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Investigation 1.0 – Determining the Quantity of Heat Energy Produced by a Geothermal Power Plant when the water is Boiled at Temperature's 65 and 80 Degrees Celsius, Using a 14.5 Ounces Metal Can which represents the Power Plant and a 3 Quarts Pot with Boiling Water, which represents the Earth:

Abstract:

The purpose of this lab was to determine the number of turns, and quantity of heat energy produced when water is boiled at temperature's of 65 and 80 degree's Celsius, which is then used to turn a pinwheel. It was predicted that if the temperature of the water is at 65 degree's Celsius then the pinwheel would produce less turns than if it were at 80 degree's Celsius, because the temperature of the water results in the amount of steam produced. If the temperature is less then less steam would be produced, resulting in less turns being produced by the pinwheel. In order to perform this investigation, a hammer and nail was used to punch a hole in the end of the 14.5 ounces metal can near the edge, and then two elastic bands were used in order to hold the can along the 12 inch wooden ruler. Put 2 quarts of water into 3 quarts pot, and covered the top of the pot with two layers of aluminum foil. Used the nail, and punched a hole in the center of the aluminum foil, and eight more holes around the edges of the foil. Placed the pot onto a hot stovetop, with the temperature at 65 degrees Celsius, and waited for water to boil. As steam came out of the top of the aluminum foil, placed the metal can onto the center hole. Carefully held the pinwheel 10 inches above the can, and counted the number of turns the pinwheel made for 20 seconds, and then recorded the results. Used oven mitts to remove the can from the pot, and waited for the water temperature to reach 80 degrees Celsius. Then held the pinwheel 10 inches above the pot. Counted the number of turns for 20 seconds, and recorded the results. When the can was placed on the pot, it represented geothermal power plants on top of the Earth's surface, (the water was at 65 degree's Celsius), and when the steam had to work it's way from the Earth's surface to the power plant, it produced 26 turns. Without the can (power plant), the pot (geothermal steam coming from the Earth's surface) produced 28 turns, as the water boiled at a temperature of 80 degree's Celsius. The number of turns decreased, because the can controls the steam, and directs it towards the pinwheel. Also, when the can is on top of the aluminum foil, some of the steam is lost, whereas when there was no can, all the steam was moving up towards the pinwheel. After the calculations were done, using the formula $Q = mc\Delta T$, the heat energy produced was 1.2 X 10^15J.

Background and Scientific Concepts:

Geothermal energy is a kind of energy that is renewable and sustainable because it replies on water moving through the water cycle and the interior heat of the earth (Science Buddies Staff, 2015). A layer of hot and molten rock called magma is found below Earth's crust. This layer produces heat continuously, mostly from the decay of naturally radioactive materials such as uranium and potassium. The amount of heat within 10,000 meters (about 33,000 feet) of Earth's surface contains 50,000 times more energy than all the oil and natural gas resources in the world. There is plenty of heat in the center of the Earth. The deeper a person digs, the hotter it gets. The core, about 4,000 miles (6,437 kilometers) beneath the surface, can reach temperatures of 7,600 degrees Fahrenheit (4,204 degrees Celsius). Heat from the earth can be used as an energy source in many ways, from large and complex power stations to small and relatively simple pumping systems.

Almost everywhere, the shallow ground or upper 10 feet of the Earth's surface maintains a nearly constant temperature between 50 degrees and 60 degrees Fahrenheit (10 degrees and 16 degrees Celsius). Geothermal heat pumps can tap into this resource to heat and cool buildings. A geothermal heat pump system consists of a heat pump, an air delivery system, and a heat exchanger-a system of pipes buried in the shallow ground near the building. In the winter, the heat pump removes heat from the heat exchanger and pumps it into the indoor air delivery system. In the summer, the process is reversed, and the heat pump moves heat from the indoor air into the heat exchanger. The heat removed from the indoor air during the summer can also be used to provide a free source (Geothermal Energy, 2016).

Geothermal power plants drill their own holes into the rock to more effectively capture the steam. There are three basic designs for geothermal power plant, all of which pull out water from steam from the ground, use it, and then return it as warm water to prolong the life of the heat source. In the simplest design, known as dry steam, the steam goes directly through the turbine, then into a condenser where the steam is condensed into water. In a second approach, hot water is depressurized into steam, which can then be used to drive a turbine. In the third approach (binary cycle system), the hot water is passed through a heat exchanger, where it heats a second liquid (isobutene) in a closed loop. Which is then converted into steam to run the turbine (How Geothermal Energy Works, 2016).

Purpose:

The purpose of this lab was to determine the number of turns, and quantity of heat energy produced when water is boiled at temperature's of 65 and 80 degree's Celsius, which is then used to turn a pinwheel.

Experimental Hypothesis:

If the temperature of the water is at 65 degree's Celsius then the pinwheel would produce less turns than if it were at 80 degree's Celsius, because the temperature of the water results in the amount of steam produced. If the temperature is less then less steam would be produced, resulting in less turns being produced by the pinwheel.

Variables:

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Controlled:
-Amount of water (2 quarts)
-Amount of time (20 seconds)
-Height of pinwheel from pot (10 inches)
-Layers of aluminum foil (2)
-Number of holes in aluminum foil (9)

Manipulated:
-Addition of metal can, and removal of metal can (14.5-ounces, also known as the "power plant")
-Temperature (65 degrees Celsius, and 80 degrees Celsius)

Responding:
-Number of turns the pinwheel consisted of

Materials:

-Clean metal can with one lid removed (14.5-ounces)
-Hammer
-Nail (1/8-inch diameter)
-Wood ruler or thin piece of wood (12 inches long)
-Rubber bands (2)
-Medium-sized pot (3 quarts)
-Aluminum foil
-Stovetop
-Pinwheel (10 cm, 0.009kg)
-Permanent marker
-Timer
-Oven mitts

Procedure:

1. Used the hammer and nail, made a hole at the edge of the lid of the metal can. Made another hole directly opposite of the first hole.
2. Attached the ruler, vertically, to the side of the can, using rubber bands. Positioned the ruler so that it was between the two holes. Made sure the open end of the can was facing down.
3. Filled the 3-quart pot with 2 quarts of tap water. Took a piece of aluminum foil, and placed it on top of the pot. Made sure the top of the pot was sealed. Took another piece of aluminum foil and placed it on top of the first piece of foil. The foil-covered pot modeled the earth. The aluminum foil was the crust, which covered the heat that was within the earth.
4. Used the nail to gently poke a hole in the center of the aluminum foil pieces, and 8 holes around the aluminum foil.

5. Placed the pot on top of the stove, which was set on medium
6. Made on large mark on the back of the pinwheel at the base of the spokes with the permanent mark to help indicate whether the pinwheel was spinning.
7. Waited for the water to boil until temperature reached 65 degree's Celsius.
8. As soon as steam came out of the hole, placed the can and ruler on top of the hole in the foil. Using the timer let the can sit for 30 seconds. This represents a power plant, which collected steam from a reservoir in the earth.
9. Held the 10 cm pinwheel 10 inches above the can over both holes.
10. Noted the location of the mark on the back of the pinwheel, as it made complete turns. Counted the number of turns in 20 seconds. Recorded the number of spins. Repeated this step two more times.
11. Used the oven mitts and removed the can from the top of the pot and placed it to the sit. Waited for the water temperature to reach 80 degrees Celsius.
12. Held the pinwheel over the hole in the foil at the same height as step 9. Counted the number of complete spins the pinwheel mad in 20 seconds. Recorded the results. Repeated this step two more times. Holding the pinwheel over the bare foil without the can represented the power of geothermal steam from the earth without a power plant.

Diagrams:

Diagram 1: Used a Metal Can Placed on top of a Medium Sized Pot covered in Aluminum Foil to Display a Geothermal Power Plant Model:

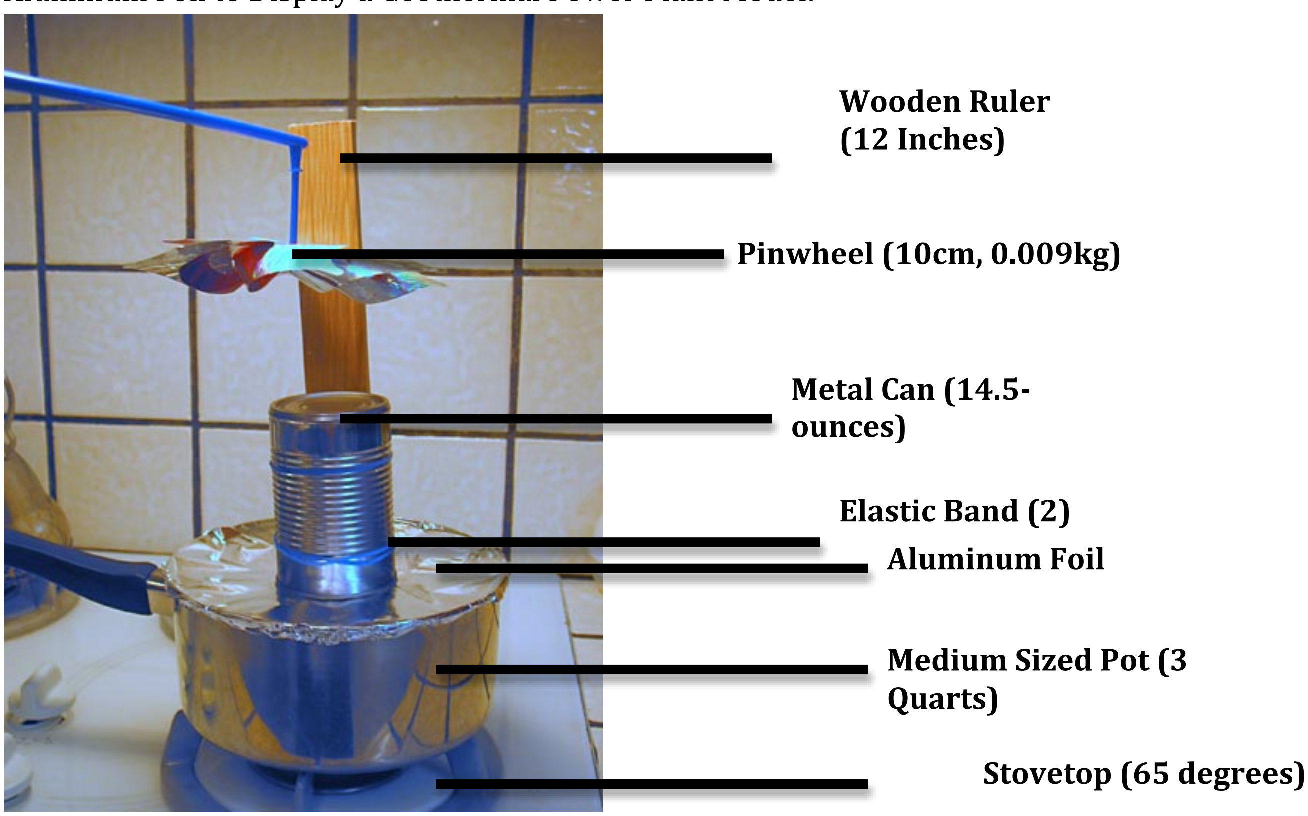

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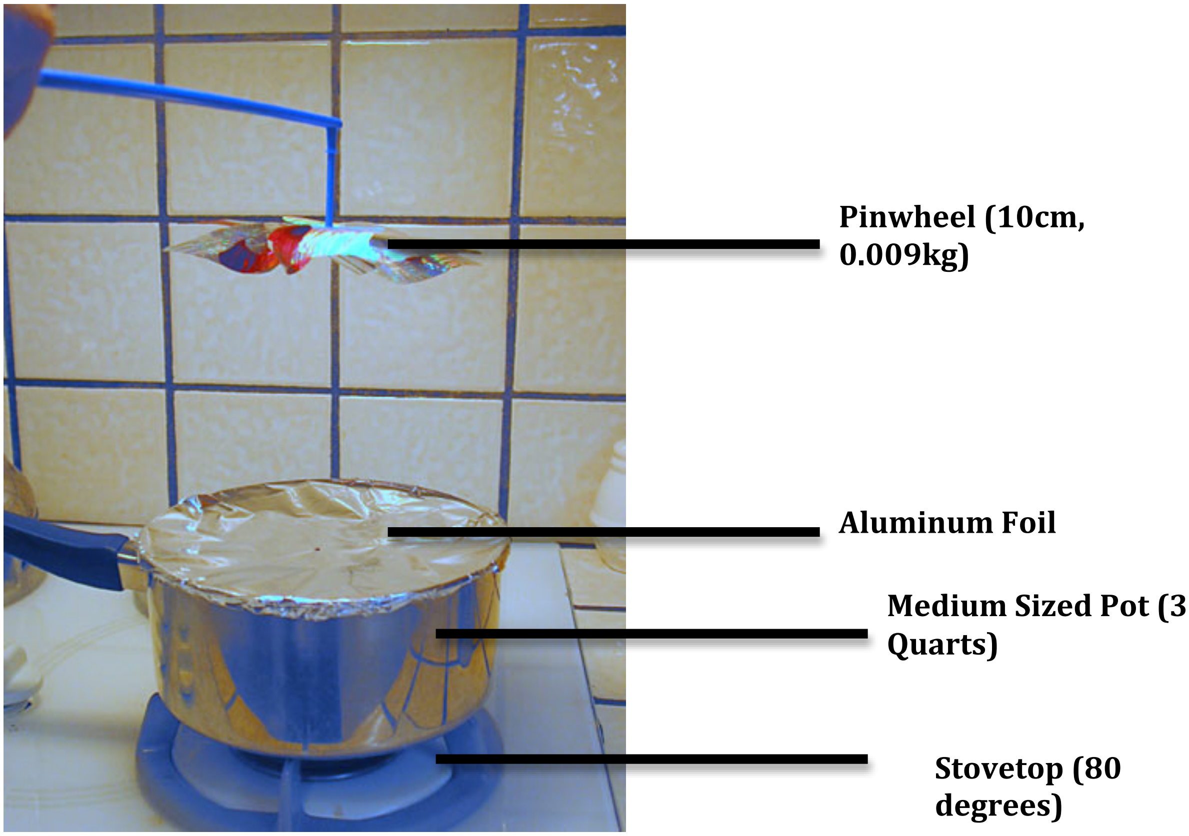
Diagram 2: Removed the Metal Can, and Counted the Number of Turns over Aluminum Foil to Display the Power of Geothermal Steam from the Earth without a Power Plant:



Data:

Table 1: Determining the Number of Turns produced by a Geothermal Power Plant when the Temperature is 65 Degrees Celsius and by Geothermal Steam from the Earth when the Temperature is 80 Degrees Celsius:

	Geothermal Power Plant (With Metal Can)	Geothermal Steam from the Earth (Without the Metal Can)
Number of Turns:	26	28
Temperature:	65 degrees Celsius	80 degrees Celsius

Calculations:

$Q = mc\Delta T$

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Q = quantity of heat energy (J or kJ)
m = mass of water (g or kJ)
c = specific heat capacity of water (4.19 J/g ◦C)
ΔT = change in temperature
Q = ???
m = 2 quarts of water (1892.7059 grams)
c = 4.19 J/g ◦C
ΔT = 80 degrees – 65 degrees = 15 degrees Celsius

Q = (1892.7059 grams)(4.19 J/g ◦C)(15 degrees Celsius)

Q = 118957 J

Q = 1.2 X 10^5 J

Analysis:

During this investigation, a 14.5 ounces metal can (represented a geothermal power plant) was placed on top of a 3 quarts pot filled with 2 quarts of boiling water. The water was at a temperature of 65 degree's Celsius. When the pinwheel was placed on top of the metal can it had produced 26 turns. When the metal can was extracted from the experiment, the water temperature was at 80 degree's Celsius. As the pinwheel was held on top of the pot covered with aluminum foil, the pinwheel had produced 28 turns. The reason being for the decreased number of turns with the metal can (65 degrees Celsius) was because the can controlled the steam, and directed it towards the pinwheel. Also, when the temperature was at 65 degree's Celsius, a few amount of steam was being produced, therefore the number of turns presented were less. As the temperature rose, the molecules present in the water moved around extremely fast, which caused the pressure to increase in the pot. According to the first law of thermodynamics, energy cannot be created or destroyed, therefore, when this occurred, the molecules separated and became a gas (steam), which then travelled out the holes in the aluminum foil. The more steam that was produced, the greater the increase of the number of turns occurred. Using the results presented, the quantity of heat energy was calculated. In order to calculate the quantity of heat energy, the mass of the water was converted from 2 quarts to 1892.7059 grams, and the change in temperature was calculated (15 degree's Celsius). The formula Q=mcΔT was used, and the specific heat capacity of water was acquired (4.19 J/g ◦C). After the calculations were done, the heat energy produced was 1.2 X 10^15J.

Graph 1: Determining the Number of Turns a Pinwheel makes when placed on top of A 14.5 Ounces Metal Can (Geothermal Power Plant, Temp: 65 degrees Celsius), which is on top of a 3 Quarts Pot, Compared to when the Pinwheel is placed on top of the 3 Quarts Pot only (Geothermal Steam from the Earth, Temp: 80 degrees Celsius):

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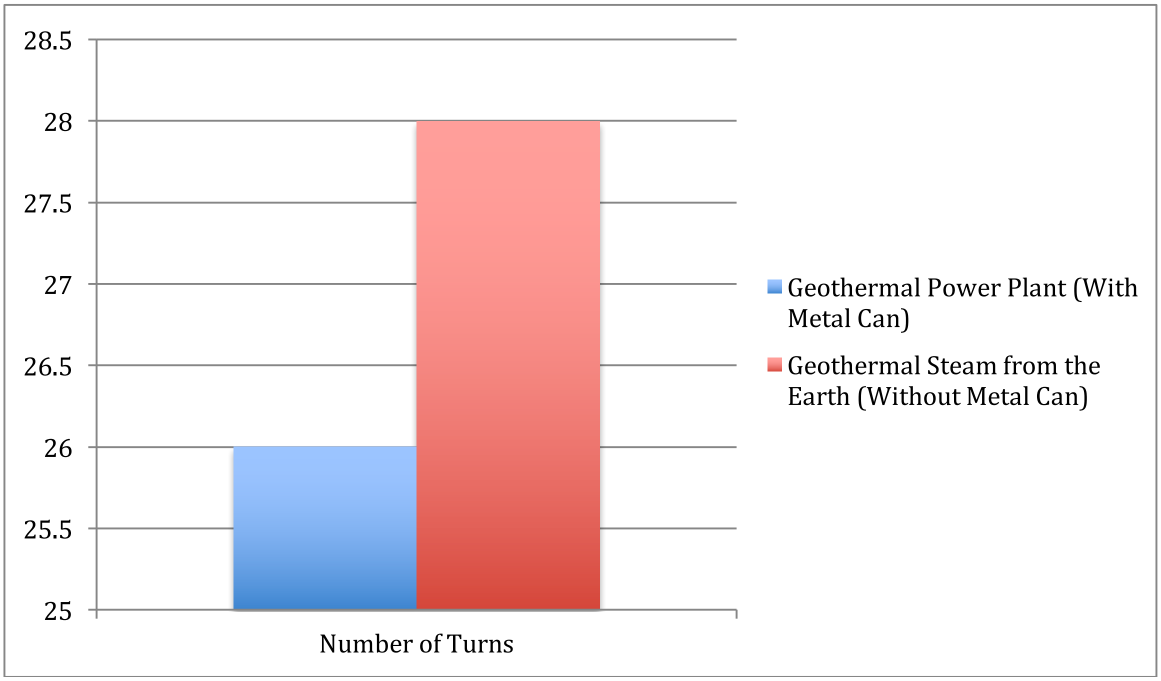


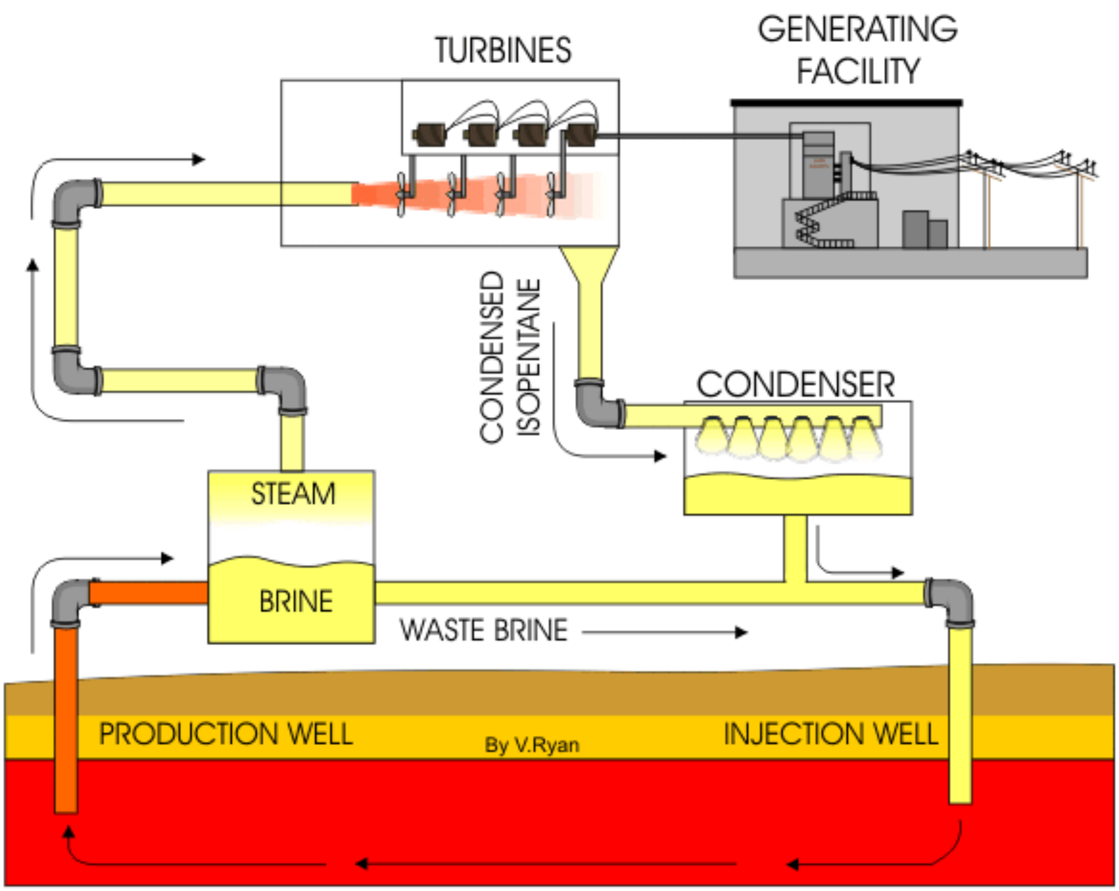
Conclusion:

According to the evidence, when the water boiled at a temperature of 65 degree's Celsius, the pinwheel produced less turns than when it was at 80 degree's Celsius. It was predicted if the temperature of the water is at 65 degree's Celsius then the pinwheel would produce less turns than if it were at 80 degree's Celsius, because the temperature of the water results in the amount of steam produced. The evidence presented in this investigation proved the prediction to be correct, because the lower the temperature was the less number of turns were produced. During the execution of this lab, three errors had taken place. These errors include friction involving the pinwheel, the loss of heat, and draft in the room.

Extension:

The investigation that had taken place above is known to be a Flash Steam Power Plant. Flash Steam Power Plants are the most common form of geothermal power plants. The hot water is pumped under great pressure to the surface. When it reaches the surface the pressure is reduced, and as a result some of the water changes to steam. This produces a 'blast' of steam. The cooled water is returned to the reservoir to be heated by geothermal rocks again (Ryan, V., 2005-2009). Most geothermal areas contain moderate temperature water (below 400 degrees Fahrenheit). Energy is extracted from these fluids in binary cycle power plants. Hot geothermal fluid and a secondary (hence "binary") fluid with a much lower boiling point than water pass through a heat exchanger. Heat from the geothermal fluid causes the secondary fluid to flash to vapor, which then drives the turbine (Reports and Documents, 2016).

Figure 1: Illustration of how Flash Steam Power Plants Work in order to Produce Electricity:



Error Analysis:

During this investigation, three errors had taken place, friction involving the pinwheel, the loss of heat, and draft in the room. When the pinwheel moved over the aluminum-covered pot, there was resistance between the two, which caused friction. When friction occurred, the pinwheel would not spin, which prevented the investigation to follow through. In order to prevent this error a homemade pinwheel must be created using aluminum pie pins, and a wooden skewer (at least 20 cm long, with sharp point). This would help reduce the friction between the two objects, since both would be made out of the same material (Rowland, Teisha, 2015). When heat is being transferred, the input value would always be greater than the output value. In this experiment, when the metal can was placed on top of the aluminum foil, the amount of heat produced by the boiling water was lost as it exited the metal can. The reason being for this is because the can absorbed some of the heat as it travels throughout the can. This error lead to incorrect calculations, because the amount of heat lost was not taken into consideration. No matter how many solutions are provided to prevent this error, the heat transfer would never be 100%. However, there are ways to reduce the amount of heat lost, such as carrying out the experiment over as short a period of time as possible, because the shorter the time allowed, the less heat would be lost (Domen, Steve R., and Paul J. Lamperti, 1974). When the investigation was performed, it was important for the steam to move directly towards the pinwheel, but something that should be taken into account is draft in the room. The slightest bit of wind would cause the steam to move in a different location than straight up. This would lead to the number of turns to be different than what was achieved throughout the execution of the experiment. In order to prevent this error, all areas wind could enter from must be closed off, such as windows or the bottom of doors. To do so, door snakes could be used. Door snakes are 3 – or 4-foot long fabric tubes, stuffed with an insulating material, that, when positioned on the floor in front of a drafty door, it stops cool air from entering along the bottom (Erlam, Linda, 2016).

Sources:

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