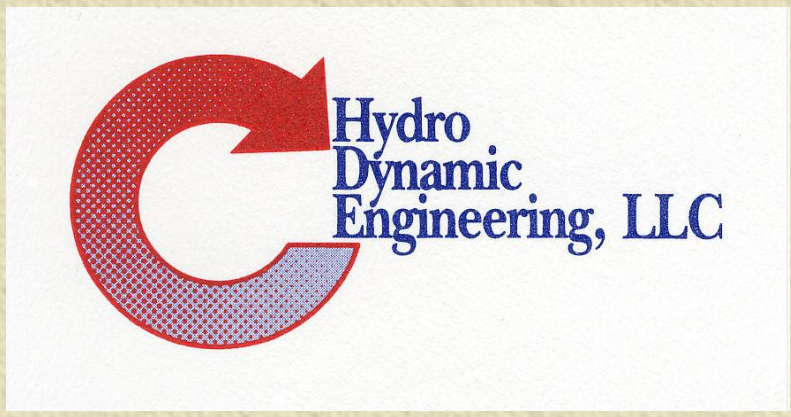
Geothermal Heat Pump Basics



- Presentation to Connecticut Environmental Health Association - Sept. 24, 2021

Topics

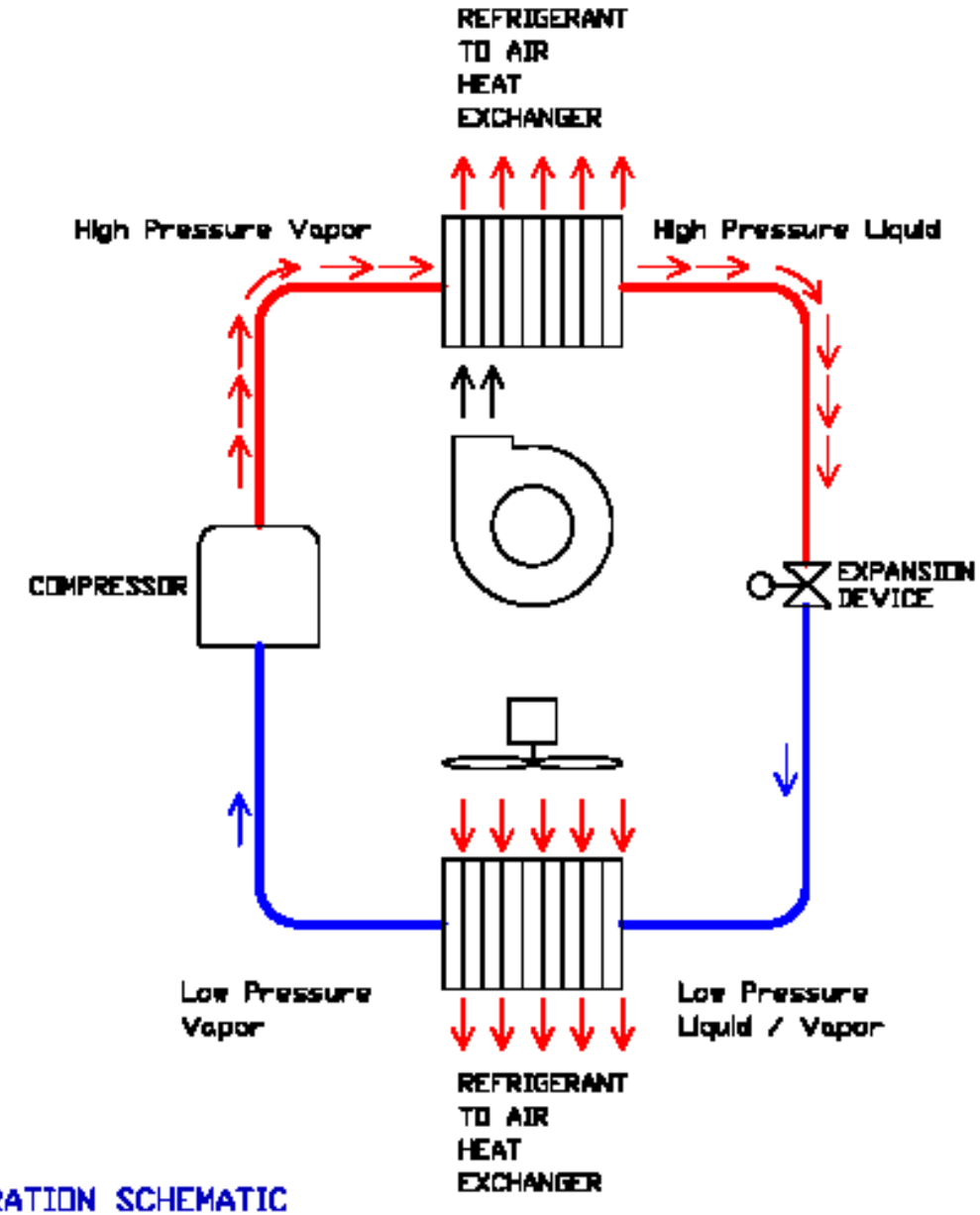
- How Geothermal Heat Pumps Work
- What are the different variations on installing a Geothermal System?
- Elements of Designing Geothermal Systems
- Advantages of Geothermal Systems
- Careful design is critical

How Geothermal Works

- Geothermal heat pumps are built the same as ordinary air-source heat pumps, EXCEPT that geothermal heat pumps exchange heat with the earth, not with the outside air.

How Geothermal Works

- Ordinary air-source heat pumps rely on outside air as their heat sink / heat source.
  - Cooling: If it's 90 degrees out, these machines need to 'pump' heat from the 70-degree building 'uphill' to the outside air.
  - Heating: If it's 20 degrees out, these machines need to 'pump' heat from the outside air into the 70-degree building (a long way uphill).



REFRIGERATION SCHEMATIC

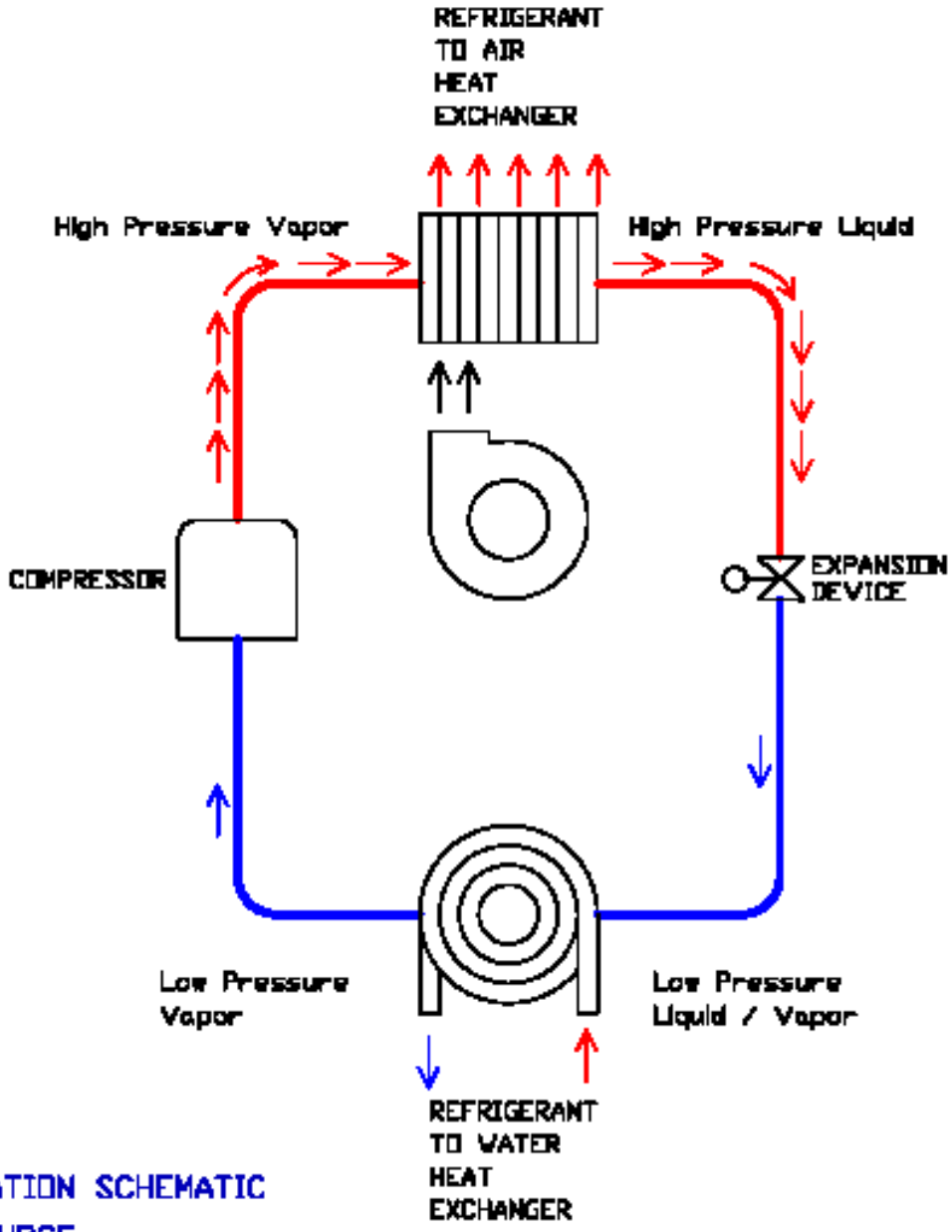
AIR SOURCE

HEATING ONLY

refrigcycle ht only 3 airdeg

How Geothermal Works

- Geothermal heat pumps use the moderate earth temperature as their heat sink / source.
  - Cooling: Geothermal heat pumps only need to ‘pump’ heat ‘downhill’ from the 70-degree building into the 52-degree earth.
  - Heating: Geothermal heat pumps only need to ‘pump’ heat a short distance ‘uphill’ from the 52-degree earth to the 70-degree building.



REFRIGERATION SCHEMATIC

WATER SOURCE

HEATING ONLY

refrigcycle ht only 3 water.dwg

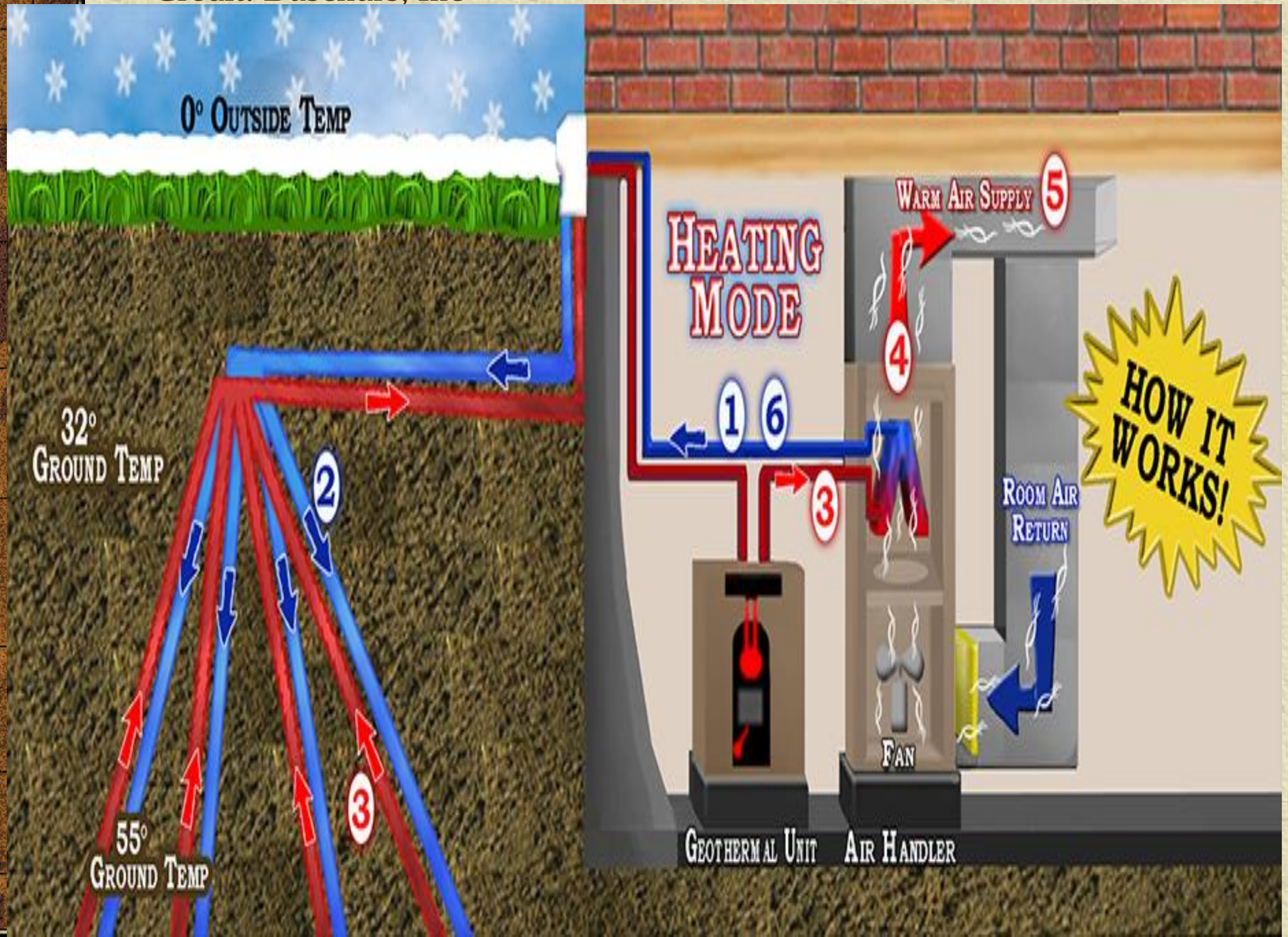
Geothermal Source Options

- Open loop
  - Water is pumped out of the ground, through the heat pump, then discharged somewhere.
- Closed loop
  - A solution of water and antifreeze is circulated within closed piping loop(s)
    - Can be vertical (wells) or horizontal (trenches)

Geothermal Source Options

- Direct Exchange
  - Copper tubes circulate refrigerant in the ground
  - Promoted to be simpler than closed loop
  - (Sounds too good to be true – because it's too good to be true.)

Credit: Buschurs, Inc



Direct Exchange

- Copper tubing is made from flat copper strips that are shaped into a tube, with the two edges of the strip being welded together.
- Sometimes the weld (a weak spot) fails, resulting in a refrigerant leak
- There’s no practical way to find or fix this leak. The whole installation needs to be scrapped.

Geothermal Source Options – Open Loop Systems

- Water is pumped from a ‘source’ well, passes through the heat pump(s), and then it is discharged somewhere.
  - Discharge to land surface (to a pond, stream, or simply a low-spot on the property)
  - Discharge to another well on the property
  - Discharge to the same well that the water was taken from

Discharge to Land Surface

- This was common during the 1980's
  - Wastes water
  - More expensive to operate than closed loop systems
  - Almost never done anymore

Discharge to Another Well

- This was also common during the 1980's
  - Water is pumped from one well, passed through the geothermal heat pump, then discharged to another well
  - This has the advantage of recycling the water to the aquifer it was drawn from
  - It's 'easier said than done' – It is actually difficult to get a well to accept the discharge water.

Discharge to Same Well

- This was also done during the 1980's, and even later
- Water is circulated back to the well it was drawn from
- It has been promoted as the 'Standing Column' design
  - There usually needs to be a place to 'dump' water when the water temperature becomes too cold (heating mode) or warm (cooling mode).

Closed Loop Geothermal

- Although there are several options, the best one is closed loop. The remainder of this talk will cover that topic.

Careful Design is Important!

- As the geothermal heat pump runs (constantly) the circulating fluid's temperature changes.
  - If the system is designed right, that change will be small, and the geothermal heat pump will run efficiently.
  - If the system is designed by rule-of-thumb, it might not run efficiently. Worse, if it is designed to meet a low first cost price, it surely will not run efficiently.

Careful Design is Important!

- If the geothermal heat-exchange loop is short, the system will be expensive to operate.
- You might as well install an ordinary air-source heat pump, and save the up-front installation cost.

Elements of Geothermal Design

- Load Calculations
- Equipment Selection
- Forced air vs. Hydronic Systems
- Duct Sizing and Installation
- Geothermal Heat Exchange Fluids
- Manifolding Loops

Load Calculations

- Today, there is software we can use to estimate the cooling and heating loads of a building
  - Geothermal heat pump manufacturers offer this software to dealers for free
  - Software is available from developers too
  - There’s no excuse to use rules of thumb to estimate the loads

Equipment Selection

- Good practice dictates ‘sizing’ the equipment so heating capacity at the design condition is slightly smaller than the peak heat load.
  - Example - For a 30,000 Btu/hr peak heating load, a heat pump having 28,000 Btu/hr heating capacity at 32 degree entering fluid temperature, is a good match.
- Software helps us to choose the right equipment

Equipment Selection

- In New England, equipment is generally not sized according to the cooling load. (Unless west-facing glass results in an unusually high cooling load)
- Cooling capacity of the heat pump is usually greater than the cooling load, and conventional wisdom warns of insufficient dehumidification. Not true in New England.

Forced Air vs. Hydronic Systems

- Geothermal heat pumps are usually installed as forced air systems.
  - This takes advantage of their fantastic performance in the air conditioning mode.
- Geothermal water-to-water heat pumps work well with radiant floor heating systems, because the temperature is right.
- Geothermal water-to-water heat pumps are not suited for baseboard radiant heat.

Duct Sizing and Installation

- Ducts are sized, sealed and insulated to minimize energy losses.
  - Design for maximum 0.5” total w.c. pressure loss
  - Seal all joints with tape, mastic, or ‘Aeroseal’
  - Insulate ducts to R-6 in basements and R-8 in attics.

Geothermal Exchange Fluids

- Several antifreeze additives have been tried
- Propylene Glycol, all things considered, is the best option.
- There is currently no ‘code’ in Connecticut, but the draft version specifies that only propylene glycol is approved.

Geothermal Heat Exchange Fluid

- The most commonly used heat exchange fluid is a 20% solution of Propylene Glycol
  - Circulating pumps must be designed to accommodate increasing viscosity at low temp.
- Denatured Ethanol at 70% provides the same freeze protection without increasing viscosity at low temperature
  - More expensive to buy and install than propylene glycol, is dangerous, and is not approved

Heat Exchange Fluids

- Other antifreeze additives have largely been weeded out in practice
- Plain water can be used if the loop field is designed to remain safely above freezing

Manifolding

- Geothermal exchange wells can be manifolded together within the building, or outside, underground.
  - Indoor manifolding has the advantage of making sure that each well is properly purged of dirt and air
  - Underground manifolding saves space in the building, and is more practical for very large installations

Manifolding Loops Outdoors

- For large systems, underground manifolds minimize manifold work that must be done inside the building, saving cost and space inside the building
- Manifold systems must be carefully designed for effective flushing, with the first loop ‘supplied’ being the last one ‘returned’ (reverse-return)

Manifolding Loops

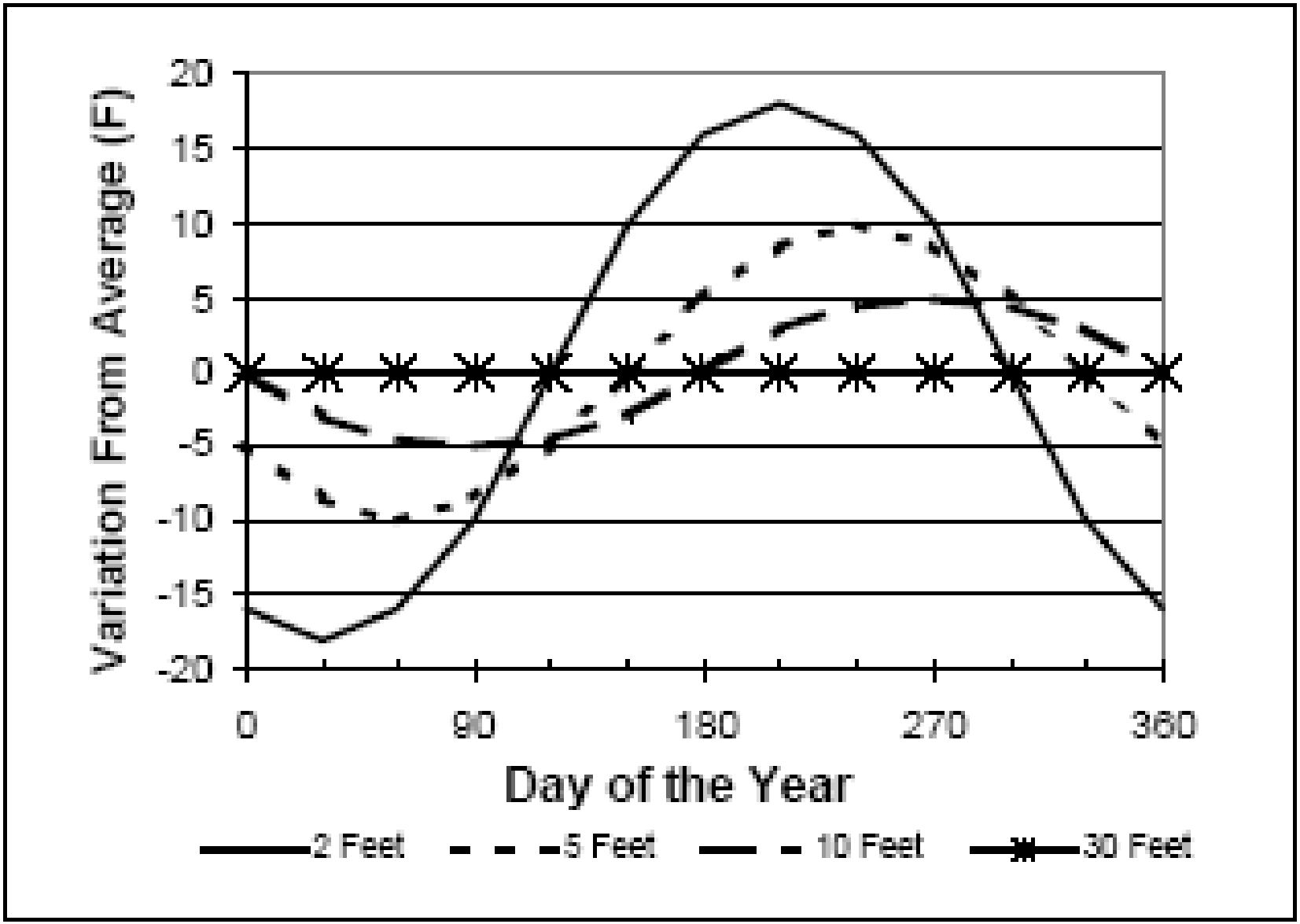
- For private homes it is practical to bring each loop into the basement individually.
  - Provide isolation/balancing valves at each end of each loop
  - For larger projects underground vaults may be incorporated for individual manifolding

Loop Field Design Options

- Vertical Heat Exchangers (wells)
- Horizontal Heat Exchangers (trenches)
- Ponds

Ground Temperature Fluctuates Seasonally

Credit ASHRAE



Vertical Heat Exchangers

Credit McQuay

Vertical Heat Exchangers

- Wells (Vertical Closed Loop Heat Exchangers) offer advantages in New England
  - Space required on the lot is minimized
  - Bedrock is an excellent heat-exchange medium
  - Earth temperature is constant below 30 ft
  - System operating cost is minimized

Horizontal Heat Exchangers

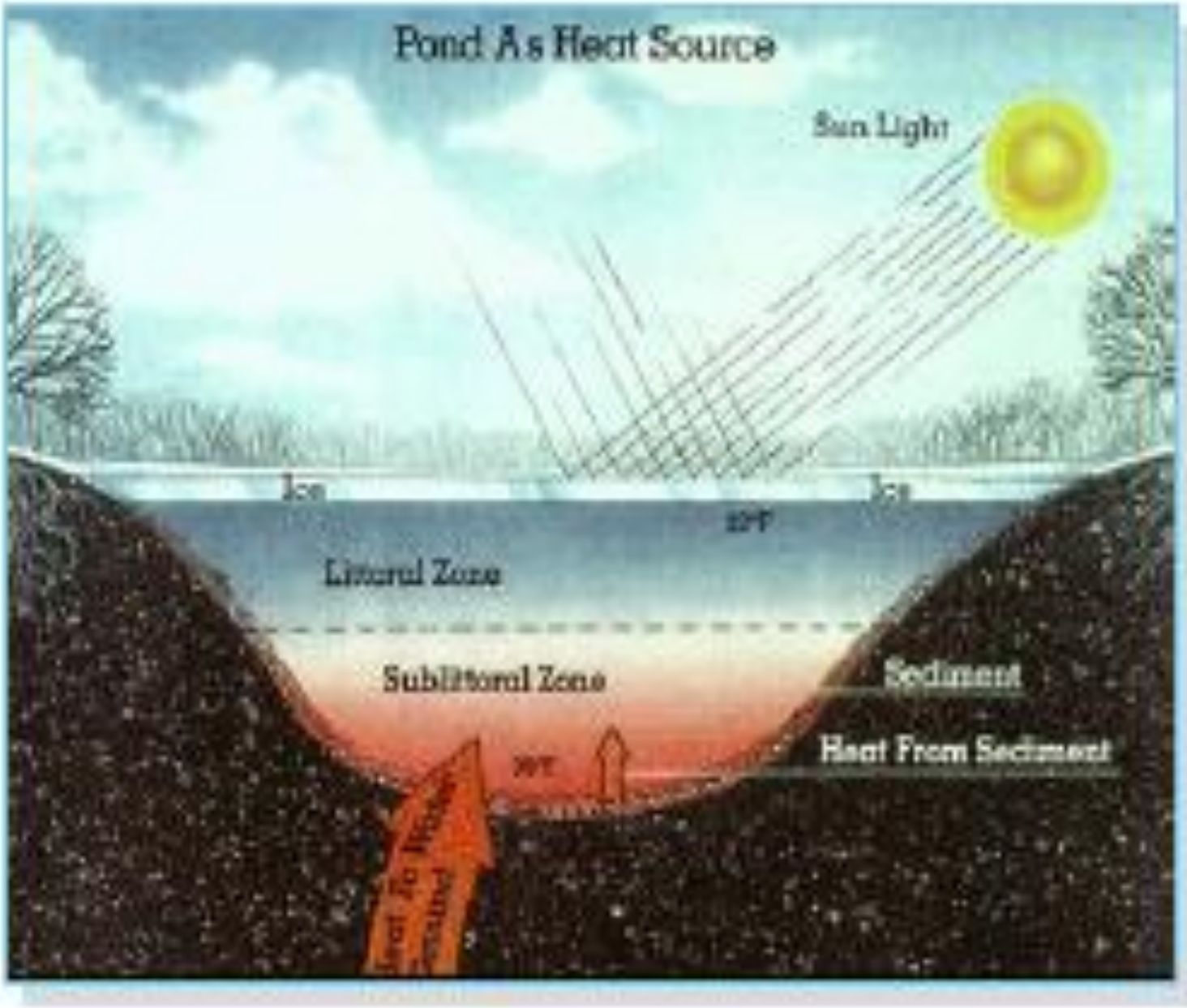
Credit McQuay

Horizontal Heat Exchangers

- Horizontal loop fields work well if carefully designed and constructed.
  - Total loop length is much longer than for vertical systems
  - For trenches deeper than four feet, precautions must be taken for worker safety
  - Deeper is better
  - Avoid dry sand

Loops in Ponds

- Water temperatures in ponds fluctuate seasonally.
  - Deeper is better, and the loop is installed at the bottom of the ponds
  - Every pond is different, so seasonal temperature variations should be determined before designing a system – 39 degrees seems to be the magic number


Pond As Heat Source
Sun Light
Ice
Ice
32°F
Littoral Zone
Sublittoral Zone
Sediment
Heat From Sediment
39°F

Pressure Testing

- Mechanical Code calls for pressure test with water for 100 psi for 30 minutes with no leaks
  - In practice, contractors test with air
  - The pressure test specified in the draft new Well Drilling Code is two times working pressure. (2 x 30 psi = 60 psi)

Advantages of Geothermal

- Most of the heat delivered to the building actually comes from the earth (for free!)
- Operating cost is significantly lower than fossil fuel with air source a/c
  - (electricity @$0.192/kWhr)
  - Only 45% of the cost of oil (@$2.91/gal) with air-source a/c
  - Only 35% of the cost of propane (@$3.26/gal) with air-source a/c

Advantages of Geothermal

- Use of fossil fuel is limited to that needed to generate electricity to run the heat pumps
- CO_2 emissions are minimized
- Systems require less service and maintenance than oil burners
- No need for oil or propane deliveries
- Electric prices are more stable than oil and propane

Questions & Comments?