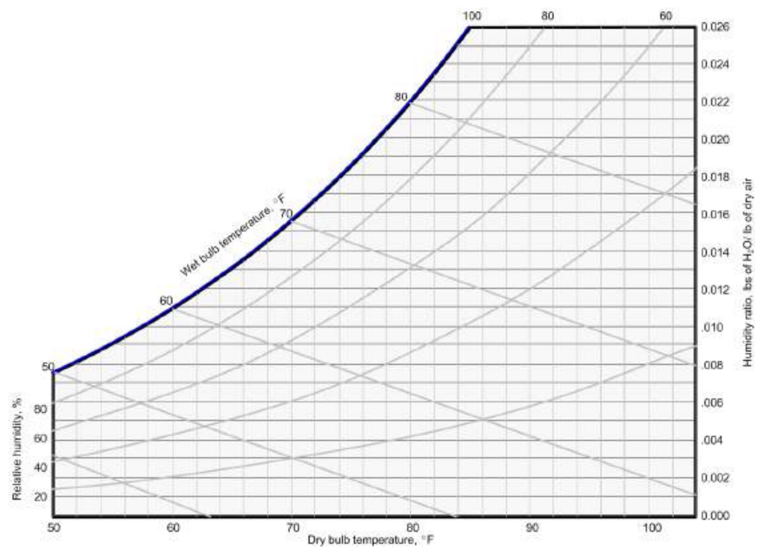
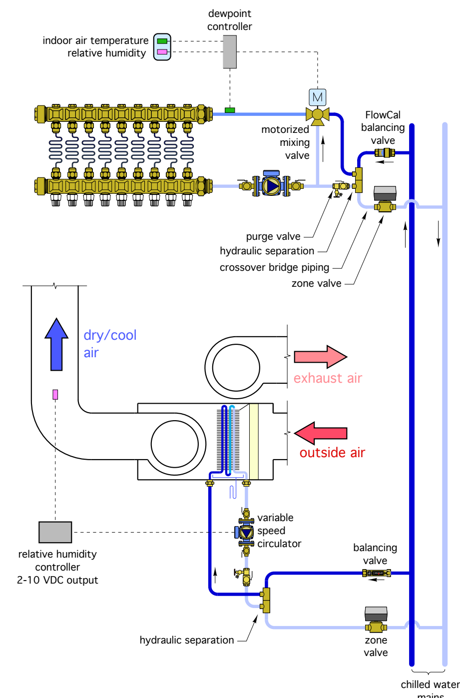
MODERN HYDRONICS SUMMIT 2019

International Centre,
Mississauga, Ontario
September 19, 2019

Small Scale Hydronic Cooling

An emerging market opportunity for HVAC professionals





Siggy & The Bean

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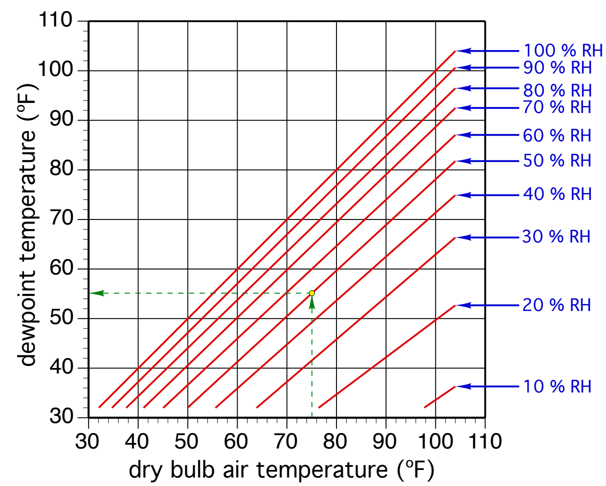
An emerging market opportunity for HVAC professionals



Bean's topics:

- Sensible & latent cooling loads
- Psychometrics of hydronic cooling
- Ventilation consideration
- Dewpoint considerations
- Radiant cooling

Siggy's topics:

- Chiller options
- Terminal unit options
- Piping options
- Control concepts
- System Examples

Man discovers chilled water cooling...

Why small scale chilled water cooling makes sense:

- **Wide range of products available to serve as the chiller:**
  - Ground source, reversible water-to-water heat pumps
  - Air-cooled chillers (e.g. air-to-water heat pumps)
  - Small gas-fired absorption cycle chillers that can dissipate heat to either outdoor air or an earth loop.
  - Direct cooling from a lake or large pond in Northern climates.

- **Easy to zone** a cooling system using multiple small air handlers.

- With a properly sized buffer tank **it's possible to size a heat pump to the full design heating load of the building**, and not have it short cycle during the cooling mode.

- **Eliminates concern for "frosting" the cooling coil**, which can occur with direct expansion coils operating at reduced air flow rates.

- In areas with time-of-use electrical rates, systems **can be designed with chilled water storage**.

- *Radiant ceiling panels can handle most of the sensible cooling load.* ***This shifts a significant part of the load to hydronic rather than forced-air distribution.*** *Significant savings in distribution energy. Also reduces ducting to that required for ventilation and latent cooling air flows.*

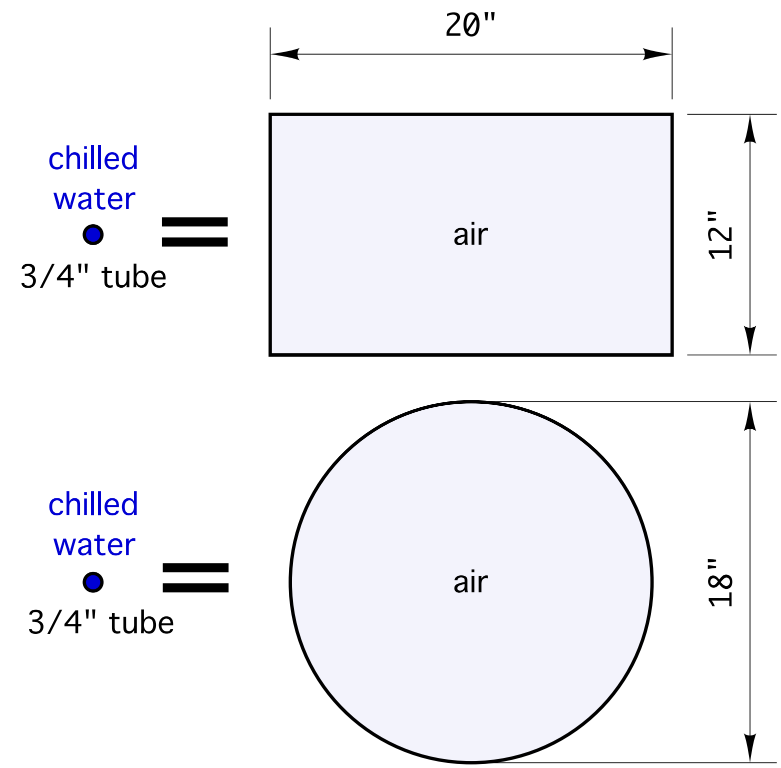
- When there's a steady demand for domestic hot water, a water-to-water heat pump can serve double duty. The hot side supplies water at temperatures up to 160 ºF, while the cold side supplies chilled water for cooling. **This nearly doubles the effective Coefficient Of Performance (COP) of a heat pump.**

Water is vastly superior to air for conveying heat

Table 1

MATERIAL	Heat Capacity ($Btu/ft^3/^oF$)
water	62.4
concrete	29.4
steel	58.7
wood (fir)	17.6
ice	28.2
air	0.018
gypsum	20.3
sand	9.5
alcohol	33.5

$$\frac{62.4}{0.018} = 3467 \approx 3500$$



A given volume of water can absorb almost 3500 times as much heat as the same volume of air, when both undergo the same temperature change.

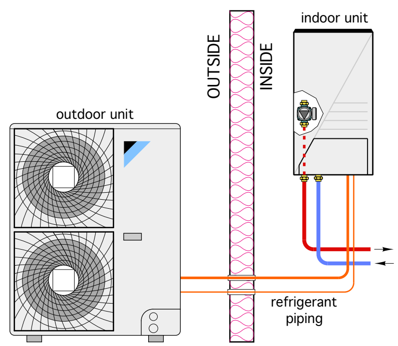
Chiller options

water-to-water heat pump

air-to-water heat pump
(unitary)

air cooled condenser

gas-fired heat pump



air-to-water heat pump
(split system)

lake in upstate NY

Chilled water cooling, with air cooled condenser...

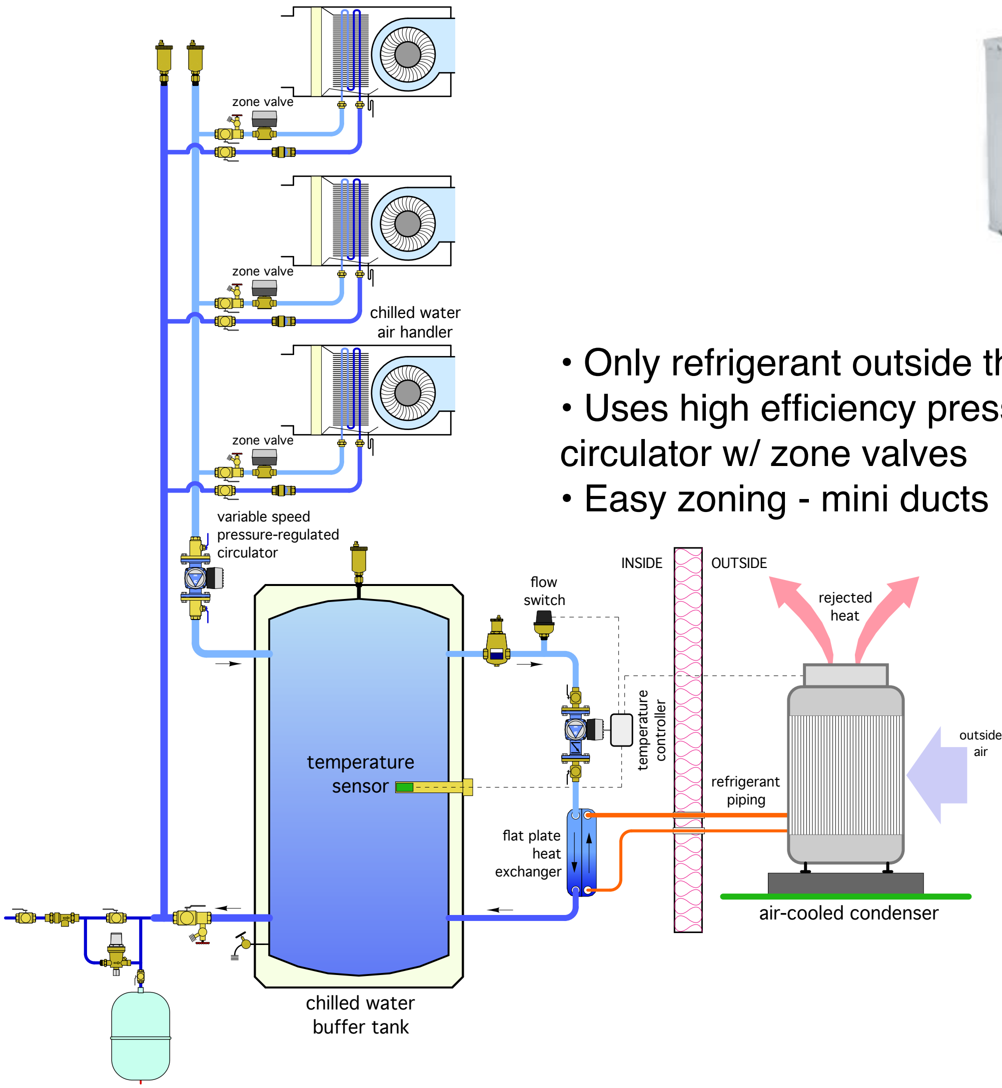
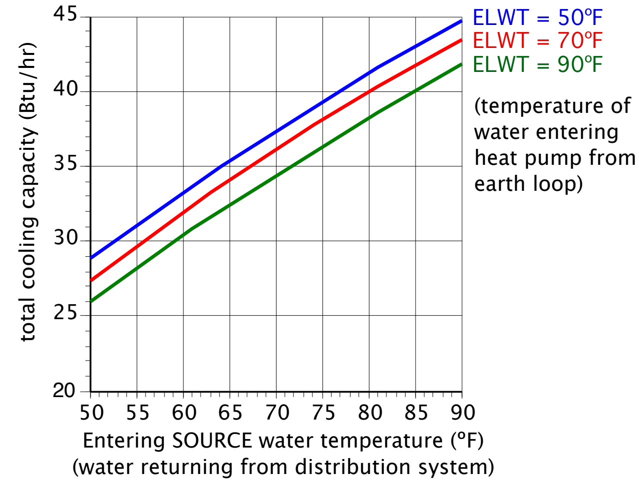


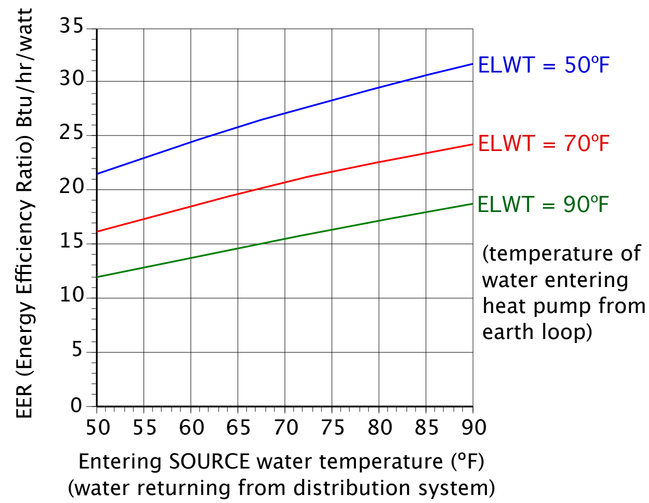
image courtesy of Mestek

- Only refrigerant outside the building (freeze protected)
- Uses high efficiency pressure-regulated distribution circulator w/ zone valves
- Easy zoning - mini ducts

Geothermal water-to-water heat pumps as chillers

image courtesy of ClimateMaster





For best COOLING performance:

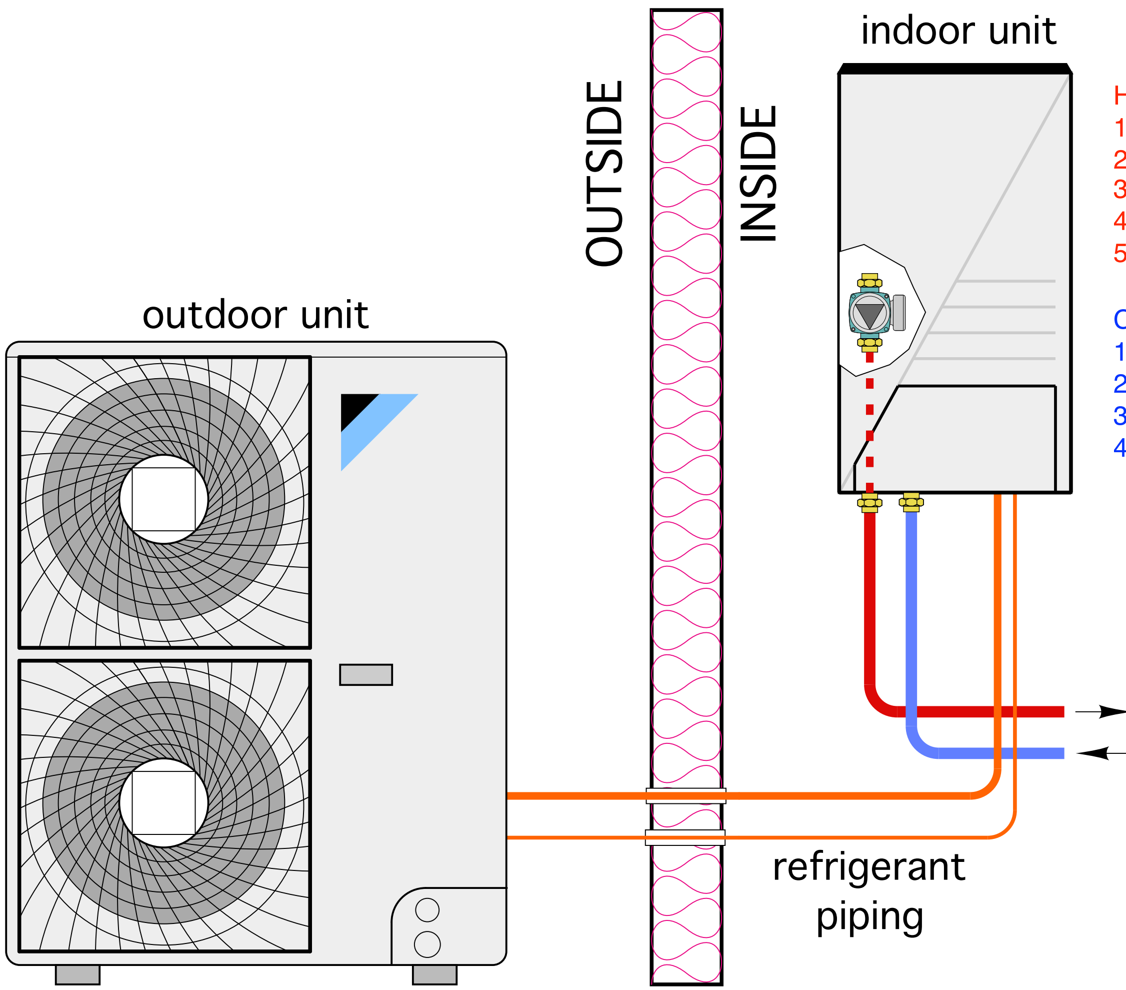
1. Keep the earth loop as cool as possible.
2. Keep chilled water supply temperature (to load) as warm as possible.

Split system air-to-water heat pump

Outdoor unit

Heating mode:
1. compressor
2. evaporator
3. expansion device

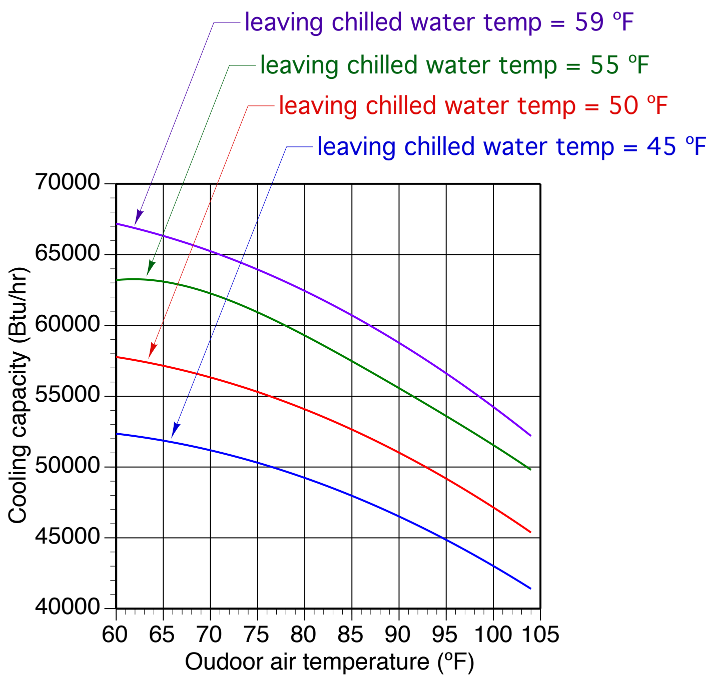
Cooling mode:
1. compressor
2. condenser
3. expansion device



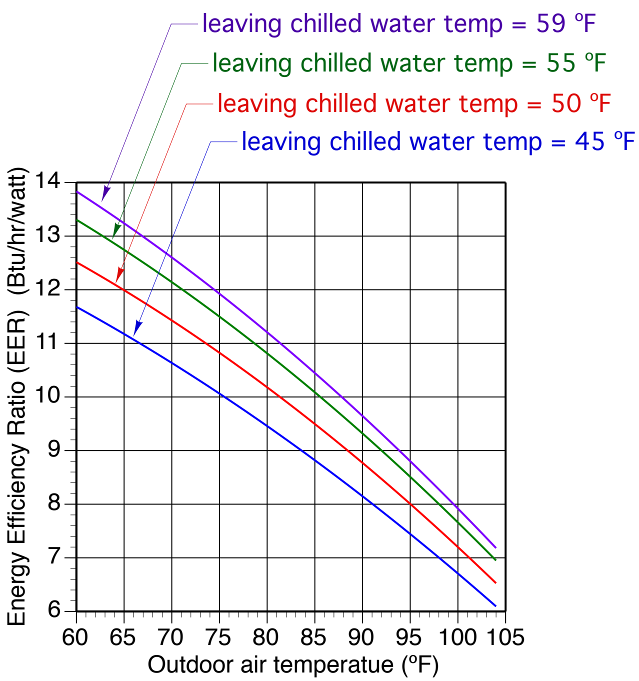
Heating mode:
1. condenser
2. circulator
3. expansion tank
4. aux element
5. controls

Cooling mode:
1. evaporator
2. circulator
3. expansion tank
4. controls

Cooling performance:

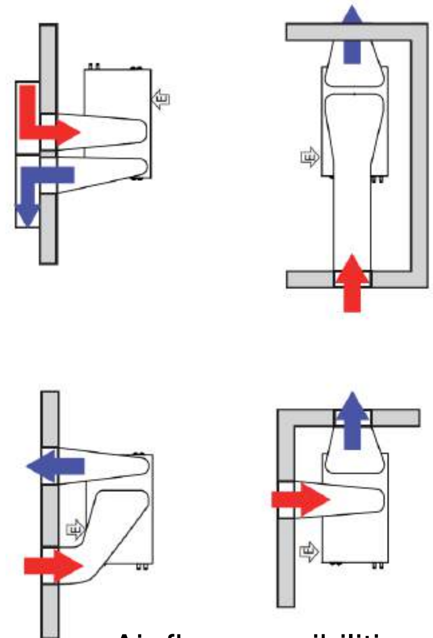


Cooling capacity
Increases with:
a. lower outdoor temperature
b. Higher chilled water temperature



EER
Increases with:
a. lower outdoor temperature
b. higher chilled water temperature

Interior air-to-water heat pump



Air flow possibilities

Advantages:

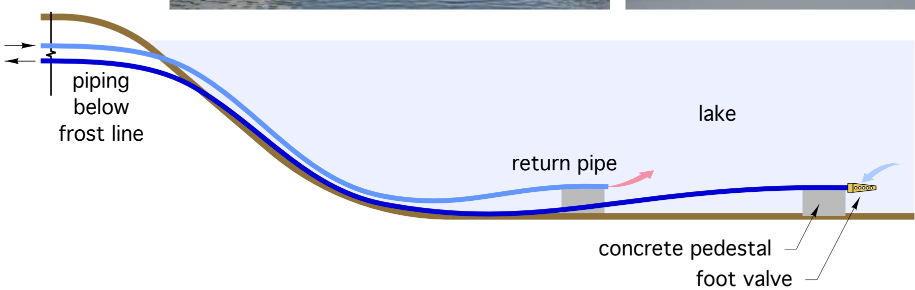
- No outdoor equipment beyond air intake and discharge grills
- Less potential to freeze water containing within the heat pump
- Less environmental weathering effect on equipment
- Reduced potential for debris on heat transfer coil surfaces

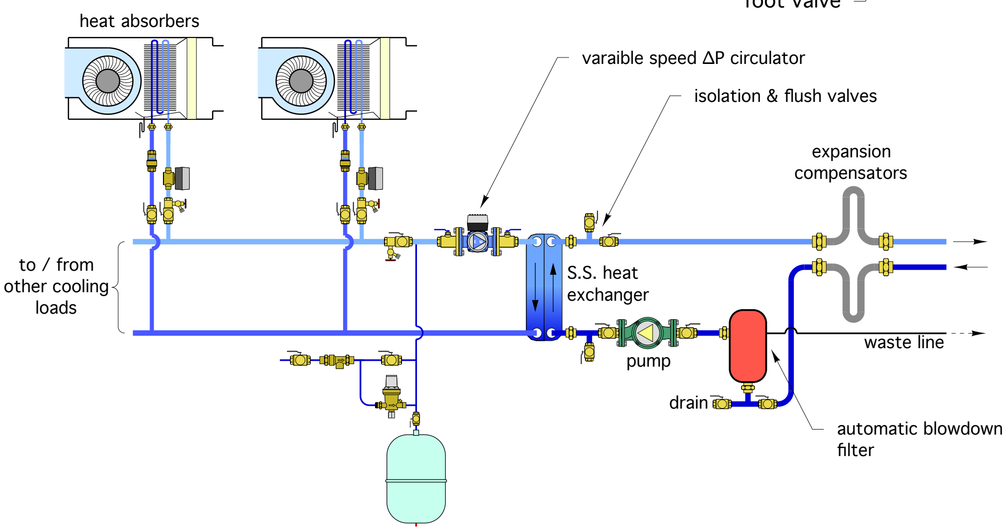
Disadvantages:

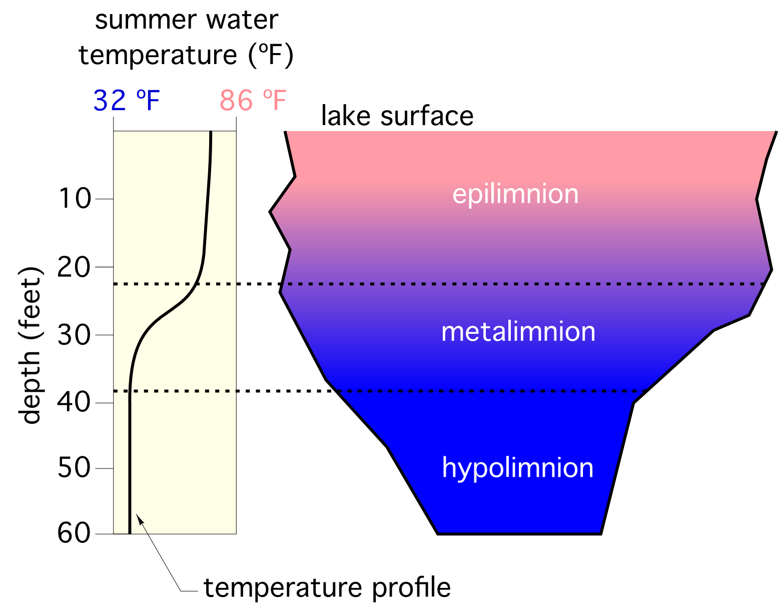
- Require more interior space
- Brings compressor sound within the structure
- Requires careful coordination with building design to ensure that adequately sized ducting can be accommodated, and terminated above snow level.

image courtesy of HotJet.cz

Lake water cooling







- highest density of water occurs at 4°C = 39.2°F
Water near bottom of northern lakes remains at or slightly above this temperature most of year

- Distribution system to chilled water air handlers is closed loop, and operates with variable speed circulator based on ΔP

- Auto-blowdown filter periodically cleans itself

Lake water cooling (Closed loop SS plate heat exchanger)

Courtesy of AWEB Supply

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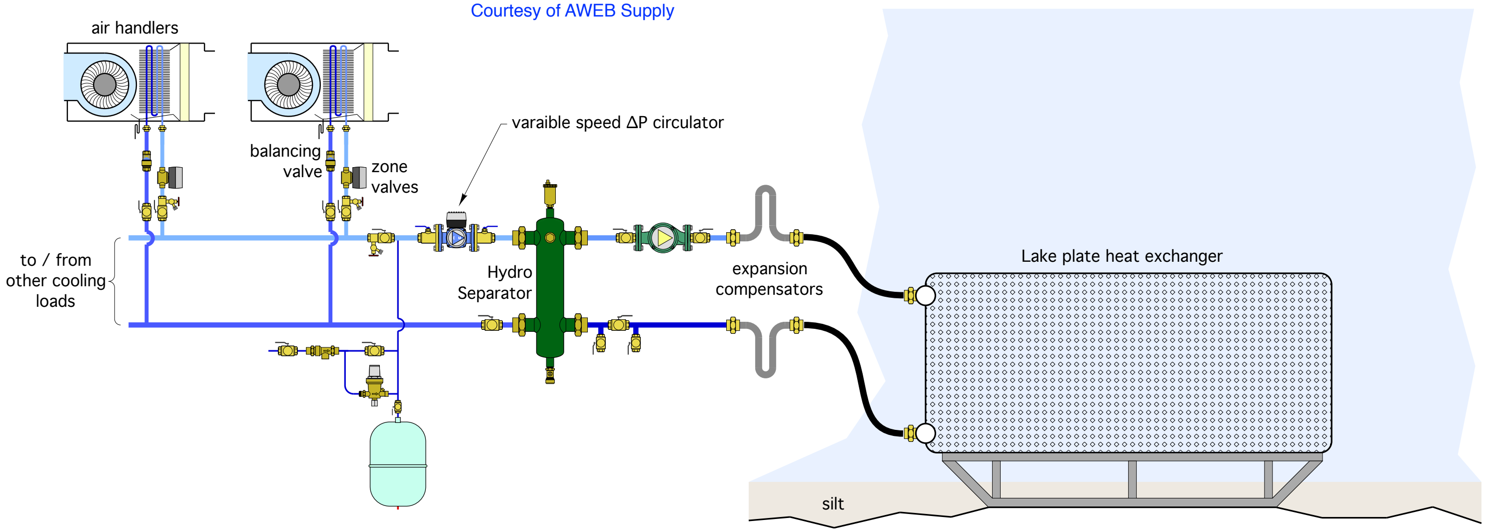
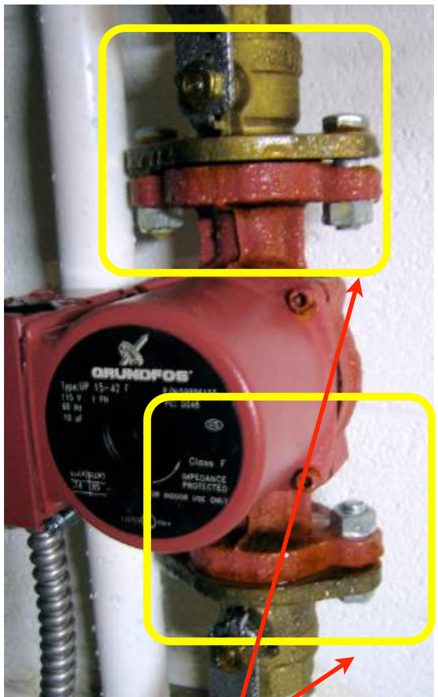


Chilled water distribution systems

All piping & components carrying chilled water must be insulated & vapor sealed.



condensation on volute of circulator carrying chilled water

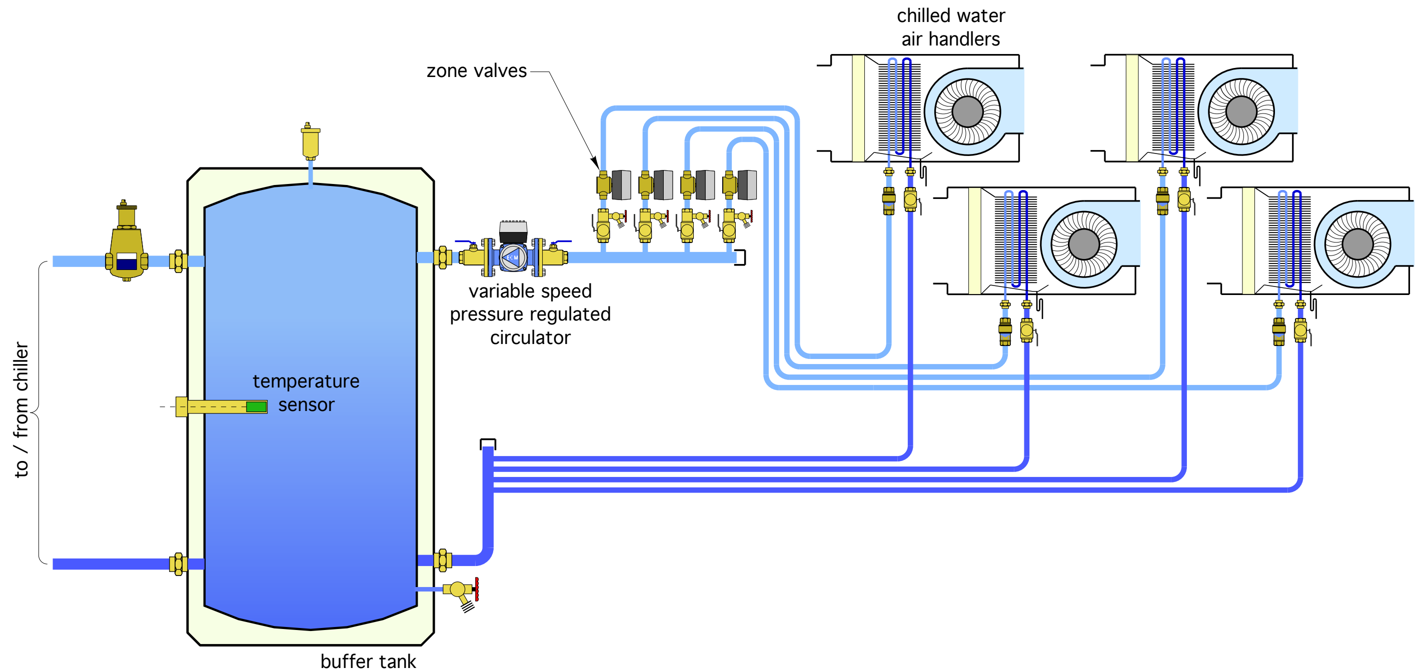
flow switches

don’t insulate actuators on zone valves

Chilled water distribution systems

Homerun distribution system:

1. Small flexible PEX tubing to each terminal unit (1/2” -1” typical tube size)
2. Same supply water temperature to each terminal unit.
3. Easy to balance each circuit
4. Easy to isolate each terminal unit
5. Ideal for variable speed constant ΔP circulator



BUFFER TANK SIZING:

Buffer tanks can be sized based on desired “on-cycle” time of the chiller:

$$\mathrm{v} = \frac{\mathrm{t}\left(\mathrm{Q}_{\mathrm{chiller}}\right)}{500\left(\Delta T\right)}$$

Where:
v = required volume of the buffer tank (gallons)
t = desired duration of the chiller’s “on cycle” (minutes)
$Q_{chiller}$ = heat output rate of the heat source (Btu/hr)
ΔT = temperature drop of the tank from when the chiller is turned on to when it is turned off (ºF)

Example: Determine the minimum buffer tank volume for a system with a 4 ton chiller. The chiller is turned on when the water temperature is 60ºF and off at 45ºF. The minimum desired on cycle for the chiller is 10 minutes.

$$\mathrm{v} = \frac{\mathrm{t}\left(\mathrm{Q}_{\mathrm{chiller}}\right)}{500\left(\Delta T\right)} = \frac{10\left(48000\right)}{500\left(15\right)} = 64\,gallons$$

Every watt supplied to a circulator is a watt added to the cooling load

Take advantage of high efficiency "ECM" circulators.

Grundfos Alpha:

Wilo Stratos ECO

Bell & Gossett ECOCIRC

Taco 0018e

Armstrong COMPASS

AquaMotion: Einstein series

Grundfos MAGNA

Wilo STRATOS circulators

B&G ECO XL

Taco Viridian

Chilled water terminal unit options

Chilled water terminal unit options...

Air handler options:
• console fan-coils
• high wall air handlers
• “high V” air handlers
• vertical air handlers

“high wall” air handler

vertical air handler

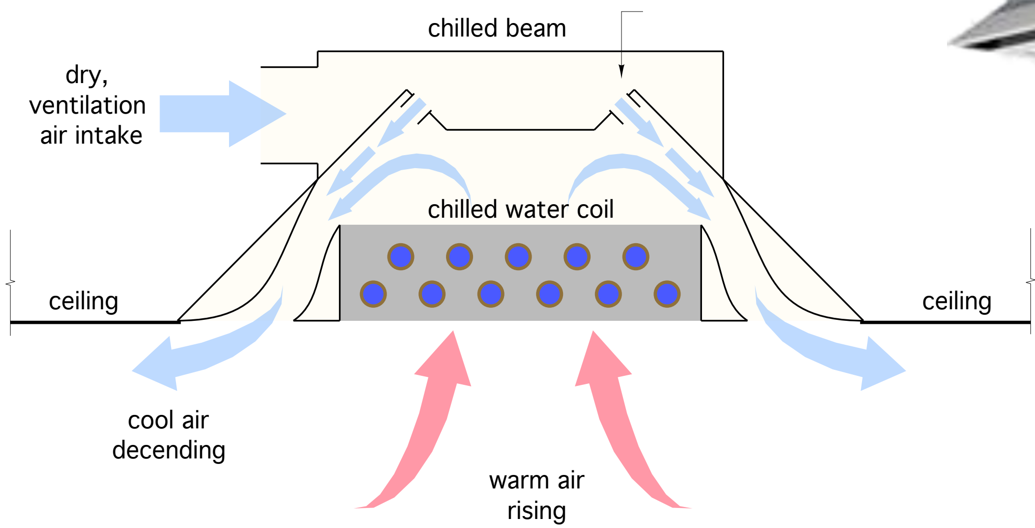
console air handler

“high V” air handler

• Any terminal unit intended for chilled water cooling must have a drip pan

Chilled Beams:

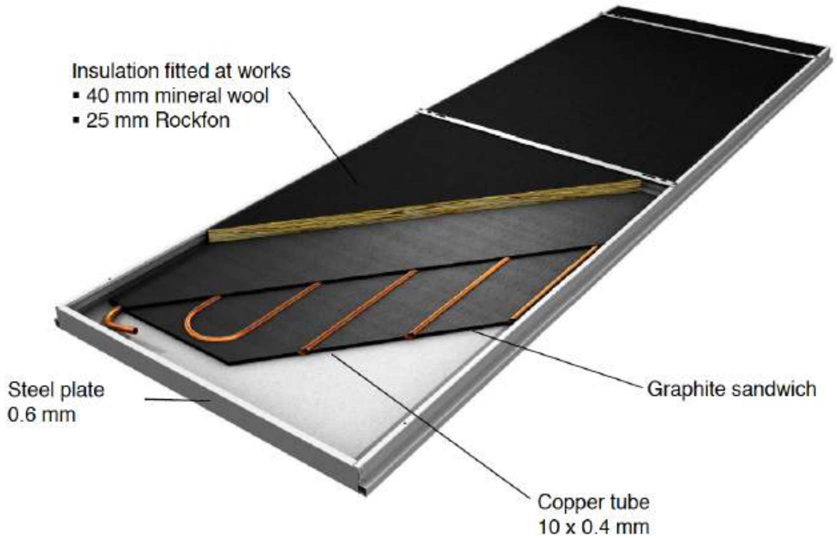
Active chilled Beam:



Courtesy of Dadanco

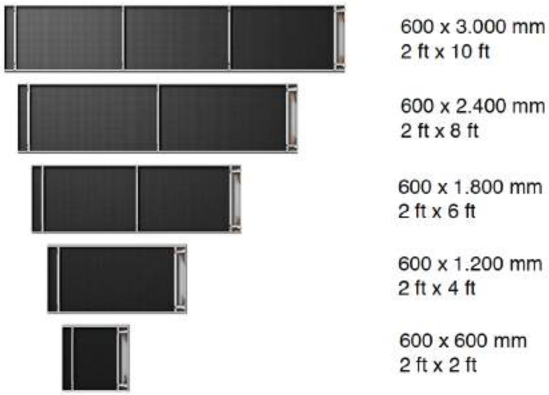
- **All chilled beams must operate above dewpoint temperature of room**

Suspended ceiling panels (for heating & cooling)

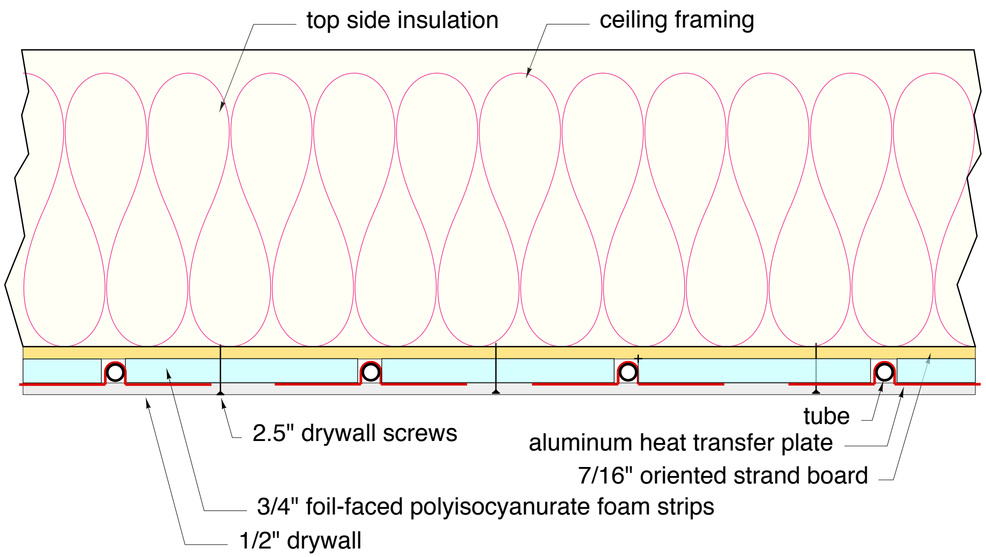


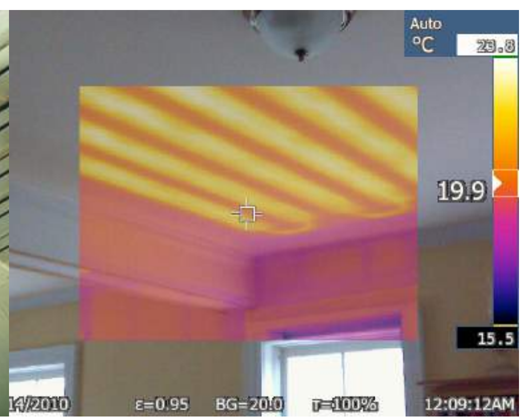
- low thermal mass
- fast response
- connect with "stab" fittings

images courtesy of Zehnder



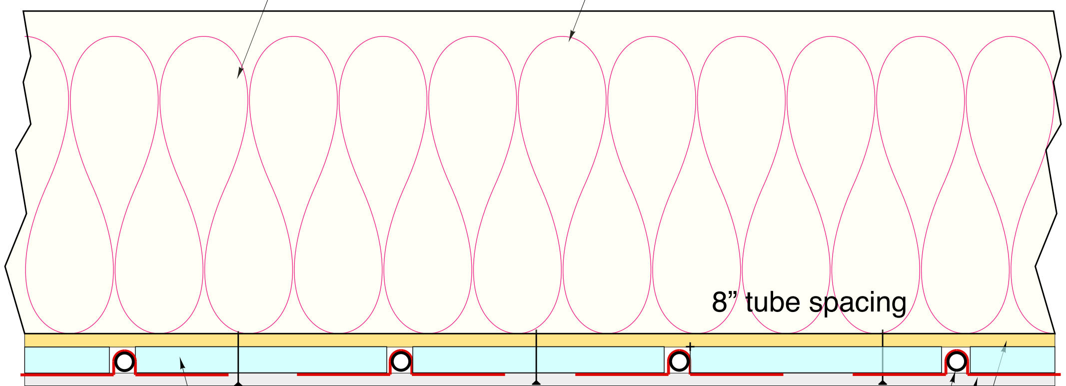
Radiant Ceiling Panels for heating & cooling





Chilled Water Cooling with Radiant Ceiling Panel

- Radiant ceilings can be used for SENSIBLE COOLING ONLY.
- Must have an air handler to handle latent load



$$q_{absorbed} = 1.48\left(T_{room} - \bar{T}_{ceiling}\right)^{1.1}$$

$q_{absorbed}$ = heat flux absorbed (Btu/hr/ft²)

$T_{ceiling}$ = **average** surface temperature of ceiling (°F)

T_{room} = room temperature (°F)

$$q_{absorbed} = 1.48(75-65)^{1.1} = 18.6\frac{Btu}{hr \cdot ft^2}$$

$$\Delta T_{W \to S} \cong 0.462\left(q_{absorbed}\right)$$

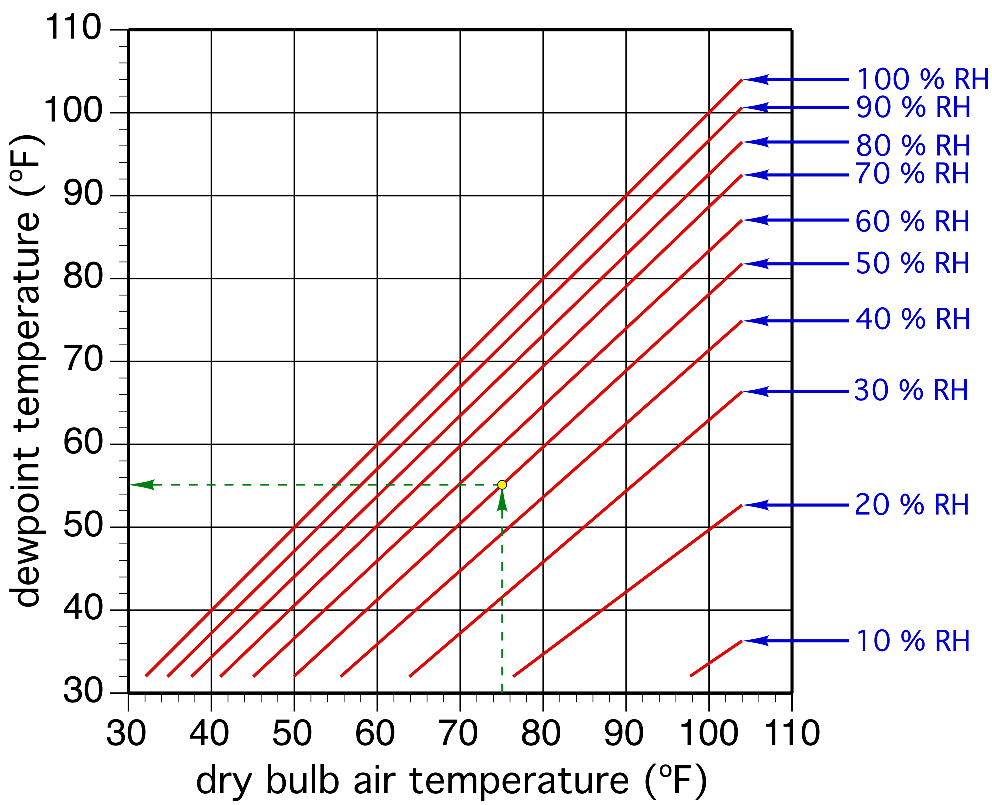
$\Delta T_{w\text{-}s}$ = difference between **average** temperature in tubing, and **average** surface temperature (°F)

$$\Delta T_{W \to S} \cong 0.462(18.6) = 8.6^{\circ} F$$

To absorb 18.6 Btu/hr/ft², the **average** water temperature in the tubing **of this assembly** needs to be about 8.6 °F cooler than the average surface temperature.

Chilled Water Cooling with Radiant Ceiling Panel

Water temperature through radiant panel circuits must be maintained above dewpoint to avoid condensation.



$$T_{(^\circ C)} = \frac{T_{(^\circ F)} - 32}{1.8}$$

$$B = \frac{\ln\left(\frac{RH}{100}\right) + \left(\frac{17.27 T_{DB(^\circ C)}}{237.3 + T_{DB(^\circ C)}}\right)}{17.27}$$

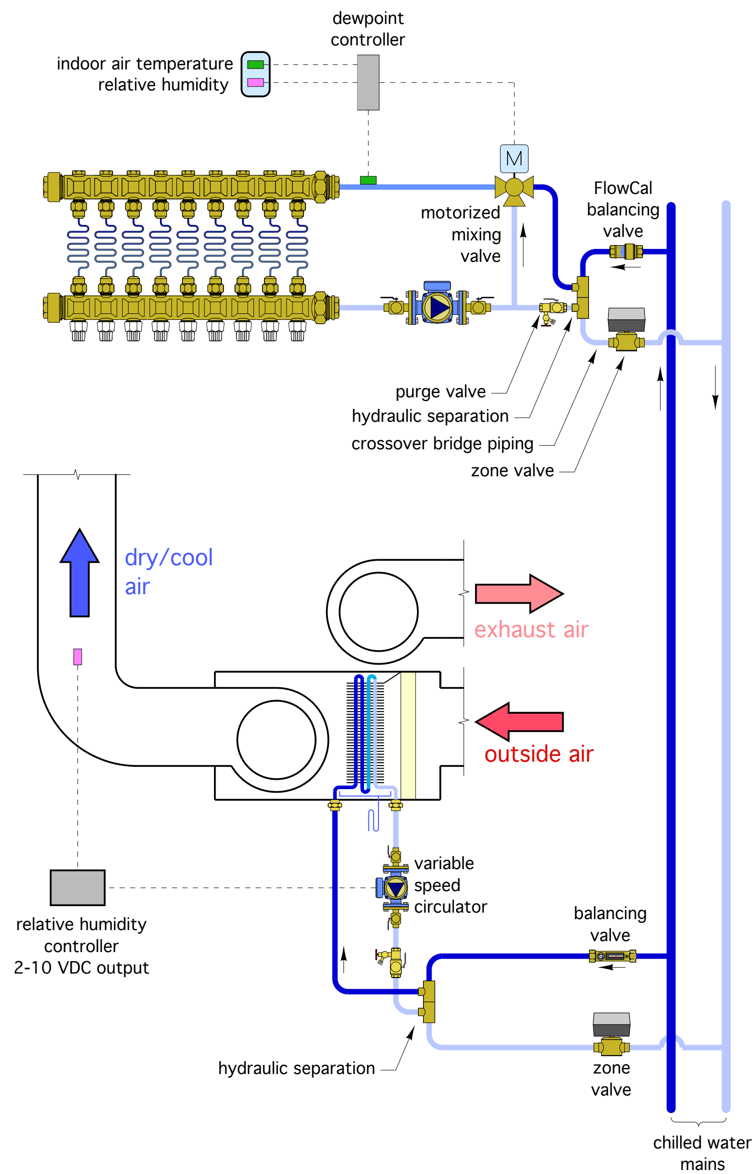
$$T_{dew(^\circ C)} = \frac{237.3B}{1-B}$$

$$T_{(^\circ F)} = 1.8 T_{(^\circ C)} + 32$$

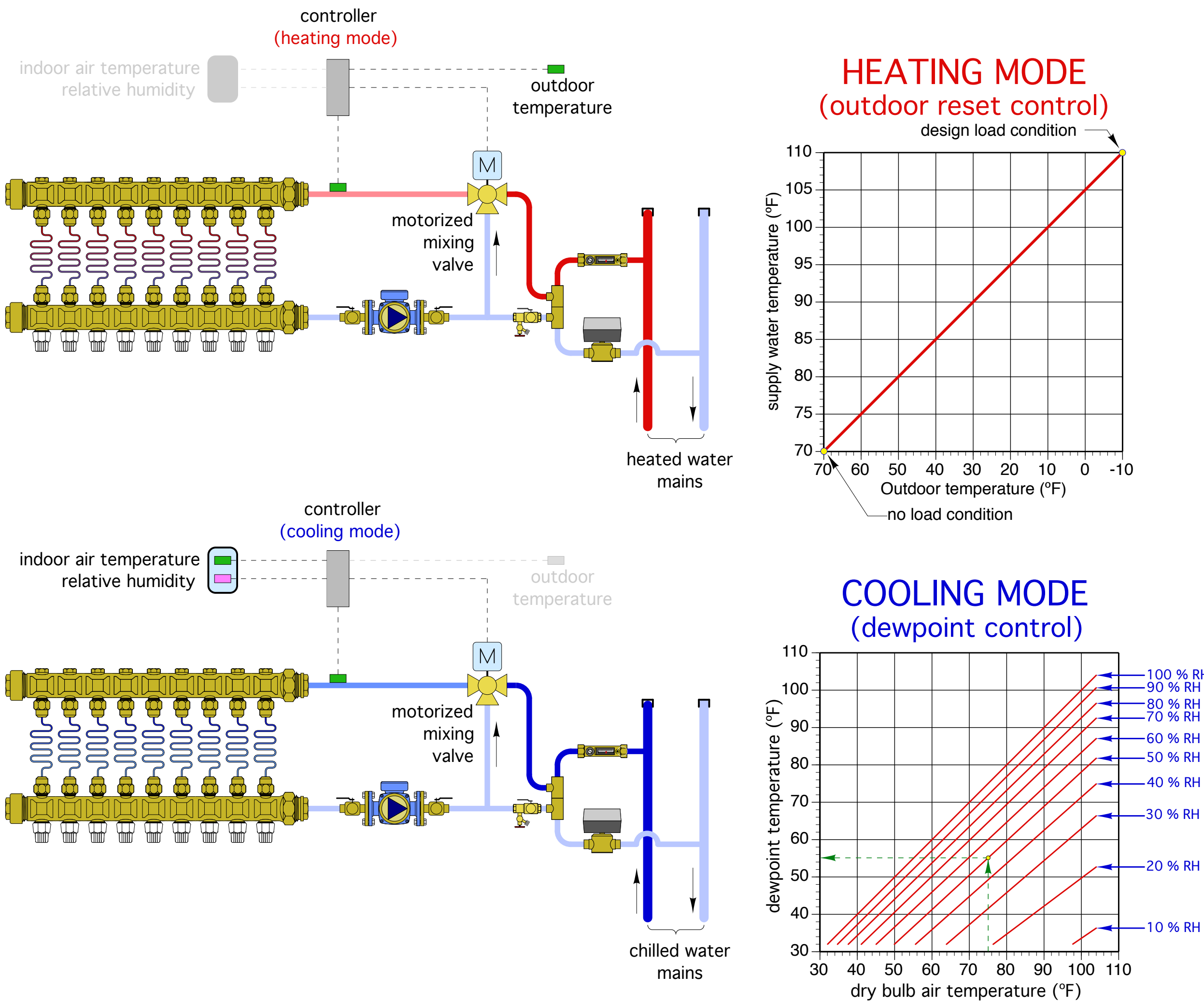
Chilled Water Cooling with Radiant Ceiling Panel

- Mixing valve operated by dewpoint controller maintain radiant panel supply temperature about 2-3 ºF above current room dewpoint temperature.

- Latent cooling, some sensible cooling, and ventilation accomplished by chilled water air handler.



Same mixing valve and radiant panel can be used for heating, but with outdoor reset control logic (rather than dewpoint control logic).

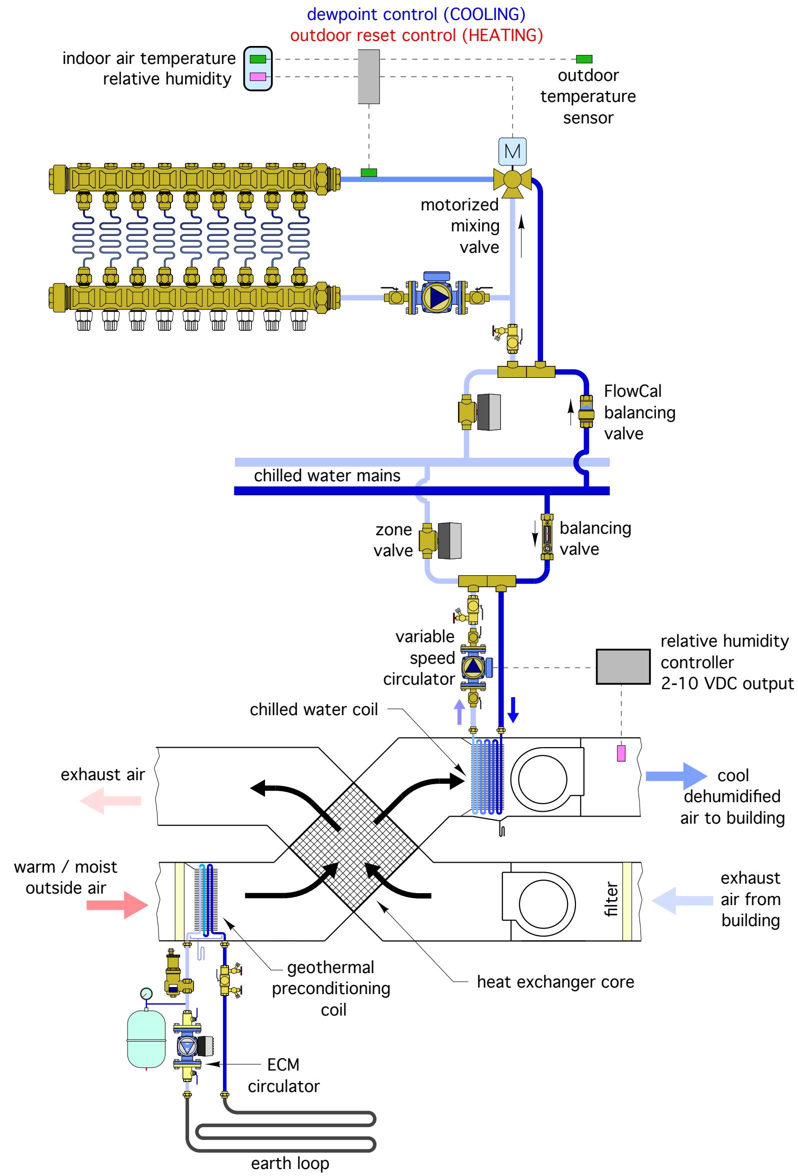


Chilled Water Cooling with HRV or ERV Ventilation

- geothermal pre-conditioning of ventilation air

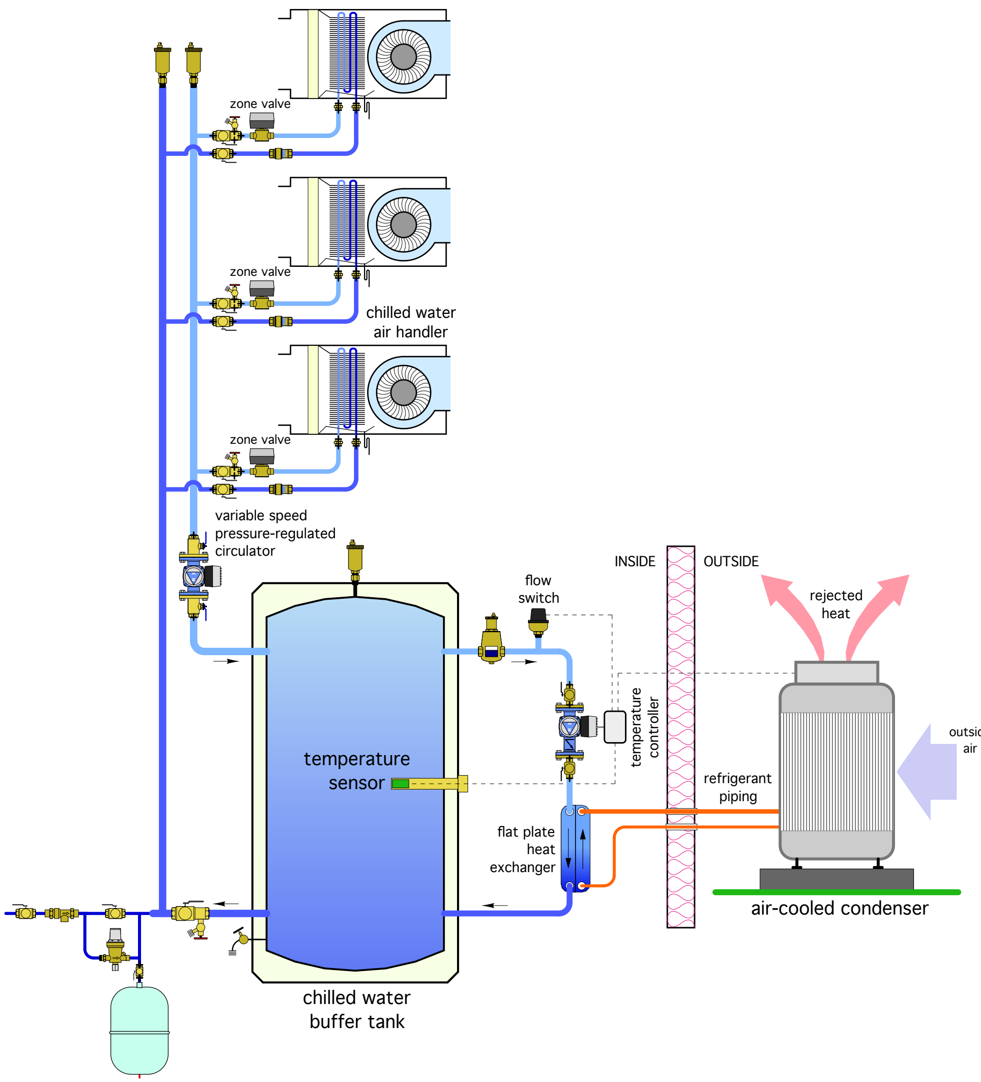
- chilled water coil provide latent cooling (moisture removal)

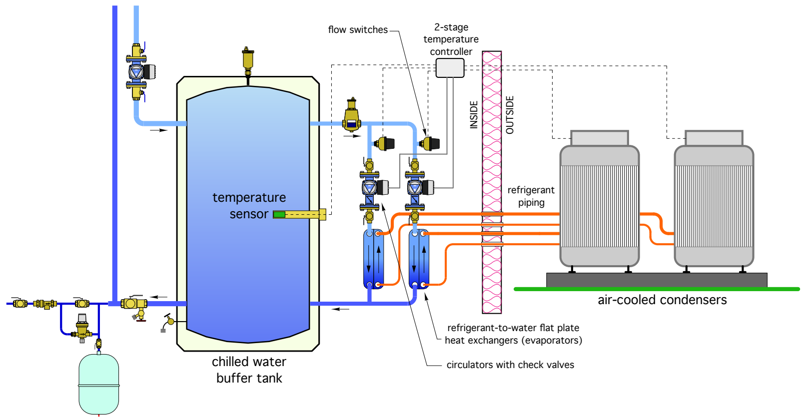
- Radiant panel(s) provide majority of sensible cooling



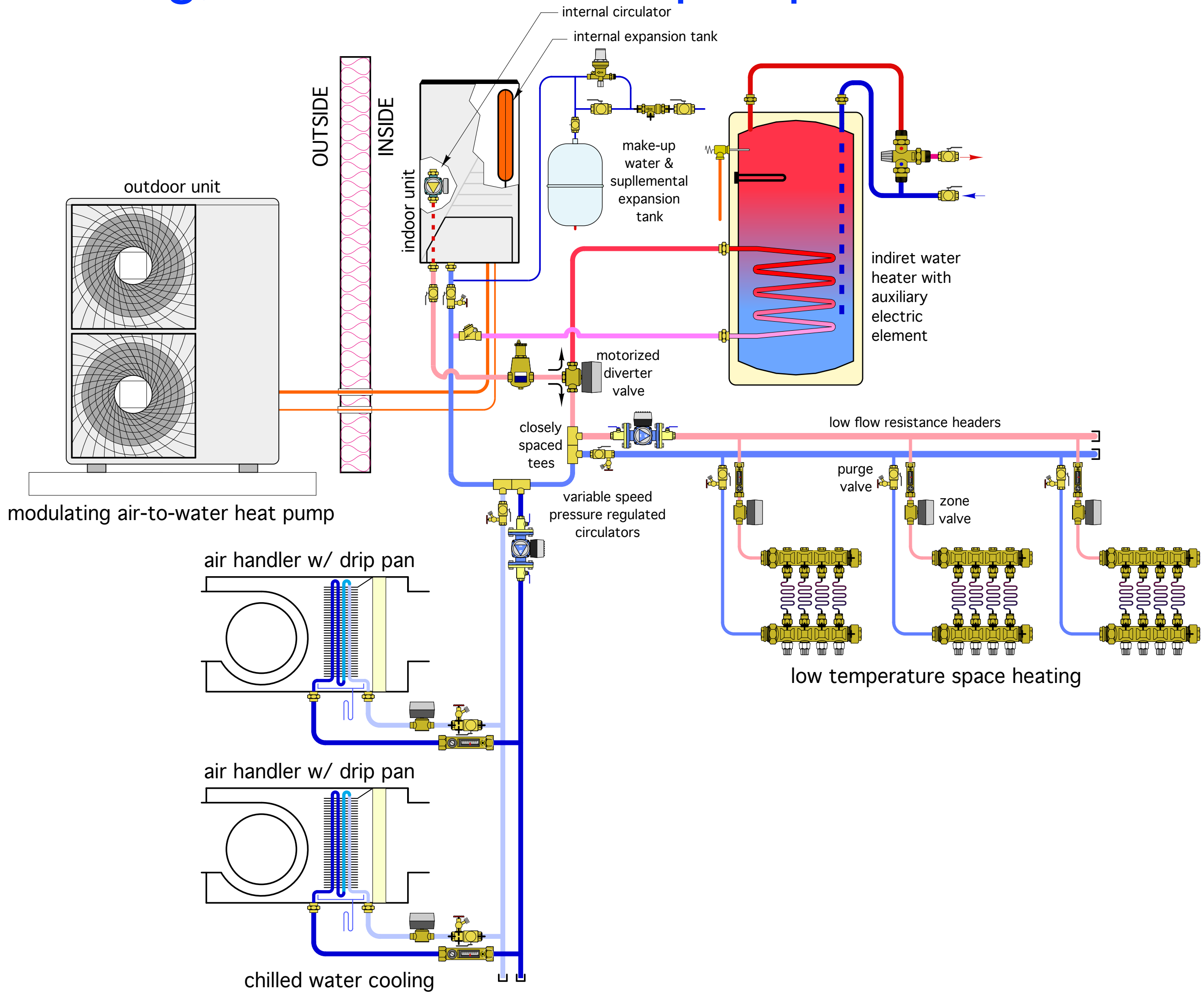
Examples of chilled water systems

Chilled water cooling, with air cooled condenser...



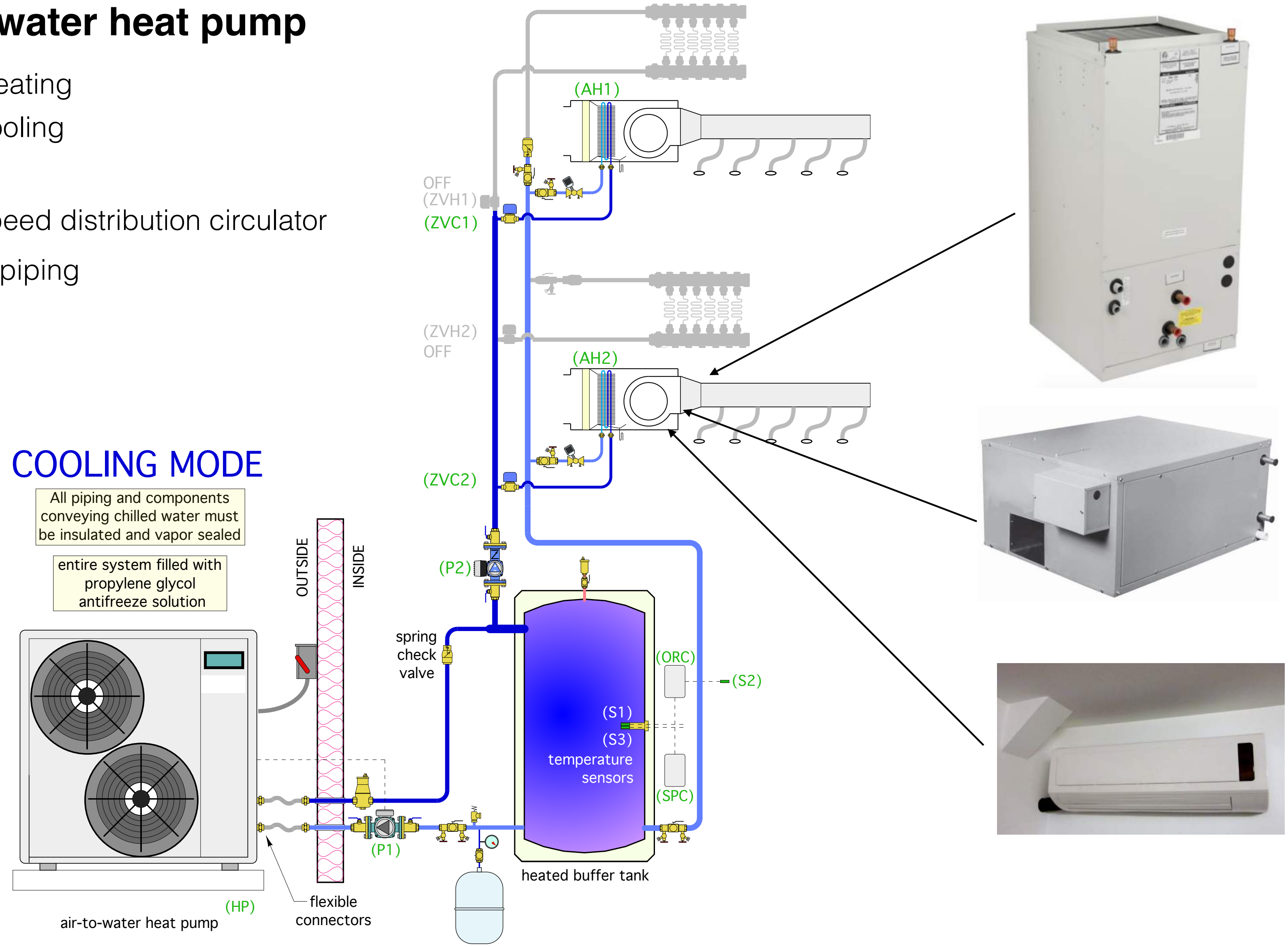


Chilled water cooling, Air-to-water heat pump...



Cold climate air-to-water heat pump

- 2 zones of radiant panel heating
- 2 zones of chilled water cooling
- 80 gallon buffer tank
- High efficiency variable speed distribution circulator
- Direct-to-load supply side piping



Cold climate air-to-water heat pump system

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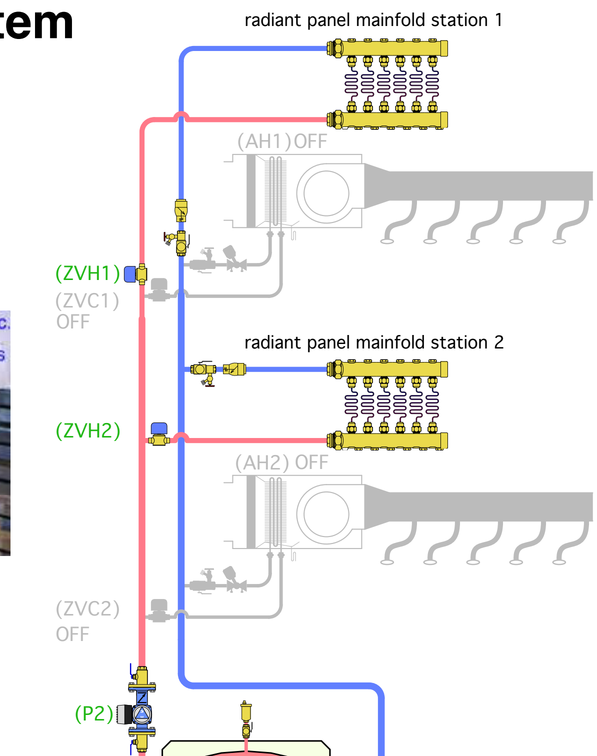
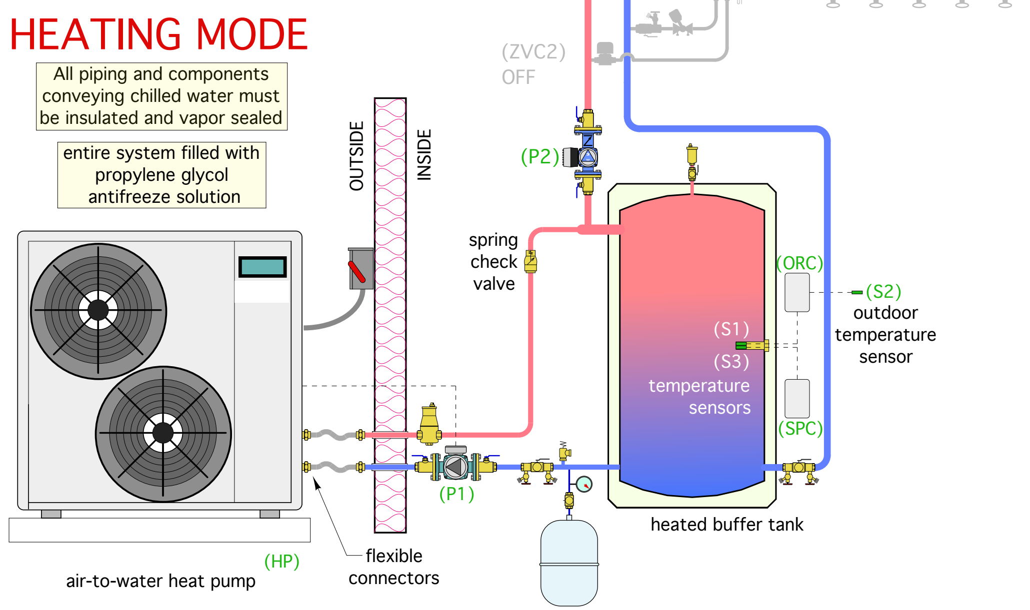
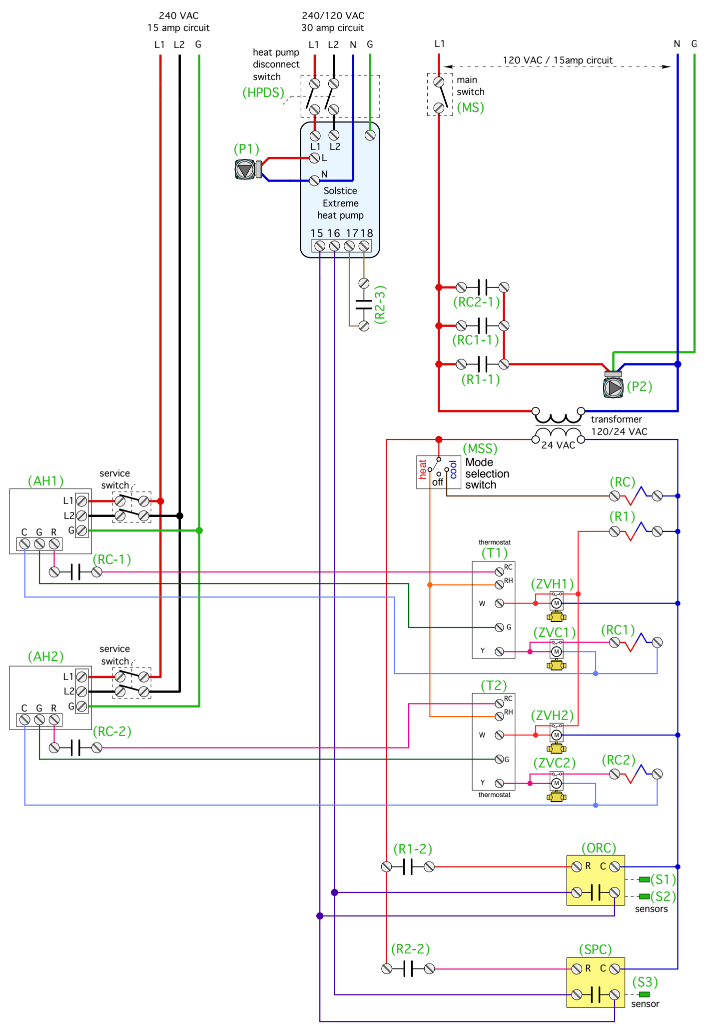




Cold climate air-to-water heat pump system



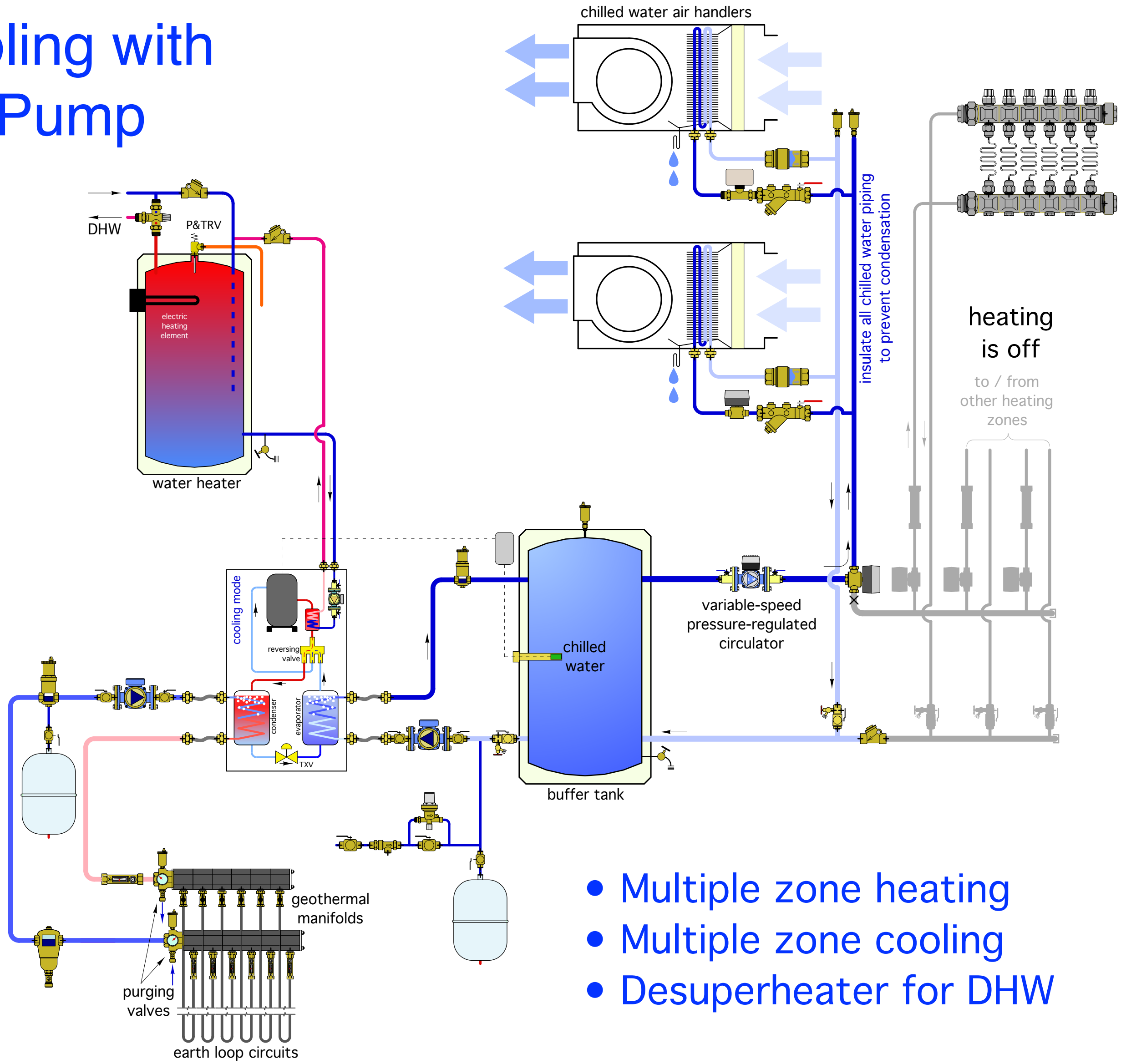
Description of operation:

Power supply: The Solstice Extreme heat pump and circulator (P1) are powered by a dedicated 240/120 VAC 30 amp circuit. The heat pump disconnect switch (HPDS) must be closed to provide power to the heat pump. The remainder of the control system is powered by 120 VAC / 15 amp circuit. The main switch (MS) must be closed to provide power to the control system. Both fan coils are powered by a dedicated 120 VAC / 15 amp circuit. The service switch for each air handler must be closed for that air handler to operate.

Heating mode: The mode selection switch (MSS) must be set for heating. This passes 24 VAC to the RH terminal in each thermostat. Whenever either thermostat demands heat, 24VAC is passed from the thermostat's W terminal to the associated zone valve (ZVH1, or ZVH2). When the zone valve reaches its fully open position its internal end switch closes, passing 24 VAC to relay coil (R1). Relay contact (R1-1) closes to pass 120 VAC to circulator (P2). Relay contact (R1-2) closes to pass 24VAC to outdoor reset controller (ODR). The (ODR) measures outdoor temperature at sensor (S2), and uses this temperature along with it settings to calculate the target supply water temperature for the buffer tank. It then measures the temperature of the buffer tank at sensor (S1). If the temperature at (S1) is more than 5 ºF below the target temperature the (ODR) closes its relay contact. This completes a circuit between terminals 15 and 16 in the Solstice extreme heat pump, enabling it in heating mode. After a short time delay the heat pump (HP) turns on circulator (P1) and verifies adequate flow through the heat pump. After a short time delay the heat pump compressor turns on it compressor. The heat pump continues to operate until the temperature at sensor (S1) is 5 ºF above the target temperature calculated by the (ODR), or neither thermostat calls for heat, or the heat pump reaches it internal high limit setting. *Note: Neither air handler operates in heating mode, regardless of the fan switch setting on the thermostats.*

Cooling mode: The mode selection switch (MSS) must be set for cooling. This passes 24VAC to relay coil (RC). normally open contacts (RC-1) and (RC-2) close allowing 24VAC from the air handlers to pass to the associated RC terminal in each thermostat. Whenever either thermostat calls for cooling, 24VAC is passed from the thermostat's Y terminal to the associated zone valve (ZVC1, or ZVC2). When the associated zone valve reaches its fully open position its internal end switch closes, passing 24 VAC to associated relay coil (RC1) or (RC2). Associated relay contacts (RC1-1) or (RC2-1) close to pass 120 VAC to circulator (P2). Associated relay contacts (RC1-2) or (RC2-2) closes to pass 24VAC to the cooling setpoint controller (SPC). The cooling setpoint controller measures the temperature of the buffer tank at sensor (S3). If this temperature is 60 ºF or higher, the (SPC) relay contact closes completing a circuit between terminals 15 and 16 on the Solstice Extreme heat pump (HP) enabling it to operate. Associated relay contacts (RC1-3) or (RC2-3) close between terminals 17 and 18 in the Solstice Extreme heat pump (HP), for cooling mode. The heat pump (HP) turns on circulator (P1) and verifies adequate flow through the heat pump. After a short time delay the heat pump compressor turns on it compressor and operates in chiller mode. This continues until the temperature at sensor (S3) drops to 45 ºF, or until neither zone thermostat calls for cooling, or until the heat pump reaches in internal low limit setting. The blowers in the air handlers can be manually turned on at the thermostats when the mode selection switch (MSS) is set to cooling. The blowers will operate automatically whenever either cooling zone is active.

Chilled Water Cooling with Geothermal Heat Pump



- Multiple zone heating
- Multiple zone cooling
- Desuperheater for DHW

Summary:

- All heat absorbers that provide latent cooling must have drip pans
- All chilled water piping must be insulated and vapor sealed to avoid condensation
- Install zone valves on return piping to minimize condensation potential
- Do not insulate the motor housing of circulators or actuators on zone valves
- Only use circulators and zone valves that are rated for chilled water service
- On/off chiller used with zoned distribution requires an insulated buffer tank
- The coolest water is drawn from bottom of buffer tank
- Ensure that heat migration from other part of system doesn’t add to cooling load
- Minimize circulator wattage, since it all adds to the cooling load
- Isolated any “ground water” from major components using heat exchanger
- All radiant cooling panels must remain above current dewpoint temperature of room
- For best chiller performance keep chilled water temperature as high as possible
- All chilled water heat absorber must be piped in parallel (same supply temperature)
- Install flow switch if water is being chilled by DX evaporator