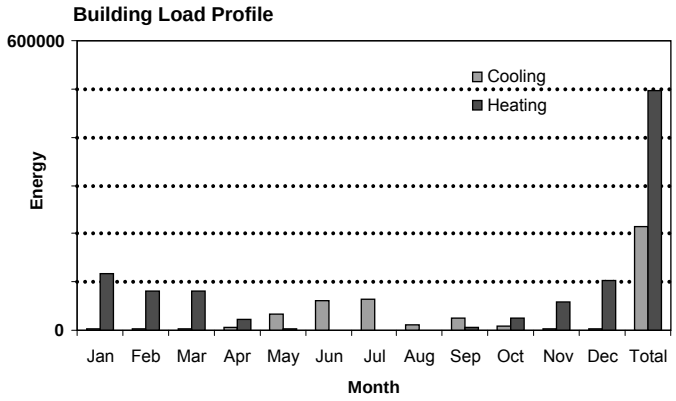
Seasonal Heating Dominate Load Profile



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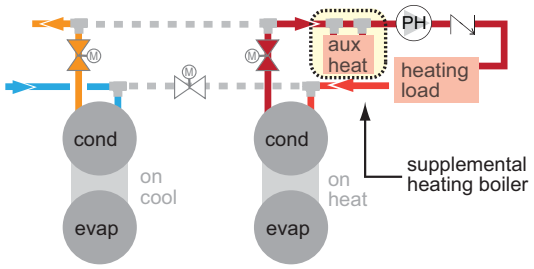
System Options

Supplemental Heating

- Boiler downstream of condenser
- Use boiler setpoint several degrees lower than chiller setpoint
  - Avoids boiler “stealing” the load



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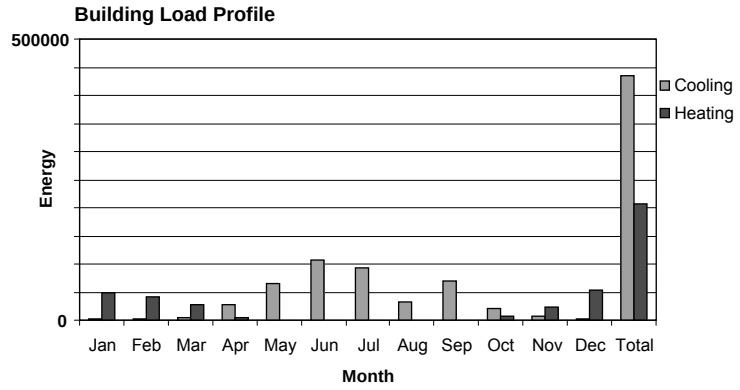
Total vs. monthly?

Seasonal Cooling Dominate Load Profile



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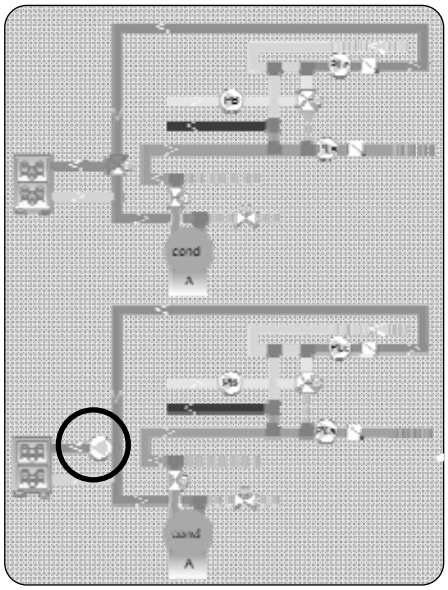
System Options

Auxiliary Energy Rejection

- Use dry cooler or evaporative fluid cooler
  - Keeps fluid loop clean
- Pump options
  - Use energy transfer loop pump
    - Pump must be sized for tower pressure drop
  - Add separate pump – sidestream
    - Simpler, but additional pump



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Building Load Profile Imbalance

- A heating dominate building
  - Auxiliary heating system (e.g. modular boiler)
  - Load shedding economizer
- A cooling dominate building
  - Auxiliary energy rejection (e.g. fluid cooler)
  - Add building heating load like domestic hot water
- Optimize the building life cycle cost
  - Reducing borefield size
  - Increasing borefield utilization for energy efficiency

Freeze Protection

- Two considerations
  - Low evaporator temperature protection
  - Air handler coil freezing
- What's unique about the bi-directional geothermal system?
  - All systems and loops are interconnected
  - A decision to use anti-freeze impacts all system elements

Freeze Avoidance Strategies

- Low evaporator temperature protection
  - Careful attention to borefield design low temperature limit
  - Limit the leaving evaporator temperature
  - Use supplemental heat (modular boiler) when evaporator temperature drops to the freezing threshold
- Air handler coil freeze protection
  - Freezestat with full coil face coverage
  - Mixed air blender
  - Pumped coils

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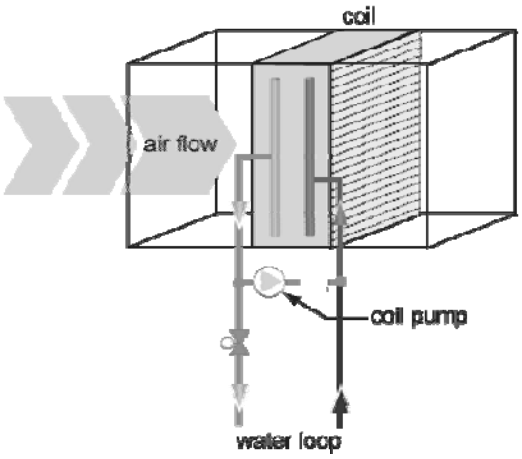
Pumped Coil



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Freeze Avoidance Strategies

- Pump and piping placement
  - Place pumps indoors
  - Bury all external piping below frost line

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Freeze Avoidance Strategies

- Anti-freeze
  - Desirable to avoid if possible
    - Cost and efficiency implications throughout the system
    - Glycol impact is worse for cooling operation than heating due to viscosity change
    - Shell and tube heat exchangers enable a lower evaporator temperature limit than plate and frame heat exchangers
  - If required, minimize its concentration.

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Considerations summary

- Optimize borefield value
  - Hybrid design
  - Balance the borefield load
- Avoid freezing
  - Limit borefield design temperatures by using auxillary heating
  - Use mechanical methods where possible
  - Minimize anti-freeze use

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Equipment performance requirements

Bidirectional Cascade

Desired Equipment Capabilities

- Efficiency
- Operating Range
  - Temperatures
  - Flow rates
- Control
  - Leaving water temperature stability
  - Ability to switch modes

Unit Efficiency

- Can be up to 18% more efficient than ASHRAE 90.1-2007 requirements
- Dependent on selection conditions
- Make sure unit can unload efficiently while simultaneously making cold chilled water and hot condenser water
  - Centrifugal compressors may surge
  - Positive displacement compressors often a good fit

ASHRAE Guidance

Temperatures

"For typical buildings, chillers normally provide hot water for space heating at 105°F to 110°F"

source: 2008 ASHRAE Handbook – HVAC Systems and Equipment, p8.20

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Example: Positive Affects of Lower Hot Water Temperature

Hot Water Temperature	140°F	130°F	Positive Affect
Cooling Capacity (tons)	131.6	149.1	+ 13.3%
Heating Capacity (MBh)	2255	2422	+ 7.4%
Power (kW)	198.2	185.3	- 6.5% (that's good!)
Heating Efficiency (COP)	3.3	3.8	+ 15.1%

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Operating Range
Temperatures

- Antifreeze (such as glycol)
  - Avoid if possible
  - Minimize amount (10% is better than 25 or 30%)
- Temperatures using water
  - 38°F chilled water
  - 140°F hot water
    - Using 130°F water
      - – Increases unit capacity
      - – Increases unit efficiency (15% better)
    - 130°F complements condensing boiler requirements
    - Proper question, "What hot water temperature do we need?

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Operating Range
Flows

Evaporator flow

- ASHRAE GreenGuide:
  - 1.2 to 2.0 gpm/ton
    - 12 - 20°F ΔT
- If Variable Primary Flow
  - Ensure adequate turndown
    - Design/Minimum > 2
  - 3-pass evaporator may be advantageous

Condenser flow

- ASHRAE GreenGuide
  - 1.6 to 2.5 gpm/ton
    - 12 - 18°F ΔT

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Desirable Unit Controls

- Operate either in cooling or heating mode
- Setpoint stability
  - Unloading compressors maintain setpoints
  - Make 38°F water with no anti-freeze
- Switch modes without turning compressor off
- Ability to respond to variable flow if applied in VPF system
  - 30% flow rate change per minute

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TRACE 700™ analysis

What's New in TRACE 700 v6.2.5

- Geothermal loop calculation methodologies
- Control algorithms for energy transfer pumps
- Default geothermal chiller-heater equipment
- Two new output reports
  - Geothermal Plant Peak Summary
  - Geothermal Energy Transfer Summary

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TRACE 700 Output
Geothermal Peak Load Summary

Geothermal Plant Peak Load Summary

Monthly Peak Heating/Cooling Loads

Alternative: 1 - Optimized EarthWise VAV
Plant: Bidirectional cascade chillers

	Time of Peak Plant Cooling Load					Peak Plant Heating Load		Time of Peak Coincident Cooling/Heating Load				
	Peak Cooling Load tons	Coincident Heating Load mbh	Available Condenser Heat mbh	Outside Air DB/WB (°F)	Date-Time	Net Available Heat mbh	Coincident Cooling Load tons	Coincident Cooling Load tons	Peak Heating Load mbh	Available Condenser Heat mbh	Outside Air DB/WB (°F)	Date-Time
Jan	55	495	1,233	29/28	Dsn - 8 am	0	0	55	495	1,233	29/28	Dsn - 8 am
Feb	99	520	1,442	33/30	Dsn - 8 am	922	99	99	520	1,442	33/30	Dsn - 8 am
Mar	140	204	2,023	45/43	Dsn - 8 am	586	43	140	204	2,023	45/43	Dsn - 8 am
Apr	188	115	2,232	53/49	Dsn - 8 am	352	26	188	115	2,232	53/49	Dsn - 8 am
May	176	156	2,233	67/55	Dsn - 8 am	1,156	86	176	156	2,233	67/55	Dsn - 8 am
Jun	177	72	2,247	86/71	Dsn - 4 pm	755	92	177	72	2,247	86/71	Dsn - 4 pm
Jul	190	72	2,249	89/73	Dsn - 4 pm	1,019	111	190	72	2,249	89/73	Dsn - 4 pm
Aug	187	72	2,251	88/73	Dsn - 3 pm	923	106	187	72	2,251	88/73	Dsn - 3 pm
Sep	168	73	2,247	83/70	Dsn - 3 pm	815	91	168	73	2,247	83/70	Dsn - 3 pm
Oct	196	98	2,233	54/52	Dsn - 8 am	302	22	196	98	2,233	54/52	Dsn - 8 am
Nov	156	227	2,232	44/44	Dsn - 8 am	0	0	156	227	2,232	44/44	Dsn - 8 am
Dec	99	380	1,442	38/35	Dsn - 8 am	0	0	99	380	1,442	38/35	Dsn - 8 am
Annual	196	520	2,251	54/52	Oct/Dsn - 8 am	1,147	111	1,831	2,484	24,062	54/52	Oct/Dsn - 8 am

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TRACE 700 Output
Geothermal Energy Transfer Summary

Geothermal Energy Transfer Summary
By Trane

Geothermal Plant - Ground-Source Heat Transfer

Alternative: 1 - Optimized EarthWise VAV
Plant: Bidirectional cascade chillers

Geothermal Plant - Ground-Source Hea

Alternative: 1 - Optimized EarthWise VAV
Plant: Bidirectional cascade chillers

Year: 1

Month	QExtracted from Geothermal Loop ton-hrs	kBtu	kWh	QRejec ton-hrs	Heat Rejected to Auxiliary Cooling peak tons	ton-hrs	kBtu	kWh	Heat Supplied from Supplemental Boiler peak MBH	ton-hrs	kBtu	kWh	k kWh
Jan	3,749	44,984	13,180		0	0	0	0	10	4	53	16	7,213
Feb	2,580	30,954	9,069		0	0	0	0	0	0	0	0	4,773
Mar	1,739	20,867	6,114	-6	0	0	0	0	5	0	0	0	3,247
Apr	443	5,319	1,559	-61	0	0	0	0	5	17	206	60	4,304
May	1,637	19,648	5,757	-11.66	0	0	0	0	13	80	964	283	12,901
Jun	422	5,068	1,485	-38.48	0	0	0	0	5	15	178	52	28,997
Jul	130	1,561	457	-43.55	0	0	0	0	3	4	47	14	31,059
Aug	453	5,432	1,592	-45.41	0	0	0	0	7	14	167	49	33,426
Sep	998	11,977	3,509	-29.01	0	0	0	0	10	38	451	132	23,837
Oct	684	8,211	2,406	-92	0	0	0	0	5	13	156	46	4,418
Nov	1,878	22,538	6,604	-5	0	0	0	0	5	0	0	0	3,500
Dec	2,660	31,914	9,351		0	0	0	0	0	0	0	0	4,000
Annual	17,373	208,473	61,082	-169.78	0	0	0	0	13	185	2,223	651	63,925

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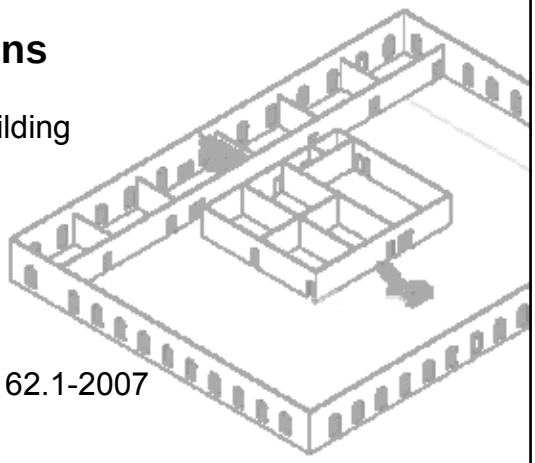
Study Assumptions

- Three-story office building
  - Atlanta, GA
  - Philadelphia, PA
  - St. Louis, MO
- 60,000 Square Feet
- Complies with ASHRAE 90.1-2007, 62.1-2007



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Bibliography

Central Geothermal System Design and Control

Industry Standards and Handbooks

available to purchase from < www.ashrae.org/bookstore > or < www.amca.org/store >

American Society of Heating, Refrigerating, and Air-Conditioning Engineers. 2008. *ASHRAE Handbook—HVAC Systems and Equipment*, p8.20, Atlanta, GA: ASHRAE.

Trane Publications

available to purchase from <www.trane.com/bookstore>

Cline, Lee. *Central Geothermal Systems* application manual. SYS-APM009-EN. April 2010.

Analysis Software

TRACE 700™ building energy and economic analysis software
Available at < www.trane.com/TRACE >