

Geothermal Research, Education & Awareness

“The Mill”

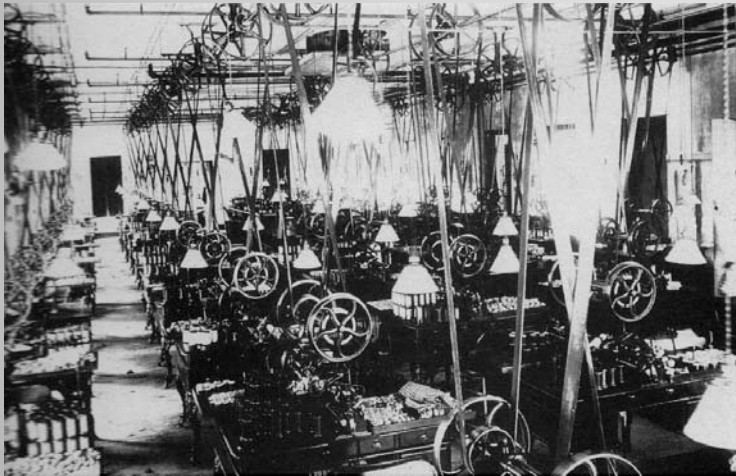
Northampton Massachusetts



“The Mill”

A Brownfield to Brightfield Story

1830's Inception



150,000+SF
Rich Early American History

Education / Awareness

Application Evaluation & Research

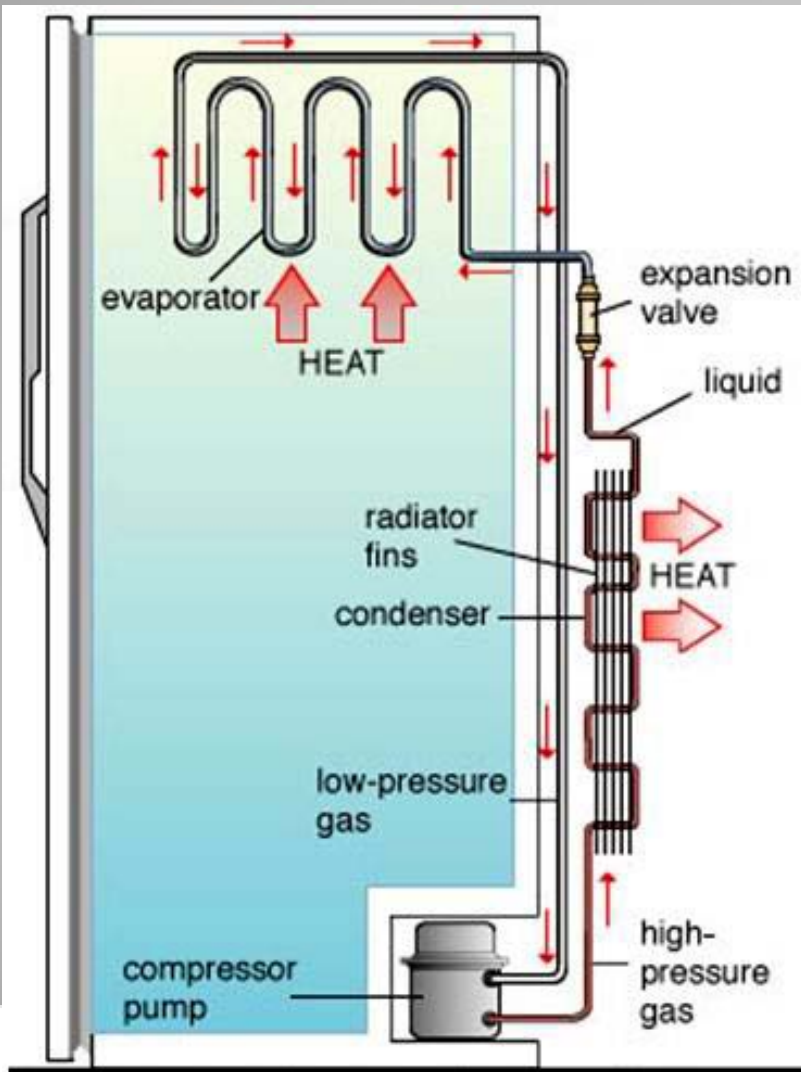
- **Geothermal System comparative analysis**
 - Direct Exchange & Water Based & Other exchangers
- **Geothermal Grout**
 - Thermally enhanced cementitious grout
- **Alternative Ground Energy Transfer System**
 - Concentric tube earth energy transfer system
 - Kelix Thermocoupler
- **Data Acquisition and Control**
 - Real time, “on-line Internet” monitoring system
 - Database build, polling to one minute, monthly cumulative
- **Alternative Energy Systems**
 - CHP Natural gas fired microturbine-geothermal hybrid & alternative energy systems

Alternative Energy

Our Goals

- Develop learning facilities
- Develop curricula for alternative energy technologies
 - Greenfield Community College
 - Holyoke Community College
 - Asnuntuck Community College
 - Piedmont Community College
- Develop alternative energy workforce
- Improved system manufacturing / cost reduction

Household Refrigerator



- Compressor**

Turns refrigerant into hot gas

- Radiator**

Fins on back of refrigerator allow gas to cool and return to a liquid

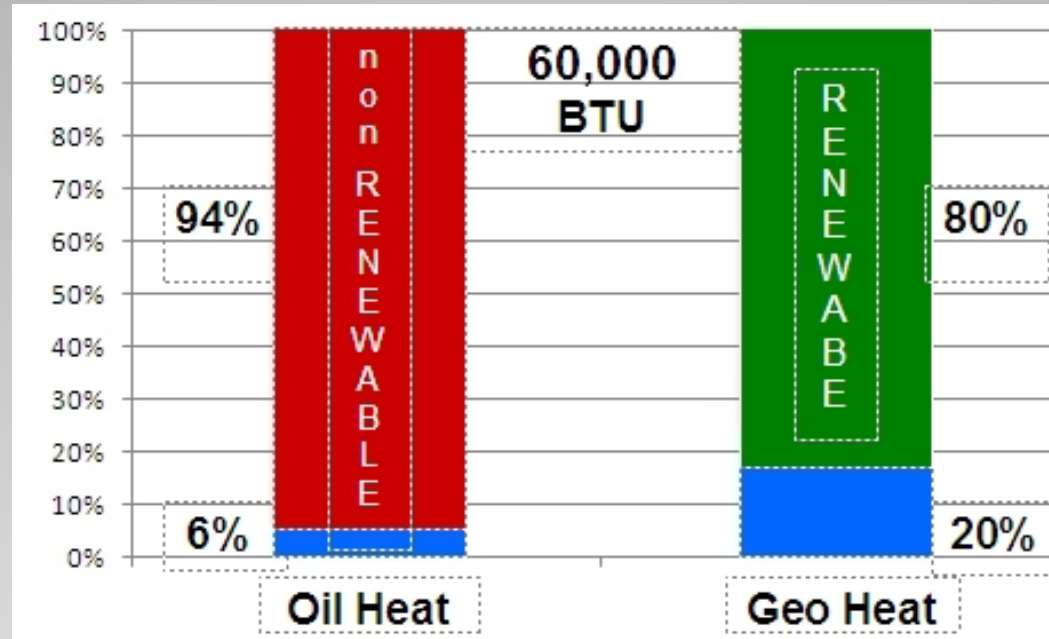
- Evaporator**

Coils inside refrigerator allow liquid to expand taking on heat from food/drink

- Back to compressor**

Low pressure gas is returned to compressor to start process over again

Renewable Energy GEO Comparison



- Red = Energy from combustion
- Blue = energy presumably from public power
 - Must work toward 100% renewable energy
- Green = Renewable (Sun's) energy in Earth

\$\$ Cost to Install

	New 2000SF Good Construction		Retrofit 2000SF Good Construction	
	36000 BTUh / 3 Tons		42000 BTUh / 3.5 Tons	
	Fossil	Geo	Fossil	Geo
System Heat/Cool	\$8,000.00	\$24,000.00	\$10,000.00	\$28,000.00
Duct System	9,000.00	9,000.00	14,000.00	14,000.00
Chimney	4,200.00	0.00	0.00	0.00
Storage Tank	1,800.00	0.00	0.00	0.00
	\$23,000.00	\$33,000.00	\$24,000.00	\$42,000.00
ARRA 30% Tax Credit		-9,900.00		-12,600.00
	23,000.00	23,100.00	24,000.00	29,400.00
Cost/Ton	\$7,666.67	\$7,700.00	\$8,000.00	\$9,800.00

Types of Geothermal

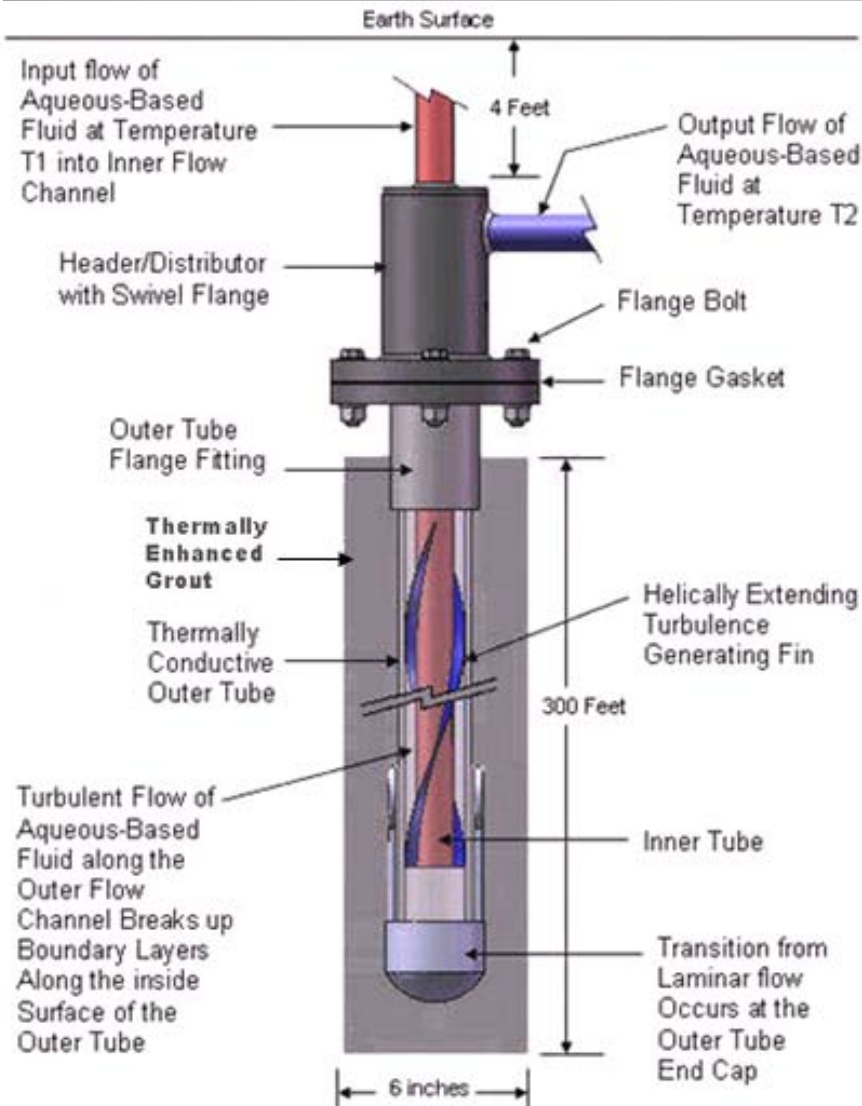
- Open Loop
 - Water to water (pump n dump)
 - Standing Column
- Closed Loop
 - Pit
 - Trench
 - Bore
 - Straight pipe, U-Loop, Slinky
 - Geo Plate
 - Other (i.e. concentric tube-in-tube)

U-Loop



- Industry standard U-Loop
 - Two x 500' x 1.25" HDPE
 - 20' separation
- Ethanol water mix
- Bentonite sand grout

Alternative Water Kelix Design



- Concentric tube heat exchangers (Kelix Thermocouple) can reduce drilling depth by more than 50% (and costs by ~10%)
- One 306 foot Kelix can provide up to 5 Tons of heating/cooling

Drilling DX Boreholes

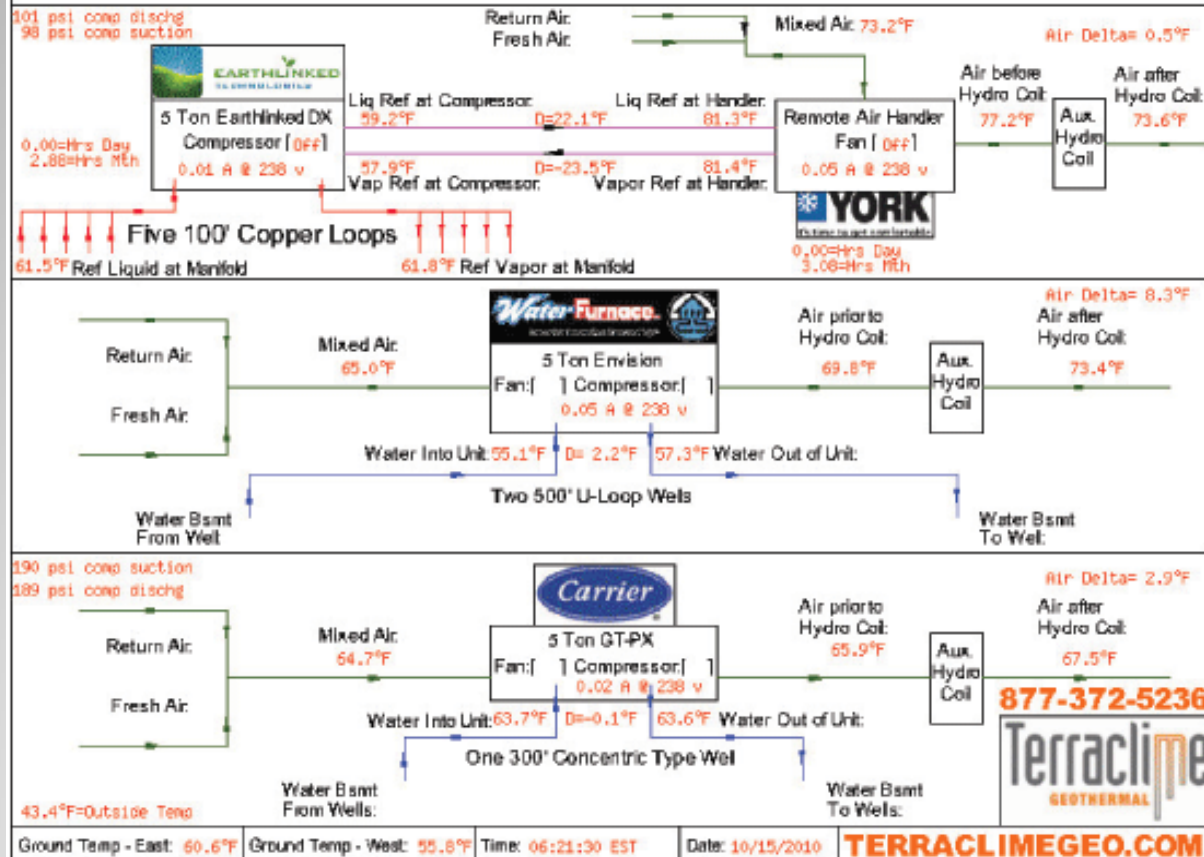


- Five 100- foot holes, 3" diameter
- Geo Supergrout
- Copper Earthloops
- One day to complete

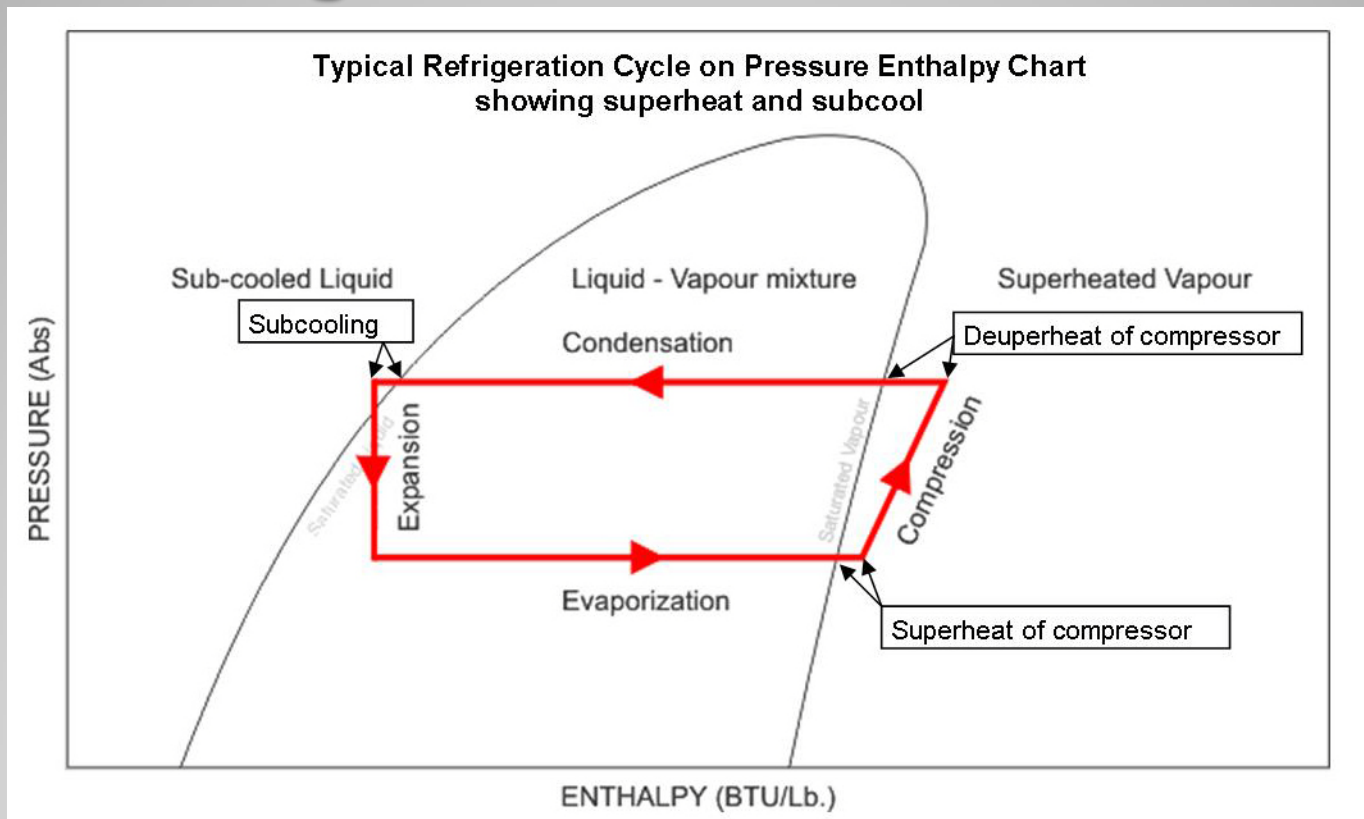
Mill Internet Instrumentation

system.png

ECS - NONOTUCK OFFICE - NORTHAMPTON, MA



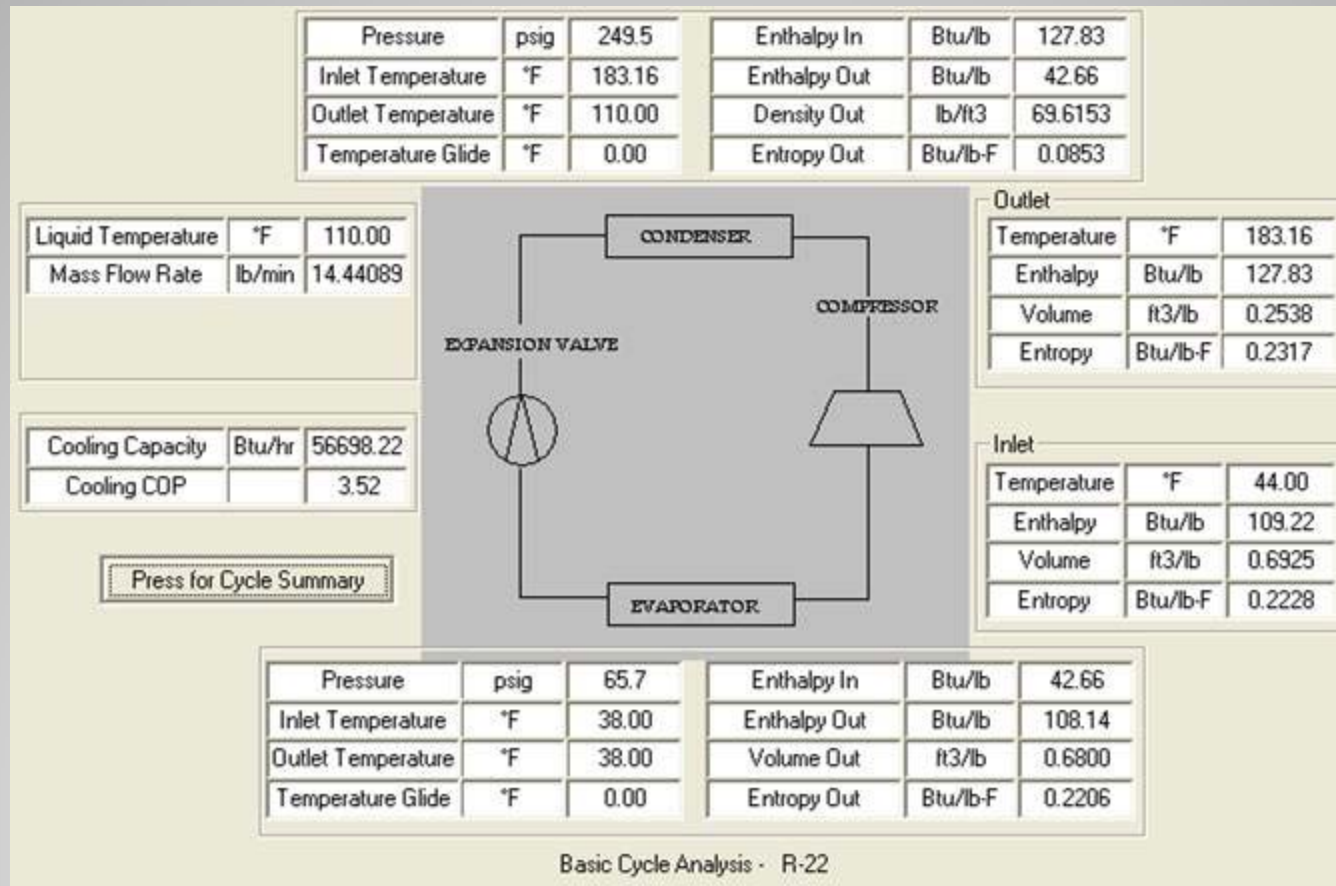
Pressure/Enthalpy System Diagram



Mill Data Internet Presentation

www.WELServer.com/WEL0201/

How do we measure performance?



Lessons Learned

- Reputable Manufacturers
- Installation Practices
- Customer Expectations
- There are no easy short-cuts
 - All engineers, technicians, contracted trades and field managers

Very Promising Future

- Electric Eel
 - 500-600V at 1 amp
- Nobel Prize Chemistry 2010
 - Developing tools for Molecular Architecture
 - New Refrigerants?
- Photovoltaic from Spinach – EPA Research Center
 - “To date, we have successfully manufactured working chlorophyll sensitized solar cells using chlorophyll from spinach leaves.”

My Favorite

- Hydrogen from Termites
- 90% efficient
 - Cellulose into sugars, CO_2 , CH_4 and 65% H – Hydrogen
- One piece of paper into 2 liters of Hydrogen
 - Drive a fuel cell car 6 miles



Terraclime
GEO THERMAL

Terraclime
GEO THERMAL

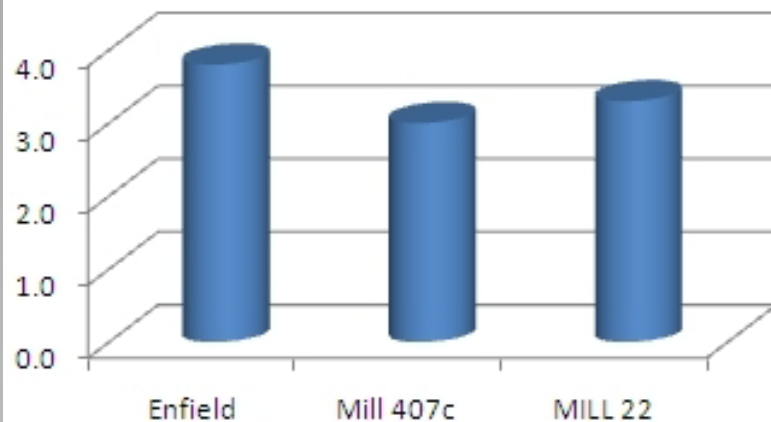
Installing KELIX



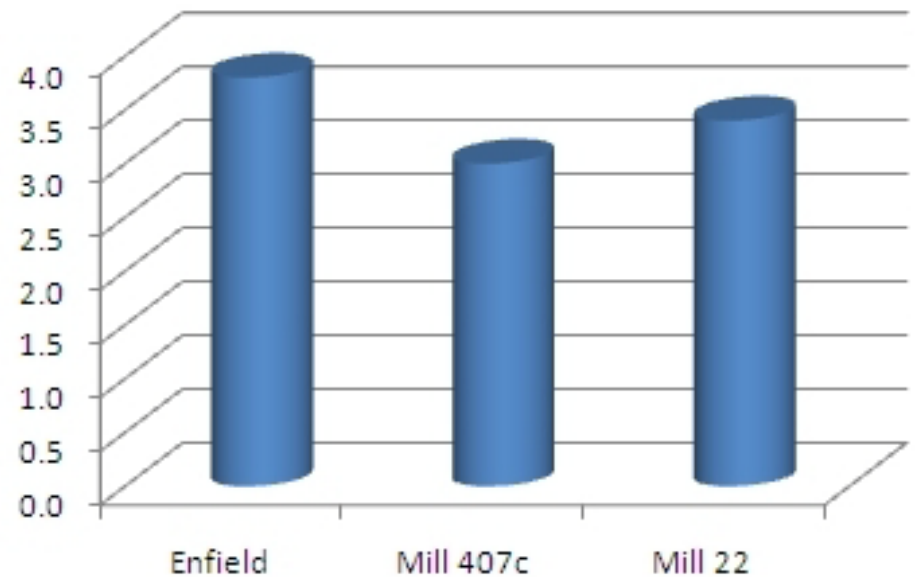
- One 306-foot borehole, 6" diameter
- Geo Supergrout
 - Cementitious TC=1.0
- 4" diameter outer casing
- 1.5 days to complete
- 5 Tons Total

DX (Direct Exchange)

COP (heating)

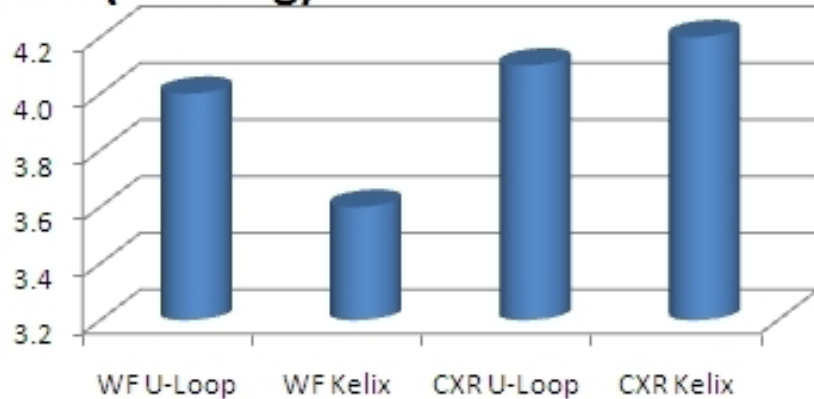


COP (cooling)



Water (25% Ethanol)

COP (heating)



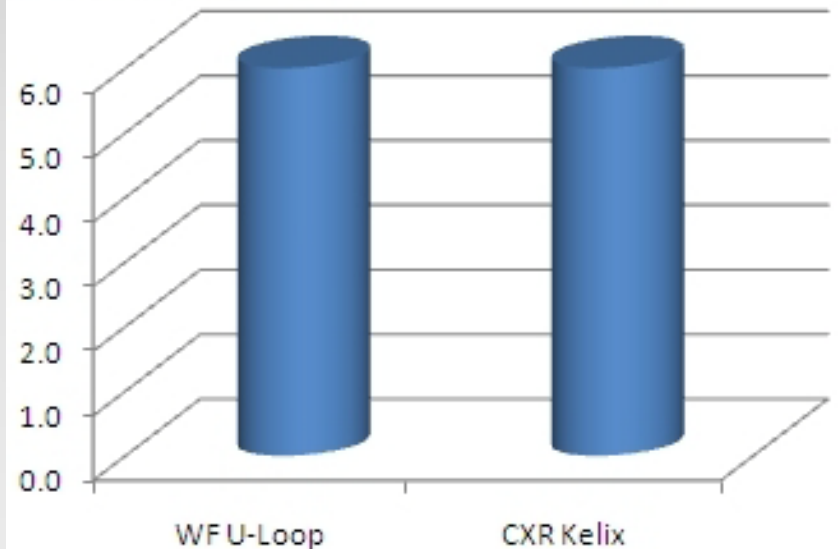
(ground systems interchangeable
with geothermal systems)

COP

3.5 – 4.1 (heating)

5.5 – 6.1 (cooling)

COP (cooling)



Mill Water Ground Loop Performance Summary

U-Loop	Keilx
U-Loop / Kelix manifold selectable either system	
•Standard drilling conventions	•Shallow hole, same ~ diameter
•Standard grouting <ul style="list-style-type: none"> •Sand / Silica 	•Easier grouting <ul style="list-style-type: none"> •High TC cementitious
•Used conservative 200'/Ton	•Used 306' targeting 5 tons
	•May deliver up to ~10% more heat / unit power
•Proven technology	•Extensive use not proven

Refrigeration Properties

Basic Cycle Summary

Mean Evaporating Temperature	°F	38.00
Mean Condensing Temperature	°F	117.00
Compressor Isentropic Efficiency	%	70.00
Compressor Displacement	ft ³ /min	10.00
Cooling Capacity	Btu/hr	56698.22
Heating Capacity	Btu/hr	73741.70
Mass Flow Rate	lb/min	14.44089
Power	Btu/hr	16111.46

Calculated Mean Evap. Temp.	°F	38.00
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Evaporating Pressure	psig	65.7
Condensing Pressure	psig	249.5

Cooling COP		3.52
Heating COP		4.58
Subcooling	°F	7.00
Superheating At Heat Exchanger	°F	0.00
Superheating At Compressor Inlet	°F	6.00

Geothermal Demonstration Site

- 5000 sq ft space, 3 separate heating/cooling systems differing geothermal technologies
 - One DX (Direct Exchange) system
 - Two Closed Loop Water systems
 - Conventional U-Loop & developmental Kelix
 - Room for additional earth system concepts
- Hands-on access for customers / gate keepers to see how the technology works.
- WEL (Web Energy Logger) web-based data acquisition system.

XX-System Performance Summary

Mill Systems		Residential Systems	
DX	Performance negatively impacted by refrigerant and building distribution layout	Enfield, CT DX 3 Tons	Superb heating & cooling & hot water ~75% cost savings
WF	Excellent performance Two stage compressor benefits demonstrated	Ware, MA Water 3.5 Tons	Very good heating & cooling ~70% cost savings
Carrier	Excellent performance Two stage R410a benefits Lower power draw	Farmington, CT DX 14 Tons	4 Units closed coupled heating & cooling & hot water 3 hydronic/air & 1 hydronic/potable water ~75% cost savings

XX-Mill Systems Performance Summary

DX	Modification Progression
COP Heat ≤ 3	<ul style="list-style-type: none">•Original installation, R407c•Pressure Oscillations due to component sizing mismatch, refrigerant characteristics
COP/EER Cooling ~3.3/11.3 Cooling capacity 5 Tons confirmed	<ul style="list-style-type: none">•R407c changed to R22•Flow control changed•Glide eliminated•System pressure losses remain due to distribution & volume

Mill Systems Performance Summary

Water Based Systems

Water Systems	Comments
Carrier COP/EER cooling $\leq 6/20+$	<ul style="list-style-type: none">•R410a Two-Stage compressor option provides max performance benefit by rejecting condensing heat @ 90F into ground @ 56F operating in 1st stage
WF COP/EER cooling $\leq \sim 6/20+$	<ul style="list-style-type: none">•R410a & Two Stage similar max benefit•North side building provides cooling advantage

U-Loop vs Kelix

Electric Power Requirement

- U-Loop
 - 1000'
 - 17 GPM
 - 4.1 amps (3 pumps)
 - $Q/P = 1.0$
- Kelix
 - 306'
 - 15.5 GPM
 - 2.1 amps (2 pumps)
 - $Q/P = 1.1$
- Kelix shows ~10% advantage this configuration
 - (fewer pumps)
- Further optimization required

DX (Direct Exchange)

- Prior Residential and Light Commercial Experience
 - Great performance
 - Lower cost to install
 - Less space
- The Mill
 - Volume of refrigerant
 - Flow control
 - Losses due to piping, head, insulation
 - Losses due to fractionation
- “Tight” configurations best
- Drilling advantage
- Hot Water
- Mill system not optimal but still COP above 3

Three Side-by-Side Systems

- 5 Tons Direct Exchange
 - Single stage Cu ground loops
 - Refrigerant distributed through ground and fan-coil
 - Manufacturer Earth Linked Technology
- 5 Tons Water Based “U-Loop”
- 5 Tons Water Based Concentric Tube/Tube “Kelix”
- Both Two stage compression R410a
- Outside water systems interchangeable
 - U-Loop 2 x 500' / Kelix 306'
- Water Based Manufactures
 - Carrier & WaterFurnace

Terraclime Geothermal Services & Products

- **Complete geothermal project management**
 - Earth energy assessment and design
 - Permitting and regulation compliance
 - Contractor certification & management
- **Building Design Services**
 - Heat loss / gain analysis & Energy audit services
 - Energy system modeling, design, economics, selection
- **Data Acquisition and Control**
 - Performance assessment
 - Performance warranty

DX Exposed Manifold



- Five 100' Earth Loops

Data Acquisition & Analysis

- Each system is instrumented at key locations
 - Ground Loop (temps and flows)
 - Air Handler (temps)
 - Geo System (temps, pressures, amps)
 - Ambient air & earth temps
- Data acquired at one minute intervals
- High level modeling and analysis performed

Alternative Energy Awareness

Who's come to visit?

- Congressman, State Regulators, Students
- Chambers of Commerce, Colleges and Universities
- HVAC Contractors, Clean Energy Fund, State DEP

Raising Congressional Interest



Senator Sanders
(VT)

Congressman Courtney
(CT)

