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Perry Center Supplemental Heating

Bekah Kruger
Olivet Nazarene University, bekahkruger@gmail.com

Sam Lonard
Olivet Nazarene University, slonard8065@gmail.com

Nick Willis
Olivet Nazarene University, nickwillis828@gmail.com

Perry Center Supplemental Heating

Final Presentation

Senior Design 2021-2022

Bekah Kruger, Nick Willis, Sam Lonard

OLIVET NAZARENE UNIVERSITY

Acknowledgements

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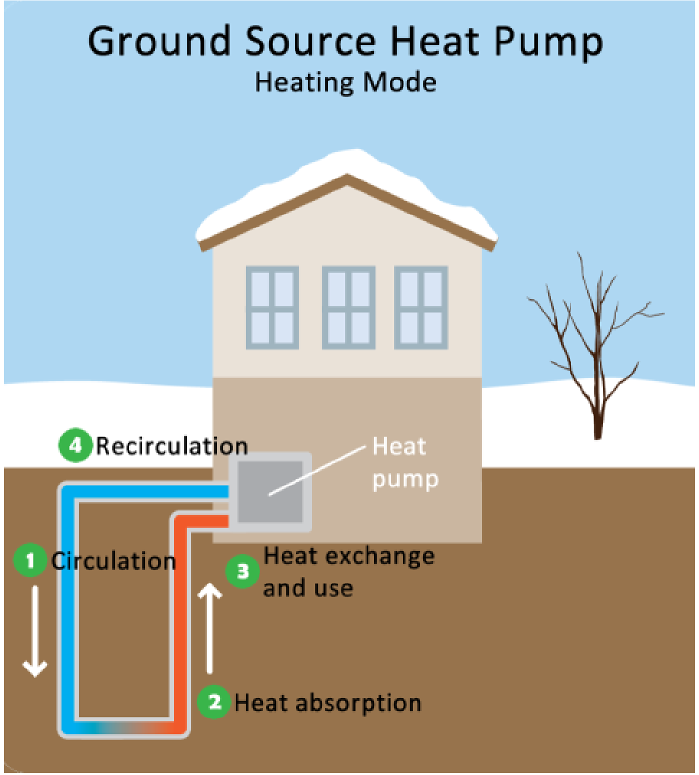
- John Domenz, Boilersource Representative

Perry Center Background

- Opened on December 12th, 2012
- 168,000 ft^2
- Operates on a geothermal heating and cooling system
- Geothermal Fluid: heat transfer medium
    - 2 parts water, 1 part ethylene glycol
- Seasonal conditions in the winter create heat deficit



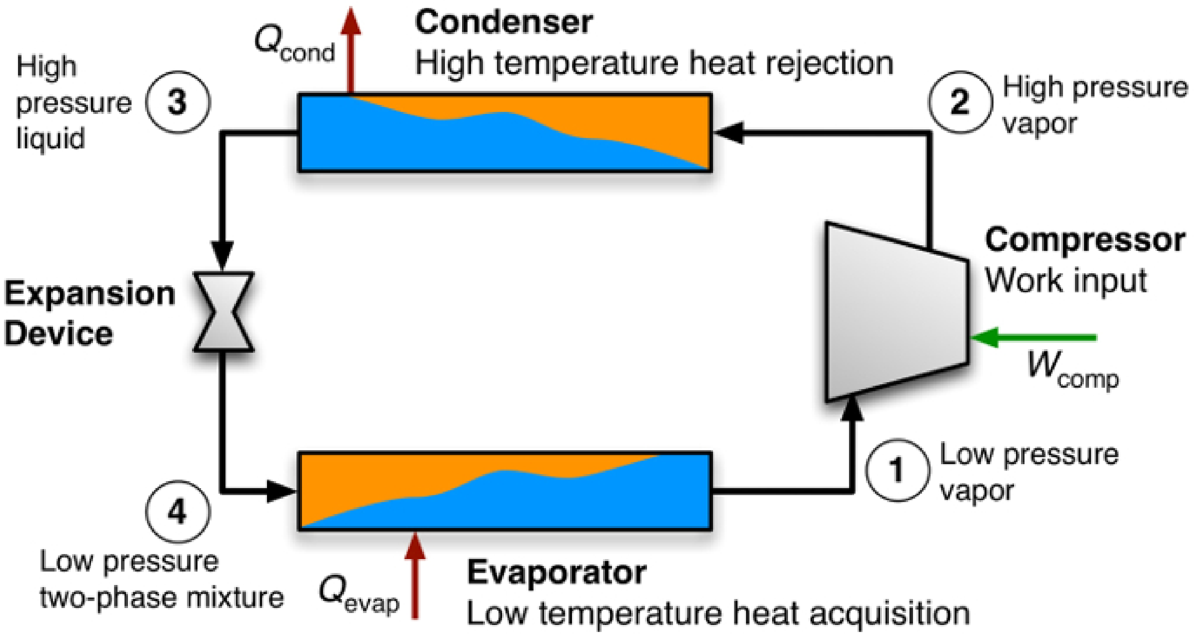
Olivet Heating Background

- Central heating system
- Capped steam lines run into mechanical room

Problem Statement

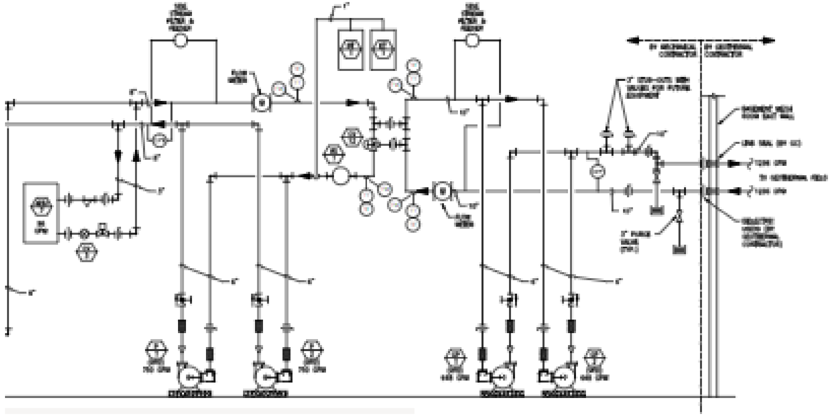
- The Perry Center uses a geothermal system for heating during the winter
- System's design specifications require 75℉ fluid
- Low air temperatures cause entering geothermal stream of 1296 gal/min to be 50℉
- Leads to the breakdown of compressors ($10,000 dollars per unit)

Refrigeration Cycle



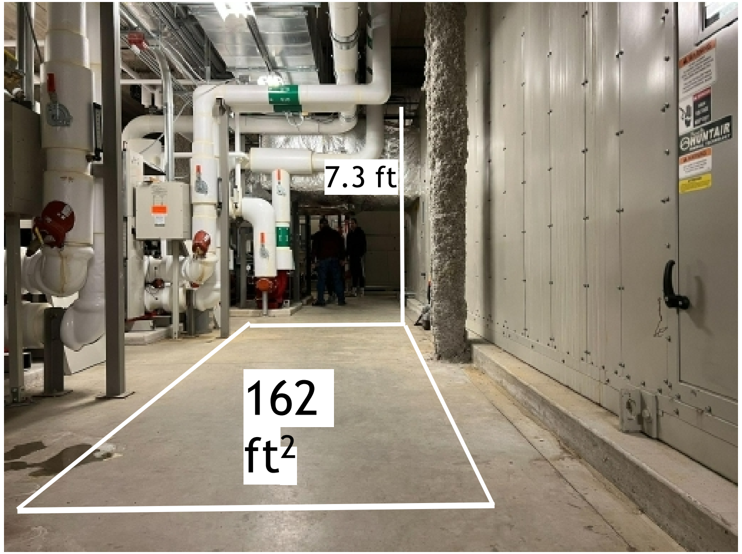
Design Objectives

- Increase the temperature of the geothermal fluid by 25℉
- Minimize rework of the existing system
- Low-cost and long-lasting
- Highly Efficient



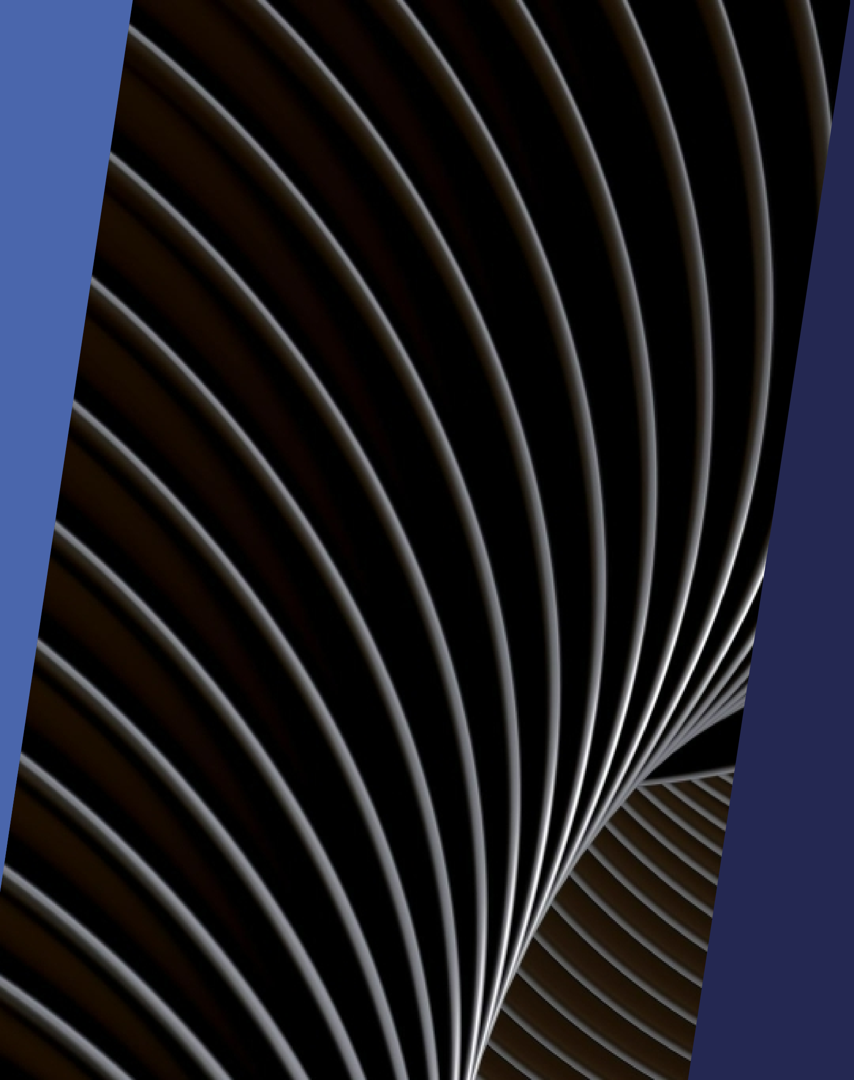
Design Constraints

- Must fit into the existing space in the boiler room of the Perry Center



Functional Requirements

- Increase the temperature of the geothermal fluid
- Receive energy from natural gas lines
- Control the amount of heat entering the fluid, depending on weather conditions

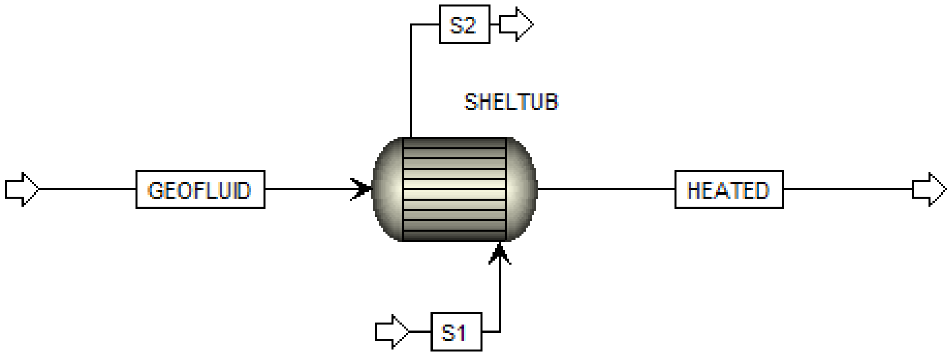


Design Iterations

- Steam Heat Exchanger
- Shell and Tube Heat Exchanger System
- Plate Heat Exchanger System
- Electric Boiler System
- Gas Boiler System
- Hydronic Boiler System

Steam Heat Exchanger

- One main stream flowing through a Shell & Tube Exchanger
- Capped steam lines available for heat source



Problems with Iteration

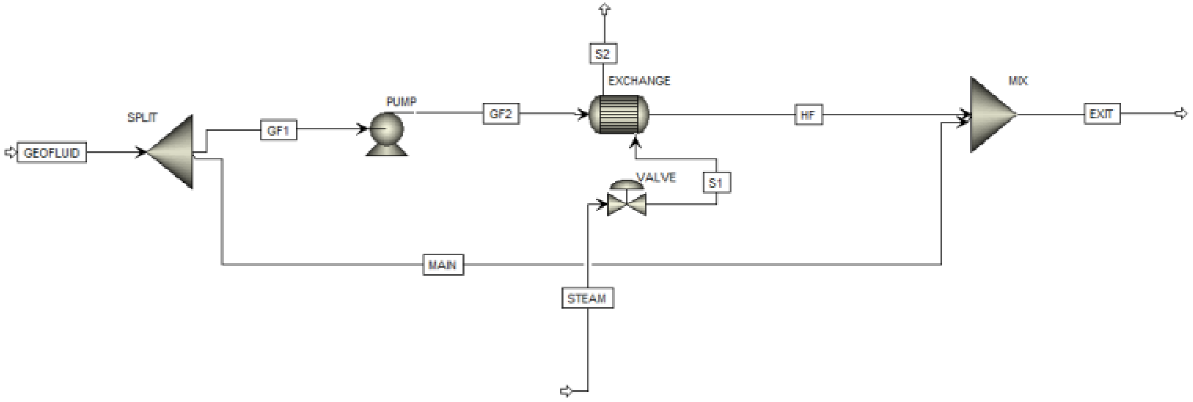
- Limited knowledge of heat exchangers
- Inefficient to run the total flow through a heat exchanger

Material Learned

- Basics of heat exchangers
  - Capacities, types, and configurations

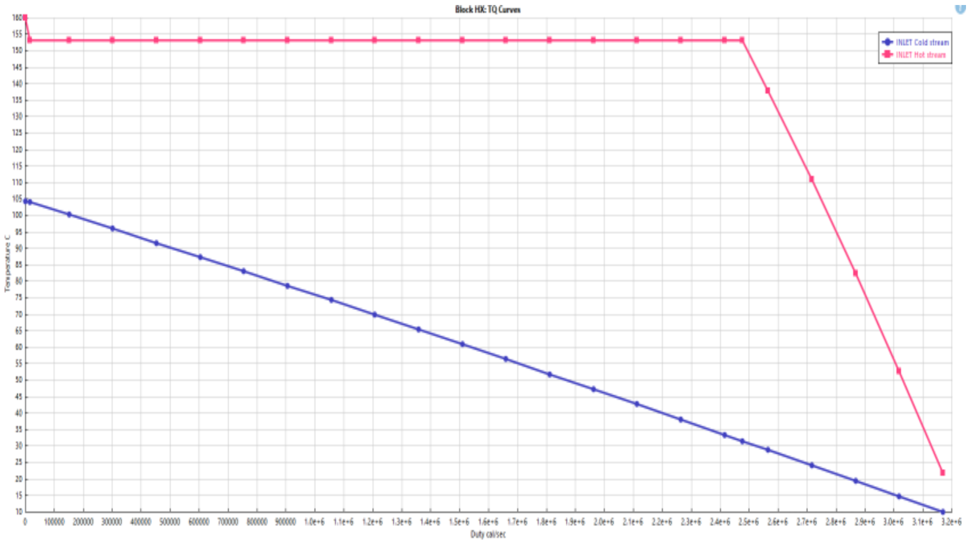
Shell and Tube Heat Exchanger System

- Shell and Tube Heat Exchanger
- Adds a Secondary Stream of geothermal fluid
- Pump and Control valve to control the flows



Problems with Iteration

- Fully reliant on ASPEN for calculations
    - Trial and error of pressure, temperature, and flow
- Temperature Crossover Errors
- **Material Learned**
- Increased steam flow rate will fix error



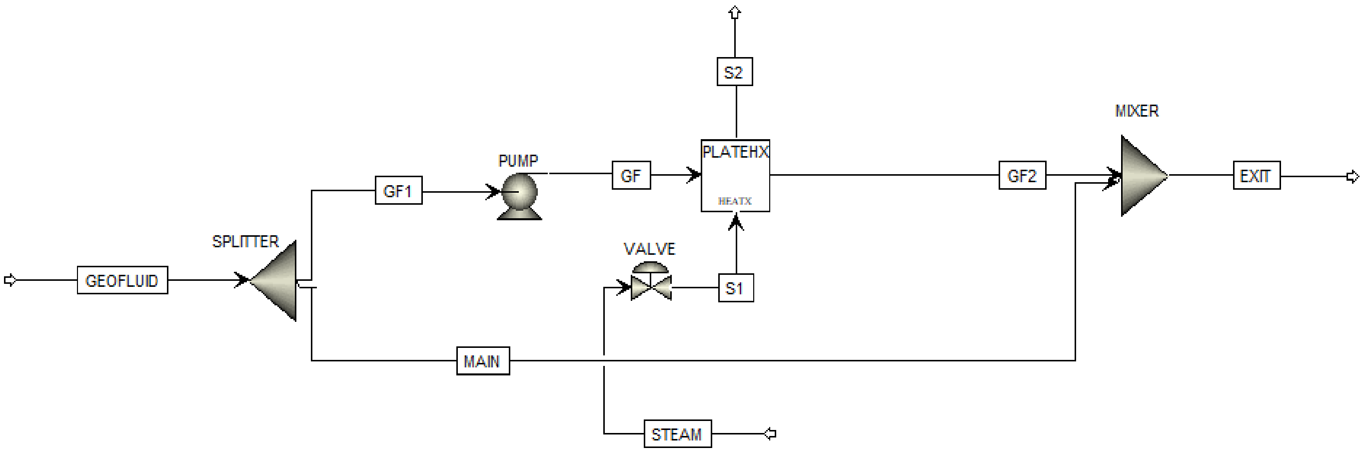
Matlab Code

```
%Calculating Final T of steam
T_2s=(m_1*C_p_gf*T_1gf+m_s*C_ps*T_1s+m_s*hfg-m_1*C_p_gf*T_2gf)/(m_s*C_ps+m_s*hfg); %[F]

%Calculating Final T of GF after HX
T_2hx=(m_2*C_p_gf*T_1gf+m_s*C_ps*T_1s-m_s*C_ps*T_2s+m_s*hfg)/(m_2*C_p_gf);  %[F]

%Final T of gf after remixing - checks calculations
T_output=(m_2*T_2hx+m_1*T_1gf)/m_t;  %[F]
```

- Easy to adjust flow rate of secondary stream and steam line for Aspen
- Verifies Aspen calculations and gives numbers for Aspen
- Calculates minimum heat transfer requirement ($\dot{Q}=\dot{m}c\Delta T$)
    - Average Density and specific heat values calculated using mass fractions
- <u>Minimum Heat transfer = 14.3 million Btu/H = 4.2 kW</u>

Plate Heat Exchanger System

- Plate heat exchanger
  - More efficient
  - Easily adjust capacity by adding plates



Problems with Iteration

- Still receiving temperature crossover error
- Realized the Insufficient Heat Load in Steam pipes

Material Learned

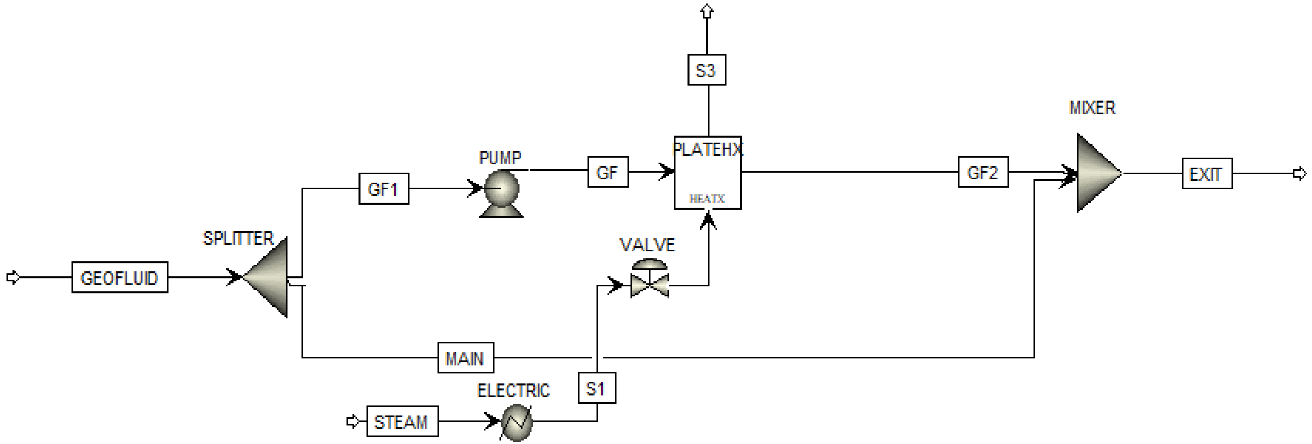
- Steam Line diameter is 3 inches
  - At 90 psia, $\dot{m}_{max,steam}$=4,243 lb_m/h
- $\dot{Q}_{steam}$= $\dot{m}_{steam}$*h_g = 5 mil Btu/h
- 9.3 mil Btu/h heat deficit

Alternate Design Idea

- Increase diameter of the pipes
- $\dot{m}_{req,steam}$= 12,075 lb_m/h
- Minimum pipe diameter is 6 inches
- Insufficient boiler load

Electric Boiler Systems

- Plate Heat Exchanger in Series with Electric Boiler
- Sufficient Heat Capacity
- No ventilation required

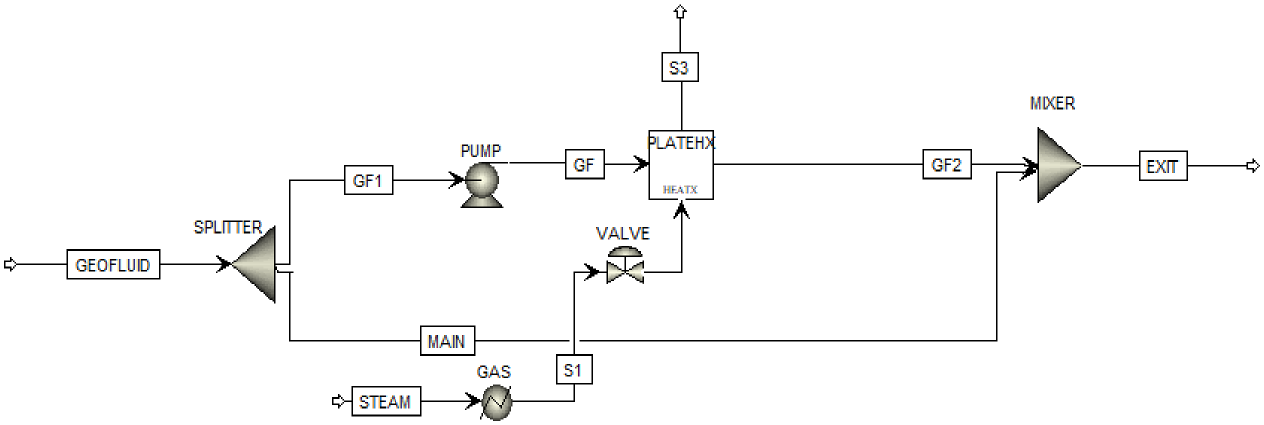


Problems with Iteration

- Electrical requirement not feasible for existing equipment
    - Voltage = 480 V - Feasible
    - Current = 3600 A - Not Feasible
- Efficiency losses due to boiler <u>and</u> heat exchanger

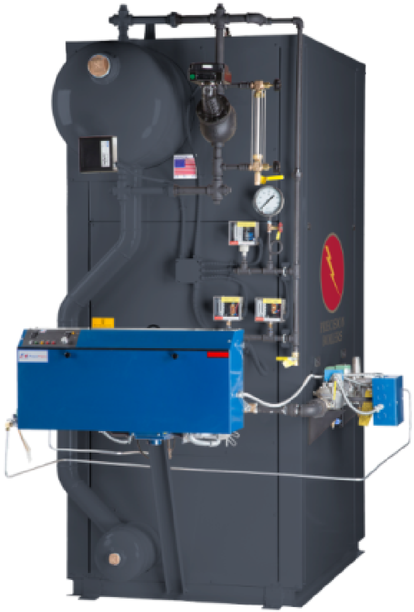
Gas Boiler Systems

- Plate Heat Exchanger in series with Gas Boiler
- Natural Gas lines required



Problems with Iteration

- Limited knowledge of boilers
- Inefficient design because of losses in boiler and HX

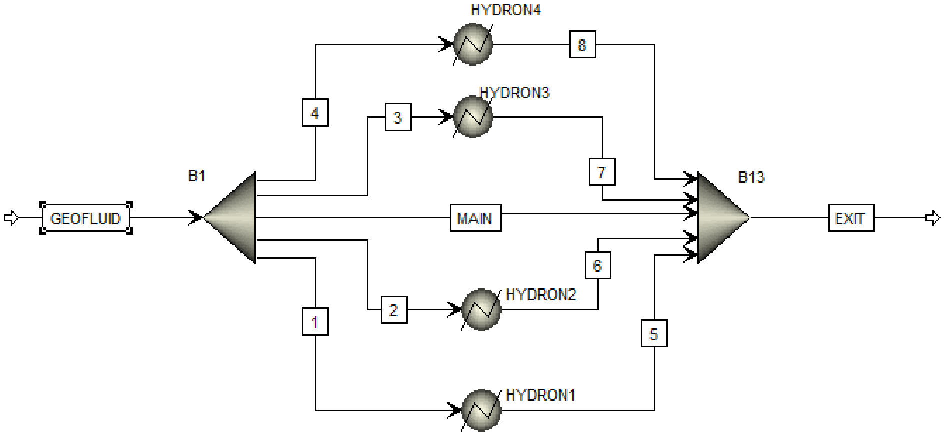


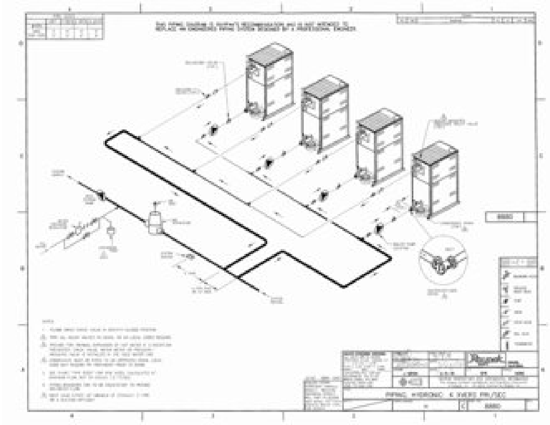
Material Learned

- A single boiler not likely to meet heat requirement
- Sufficient gas supply is available
- Gas line at 2 psi gives a 2.5” required diameter (using ratings for gas pipes)

Hydronic Boiler System

- Four Hydronic Boilers (XVers by Precision Boilers)
  - 95% Efficiency
  - 4 - 4 million Btu/h Boilers = 16 million Btu/h
  - Run in Parallel
- Natural Gas lines
- Ventilation system





Problems with Iteration

Component	Estimated Cost	Budget
Hydronic Boilers	$430,000	$300,000
Natural Gas/10 years	$400,000	
Venting/Natural Gas Piping	$6,000	
Installation Estimation	$500,000	
Total Cost	**$1,336,000+**	**$300,000**

- Final cost far exceeds available budget
- Average price per unit, $107,836.92

Design Matrix

Design Iteration	Heat Load	Minimize Rework	Space	Efficient	Cost
Steam Heat Exchanger	FAIL	PASS	PASS	PASS	PASS
Shell and Tube Heat Exchanger System	FAIL	PASS	PASS	PASS	PASS
Plate Heat Exchanger System	FAIL	PASS	PASS	PASS	PASS
Electric Boiler System	FAIL	PASS	PASS	FAIL	FAIL
Gas Boiler System	FAIL	PASS	PASS	FAIL	FAIL
Four Hydronic Boiler System	PASS	PASS	PASS	PASS	FAIL

Heat Load: Is the heat load of 14.3 million Btu/H met?
Minimize Rework: Would the components minimize rework of the inlet and exit pipes of the geothermal system?
Space: Is there space in the boiler room to house the components?
Efficient: Does the design have an efficiency of at least 90%?
Cost: Does the design fit the budget?

Conclusion

- Low air and ground temperatures cause the geothermal system to require supplemental heating
- Several design iterations, each failing a design objective
- Final hydronic boiler design would meet all design objectives, but fail on pricing
- Plans to switch all buildings from central to isolated boiler systems
  - The hydronic boiler system could be implemented in the future given adequate budget

Q&A

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