STEG

STEAM TURBINE ELECTRIC GENERATOR

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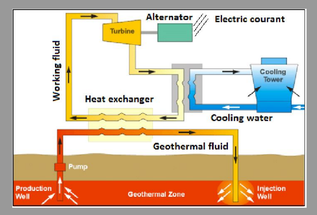
DESIGN PROCESS

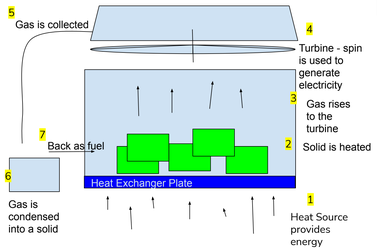
Geothermal Plant



Geothermal Cycle:
1: water is heated underground
2: heated water pipe exchanges heat to turbine
3: water enters a lower pressure environment and becomes steam
4: steam drives turbine
5: turbine spins and creates electricity
6: hot steam transfers heat to cooling tower and becomes water

We chose geothermal as our model plant because it is clean and renewable. Our goal is to increase the efficiency of turbine generators and minimize the pollution that is generated.

Initial Design



Our initial brainstormed design heats a solid (at room temperature) until it boils. It then funnels that steam into a turbine to generate electricity. Finally, the gas is collected and is condensed into a solid.

Mentor Feedback

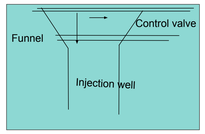
Feedback by Eric Prescott, Director of the Electric Power Research Institute

- Research specific methods of generating electricity (Cycles Research).
- Focus on the start up speed of how quickly a design can go from off to 100% generation.
- Find a way to quickly adjust to changing electrical demand.
- Currently, when power production needs to be increased, it will be fossil fuel plants that will increase production as it is easy to burn more gas or coal.
- Renewable plants cannot be controlled in this way as of yet

New Goal: Quickly change the power production of a Geothermal Plant

Our focus will be on the injection well and the heat exchangers of the geothermal system. By adjusting the water flow through these parts, we can adjust the amount of energy generated.

Initial Redesign



Funnel Design
-Control valve can close to decrease amount of water flow
-Funnel allows increased water flow
-We soon realize that

The Iris Mechanism
-The iris opens in a circular pattern
-Allows for a more dynamic way of controlling water flow

Researching Principles

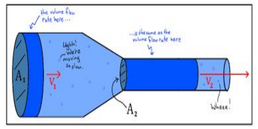
- Bernoulli's Principle

Sum of energy in all points of a streamline are constant

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

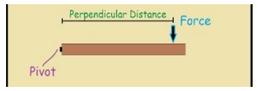
- Volume Flow Rate

how much liquid passes through an area at a given time



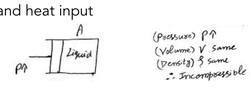
- Torque

Angular Force



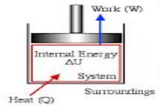
- Enthalpy

Internal Energy of a system measured by work and heat input



- Compressibility

the measure of how easy it is to restrict the volume of a gas or liquid



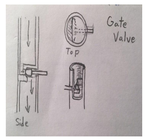
- Rankine Cycle

tracks the energy input and output in different stages of a steam turbine cycle

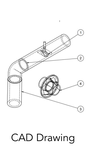
IDEAL RANKINE CYCLE

Final Redesign

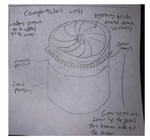
Principle concept: Increasing pressure will increase volume flow rate.
Volume Flow Rate = A (Cross sectional Area of pipe) times V (velocity of water)



Control Pipe



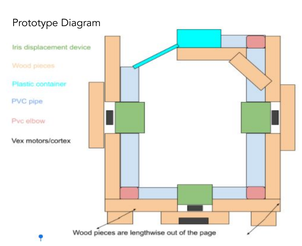
CAD Drawing



Compression Unit

(Refer to *Solution* for more information)

Prototype Diagram



New compression unit
-Thick, angled blades that will allow it to function as a pump
-Rollers and plates removed

Water flows flow through the pipes clockwise. The Iris pumps will activate in sequence.

Prototype Evaluation

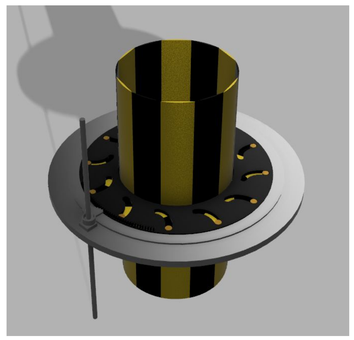
How was the prototype unsuccessful
- Physical error of Cutting pipes
- 3D printing custom parts
- Error in timing motor rotation
- Gaps between wood pieces

Proposed corrections
- Ordering specific pipes online
- Ordering custom parts
- Using a high speed camera to time rotations
- Lack of watertight ability
- Replacing potentiometers with servos
- Boring deeper holes for screws

SOLUTION

Full assembly. In actual application there would be many more compression units

Control pipe: Includes a gate valve and can decrease the amount of water flow



Compression unit: Opens and closes through rotation. Presses on the water that runs through it to increase pressure

In order to control the amount of energy that a geothermal plant can produce, we have designed a water pump or compression unit that can increase the pressure along a pipe, pushing water through. When placed along the geothermal fluid (red) or the working fluid (top orange) the pump can push the water, increasing the speed and the amount of energy in the water. This makes it so that the water of the working fluid can vaporize/boil faster. By starting at the initial energy production rate (with pumps off) and increasing pump speed to get a maximum production rate, we can use geothermal energy in response to changing power demand.

SIMILAR SOLUTIONS

Competitor 1: SM axially split	Competitor 2: GP radially split	Competitor 3: A Line radially split
		
~$40,000	~$40,000	~$40,000
Pros: -Max flow rate of 2000m^3/hour -Easy to maintain Cons: -Cost is high -Only withstands pressures of 276 bar	Pros: -Max flow rate of up to 900m^3/hour -Withstands up to 400 bar pressure Cons: -Lower pump rate -Cost	Pros: -Max flow rate of up to 1400m^3/hour -Withstands up to 450 bar pressure -Withstands up to 450 celsius

DESIGN CRITERIA

~$2M per unit

Performance:
overall heat energy loss per unit of electricity produced is less than the current steam turbines

Materials:
able to withstand the temperatures and pressures within the steam turbine chamber (at least 600°C). Turbine blades must survive rpm.

Resource usage:
be powered by abundant resources and not produce large amounts of waste or carbon

Customer Needs:
The customers want efficient ways to generate electricity. Efficient meaning lower cost.

Size and Weight:
Must not be too much larger than the current models of steam turbines,

PROBLEM STATEMENT

Almost all energy production is done with steam generators, since heat is the most common energy source, yet steam generators are only 33-48% efficient in transferring the heat energy to electricity, whereas a hydroelectric generator will have a 80% or higher efficiency, and wind turbines get about 50%. Using energy sources other than heat, higher electricity generation rates can be obtained, suggesting that turbines are not the issue.
A new way of translating heat into motion needs to be found in order to increase the efficiency of electric generation.

JUSTIFICATION

Over the next years, energy consumption will be constantly increasing. By 2050, it will be 40% more than what we consume now. Increasing efficiency of the functions within turbine generators will help us better prepare for the coming ages.

CONCLUSION

Production:
- Mass production is likely not necessary. It would only be applicable to geothermal plants that have not yet been constructed because the cost to insert our product into an already constructed and in the ground plant is much higher.

Selling commercially:
- Scale up to the size of the power plant
- Pipes rotate in a rectangular cycle at the moment. This is to prove that our pump works, but for the full-scaled version, it will simply be placed in the geothermal pipes.
- Multiple pumps can be added in series to increase the pumping ability to the desired amount
- Run other tests and simulations for evaluation of efficiency at high temperatures and pressure.
- Look at Api 90 materials (metal) to replace for the PVC pipes.