GROUND SOURCE HEAT PUMPS

An Overview

PRESENTERS:

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INTRODUCTION

OVERVIEW

- The basics
- Is the project site geothermal friendly ?
- System equipment
- Is ground source a good choice for you ?

THE BASICS

THE BASICS

DEFINITION

Geothermal Heat Pump

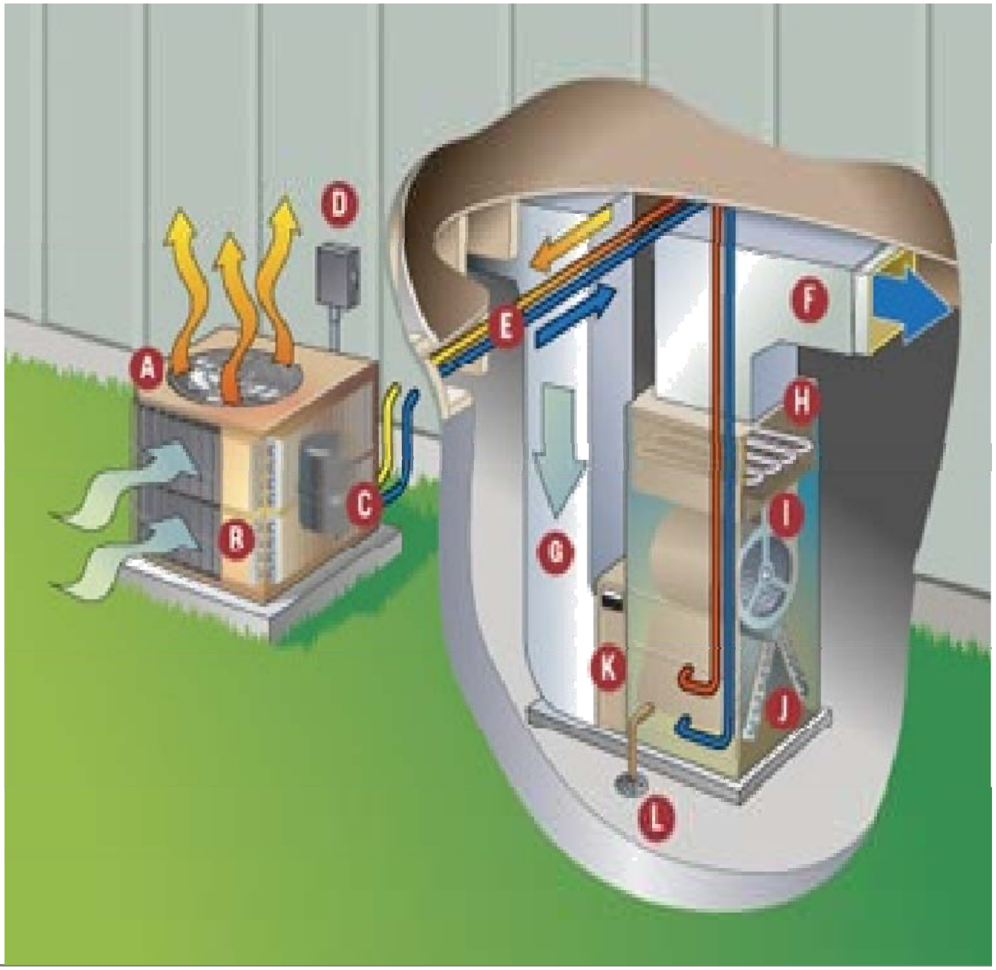
- Electrically powered system that takes advantage of the earth's relatively constant temperature to provide building heating and cooling.

THE BASICS

PROCESS

Heat Pump Refrigeration Cycle

- Air-to-Air

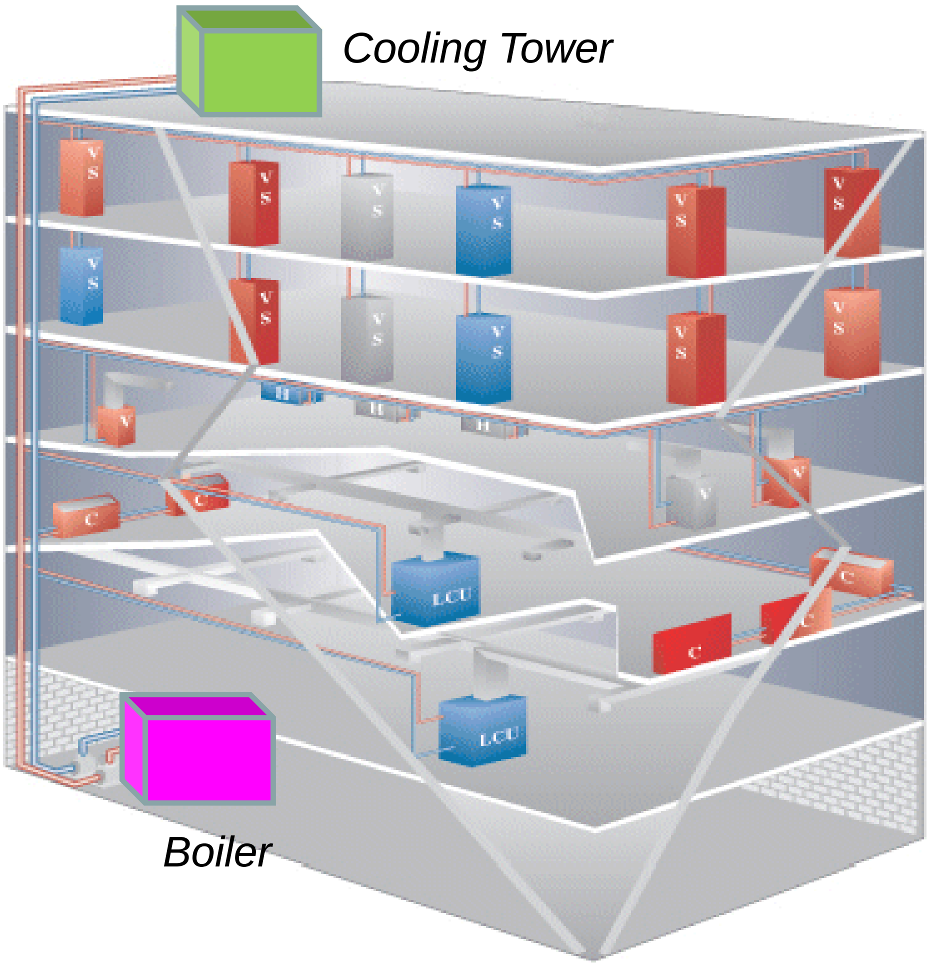


THE BASICS

PROCESS

Heat Pump Refrigeration Cycle

- Water-to-Air

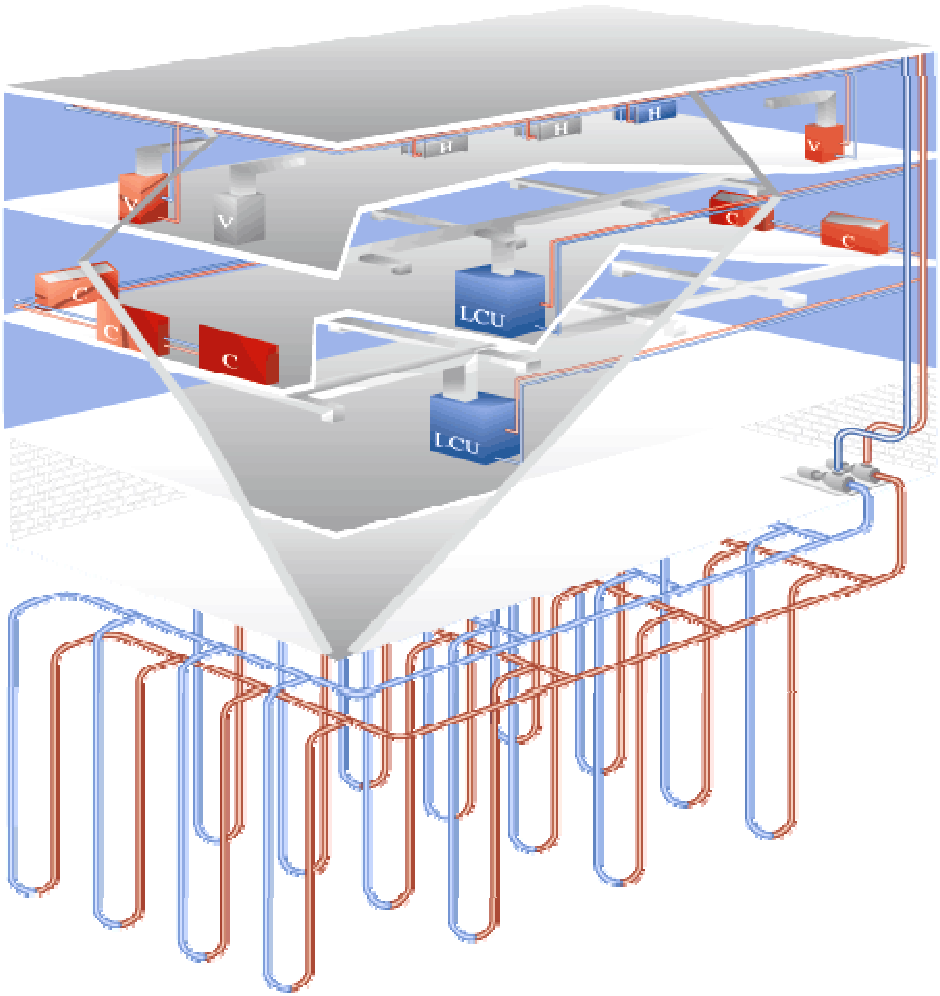


THE BASICS

PROCESS

<u>Heat Pump Refrigeration Cycle</u>

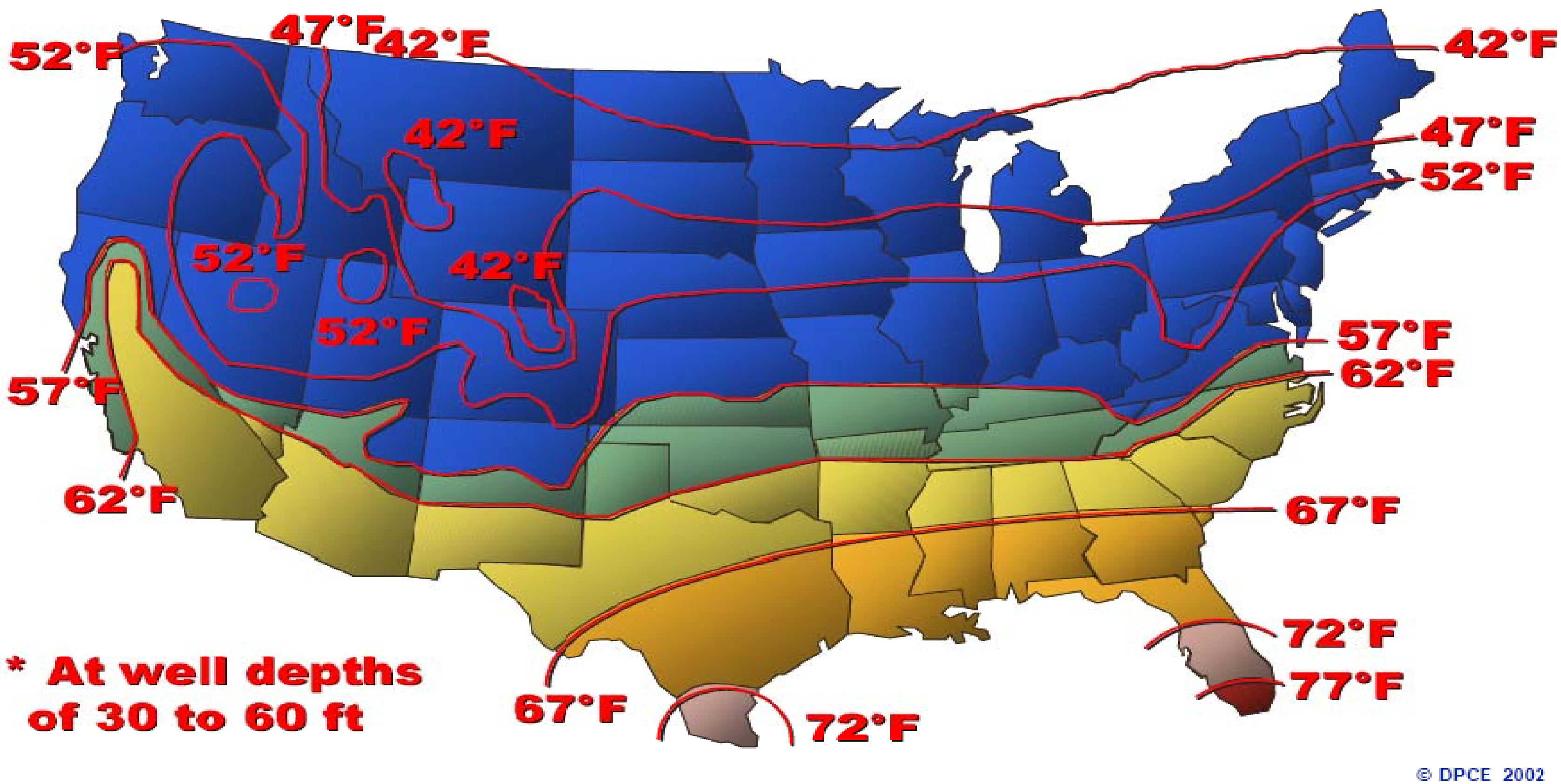
- Geothermal: replace water-side cooling tower and boiler with earth coupled system



THE BASICS

HOW DOES IT WORK ?

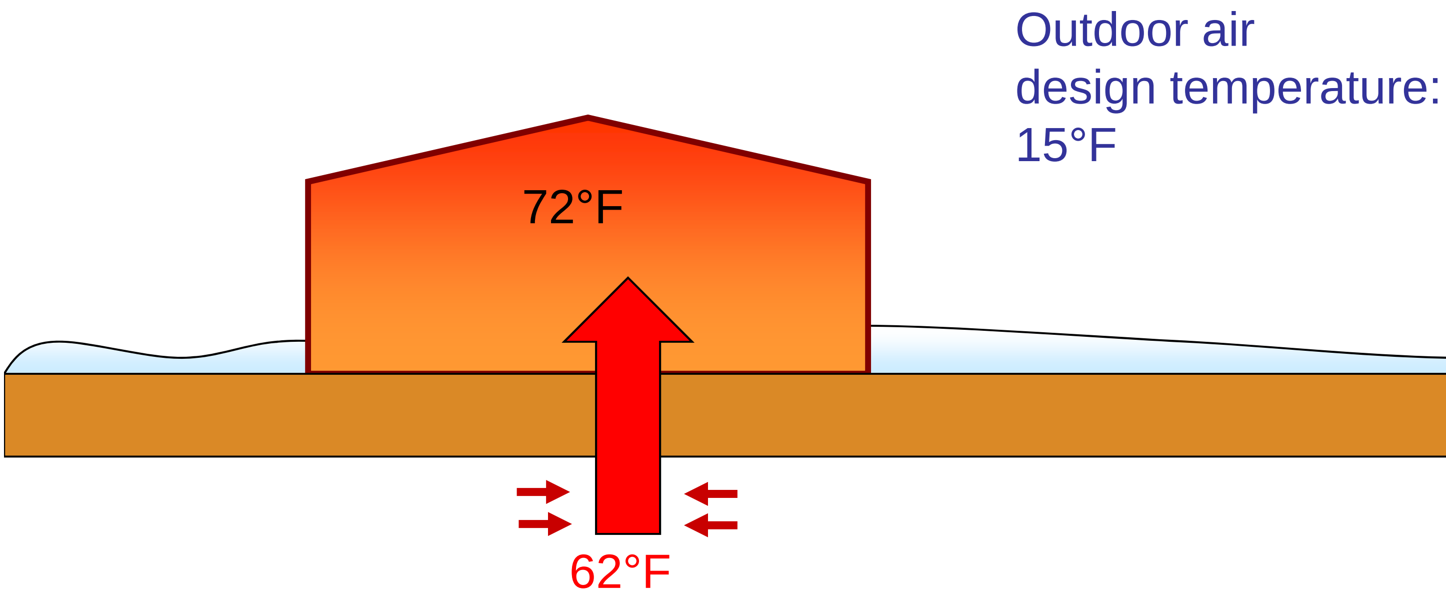
<u>Ground Water Temperatures</u>



THE BASICS

HOW DOES IT WORK ?

The earth is a source of heat in the winter

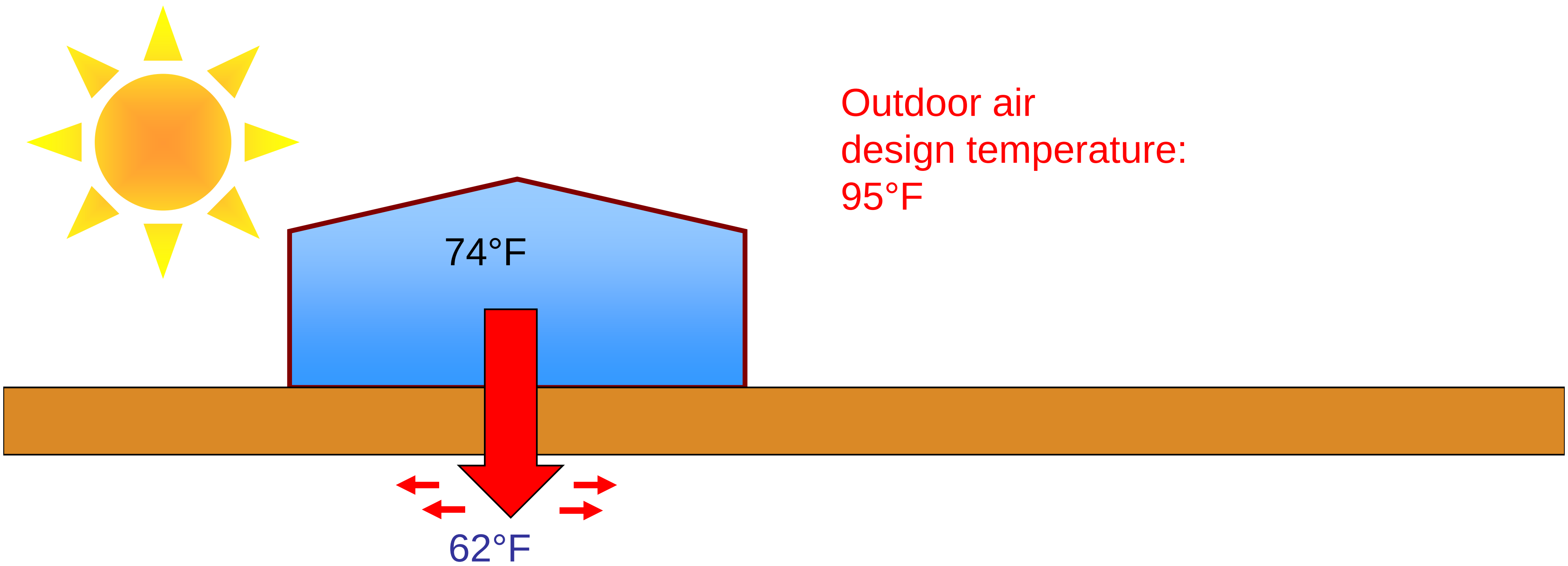


Geothermal heat pumps transfer underground heat into buildings to provide heating

THE BASICS

HOW DOES IT WORK ?

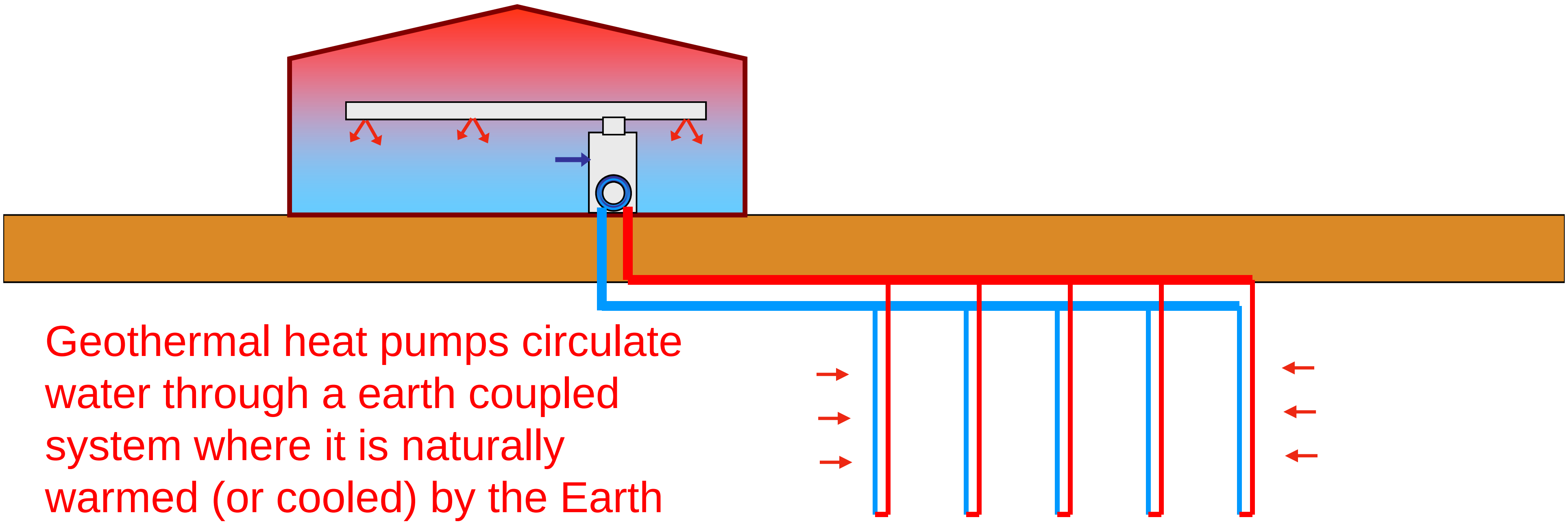
<u>The earth is an efficient way to reject heat in the summer</u>



Geothermal heat pumps transfer heat from buildings into the ground to provide cooling

HOW DOES IT WORK ?

Using water source heat pumps with the earth



Geothermal heat pumps circulate water through a earth coupled system where it is naturally warmed (or cooled) by the Earth

TYPES OF GEOTHERMAL HEAT PUMP SYSTEMS

- Ground Source Heat Pump GSHP
  - Ground Water Heat Pump GWHP
  - Surface Water Heat Pump SWHP
    - Open Loop
    - Closed Loop
  - Ground Coupled Heat Pump GCHP
    - Horizontal
    - Vertical

THE BASICS

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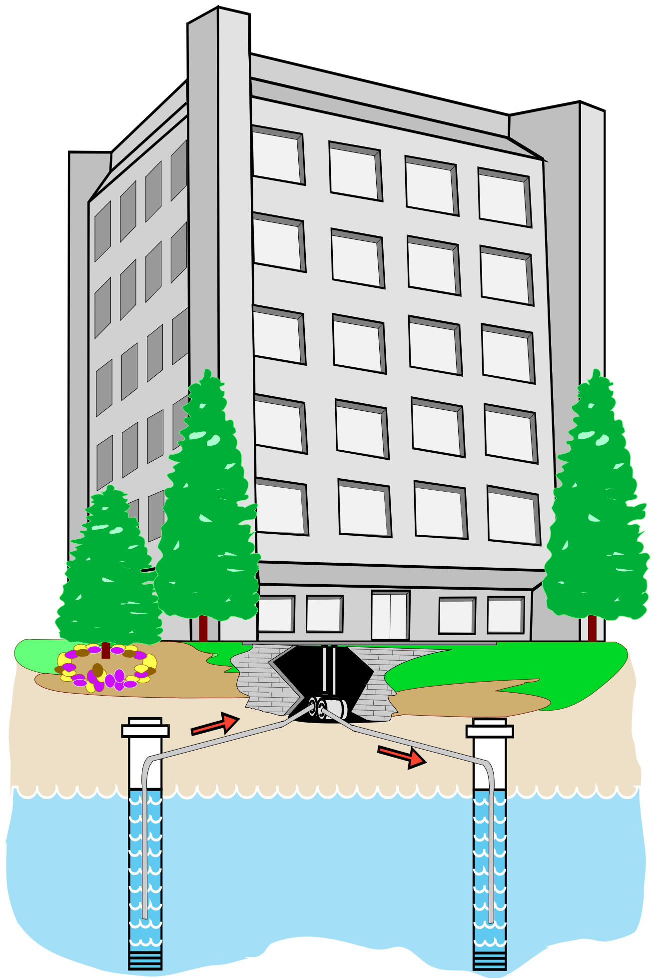

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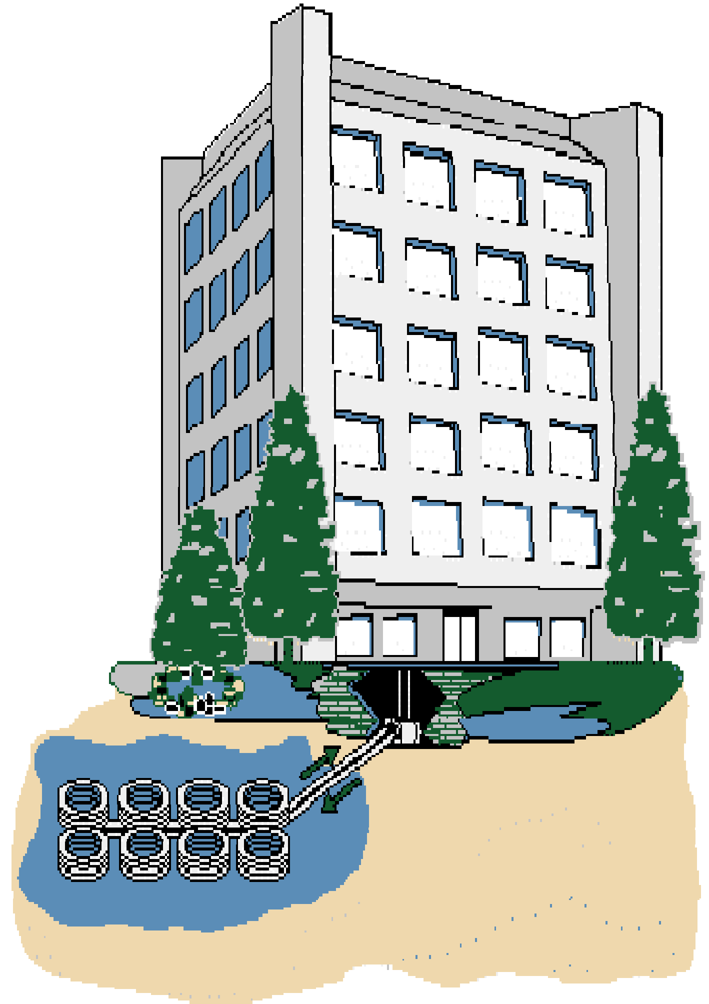

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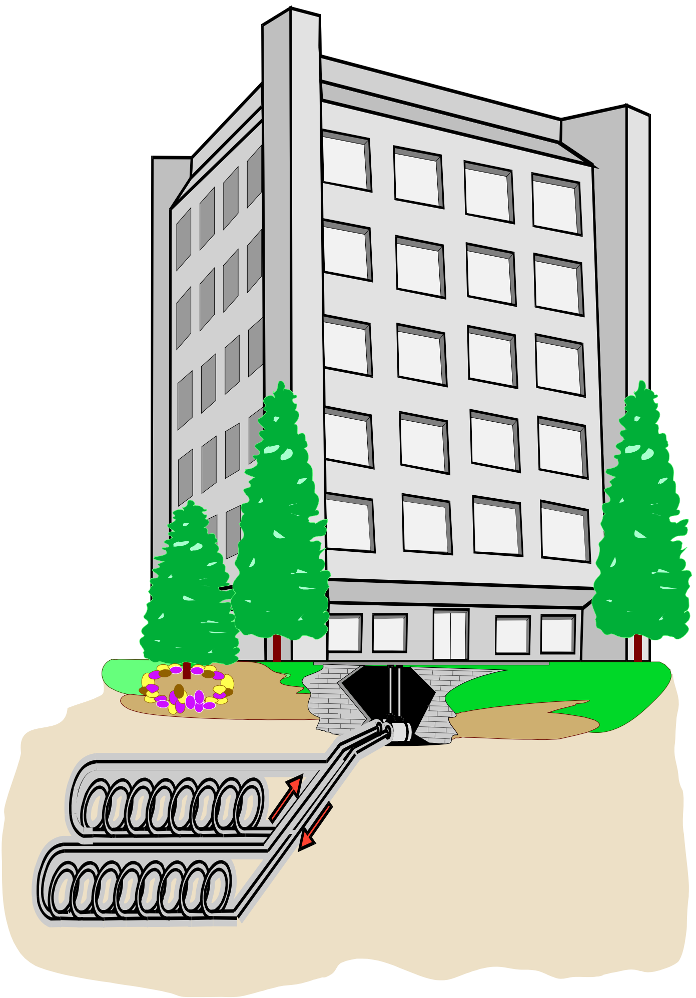

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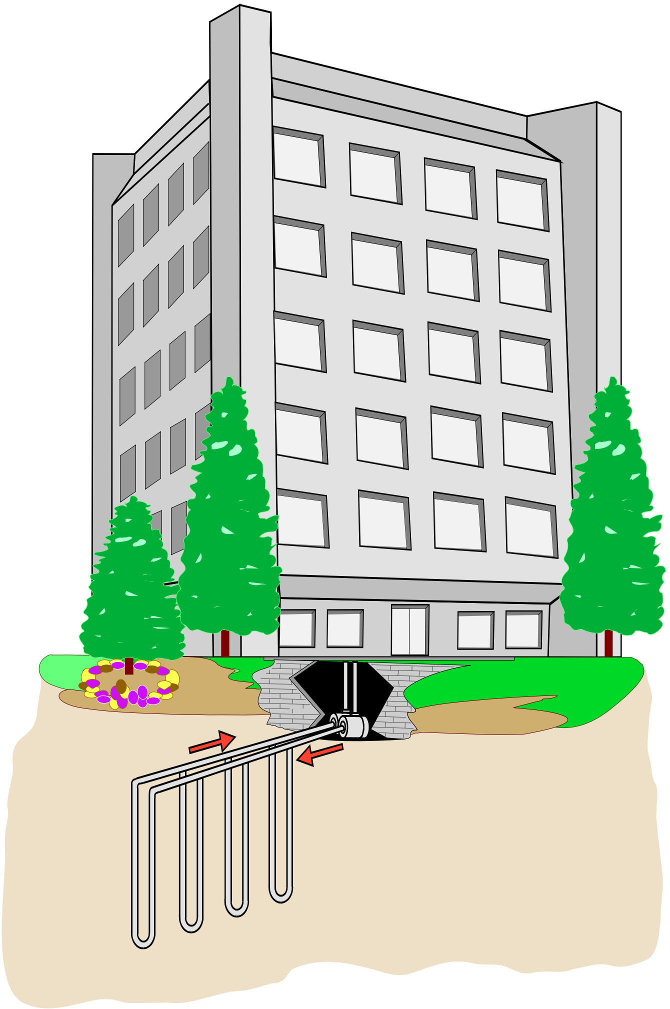
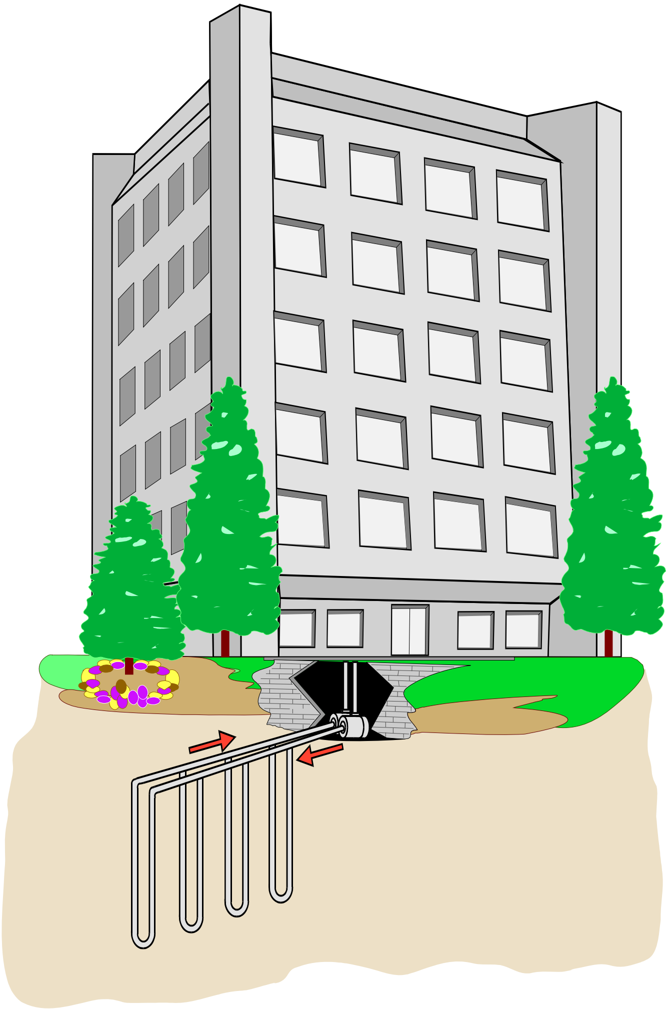


TYPES OF GEOTHERMAL HEAT PUMP SYSTEMS

- The focus of today's presentation is:

Vertical Ground Coupled Heat Pump



IS THE PROJECT SITE GEOTHERMAL FRIENDLY?

IS THE PROJECT SITE GEOTHERMAL FRIENDLY ?

GETTING STARTED

<u>Geothermal Testing Agency</u>

- Check credentials and standards
- 2007 ASHRAE Applications Handbook, pages 32.12-32.13
- IGSHPA "Closed-Loop/Geothermal Heat Pump Systems - Design & Installation Standards 2009 Edition"

IS THE PROJECT SITE GEOTHERMAL FRIENDLY ?

GETTING STARTED

<u>Geothermal Testing Agency</u>

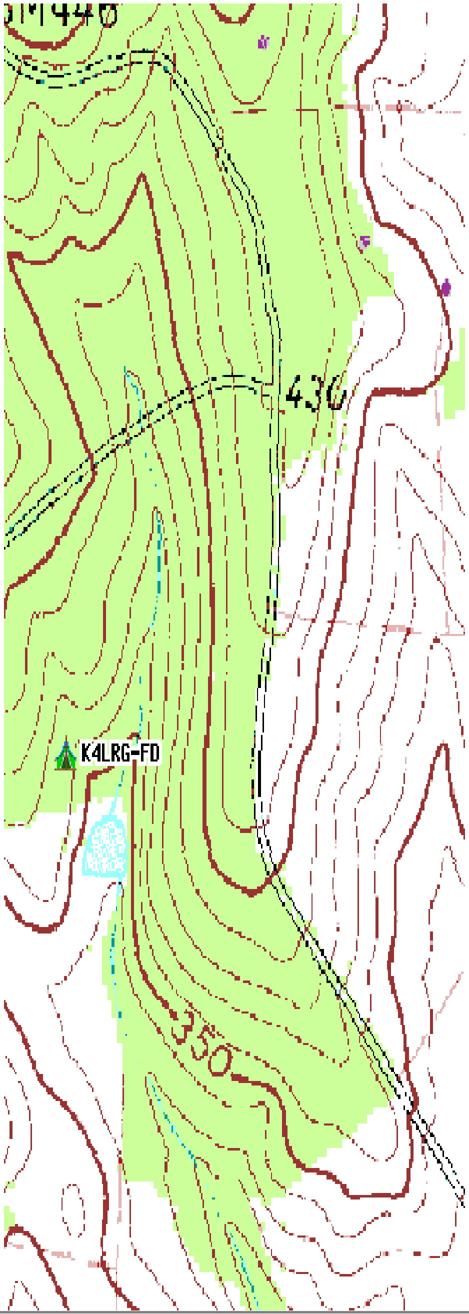
- Ensure testing agency dialogue with MEP firm
- Establish preliminary building loads
  (e.g. 350 sq ft/ton)
- Set target bore depth
  (should be same as design depth)

IS THE PROJECT SITE GEOTHERMAL FRIENDLY ?

GETTING STARTED

Geothermal Testing Agency

- Work with owner to determine test bore locations
- Test bore quantity dependent upon site topography, loopfield size, drilling conditions, etc.
- Variations in topography (depth to bedrock) may vary testing needs to properly characterize site.



IS THE PROJECT SITE GEOTHERMAL FRIENDLY ?

DRILLING

<u>Test Bores</u>

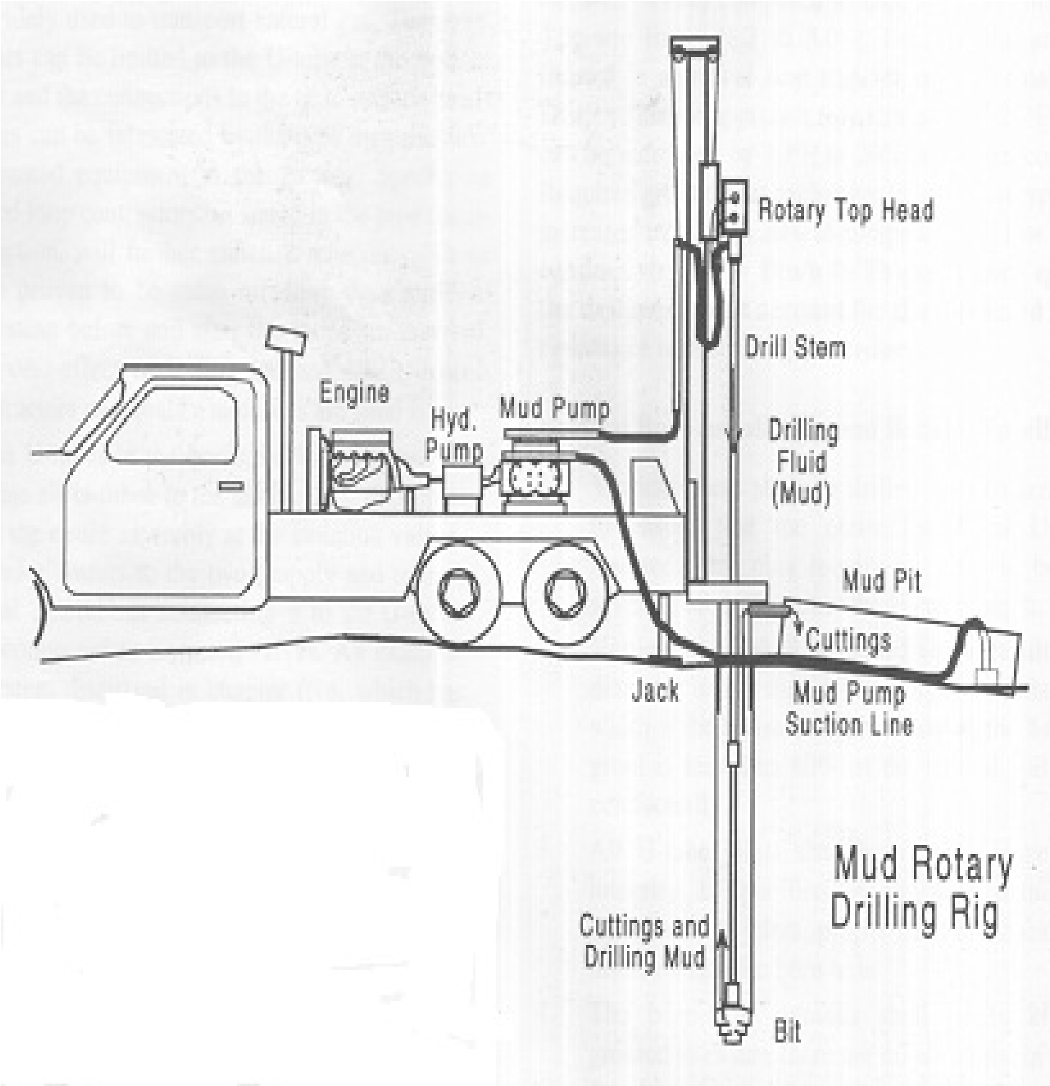
- Hire geothermal-based drilling company (IGSHPA directory, local drillers)
- Must be certified by NC Well Contractor Certification Commission
- Testing agency/MEP firm will specify test bore details (depth, u-bend size, grout mix)

IS THE PROJECT SITE GEOTHERMAL FRIENDLY ?

DRILLING

<u>Test Bores</u>

- Drilling process varies according to geology
- Mud-rotary typical for unconsolidated formations (east of I-95)
- Air-rotary typical for rock formations (west of I-95)



IS THE PROJECT SITE GEOTHERMAL FRIENDLY ?

DRILLING

Test Bores (Pre-test considerations)

- Permitting varies for well types:

- **Type 5QW** - Closed-Loop Geothermal-Water-Only Injection Well System
  This type only requires “Notification of Intent to Construct” form sent to state.

- **Type 5QM** - Closed-Loop Geothermal-Mixed-Fluid Injection Well System
  This type requires permit. Regional office of Dept. of Water Quality will conduct pre-permit inspection. Upon review by staff, permit is granted.

IS THE PROJECT SITE GEOTHERMAL FRIENDLY ?

DRILLING

Test Bores (Pre-test considerations)

- Start this process early (permits, drilling, rest period, test period, reporting)

- Site conditions: accessibility for drill rig, power source, noise restrictions, adjacent construction

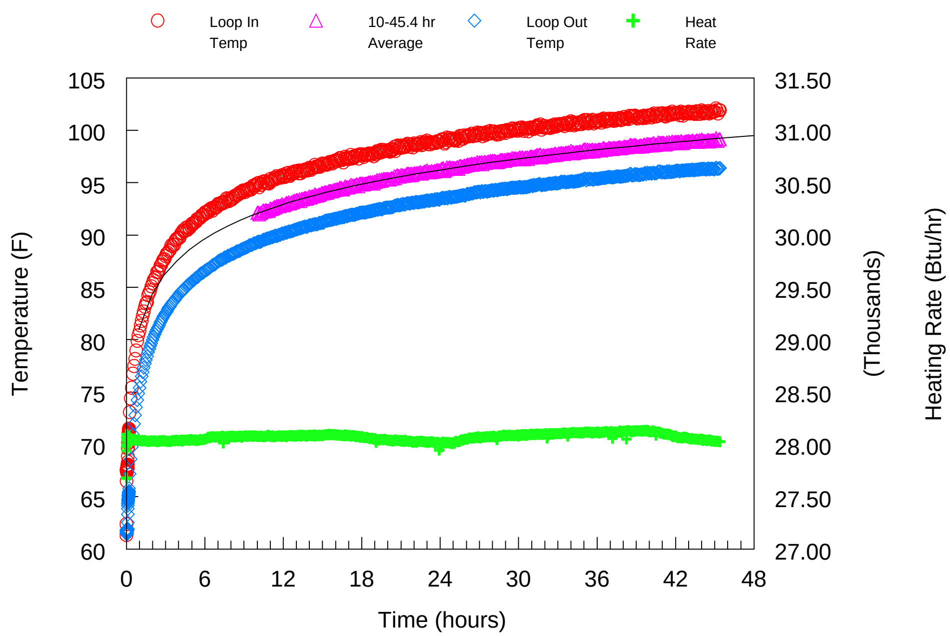
IS THE PROJECT SITE GEOTHERMAL FRIENDLY ?

TESTING

Formation Thermal Conductivity (FTC) Test

- *“A field test to determine the AVERAGE thermal conductivity of the formation throughout the entire length of the vertical bore.”*

- Also known as In-Situ Testing



IS THE PROJECT SITE GEOTHERMAL FRIENDLY ?

TESTING

Reasons

- Designing ground loop requires accurate knowledge of formation thermal properties
- Prevents over/under sizing of loop. Buildings with undersized loops result in heat pumps with reduced capacity and lower efficiencies during peak loads. Oversized loops have larger upfront cost with minimal efficiency benefit.
- Improves contractor knowledge of subsoil conditions (depth to bedrock, water production, mud seams, voids, etc.)
- Helps reduce uncertainties ($) in bid process

IS THE PROJECT SITE GEOTHERMAL FRIENDLY ?

TESTING

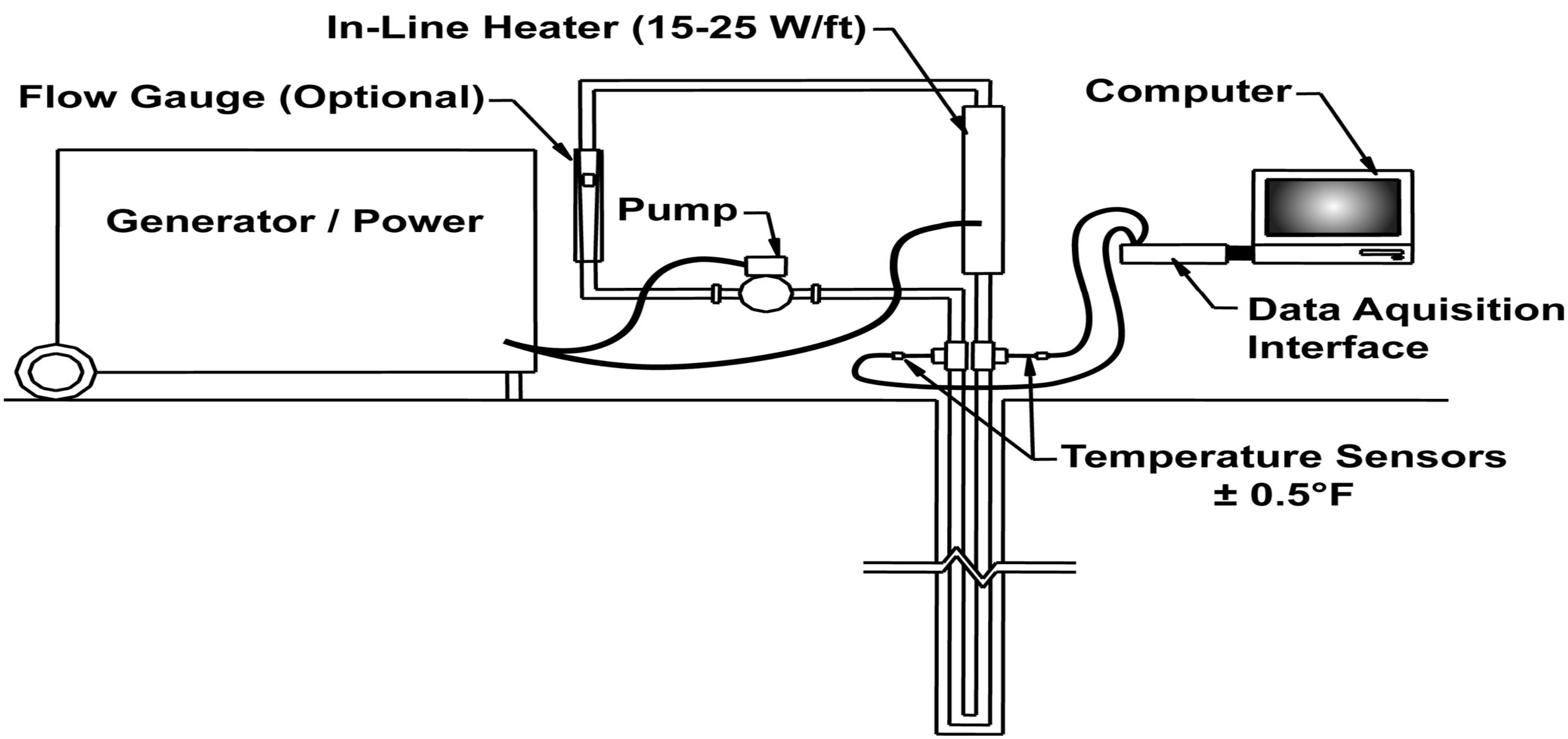
Results

- Formation Thermal Conductivity - ability of formation to transport heat
- Thermal Diffusivity – ratio of heat transport ability to heat storage capacity. Materials with high diffusivity rapidly change temperature to match surroundings
- Undisturbed Formation Temperature – average temperature of formation with depth.

IS THE PROJECT SITE GEOTHERMAL FRIENDLY ?

TESTING

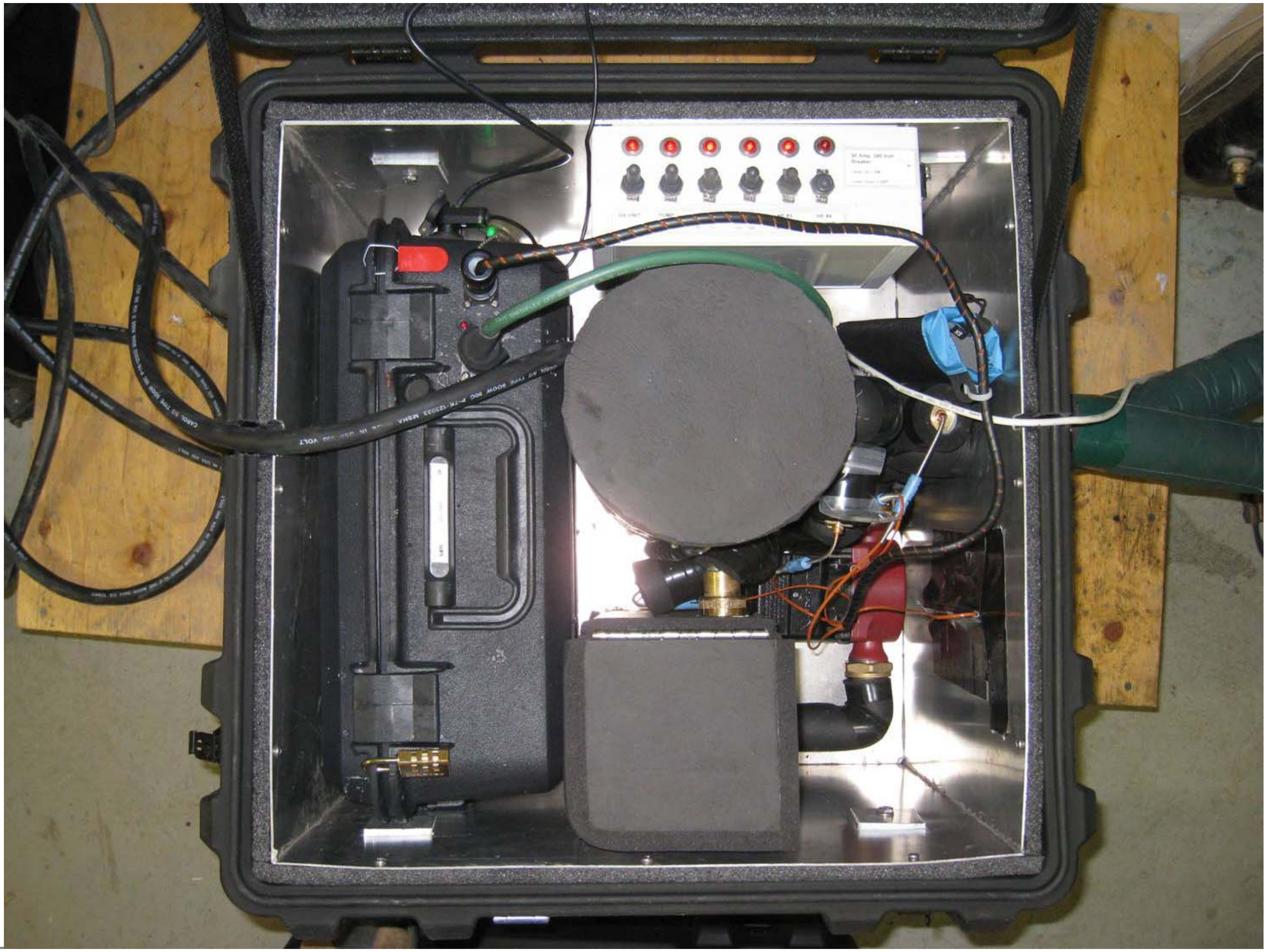
Test Rig Schematic



IS THE PROJECT SITE GEOTHERMAL FRIENDLY ?

TESTING

<u>Test Unit</u>



IS THE PROJECT SITE GEOTHERMAL FRIENDLY ?

TESTING

<u>Test Setup</u>

IS THE PROJECT SITE GEOTHERMAL FRIENDLY ?

TESTING

Example Drill Logs

Raleigh, NC (Highway Patrol Training Center)

Note: PVC casing was installed from 0-108 ft and removed at bore completion.

Drill Log ....

Red clay	0'-15'
Soft silty dirt	15'-80'
Fractured white rock with some clay seams	80'-105'
Rock (gneiss)	105'-350'

Note: The bore produced approx. 1-2 gpm water.

Elizabeth City, NC (State University Building)

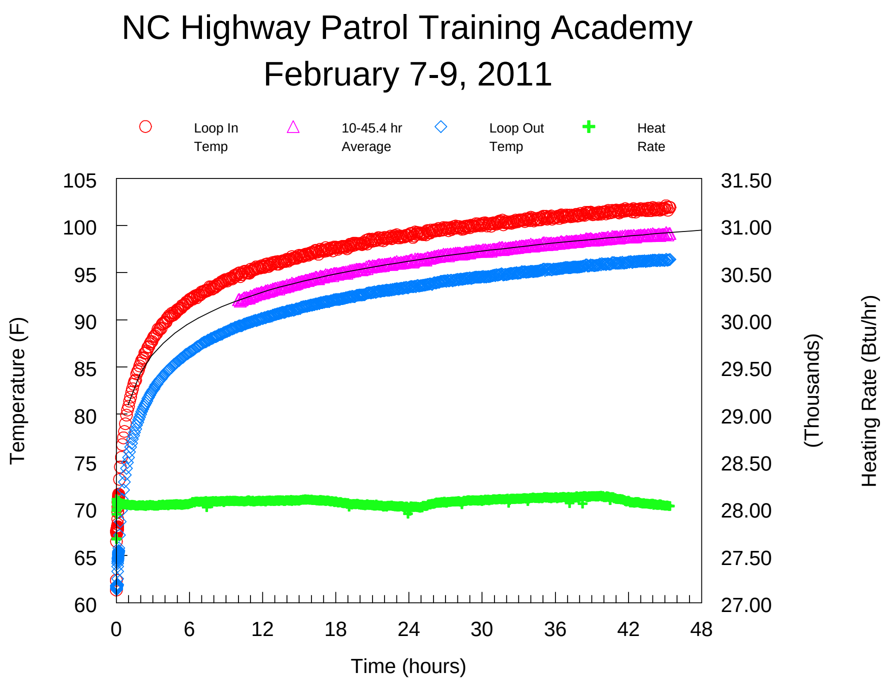
Drill Log ....

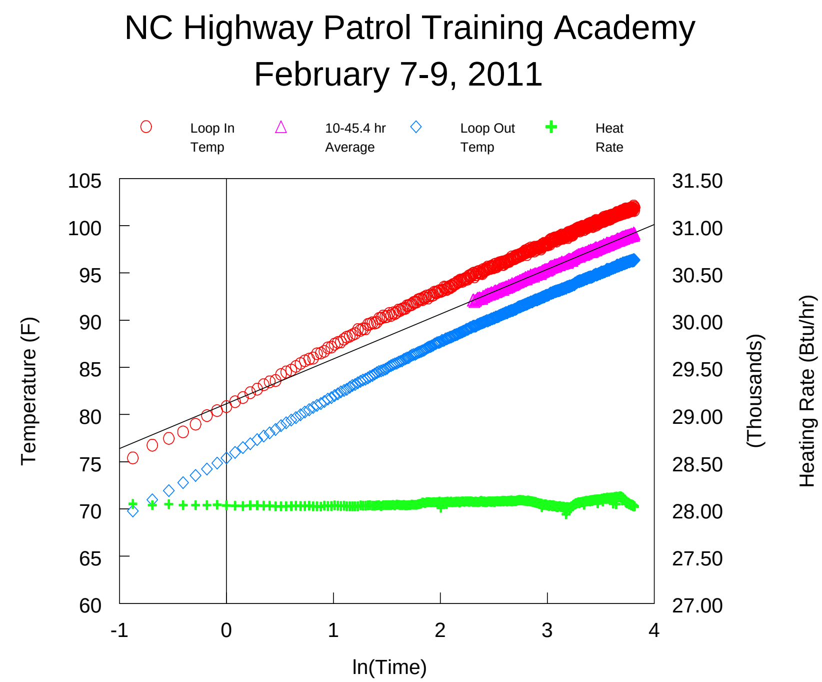
Sand / Silt mix	0'-30'
Silt / Shell rock	30'-80'
Shell rock	80'-95'
Clayey silt	95'-300'

IS THE PROJECT SITE GEOTHERMAL FRIENDLY ?

TESTING

Example Test Data/Results





IS THE PROJECT SITE GEOTHERMAL FRIENDLY ?

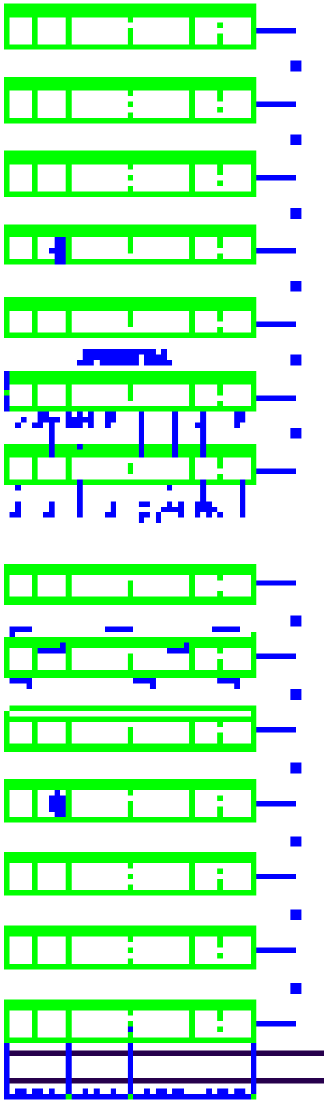
TESTING

Example Test Data/Results

	Asheville	Charlotte	Raleigh	Elizabeth City
Formation Thermal Conductivity (Btu/hr-ft-◦F)	2.03	1.25	1.34	1.04
Formation Thermal Diffusivity (ft^2/day)	1.39	0.84	0.88	0.71
Undisturbed Formation Temperature (◦F)	58.3-59	61-61.4	62	63-63.5

IS THE PROJECT SITE GEOTHERMAL FRIENDLY ?

APPLICATION



<u>Parameters for Well Field Layout</u>

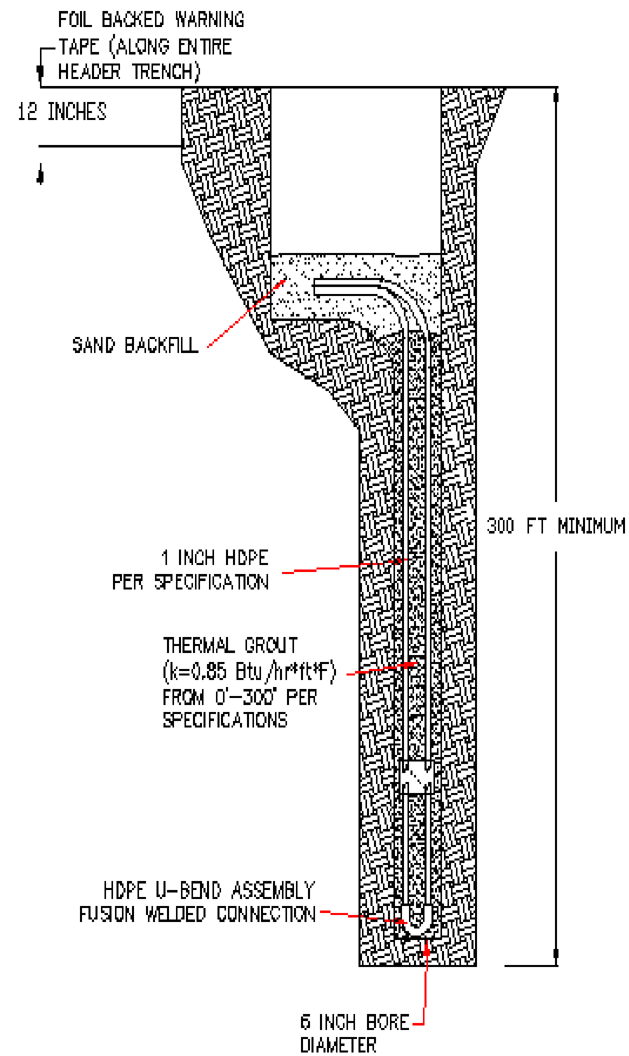
- Well depth (refer to test, what is most efficient)
- Total number of bores required
- Grout thermal conductivity
- Spacing between bores
  (20’ rule, ground water temp effect,
  drilling through adjacent bores)
- Piping sizes

IS THE PROJECT SITE GEOTHERMAL FRIENDLY ?

APPLICATION

<u>Well Grouting</u>

- First Priority: must abide by State regulations (NC Division of Water Quality, UIC Program)
- Bores should be grouted with tremie pipe from bottom to top
- Grout thermal conductivity and should be optimized with respect to performance and economics.



IS THE PROJECT SITE GEOTHERMAL FRIENDLY ?

APPLICATION

<u>Well Field Piping</u>

- High density polyethylene (HDPE)
- Heat fused – pipes are melted together
- 50 year warranty

U-Bend Pipe Diameter	Completed Bore Depth
3/4 inch	100 - 200 ft
1 inch	150 - 300 ft
1-1/4 inch	250 - 500 ft

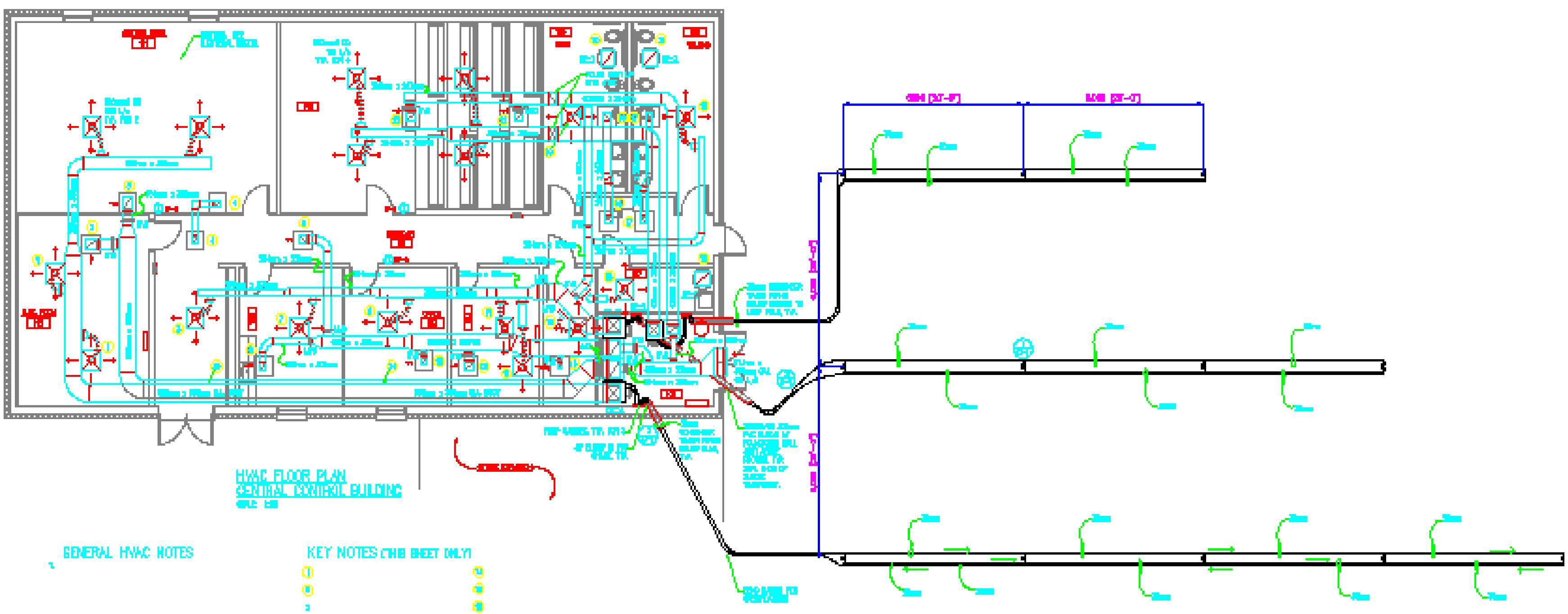
Heat Fusing

IS THE PROJECT SITE GEOTHERMAL FRIENDLY ?

APPLICATION

<u>Well Field Layout (examples)</u>

- Multiple Unitary Loops

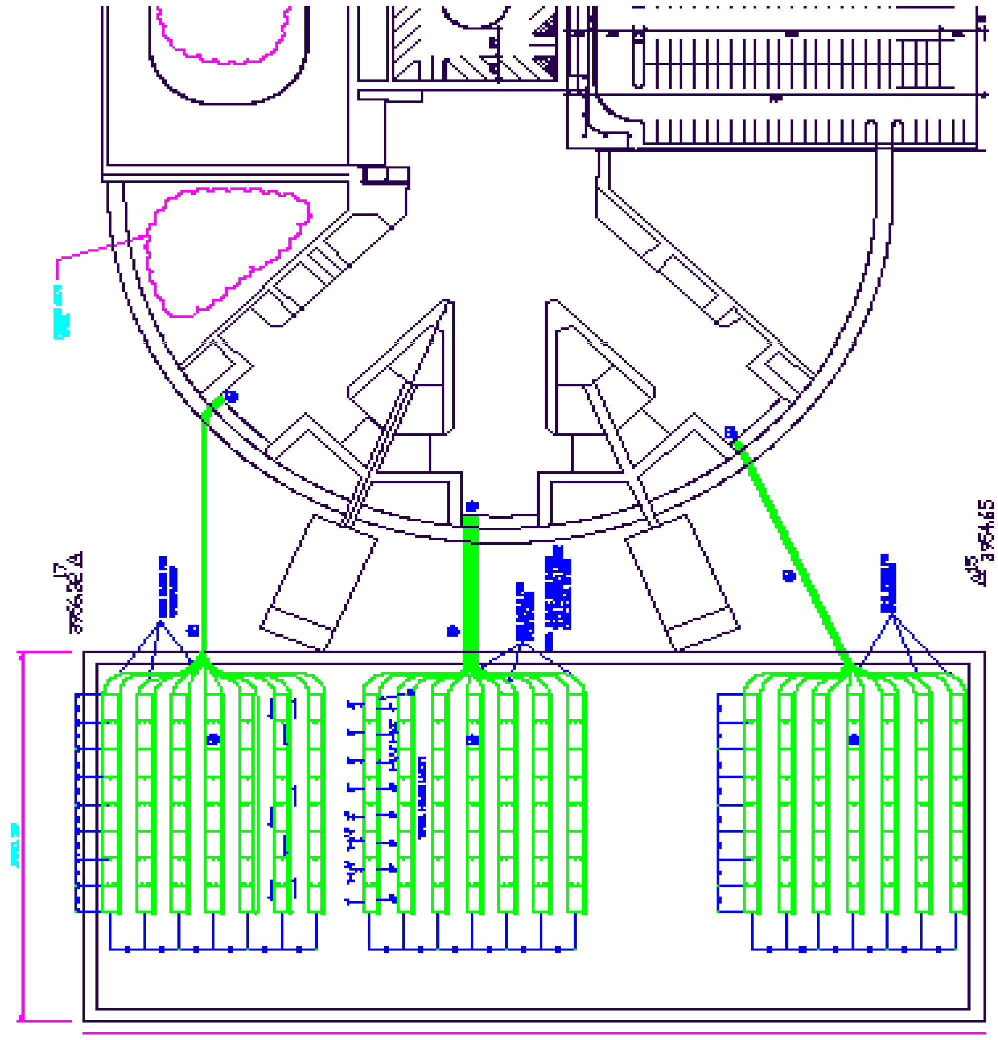


IS THE PROJECT SITE GEOTHERMAL FRIENDLY ?

APPLICATION

Well Field Layout (examples)

- Multiple Sub-Central Loops

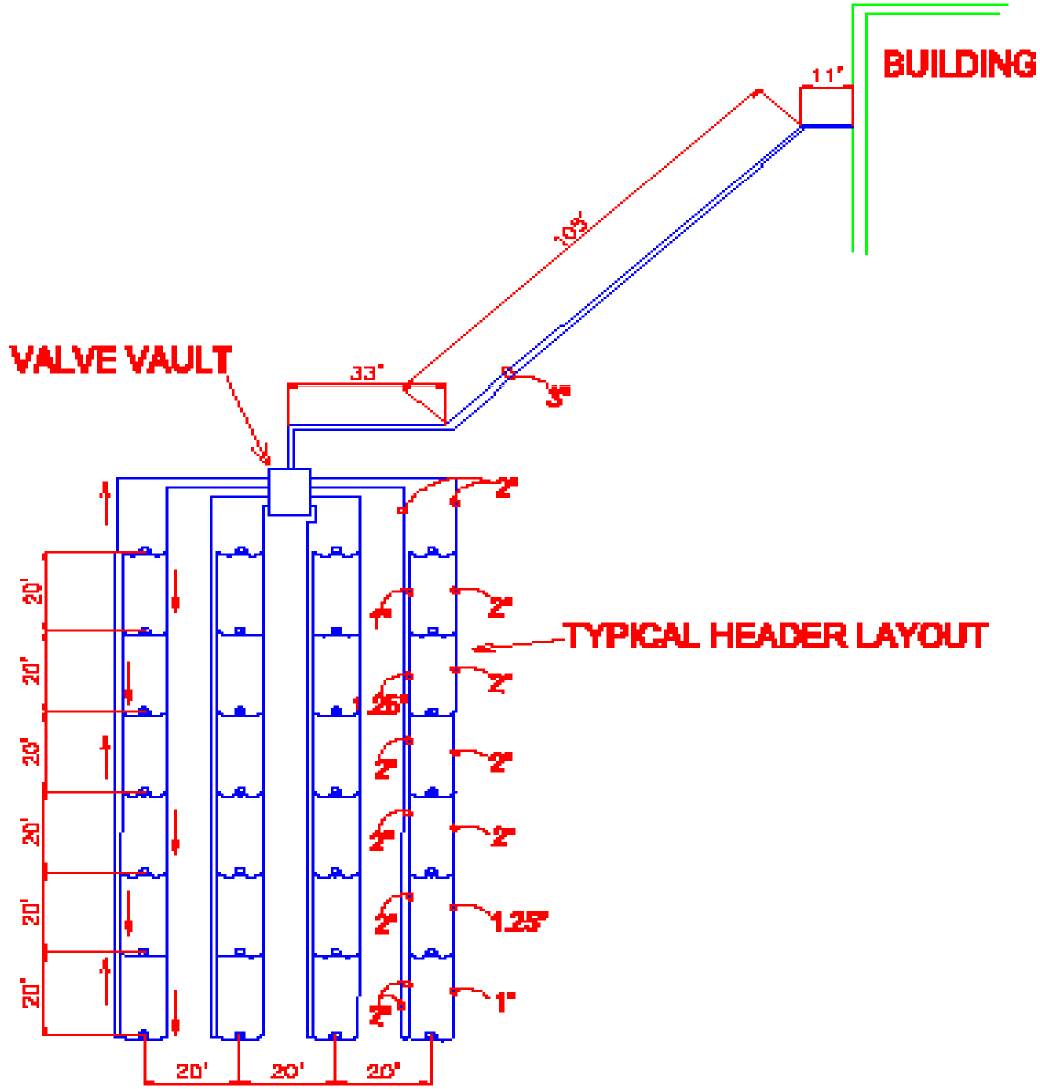


IS THE PROJECT SITE GEOTHERMAL FRIENDLY ?

APPLICATION

<u>Well Field Layout (examples)</u>

- Central Loop



IS THE PROJECT SITE GEOTHERMAL FRIENDLY ?

APPLICATION

Well Field Installation

- Using socket fusion to connect vertical loops to header piping

IS THE PROJECT SITE GEOTHERMAL FRIENDLY ?

APPLICATION

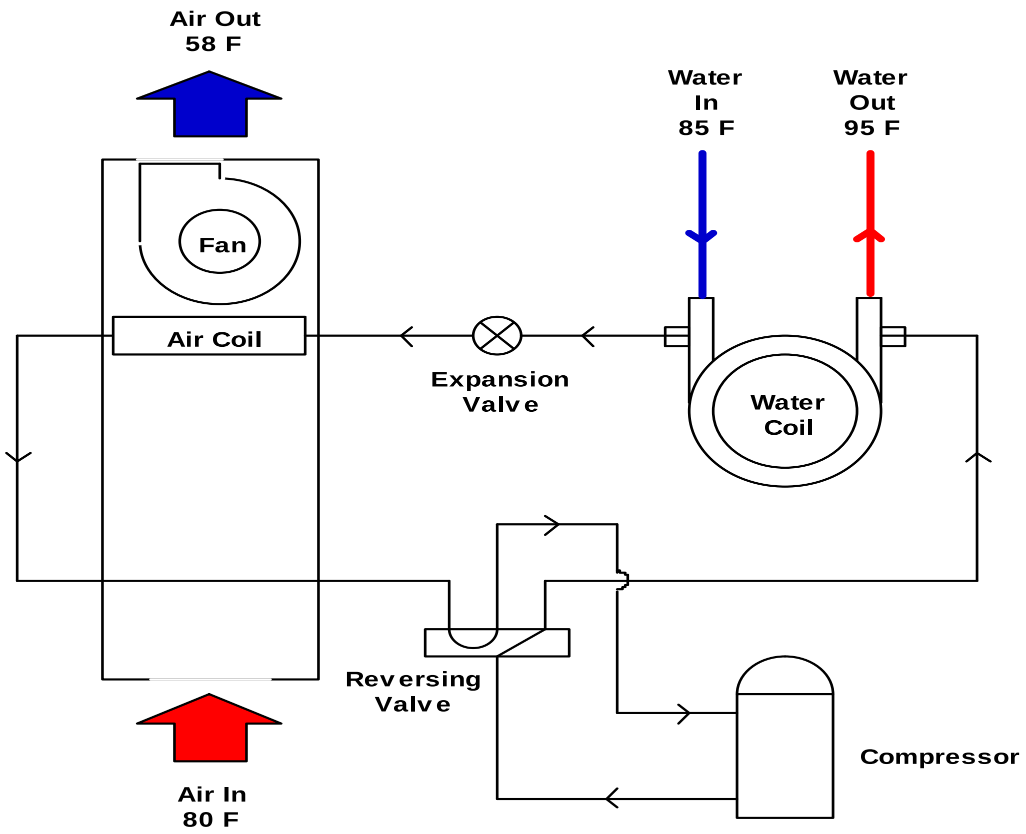
<u>Well Field Installation</u>

- Using socket fusion to connect vertical loops to header piping

SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

How Do They Operate?



Exchange Heat Between Air and Water

Heats or Cools on Demand

Operates on the Same Principle as a Refrigerator

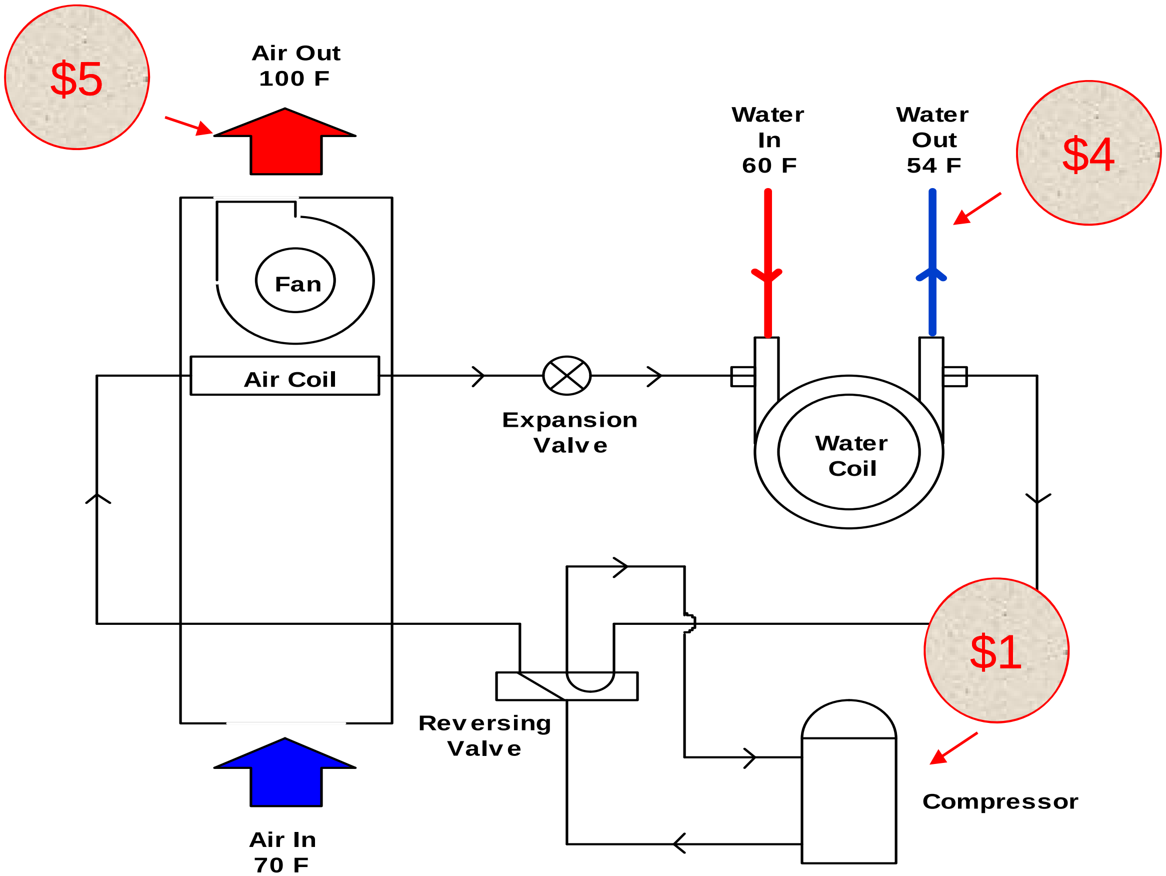
(Cooling Shown)

SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

How Do They Operate?

Moves Heat Efficiently !



$1 Worth of Electricity to Operate the Compressor and Fan

Moves $4 Worth of Heat from the Water (from other heat pumps; only in few hours from boiler in Southeast Region; “free” from geo. field)

Delivering $5 Worth of Heat into the Air

(Heating Shown)

SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

Common Equipment Types

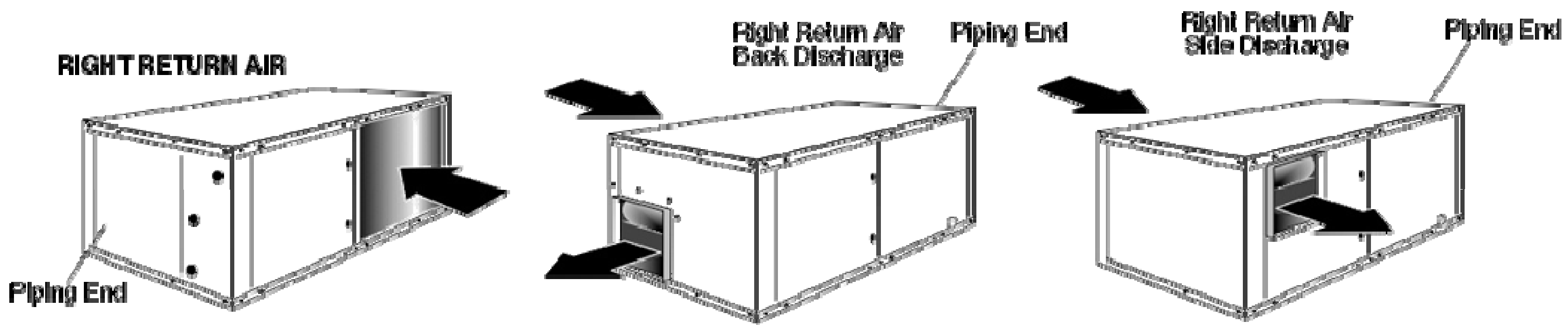
• Horizontal	½ - 10 tons
• Vertical	¾ - 25 tons
• Console	½ - 1 ½ tons
• Vertical Stacked	¾ - 3 tons
• Roof Mounted	3 - 20 tons

SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

Horizontal

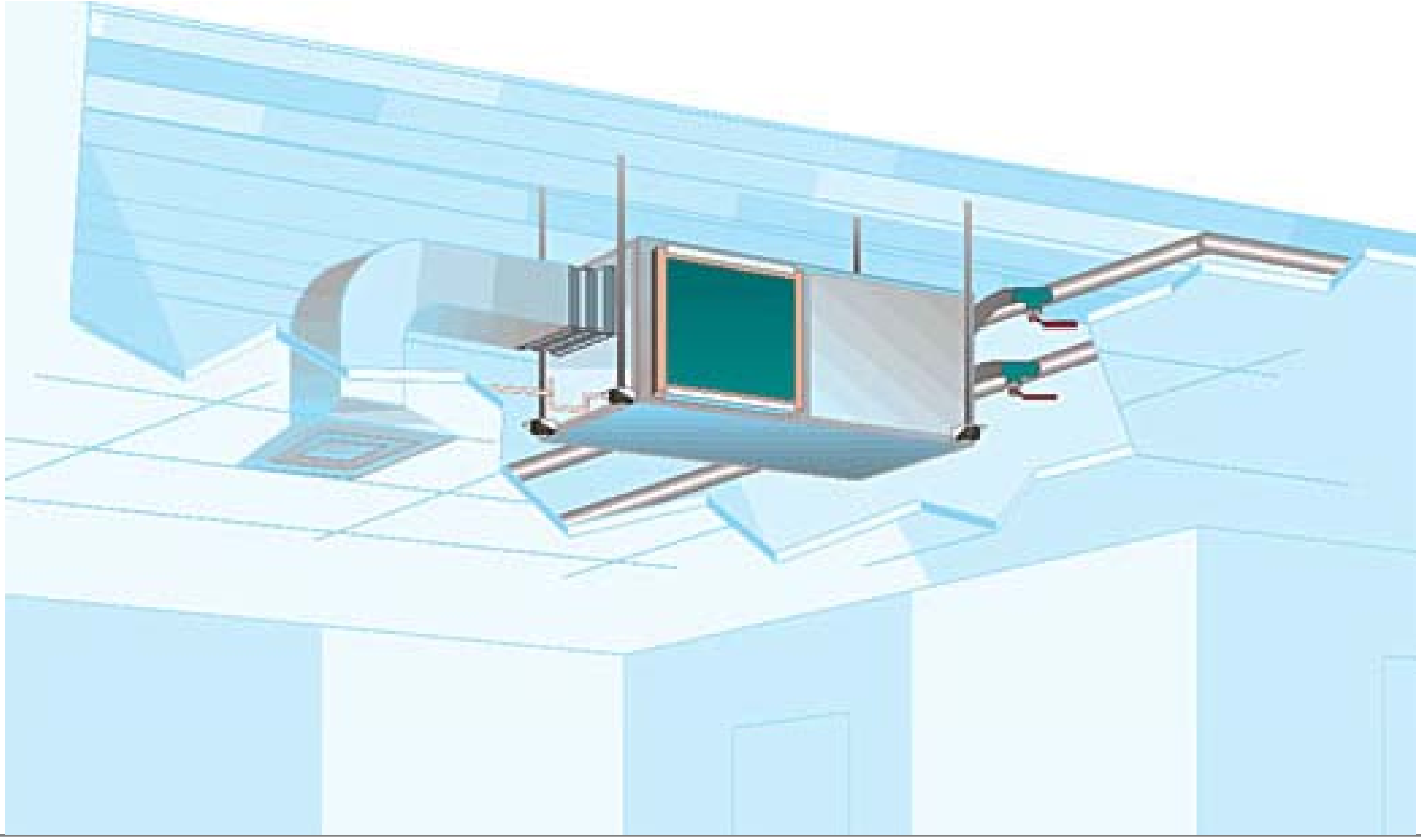
- 1/2 - 10 tons
- Typically exposed or above ceilings



SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

Horizontal

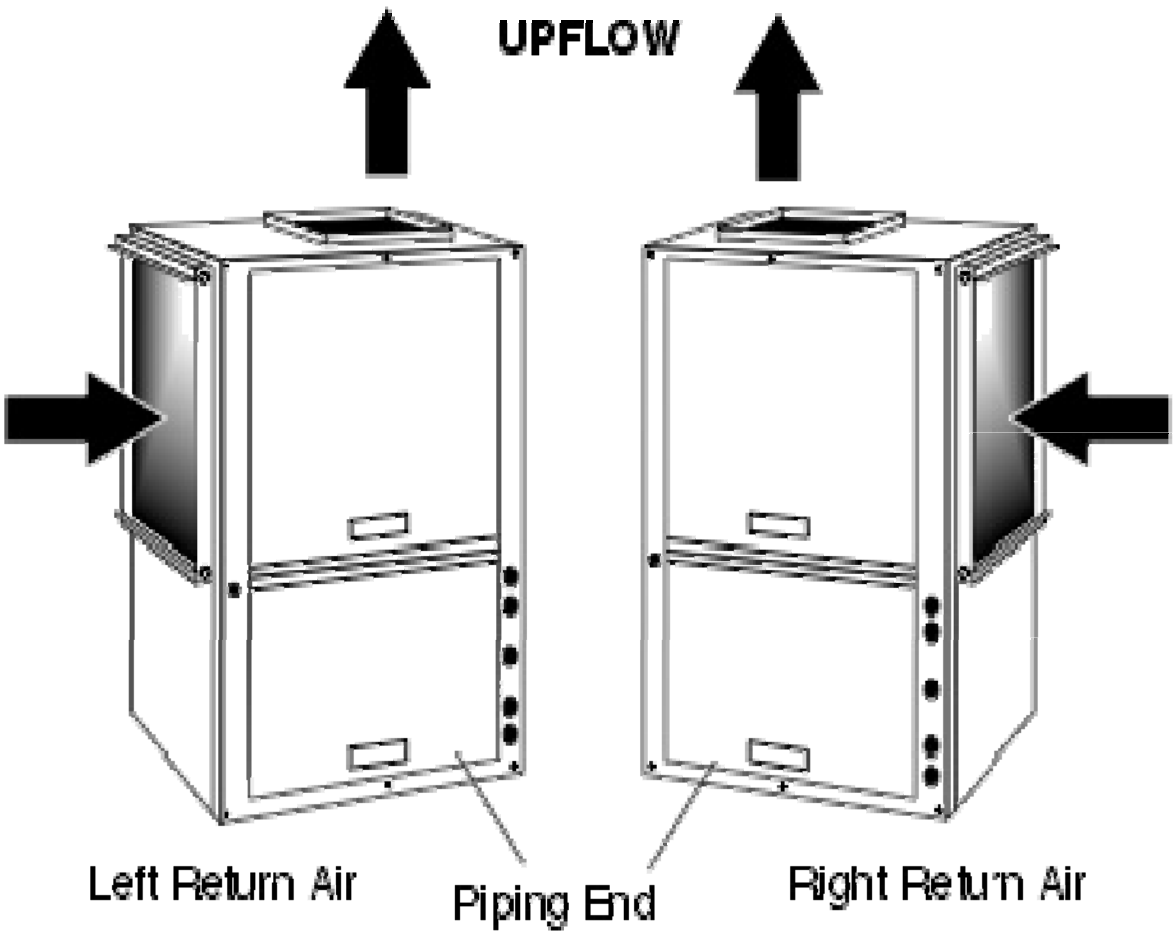


SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

<u>Vertical</u>

- 3/4 - 25 tons
- Typically in mechanical rooms or closets



WATER SOURCE HEAT PUMPS

Vertical

SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

Vertical

WATER SOURCE HEAT PUMPS

Console

- ½ - 1 ½ tons
- Low profile, finished cabinet make consoles excellent for:

  Dorm rooms
  Offices
  Corridors
  Stairwells

SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

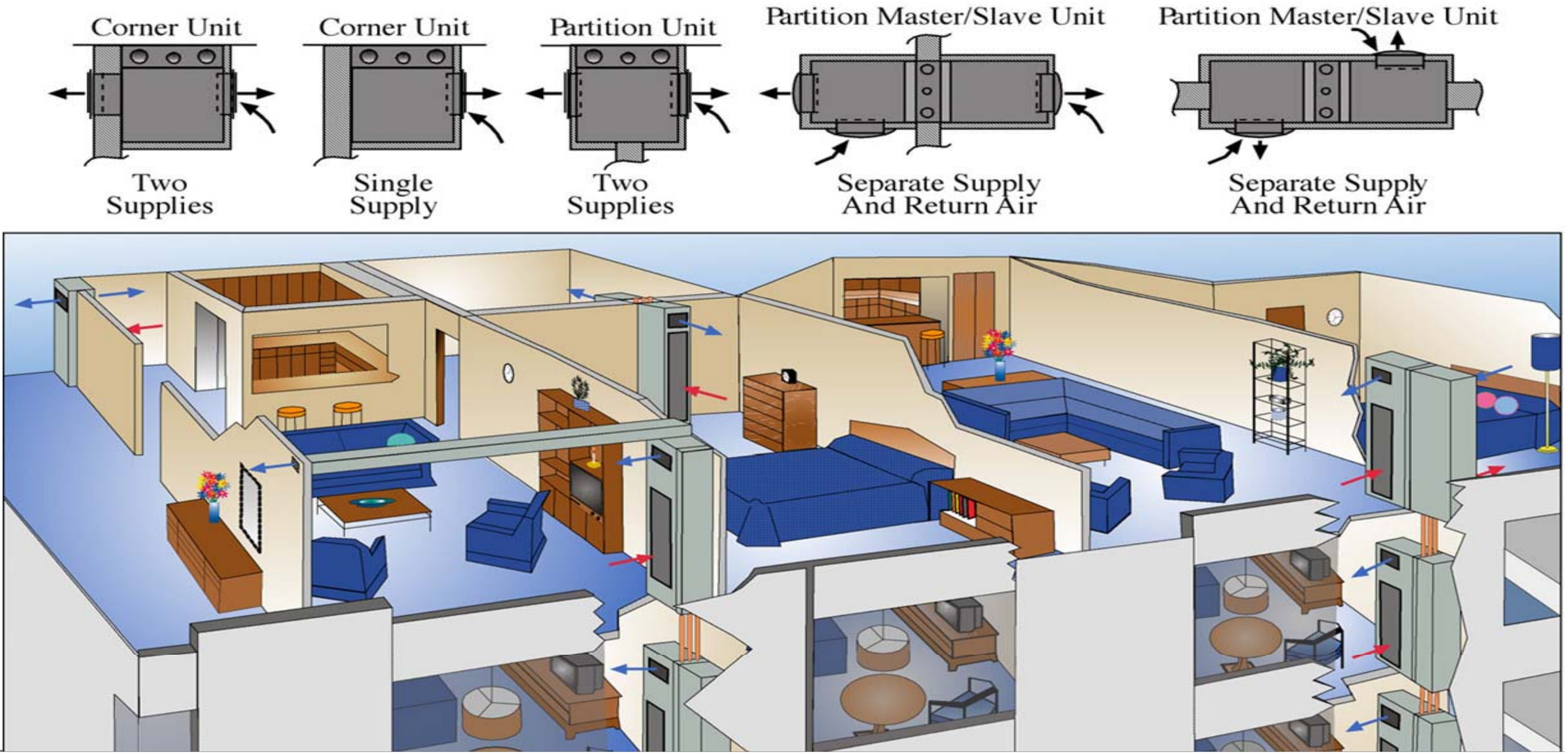
Vertical Stacked

- ¾ - 3 tons
- Versatile unit
- Built-into wall

SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

Vertical Stacked



SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

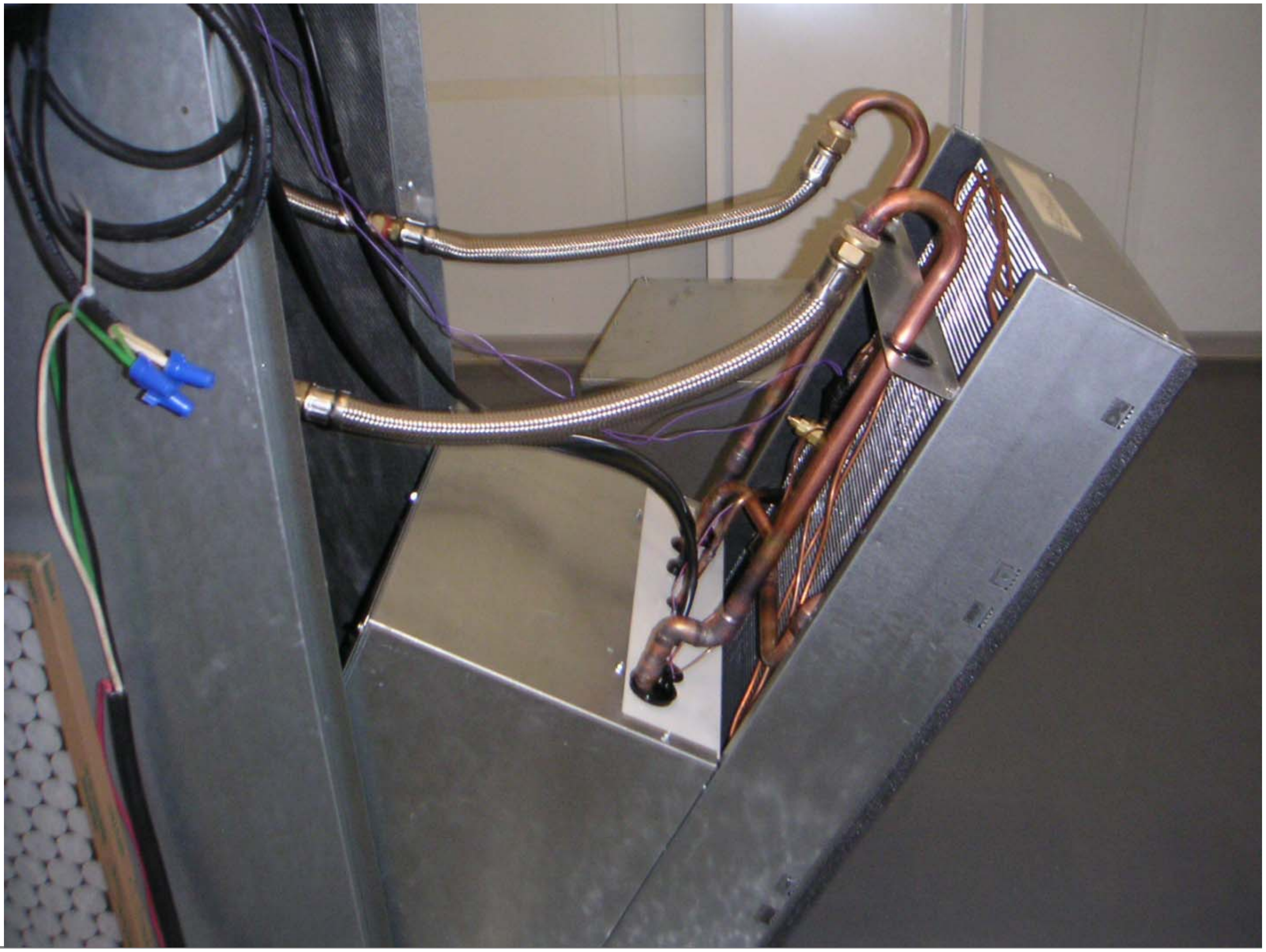
<u>Vertical Stacked</u>

SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

Vertical Stacked

•Very maintenance friendly



SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

Roof Mounted

- 3 - 20 tons

SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

<u>Equipment Ratings</u>

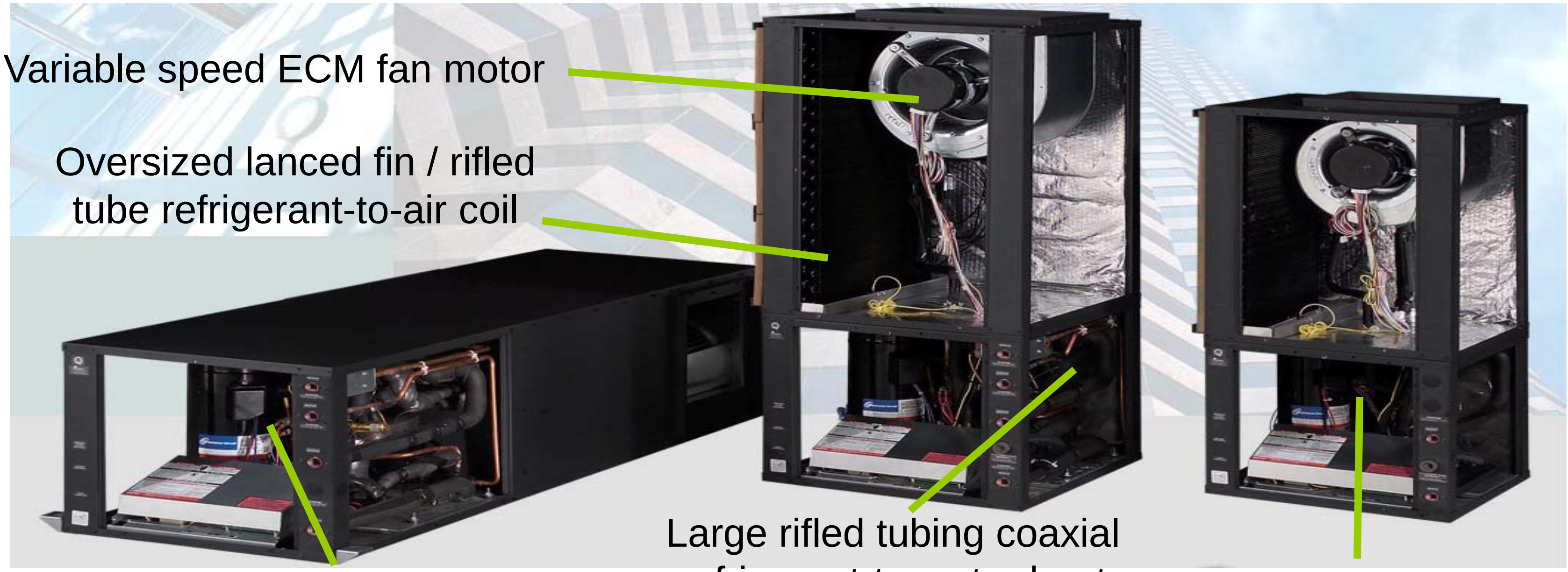
- Water side temperatures:
- 60F – 95F for boiler/cooling tower systems
- 20F – 120F for geothermal systems

SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

<u>Equipment Ratings</u>

- Enhanced construction for geothermal applications:



SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

Equipment Ratings

- Enhanced efficiency rating choices:
- 12.0 EER “Good”
- 12.5 EER “Better”
- 15.0 EER “Best”
- 20 EER* “Better than Best”
- 27 EER* “Best of the Best”

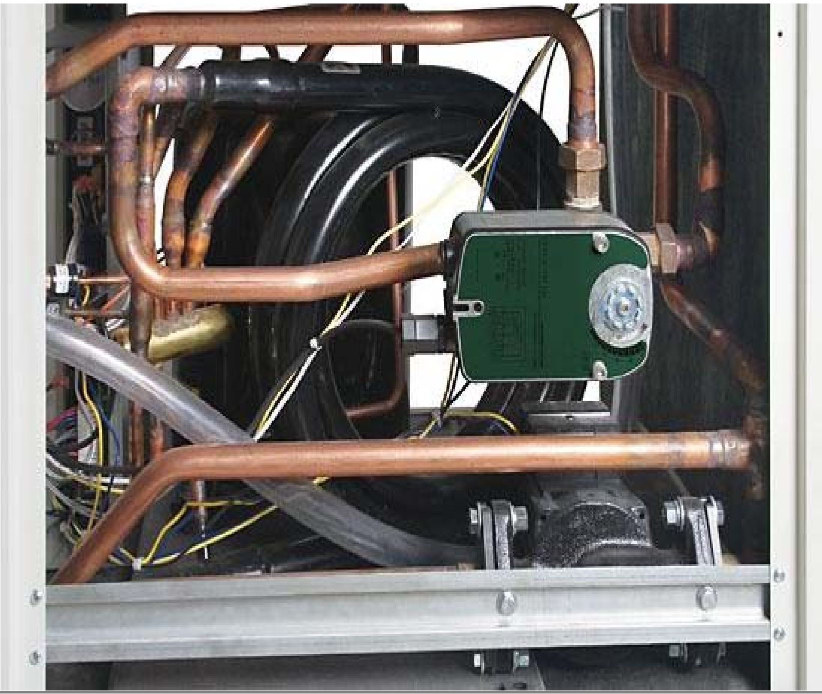
*GLHP EER ratings

SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

Performance Options

- Reduced noise (extra compressor isolation)
- Soft start variable speed fan
- Integral reheat (humidity control)
- Domestic hot water system interface



WATER SOURCE HEAT PUMPS

Outside Air

"It is an infinitely varying load condition that is sized at peak design load and must operate at all operating conditions above the design leaving air dewpoint."

SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

Outside Air

- PITFALL: “standard” heat pumps are not designed to handle 100% outdoor air
- 3 Row Coils too light for 95/78 conditions (compressor suction temperature way above design)
- Generally cannot heat air below 50 - 55º entering air temperature

SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

<u>Outside Air</u>

•US dew point temperatures

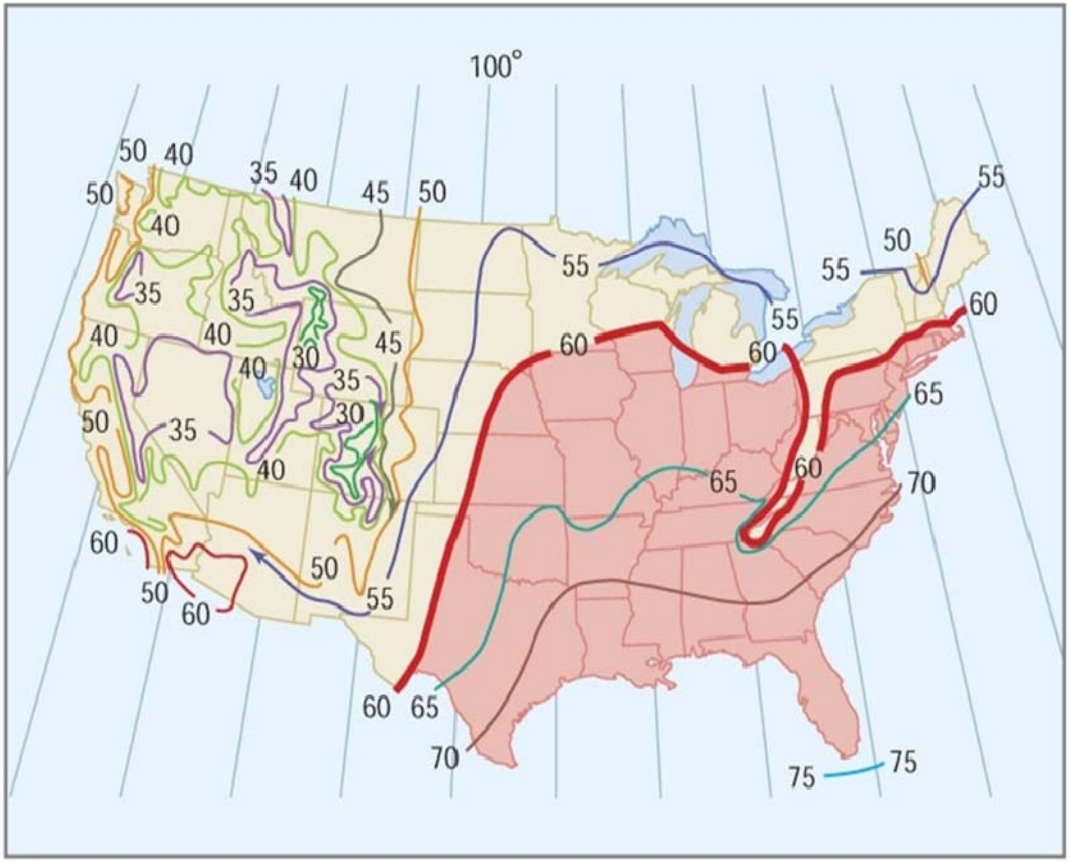


FIGURE 1. Mean dew-point temperature isolines for August (1946 to 1965).
Source: Climatic Atlas of the United States.

SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

Dedicated 100% Outside Air Water Source Heat Pump Units


VERTICAL UNIT


HORIZONTAL UNIT

SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

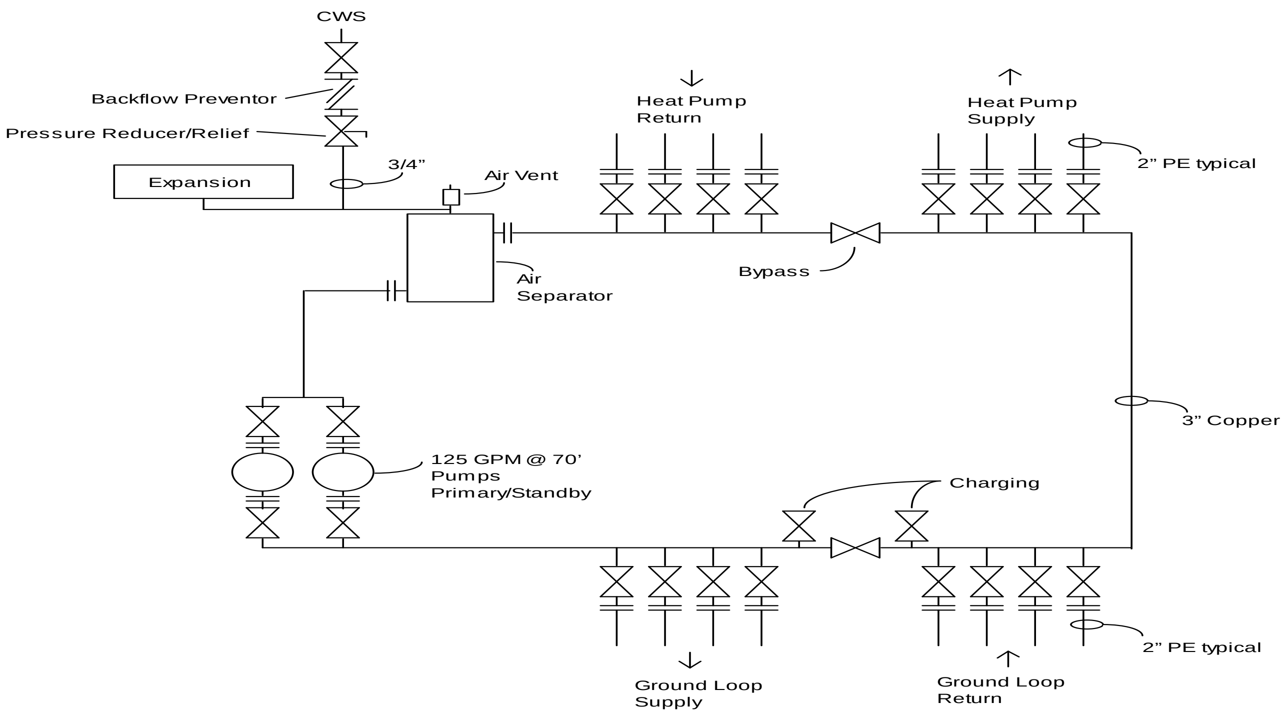
Dedicated 100% Outside Air Water Source Heat Pump Units

SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

<u>Pumping</u>

- Affects system performance
  (temperatures, flows, controllability, energy usage)



Geothermal Mechanical Room

SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

Pumping Options

- Option 1 - Redundant Alternate – Full flow pump with duplicate redundant pump in parallel (control alternately)
- Option 2 - Redundant Staged - Two pumps in parallel to handle load (lead-lag control)
- Option 3 - Variable speed pumps with solenoid valves at each unit
- Option 4 - Distributed pumping - Pumps at each heat pump with single pipe system and continuous circulation

SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

Pumping Examples

SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

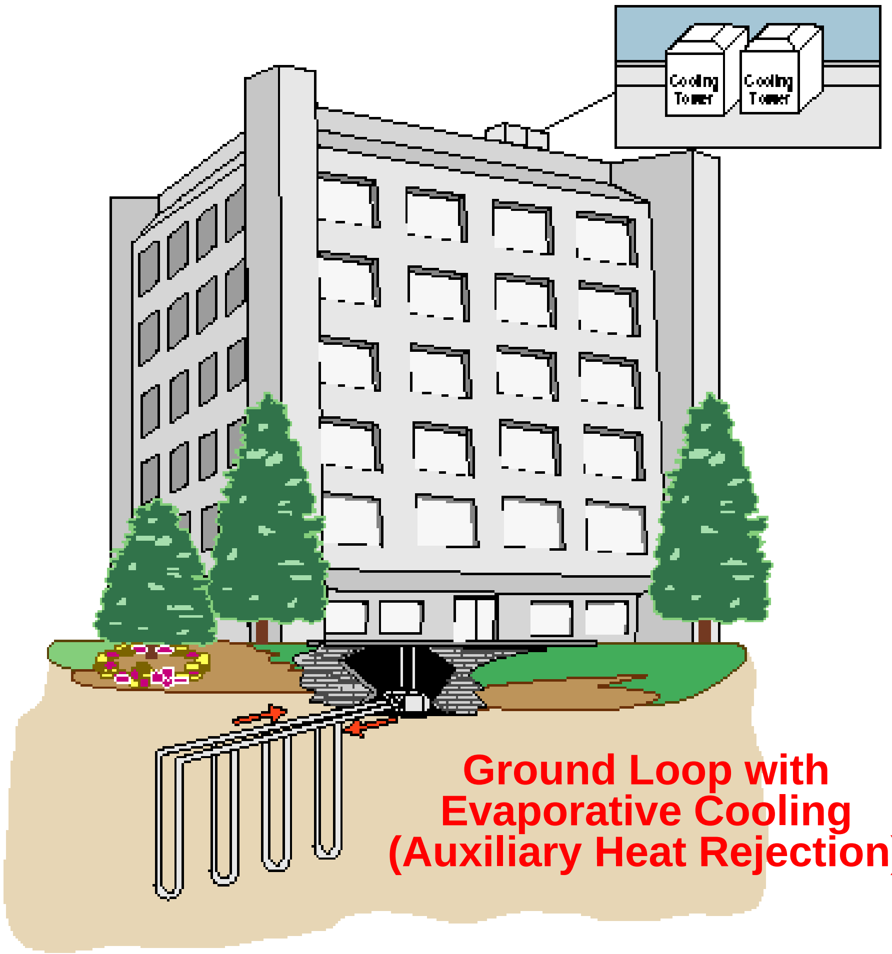
<u>Pumping Examples</u>

SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

Hybrid System

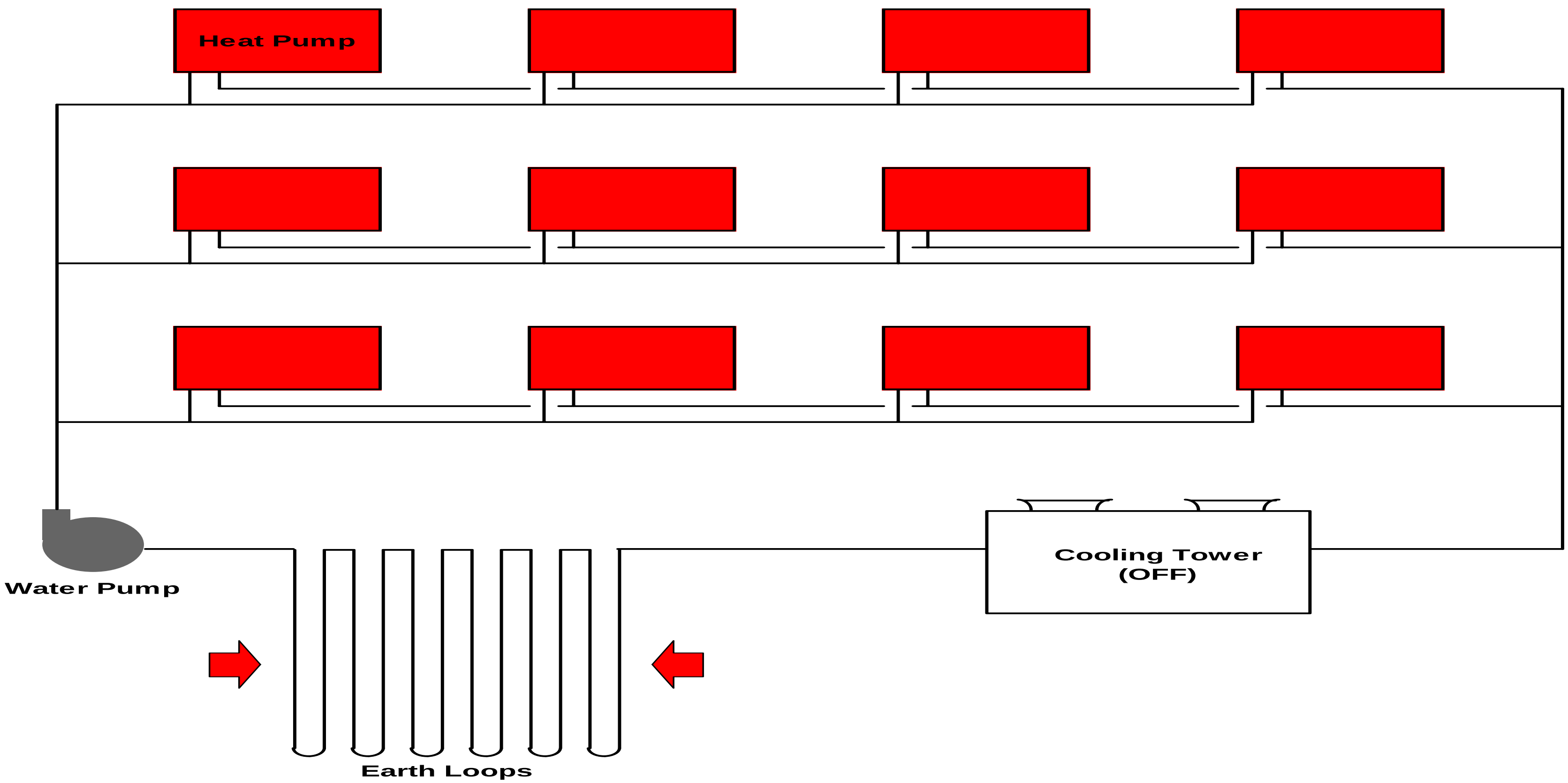
- Very cost effective initial costs and life cycle costs
- In most moderate and southern climates, hybrid geothermal systems have a lower life cycle cost than other options
- Reduces well field size and cost



SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

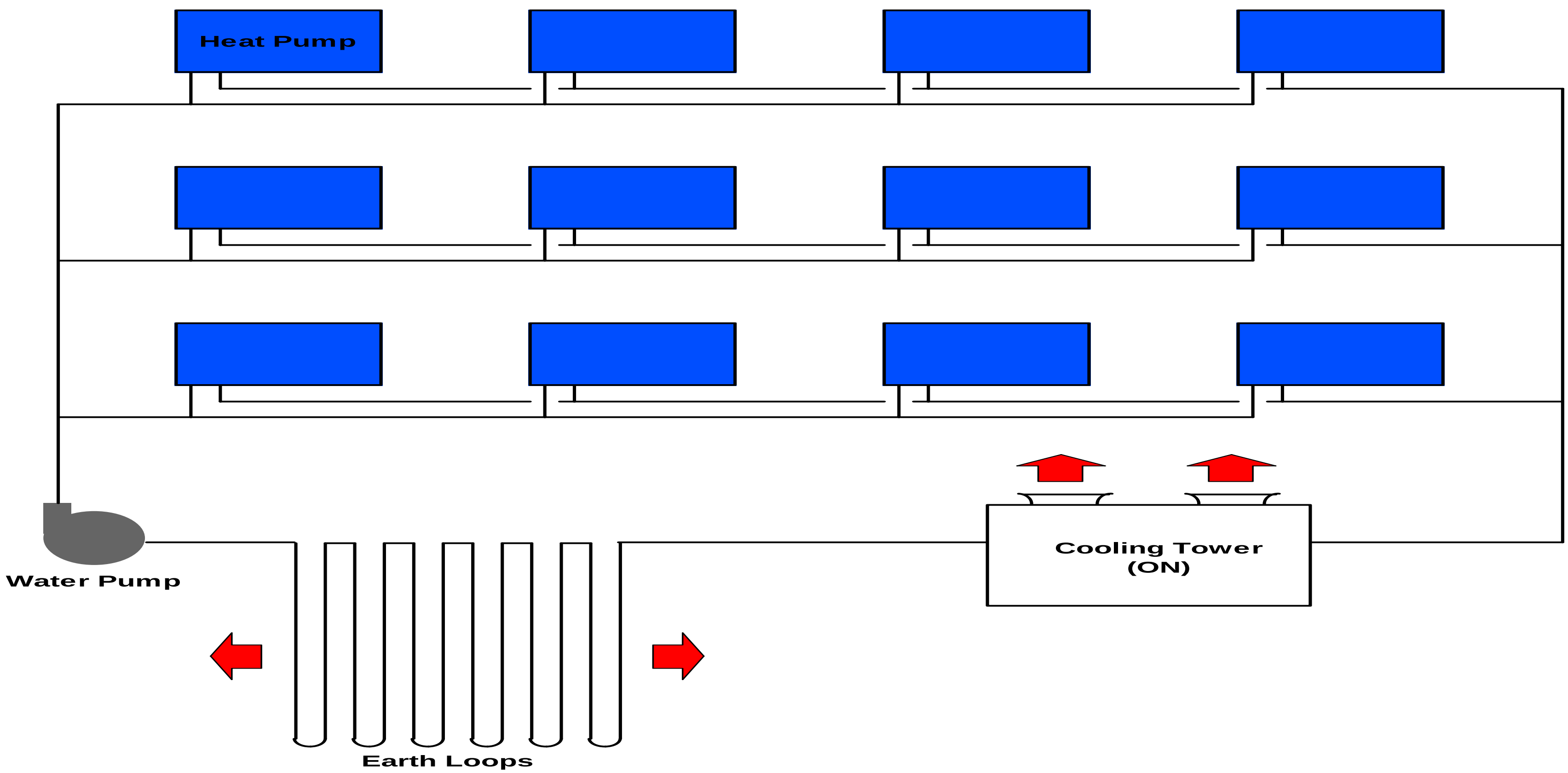
Hybrid System – Winter Operation



SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

<u>Hybrid System – Summer Operation</u>



SYSTEM EQUIPMENT

WATER SOURCE HEAT PUMPS

<u>Maintenance (3 Important Points)</u>

- **Proper water flow** - ± 5% Automatic Flow Regulators or Pressure Independent Control Valves on WSHP's.
- **Clean water (Clean Heat Transfer Surfaces)** – Combination Air Separator / Particle Separator or small side stream separator for continuous cleaning of water.
- **Proper air flow** – Regular Scheduled Air Filter Replacement and/or differential pressure alarm across air filter.

IS GROUND SOURCE A GOOD CHOICE FOR YOU ?

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EXAMPLE PROJECT

<u>Life Cycle Cost Comparison</u>

- New 8600 SF Visitor Center
- Energy Simulation Software: eQuest DOE2.2 Software
- Well Design Software: Gaia GLD2010
- Baseline: Air Cooled Heat Pumps (ASHRAE 90.1)
- Alternate: Geothermal Heat Pump
- First Cost is incremental to Baseline

IS GROUND SOURCE A GOOD CHOICE FOR YOU ?

EXAMPLE PROJECT

Well Test Data (different locations)

City	Depth	Thermal Conductivity	Thermal Diffusivity	Formation Temperature
Asheville	450	2.03	1.39	58
Charlotte	300	1.25	0.84	61
Raleigh	300	1.73	1.2	61
Elizabeth City	300	1.04	0.71	63

IS GROUND SOURCE A GOOD CHOICE FOR YOU ?

EXAMPLE PROJECT

Asheville

Air cooled HP:

Energy Performance	60.8 kBtu/sqft/yr
Utility Cost	$10,275
30 Life Cycle Cost	$843,549

Geothermal:

Energy Performance	36.8 Kbtu/sqft/yr
Utility Cost	$6,310
30 Life Cycle Cost	$726,623
SIR Value	2.58

IS GROUND SOURCE A GOOD CHOICE FOR YOU ?

EXAMPLE PROJECT

Charlotte

Air cooled HP:		
	Energy Performance	59.2 kBtu/sqft/yr
	Utility Cost	$10,012
	30 Life Cycle Cost	$915,581
Geothermal:		
	Energy Performance	37.2 kBtu/sqft/yr
	Utility Cost	$6382
	30 Life Cycle Cost	$772,903
	SIR Value	3.92

IS GROUND SOURCE A GOOD CHOICE FOR YOU ?

EXAMPLE PROJECT

Raleigh

Air cooled HP:

	Energy Performance	61.5 kBtu/sqft/yr
	Utility Cost	$10,402
	30 Life Cycle Cost	$915,172

Geothermal:

	Energy Performance	37.2 kBtu/sqft/yr
	Utility Cost	$6380
	30 Life Cycle Cost	$783,844
	SIR Value	6.72

IS GROUND SOURCE A GOOD CHOICE FOR YOU ?

EXAMPLE PROJECT

Elizabeth City

Air cooled HP:

Energy Performance	64.6 kBtu/sqft/yr
Utility Cost	$10,913
30 Life Cycle Cost	$963,222

Geothermal:

Energy Performance	36.6 kBtu/sqft/yr
Utility Cost	$6281
30 Life Cycle Cost	$763,327
SIR Value	8.50

IS GROUND SOURCE A GOOD CHOICE FOR YOU ?

EXAMPLE PROJECT

Conclusions

- Geothermal Heat Pump Systems are significantly more efficient than Air-to-Air Heat Pump Systems
- Drilling cost is more important to payback than thermal conductivity, although, both are important factors.

IS GROUND SOURCE A GOOD CHOICE FOR YOU ?

CONSIDERATIONS

<u>Challenges</u>

- Limited zoning capabilities
- Heat pump unit noise must be considered in their placement.
- Higher first cost
- Requires well field installation expertise

IS GROUND SOURCE A GOOD CHOICE FOR YOU ?

CONSIDERATIONS

Advantages

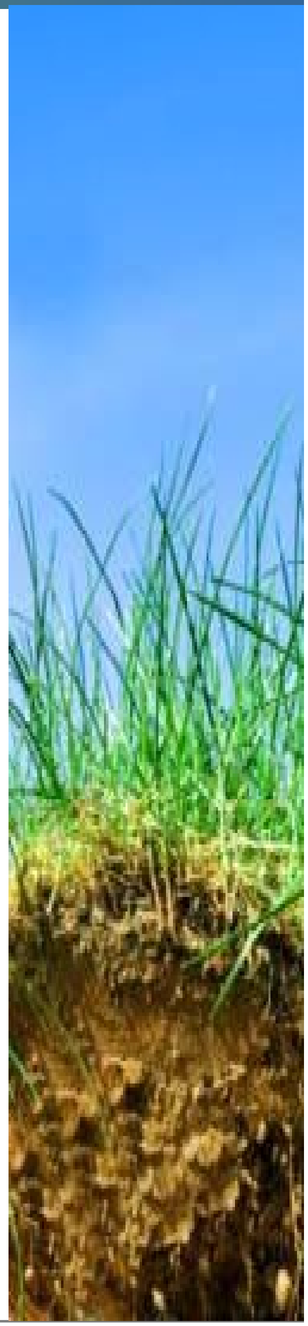
- Improved Energy Efficiency
- Water is a better heat transfer medium (requires 90% less transport energy than air)
- Heat or cool on demand, during or after hours, regardless of season, regardless of what other zones are doing
- Failure of one unit does not affect any others

IS GROUND SOURCE A GOOD CHOICE FOR YOU ?

CONSIDERATIONS

<u>Advantages</u>

- Piping typically does not require expensive insulation
- Basic thermostat is all that is required (easily adapts to BMS control)
- No equipment outside (improved aesthetics)
- Simple maintenance (smaller uncomplicated units are easy to service or remove and exchange if required)



SUMMARY

SUMMARY

WHAT HAVE WE LEARNED ?

- Heat pump basics
- Geothermal basics
- How to mange site design
- Equipment offerings
- Performance factors
- Considerations for your next project

THANK YOU FOR YOUR TIME