MINI PROJECT 3 - ART + THERMODYNAMICS

A DAY IN WALTER'S LIFE

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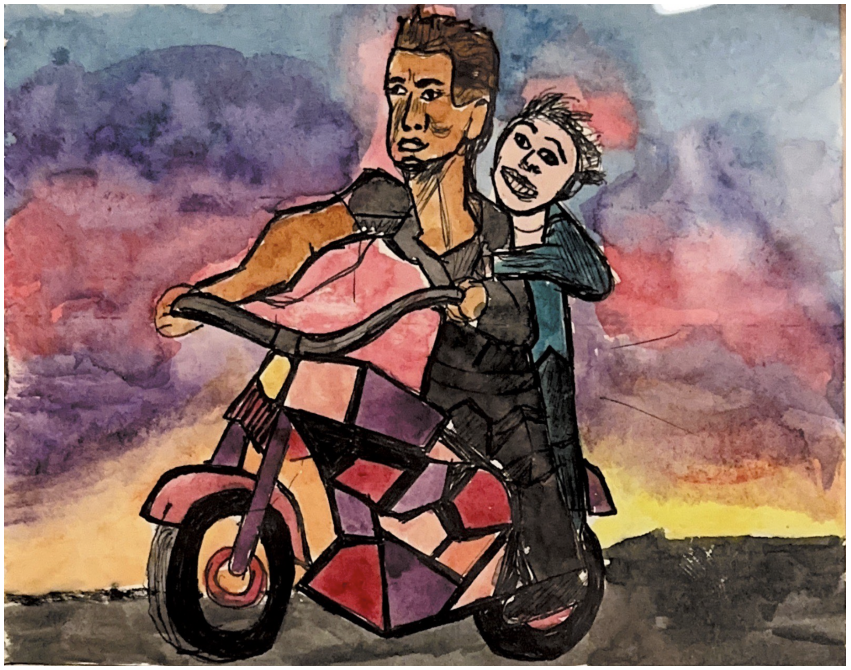
Project Summary

"A Day in Walter's Life" is a short story produced through the collaborative efforts of Spring 2023 ME200 students Madi Whitlock, Matthew Wunsch, Jeanjuella Tipan, and Juni Heo for Mini Project 3. The story centers around Walter Rankine, a man whose primary purpose in life is to exercise. Through the life of Walter Rankine, the story illustrates the process by which the Abbott Power Plant in Champaign, Illinois, provides electricity and heat for the University of Illinois Urbana-Champaign campus. The Abbott Power Plant can be modeled by what is known as the Rankine cycle. The Rankine cycle provides a simplified demonstration of how heat can be exchanged to produce meaningful work, like electricity. This model can then be used to perform calculations on a physical process in order to analyze aspects of the process like the efficiency, the work that is outputted, the heat that is inputted, and so on. "A Day in Walter's Life" parallels parts of Walter's daily routine to segments of the Rankine cycle to concisely build a basic understanding of the process for individuals that are not familiar with concepts within thermodynamics. The story also highlights the pollution that is produced as byproducts of burning carbon-based fuel and offers potential solutions to help mitigate the resulting negative environmental impact. All illustrations of Walter's life were hand-drawn and hand-painted to match the accompanying original narrative. More straightforward explanations supported by further research are also included to bridge the gap between fiction and reality.

Somewhere, in a place not unlike our own, lives a man named Walter. He lives a life full of what others would consider bizarre. His purpose in life is to work out, and that is all he does daily. This is a little glimpse into the life of Walter Rankine.

While reading the story of Walter's life, you will see these sections in red mixed in. Walter is secretly a representation of the Rankine cycle at the Abbott Power Plant. The red sections will provide insight for how Walter's life relates to the Rankine cycle and the Abbott Power Plant.

Working out is the highlight of Walter's life, which is why he commits to it hardcore each and every day. The second he opens his eyes in the morning, adrenaline pumps through his blood, and he is itching to go to the gym—the only thing in his way: a huge mountain. This hill can only be conquered on a mountain bike, so Arnold Schwarzenegger comes every morning to pick him up. On the way there, they listen to "Here Comes the Sun" by the Beatles.



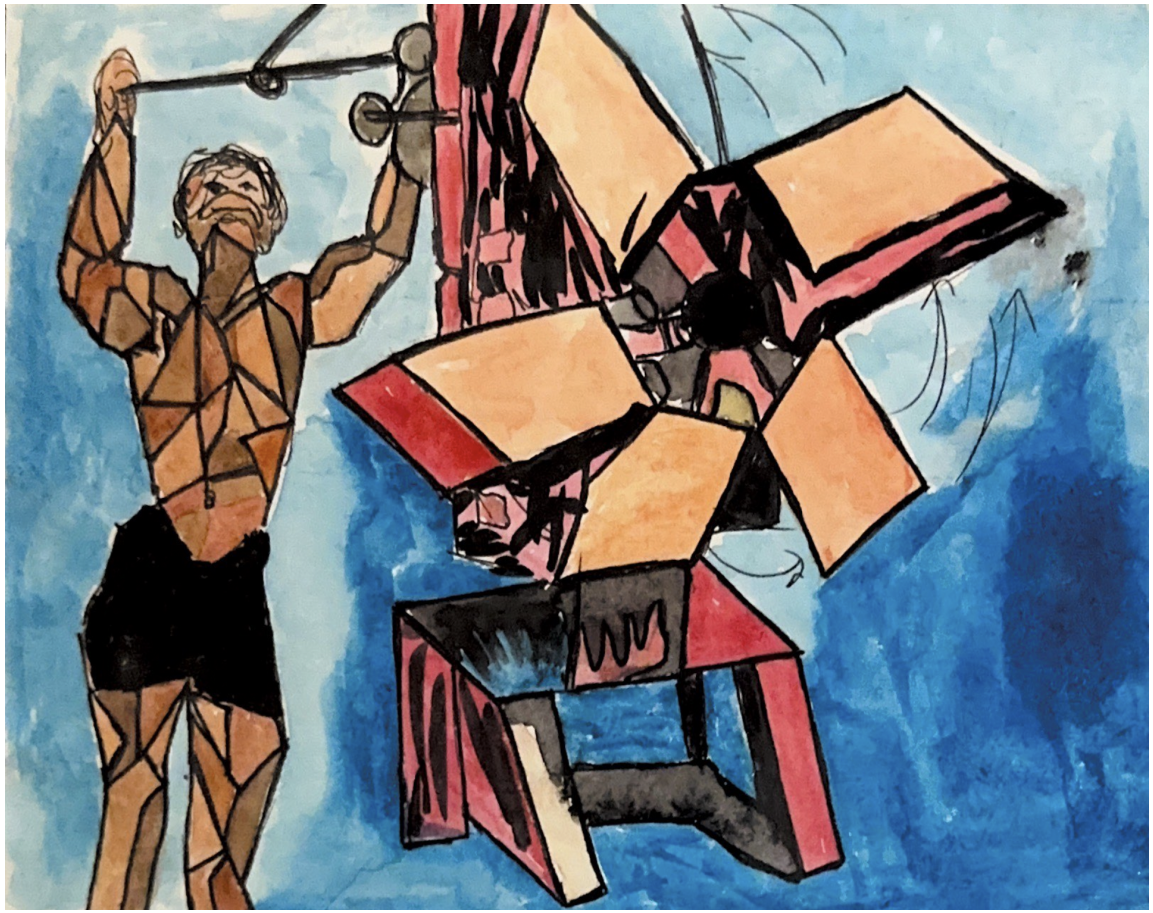
The pump is represented by Walter’s ride to the gym on his friend’s motorcycle. There is a work input done (getting a ride on Walter’s friend’s motorcycle) to create high-pressure subcooled water (high pressure is represented by Walter being excited to work out).

The first thing Walter does at the gym is hit the sauna. Why? To warm himself up, making his regime even more effective. Every muscle and tendon stretches out into something magical, and then he is ready to go. Right before he leaves, a demon appears and forces him to get his daily dose of jalapenos.

The next step in the Rankine cycle is the boiler. In the boiler, subcooled water is heated until it is superheated steam. This is done by adding heat, which comes from natural gases being burned in a combustion chamber.

Walter feeling the heat from the sauna and eating the spicy jalapenos represents the heat that enters the system.

What makes Walter's routine the best in the world? He uses a contraption to turn an enormous fan that spins as he pulls down on the cables, cooling the room while his body soaks in sweat. Walter ensures everyone in the world stays cool.



In the Rankine cycle, the third stage is where steam spins the blades of a turbine to generate a work output. Walter pulling the cable machine to do his exercises is like the steam spinning the turbine blades. In both scenarios, there is an output of work. Walter spins a fan while the Abbott power plant creates electricity.

After he finishes working out, Walter is practically boiling. Since he is on top of the hill, he has to slide down the waterfall to cool down and get home. The second he hits the hay, his body knows that it is time to rest. Upon hitting the pillow, he knows he will do this every day for the rest of his life.

In the Rankine cycle, the final stage is the condenser. The condenser cools down the steam at a constant pressure to get it ready to go through the cycle again. Walter gets cooled down by the cold river to be ready to warm back up for his next workout tomorrow. He starts and ends the same way, just like the Rankine cycle is a loop that can be repeated sequentially.

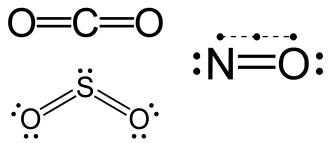
Walter dreams of Arnold and their magical rides up the hill at night. Arnold explains that although the ride might be fun, they pollute the environment each time they go. Rather than sulk, they plan on opening a gym closer to Walter's house to eliminate the need to travel so far when making the trip.

The Abbott Power Plant is not perfect, just like Walter’s daily routine. It produces pollution.

Emissions of a Typical Natural Gas-Fired Power Plant vs. Abbott Power Plant

Common pollutants produced by burning natural gas:

- ➔ Carbon Dioxide (CO_2)
- ➔ Nitrogen Oxides (NO_x)
- ➔ Sulfur Dioxide (SO_2)
- ➔ Particulate Matter



Abbott Power Plant

- ➔ CO_2 emissions: approximately 97,346 metric tons
- ➔ Calculation:
  - ◆ heat produced by boiler: 66,179.05 kWh
    - based on calculations for a standard steam power plant operating on the Rankine cycle
  - ◆ 0.2034 kg of CO_2 is produced per kWh of natural gas burned
    - according to the Environmental Protection Agency (EPA)
  - ◆ power plant is operational 10 months out of the year
  - ◆ $66179.05\ [kWh] \cdot \frac{0.2034\ [kg\ CO2]}{1\ [kW]} \cdot \frac{24\ [h]}{1\ [day]} \cdot \frac{30\ [days]}{1\ [month]} \cdot \frac{10\ [months]}{1\ [year]} = 97346735.39\ [kg\ CO2]$

Average Natural Gas-Fired Power Plant

- ➔ CO_2 emissions (in 2020): 823 pounds of CO_2 per MWh of electricity
  - ◆ according to the U.S. Energy Information Administration (EIA)
- ➔ CO_2 emissions of a 500 mW power plant: 1.8 million metric tons
- ➔ pollution output can vary depending on plant size, efficiency, and emissions control methods

To reduce pollution, one of the solutions suggested to Walter is that he build a new gym closer to his home, likely inside the giant hill. To keep carbon dioxide emissions from factories and other industrial sources from entering the atmosphere, carbon capture and storage technology collects and stores them underground. Although it can significantly reduce a power plant's greenhouse gas emissions, its implementation can be costly.

The next suggestion was to make less trips to the gym, which is meant to refer to running the plant more efficiently. Power plants can increase their energy efficiency by utilizing cutting-edge technologies and operational procedures that lower the amount of energy required to produce electricity. Turbines, engines, and even materials may fall under this category.

Walter and his friend talk some more and decide the best solution is to work with the surrounding community. Walter is going to expand the gym down into the big hill. He'll now be able to enter through the lowest level, so less work will be required to get him up the hill. New machines will be added in this new space that will help make travel to the gym more efficient, similar to how the fan cools down the gym.

The best solution for the Abbott Power Plant is working with the community. Implementing agricultural techniques that store carbon in the soil, like incorporating organic matter and planting cover crops, is known as "carbon farming." The Abbott power plant might collaborate with nearby farmers to put carbon farming techniques into practice on farmland, which would reduce the plant's carbon emissions and benefit the neighborhood's agriculture. Solar, wind, and energy storage systems could all be included in a renewable energy microgrid that is built around the Abbott power plant. This could give the plant a dependable and sustainable energy source, thereby lowering its reliance on fossil fuels.

Citations

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