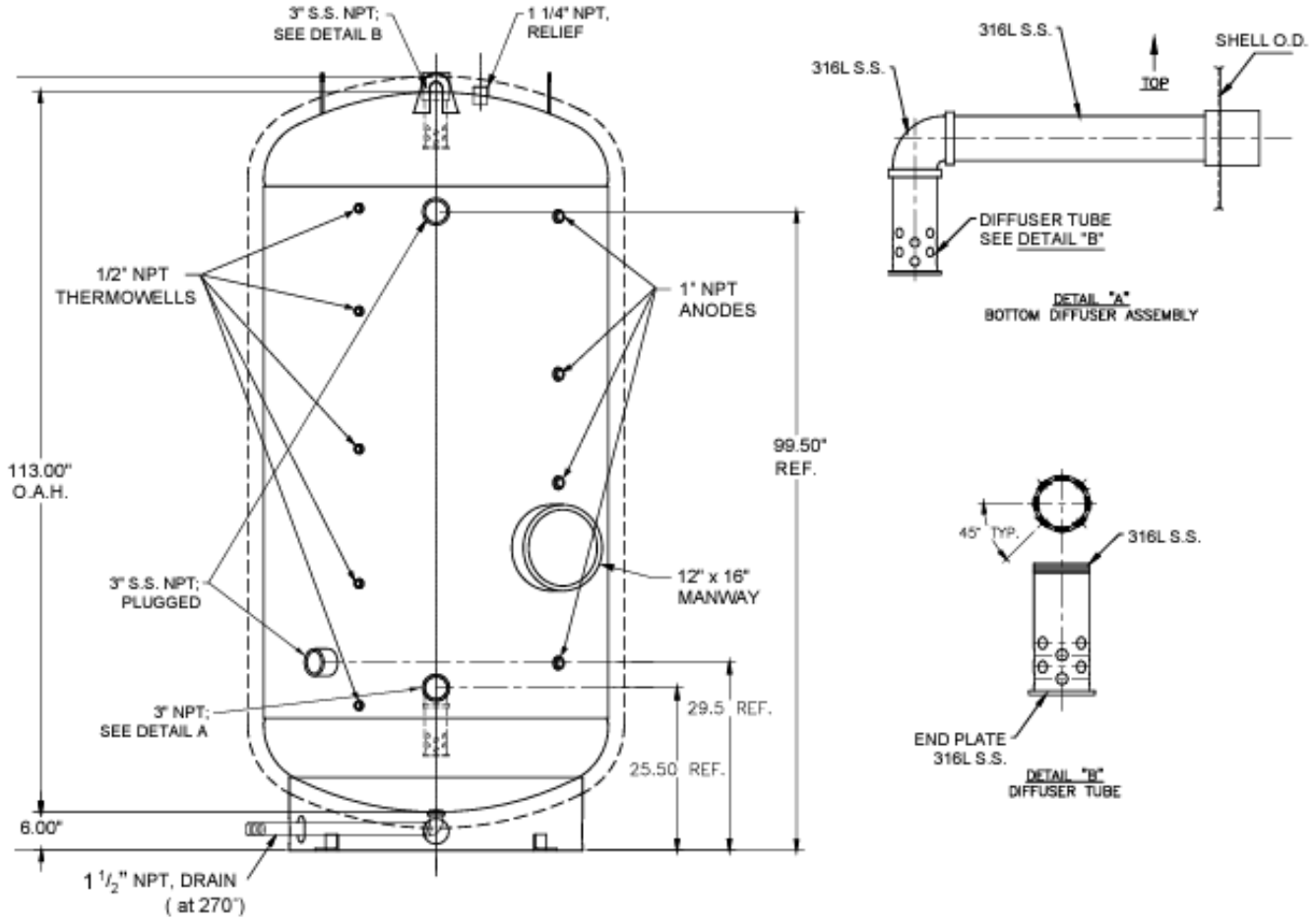
Single Pass Stratified Tank



- It is important to use tanks designed for use with single pass heat pumps
- These “stratified tanks” have diffusors located at the water inlet and outlet ports
- Diffusors minimize water mixing to help maintain stratification
- Thermowells are also located along the side of the tanks to allow for optimal temperature sensor placement depending on application needs

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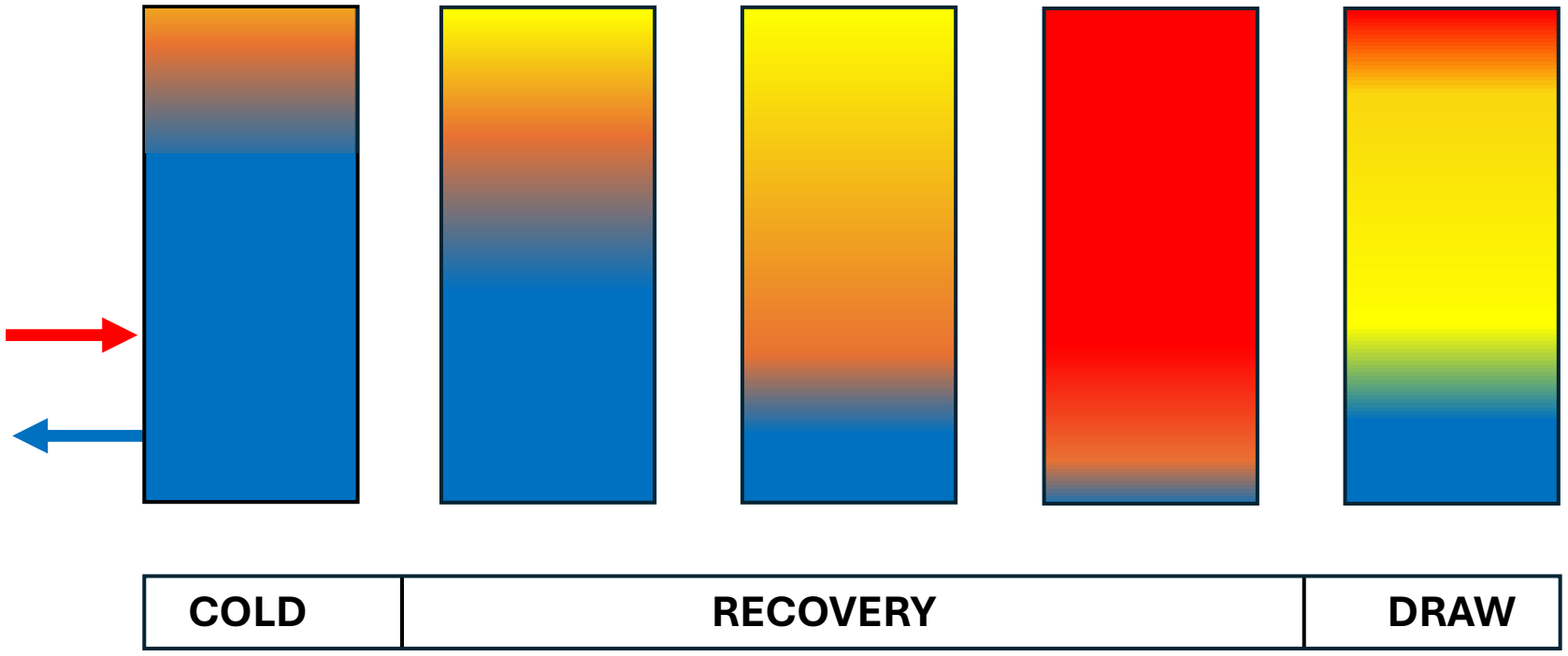
Multi Pass (Mixed) Storage



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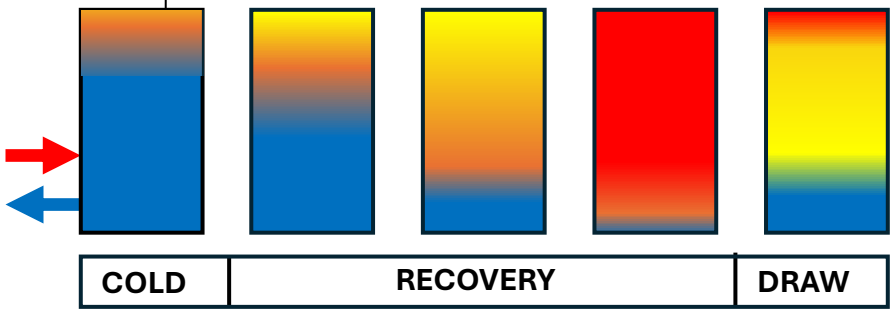
Multi Pass (Mixed) Storage



- Multi Pass storage is piped similar to traditional volume water heating systems
- Heating occurs at the mid-lower portion of the tanks

- Multi pass heat pumps deliver water at varying temperatures throughout the heating cycle due to small temperature lift
- Multi-pass only delivers the desired water temperature near the end of the heating cycle
- Therefore, the heated water cannot be pumped back in the top of the tank
- It is piped in near the lower third to halfway up the tank
- As the water heats up, the hotter water gradually rises to the top. The tank gradually comes up to temperature as the heat pump adds energy
- Draw results in the entire volume dropping in temperature. First the lower section, but the upper half drops much more quickly than stratified storage
- The inlet water to the heat pump starts out cold but rises gradually over the heating cycle. (Averages out to much higher overall than stratified)
- The heat pump is turned off when it is sensed that the desired storage temperature is reached

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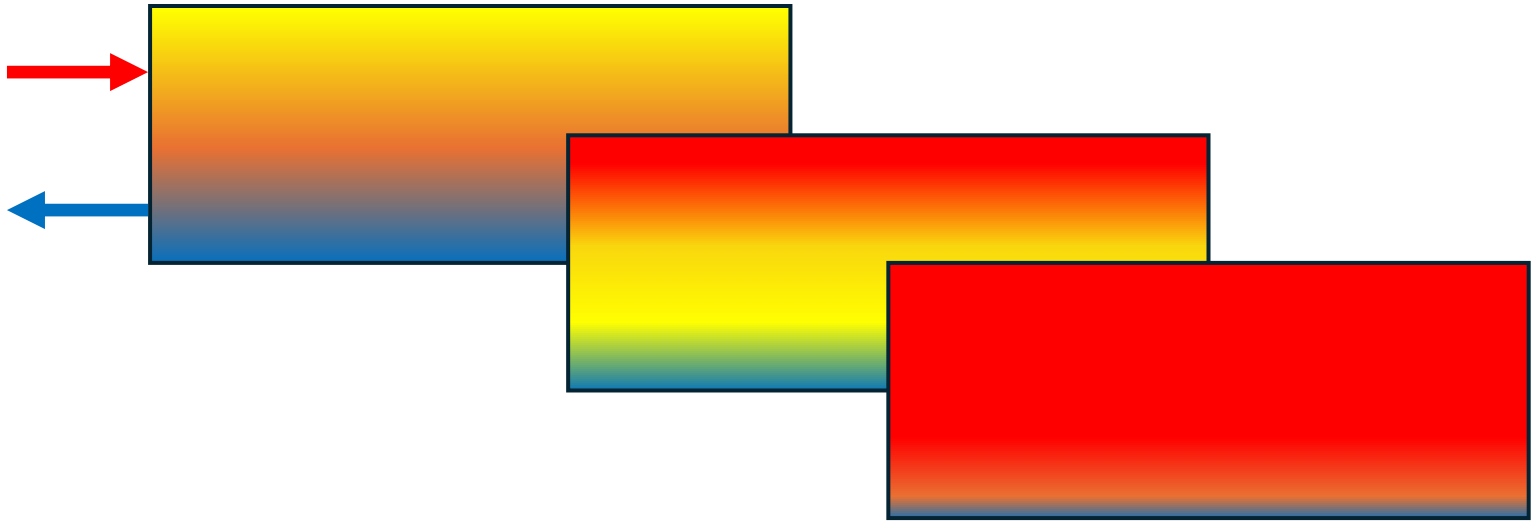
Note on Horizontal Tanks



- Horizontal tanks always mix due to the large amount of contact area between the hot and cold water
- They should *never be used* with Single pass heat pumps. Doing so will greatly reduce overall system efficiency and negate the benefits of high lift, single pass heat pumps

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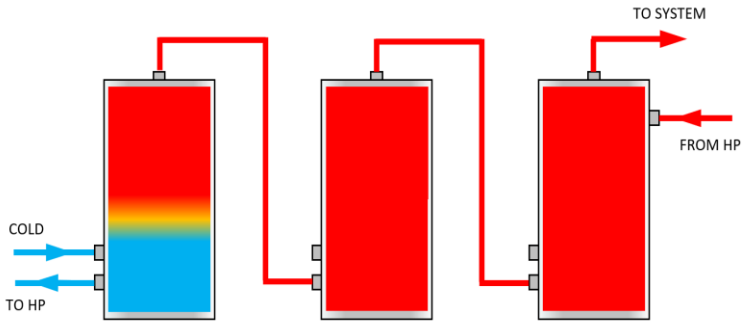
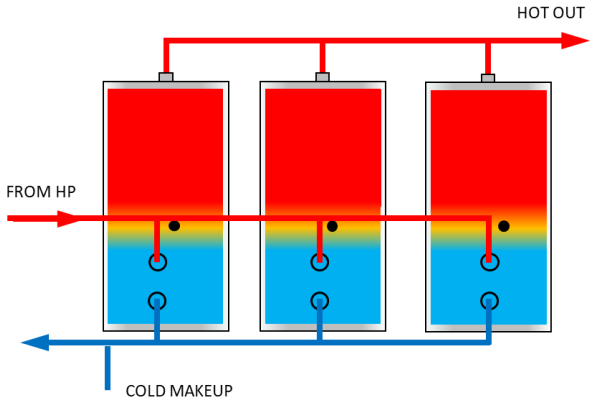
Heat Pump Tank Arrangements

SERIES



PARALLEL



- In most commercial applications, multiple tanks are required to achieve the required storage capacity
- They can be arranged in two ways, Series or Parallel, depending on which heating method is used
- Single pass with stratified storage can be arranged in either series or parallel
- Mixed storage must be arranged in parallel
- Both have their own advantages, and applications where they make more sense

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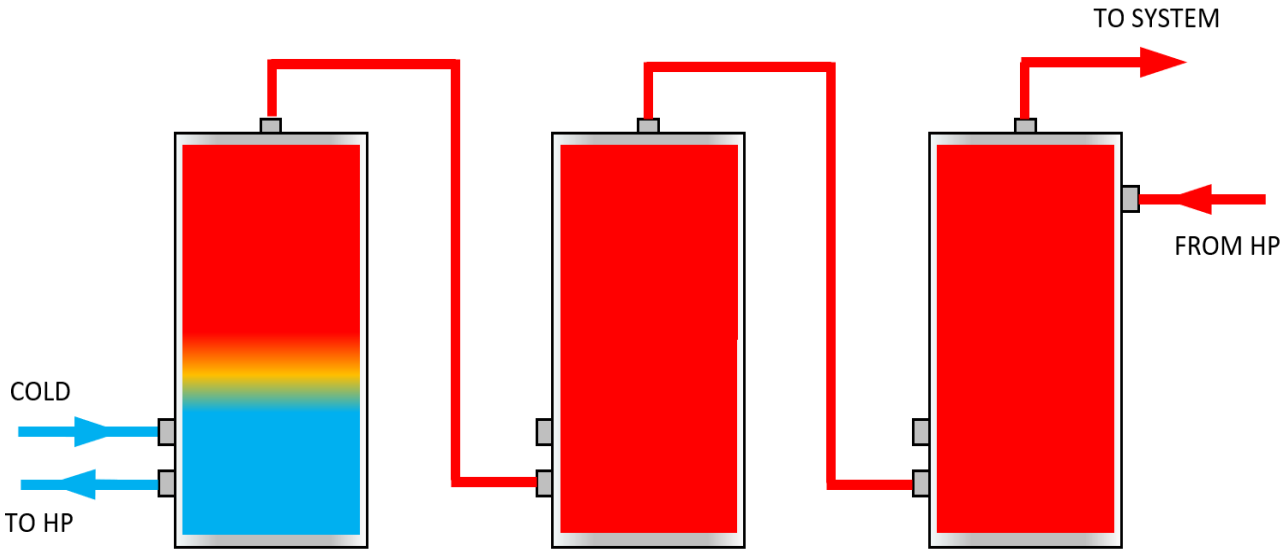
Series Tank Single Pass



- Series tanks mimic the performance of one single tall tank
- This allows the total volume of the “hot” tanks to be heated, leaving only the small area near the heat pump supply connections as a gradient
- Advantages:
  - Better storage efficiency (more fully heated volume)
  - Easier to sense multiple points and stage heat pumps
  - More control for load shifting
- Disadvantages:
  - Limited full system flow due to all water going through single connections
  - Removing a tank from service requires temporary piping or adding normally closed bypass lines that have stagnant water

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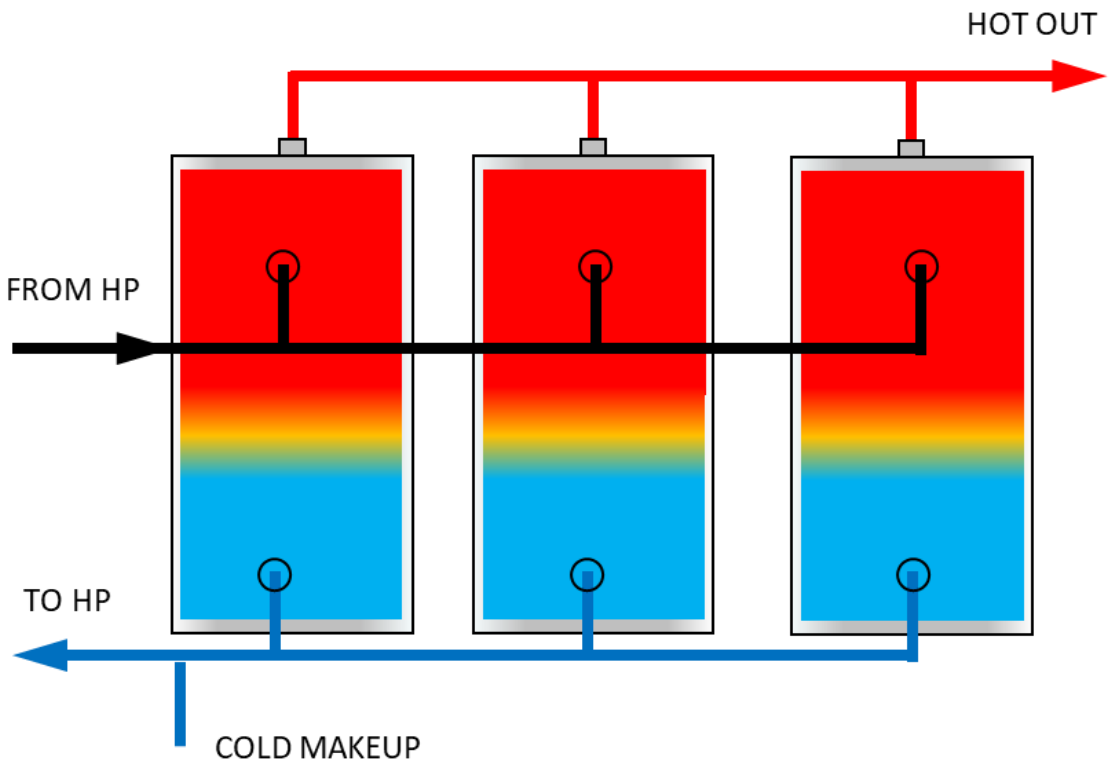
Parallel Tanks, Single Pass



- Parallel tanks allow for higher system volumes because the flow is divided equally across all tank connections.
- Lose some fully heated storage volume across the bottom of tanks.
- Balanced flow is incredibly important to ensure full storage heating or water can bypass.
- Advantages:
  - Higher system flows
  - Easy to remove a tank from service with no special piping
- Disadvantages:
  - Lower storage efficiency
  - All tanks must have a sensor to ensure equal heating
  - Even flow headers can be difficult to build/arrange

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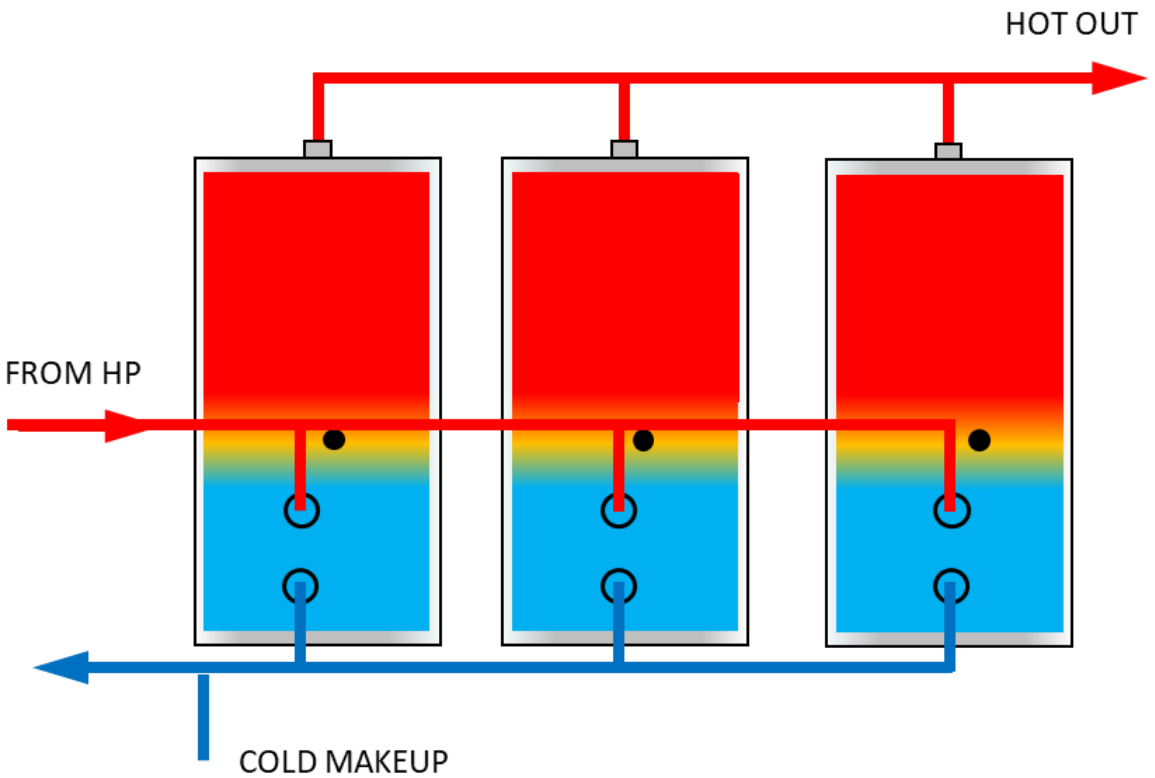
Parallel Tanks Multi Pass



- Multi pass heat pumps do not output “at temperature” hot water, therefore they must be piped in a parallel tank configuration
- This is to ensure that low temperature water isn’t pumped near the hot outlet, resulting in colder discharge water to the system
- Advantage:
  - Much easier to bring recirculation back to primary storage tanks with no issue

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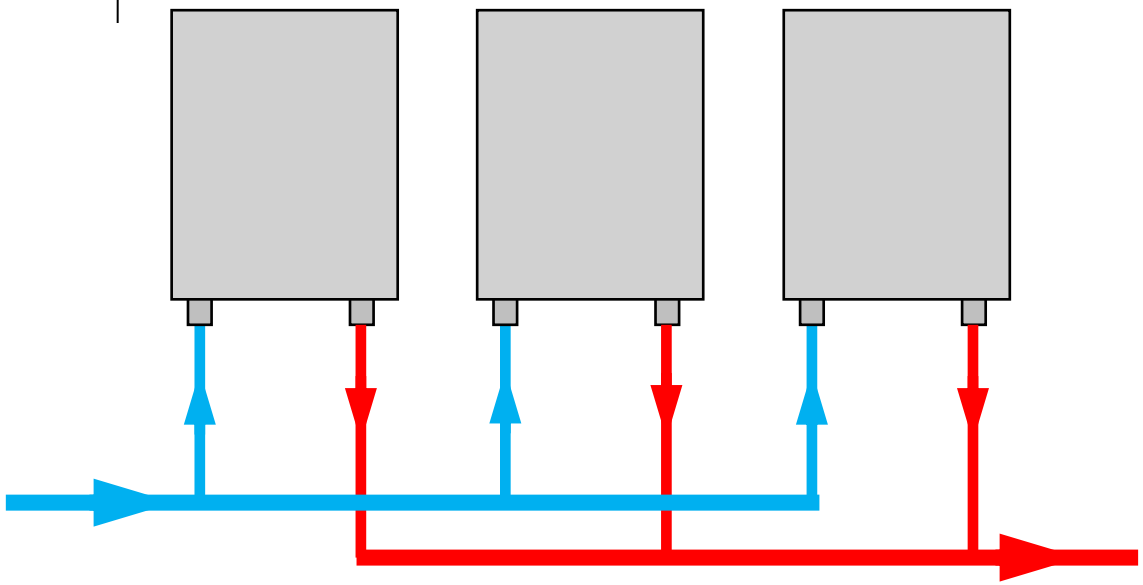
Unit Array Piping



- Multiples of both types of heat pumps are piped in parallel with reverse return headers
- This allows for balance flow and pressure drop across all units
- Any number of the units can run without impacting the others

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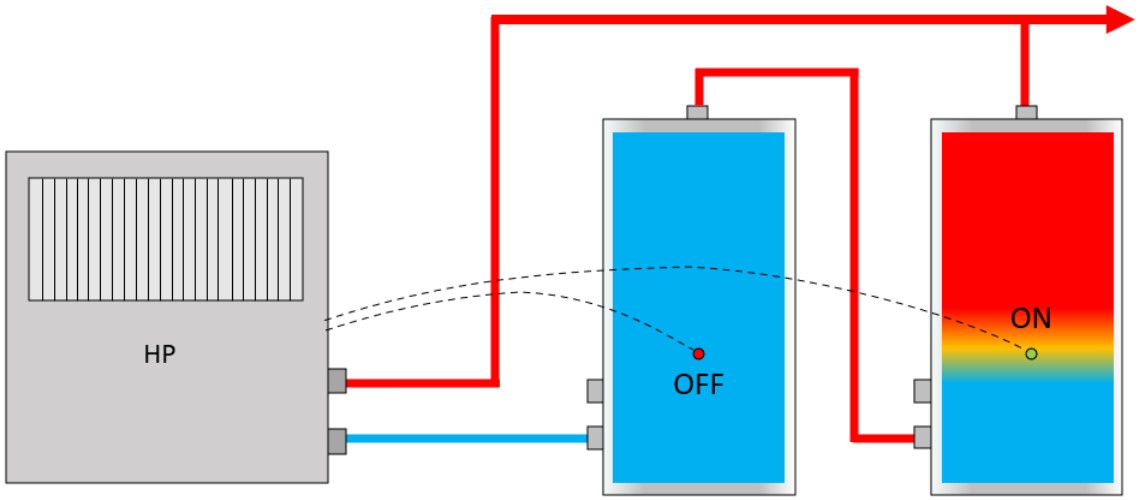
Single Pass Controls



Single pass control typically uses temperatures at two points.

Rule of Thumb: If the off sensor is close to the heat pump inlet piping the sensor should be at minimum 20°F below heat pump output temperature setpoint. Extra volume does not outweigh loss of efficiency due to hot water returning to heat pump.

- ON Sensor: Hot water drawn until the temperature drops at this sensor. The temperature stays stable until the boundary layer hits that location, then it drop sharply.
- OFF Sensor: Heat pump(s) are energized and run until hot water is recovered back to this sensor. Again, this will be stable at cold temperatures until boundary reaches it, then sharp increase.
- OFF location: temperature entering heat pump must not exceed maximum allowed.
- Setpoint temperatures are not Storage Temperatures. Sensors are just detecting when the boundary layer passes.
- In single pass, because the heat pump is making hot water to set point, the tank sensors are not controlling storage temperature, but rather when to turn on and off.
- The off temperature is typically set lower than setpoint temperature to ensure hot water does not return to the heat pump.
- The closer the off sensor is located to the heat pump inlet piping the lower the sensor setpoint temperature must be (i.e. cannot be higher than inlet temp limit)

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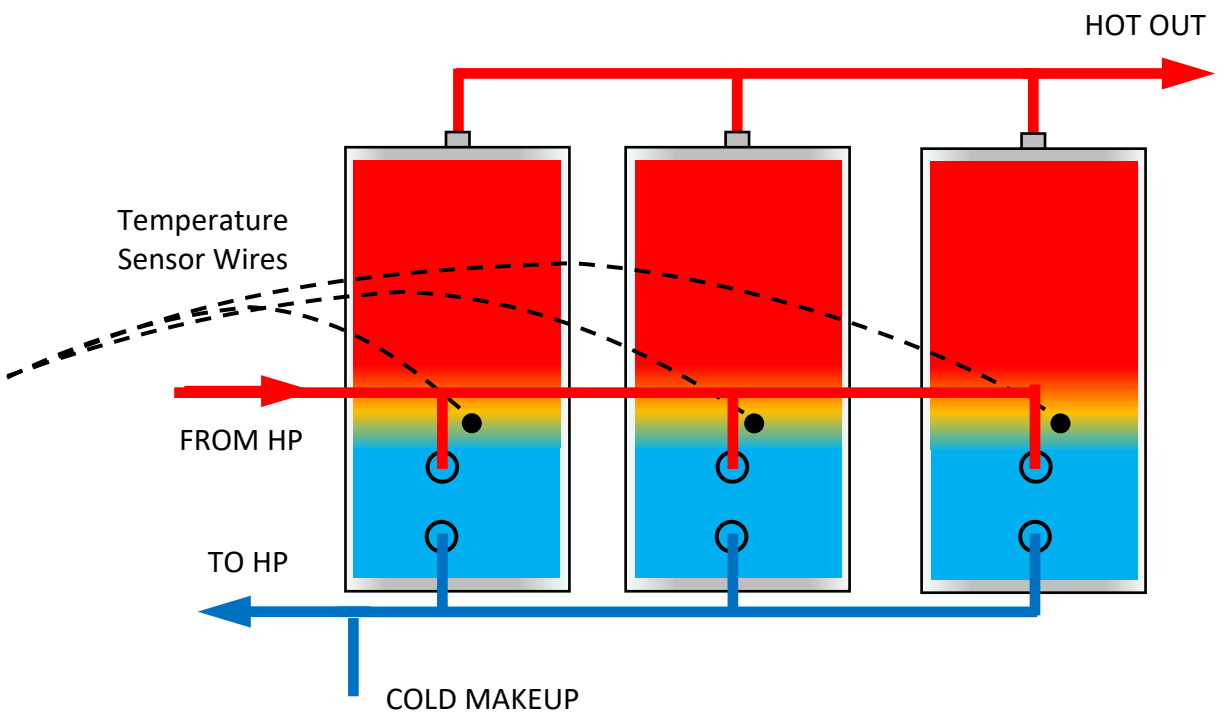
Multi Pass Controls



- A sensor is located in the lower 1/3 of tank, above the heat pump water supply connection
- As the temperature at that location drops the heat pumps are staged on
- In multi pass, you must set the off sensor setpoint to the desired tank storage temperature. Unlike in single pass
- Once the desired storage temperature setpoint is reached, the heat pumps turn off
- If using multiple tanks, each tank must have a sensor. The heat pumps are turned ON by the coldest tank and OFF by the warmest
- This can limit heated volume if not perfectly balanced

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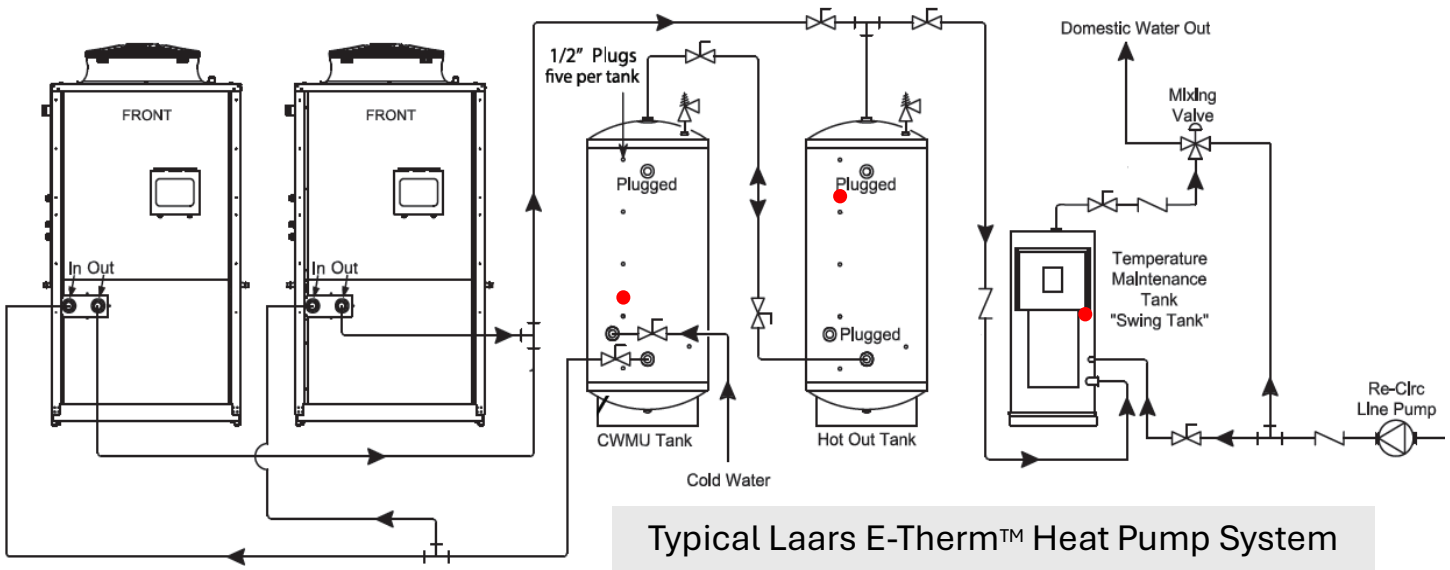
Note About Temperature Control

Key differences between multi pass and single pass:

- Single pass is controlling based on the volume change in available hot water
- Multi pass is controlling based on a temperature change at a single point

Single Pass Recirculation Heating – “Swing Tank”



Typical Laars E-Therm™ Heat Pump System

A “Swing Tank” is used with single pass heating to maintain the temperature of the DHW recirculation loop.

- The swing tank is heated in two ways
  - Hot water flows though the tank during DHW usage periods
  - Or an electric element engages for times when there is no HW usage to maintain setpoint temperature.
- Stored temperatures typically range from 140-180°F and mix with 110°F recirculation return at the mixing valve to go out to the system at 120°F
- This system works more efficiently for high DHW usage vs. recirculation losses, by minimizing duration of electric element use
- Not using a swing tank and bringing recirculation water back to the main storage tanks would:
  - Mix with the stored hot water and disrupt stratification
  - Reduce efficiency due to higher hot water temperatures returning to the heat pump
  - Can cause HP to hit maximum EWT limit too often

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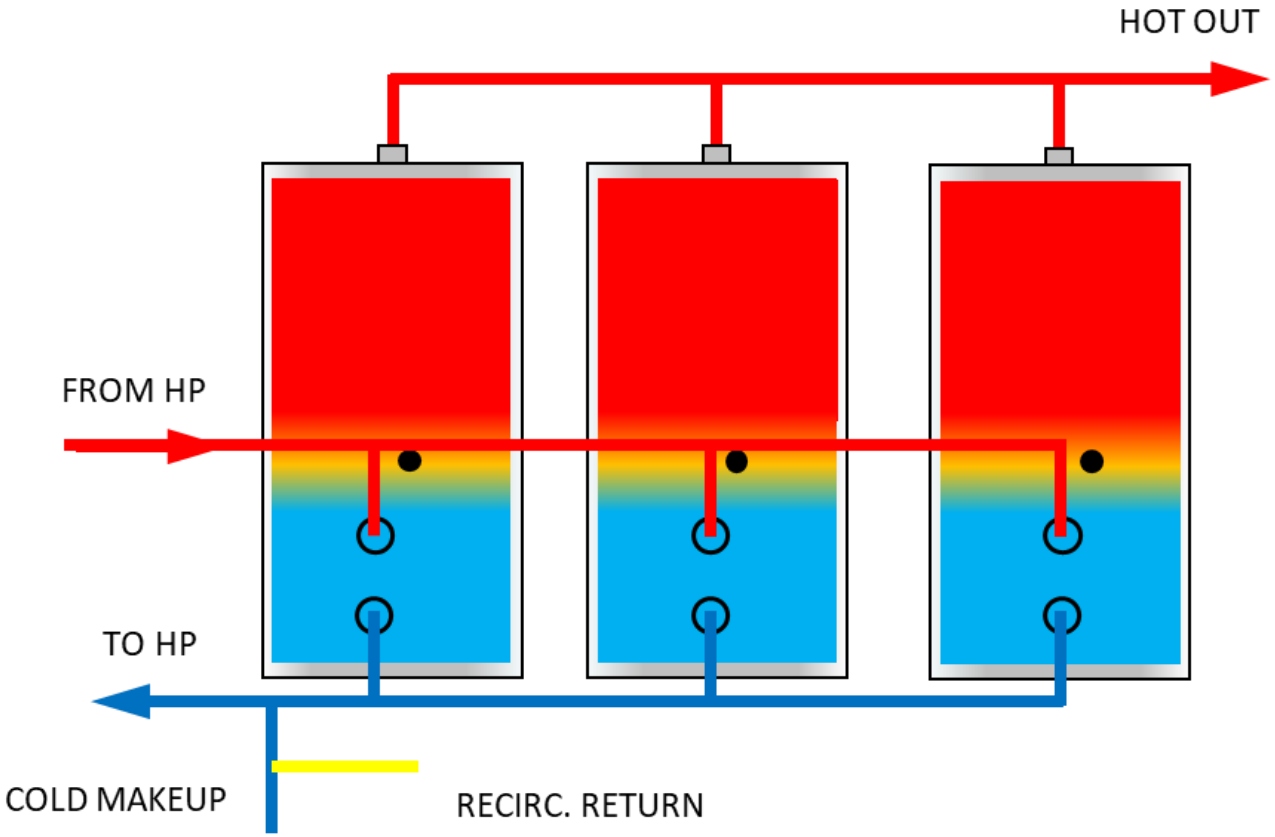
Multi Pass Recirculation Heating



- In a multi pass system the recirculation loop can be brought back to the main storage tanks
- This must be done in such a manner that all tanks see equal recirculation flow
- Multi pass systems have an additional system efficiency reduction due to the recirculation return water raising the inlet temperature to the heat pump

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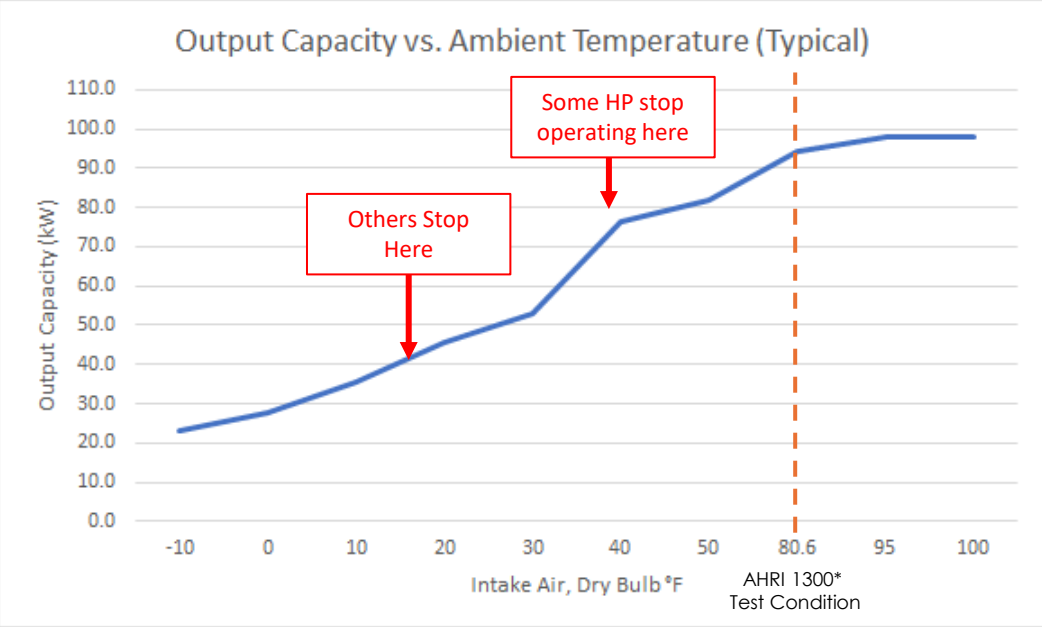
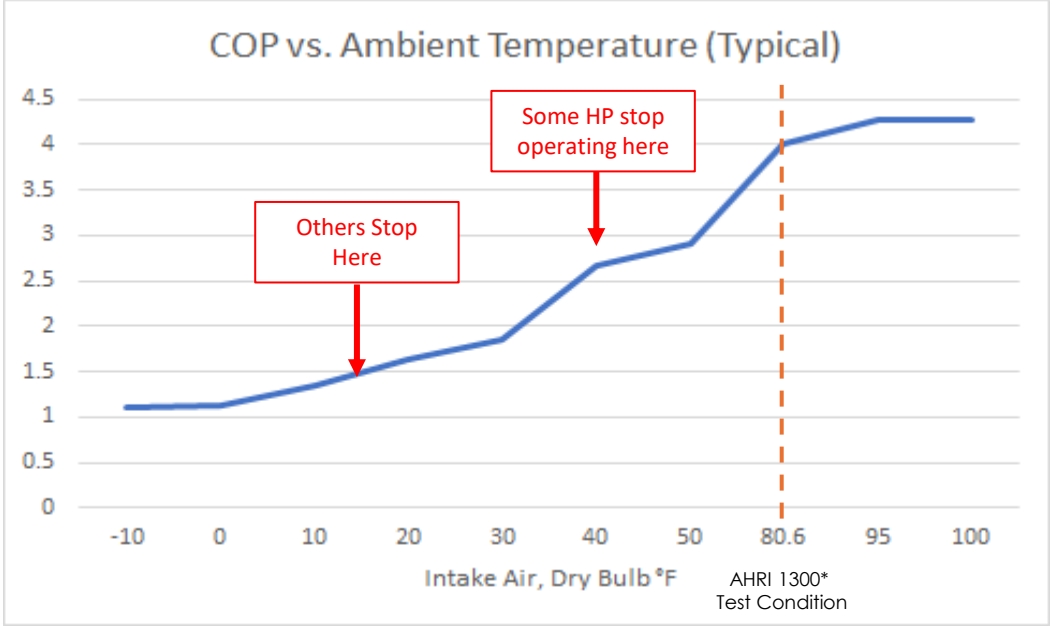
Performance Data, Heat Pump Limits





- Key to Check - What is the heat pump's maximum outlet DHW temperature at the expected low incoming air temperature?
- Many multi-pass synthetic refrigerant heat pumps drop DHW outlet temperature in cold weather, impacting DHW plant performance.

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* AHRI Standard 1300 test condition of 70°F inlet and 120°F outlet water temperature at 80.6°F incoming air temperature.

Single Pass Operation Summary

ADVANTAGES

- Higher Output Temps: Up to 180°F
- Maximum Efficiency: COPs 3-5
- Operate to Lower Ambient Temps
- Smaller Pipe Sizes
  - Lower heat losses
  - Lower pressure drops
  - Smaller pumps needed
- Longer Piping Distances

DISADVANTAGES

- Maximum Entering Water Temp Limitations
- Limited Recirculation Piping Options

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Multi Pass Operation

ADVANTAGES

- Operates with Smaller Temperature Differentials
- Simple Recirculation Heating
- Familiar Piping Arrangement

DISADVANTAGES

- Less Efficient Overall
- Limited Low Ambient Operation

  (Either the heat pump will shutdown or outlet temperatures will drop to 130°F or below.)
- Limited High Temp Output
- Larger Pipe Sizes
  - Higher heat losses
  - Higher pressure drops
  - Larger pumps needed

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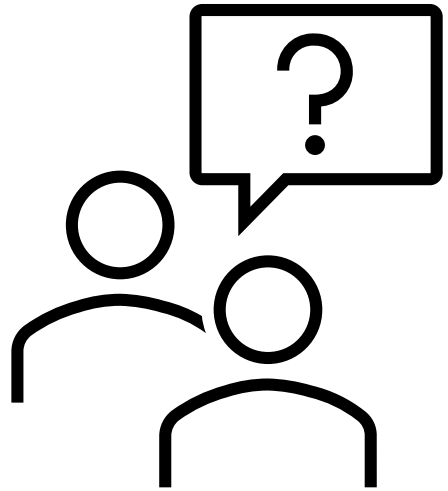
Thank You



Laars Heating Systems Electric Portfolio

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