Methods and Materials:

There were many materials that were needed throughout the five labs that were conducted. The most important of which was a Mr. Coffee brand coffee machine model number TF12. Also 8 O'clock Coffee brand coffee beans were used in multiple experiments. In addition to the Mr. Coffee brand coffee machine, a Mr. Coffee brand coffee grinder, model number IDS57, was also used. Some lab equipment was also used during the experiments. An analytical balance was used in most of the labs to measure mass to the nearest milligram. In labs where absorbance had to be measured, a Milton Roy single-beam Spectrophotometer set at 640 nm was needed. When measuring temperature, thermocouples were used. In order to measure power, a wattmeter was used. In the final lab where flow rate was measured, a Cole Parmer rotameter was necessary. Finally, in the lab where the coffee machine was taken apart, a Phillips head screwdriver was needed.

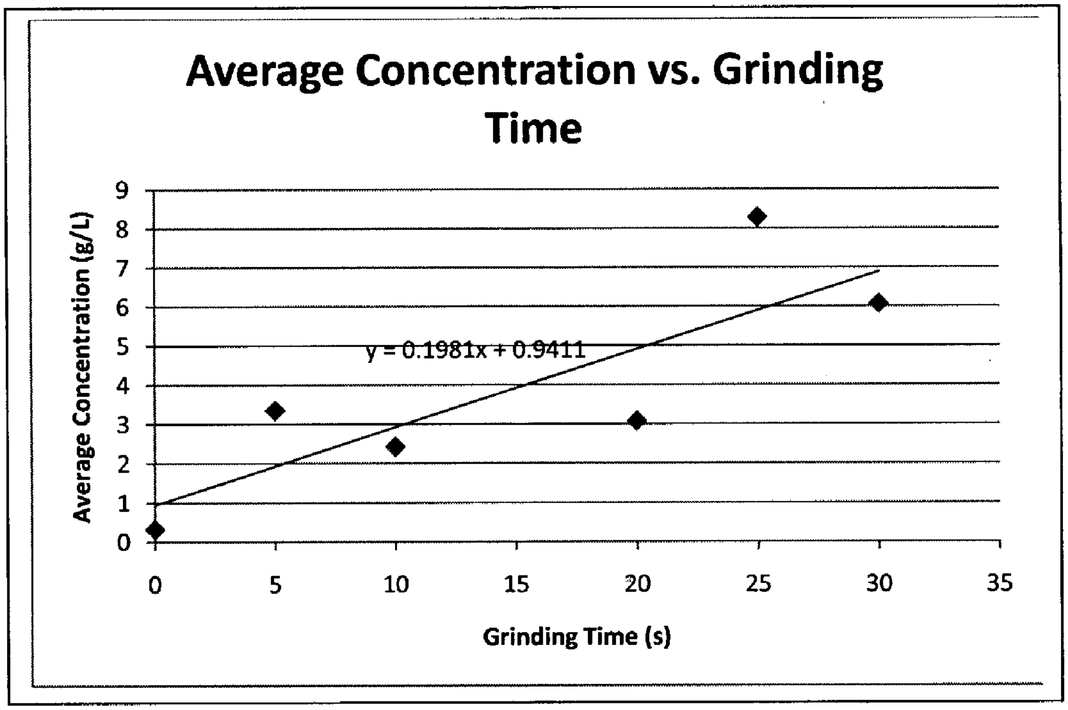
Experimental Procedure:

Begin by inspecting the packaging for the coffee machine. Read the manual including the safety instructions and operating instructions. Record and information on the coffee machine itself such as the rated power. Make external measurements including the suggested volume of a cup of coffee and the maximum volume in the reservoir and coffee pot. Record all external dimensions on the coffee machine. Next, determine the average flow rate of the machine by adding a measured amount of water to the reservoir and timing from when the first drop enters the pot until the time at which there are two seconds in between drops. After that, measure the temperature in the reservoir and at the bottom of the coffee pot every thirty seconds during the brewing process and every minute for fifteen minutes after brewing. Record the power consumption of the coffee machine using a wattmeter at regular intervals during brewing and for fifteen minutes afterwards.

Results and Discussion:

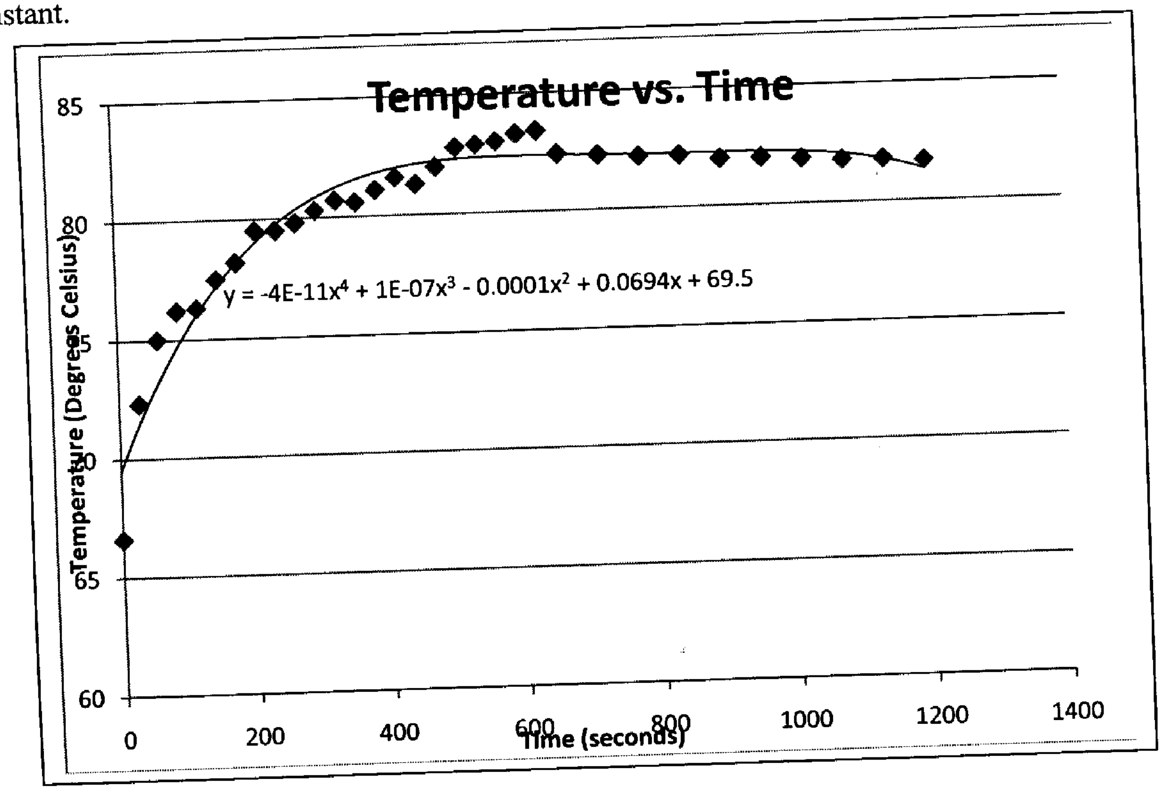
Experiment 1: Mass Transfer; Particle Size

The results calculated in this lab focused on concentration that is dependent on the particle size of the coffee beans. To determine how finely ground the beans were, the time that they were being ground for was recorded. After that, the coffee was brewed and the following results were collected:



This graph was plotted using data points for average concentrations in relation to the grinding times it corresponds to. Though it is not obvious, there does seem to be a direct linear relationship between these two values. This graph makes sense because the concentration of the coffee should increase as the grinding time increases. A longer grinding time provides more time for the surface area of the coffee beans to increase and concentration is maximized as surface area is maximized. The concentrations are average values because there were two calculated concentrations for every length of grinding time. The data may not seem very precise, but it is fairly accurate and consistent.

had a volume of around 140mL which means that each of our cups is 4.7 fl oz which is only a little more than half of the standard. When the coffee machine was filled, it was filled with 1L of water. However there is a final accumulated total of 872mL. This means that some water had to have been absorbed in the remaining coffee grounds or it had to have evaporated. As the coffee brewed in the pot, the temperature steadily increased until it reached a point where it remained constant.



The reason that this graph uses a polynomial trend line is because Excel is unable to create a logarithmic trend line, which would be more appropriate for this data. The average power consumption of this machine is about 860 watts, which it used constantly during the brewing process and at two and a half minute intervals during the warming process.

Conclusion:

Over the course of the five labs that were conducted many things were determined. In the first lab, we found how the time spent grinding the coffee beans effected the strength of the brewed coffee. From the data collected we can see that the more time spent grinding the coffee beans the stronger the coffee tends to be. We can see this not only from the taste test but also from the absorbance and concentration values for the different grind times. In the second lab that was conducted we determined that the strength of the coffee brewed also has to do with how long the coffee has been brewing for. This is displayed in the data, which shows that the first cup of coffee brewed has a much higher absorbance as well as a much higher taste rating than that of the last cup of coffee brewed. The third lab was different from the first two experiments. The external features of the coffee machine were examined as well as the operating specifications of temperature, flow rate, and power consumption. In this lab we learned a lot about how the coffee machine worked. In lab 4 we took it a step further by taking apart the coffee machine. This furthered our knowledge of how the coffee machine was put together and how it worked. We now knew that it used a tubular heating method to heat the coffee. We also discovered the way that the water flowed through the machine during brewing. In the last lab we investigated the relationship between water flow and outlet water temperature. From the data our group determined that when the flow rate is decreased the outlet temperature in much greater. From these five labs we were able to learn a lot about how a coffee machine works and what factors go into making a good cup of coffee.

References:

1. Lim, Zack. "The Interesting Facts About Coffee Maker." *Ezine Articles*. Web. 12 Dec. 2010. <http://ezinearticles.com/?The-Interesting-Facts-About-Coffee-Maker&id=400585>.

2. Villanueva, Cristina M; Cantor, Kenneth P; King, Will D; Jaakkola, Jouni JK; Cordier, Sylvaine; Lynch, Charles F; Porru, Stefano; Kogevinas, Manolis (2006). "Total and specific fluid consumption as determinants of bladder cancer risk". *International Journal of Cancer* **118** (8): 2040–47.

Abstract: How does the concentration of the coffee in your cup determine if it's good or not? That's exactly what the objective of this experiment was. Does a higher concentration of coffee make the coffee better? There were five experiments conducted to test the how to get a good concentration of coffee in the water. In the first part the coffee beans were ground for different times before they were put into the machine. The grinding times were 0, 10, 15, 20, 25, and 30 seconds. The concentration of coffee increased, as the coffee beans were ground for a longer time. As the beans were ground for a longer time they became smaller therefore increasing the surface area of each particle. This gave the water more places to come in contact with the bean and it could absorb more coffee. The temperature of the coffee coming out of the coffee machine was directly related to the flow rate of the water going through the coffee machine. The faster the water was going through the system the less time it had in contact with the heater. This meant the water was cooler when it needed to be hotter to absorb more of the coffee. The highest temperatures were collected when the flow rate was the slowest. Therefore, this gave us the highest concentration too. However the heater had the best efficiency when the flow rate was going faster. The best efficiency we got was at 96% with the fastest flow rate. The amount of water used to make the coffee also determines the concentration of the coffee. As water flows through the coffee grounds it absorbs as many coffee particles as possible leaving less for the water behind it. This means the coffee coming out first has the highest concentration of coffee in it. As more coffee comes out it has lower concentrations so it dilutes the coffee already made. This brings down the concentration as more water flows through the machine making more coffee. This also brings more mass of the coffee into the carafe. The more mass there is of coffee the higher concentration the coffee has. This is because if there is more coffee in the same amount of water it will have a higher concentration by definition. Therefore, The concentration of coffee is higher when the beans are ground the longest to give more surface area, the flow rate is the slowest allowing the coffee to heat up the most, and the least amount of water is used.

Results:

Part 1: Mass Transfer

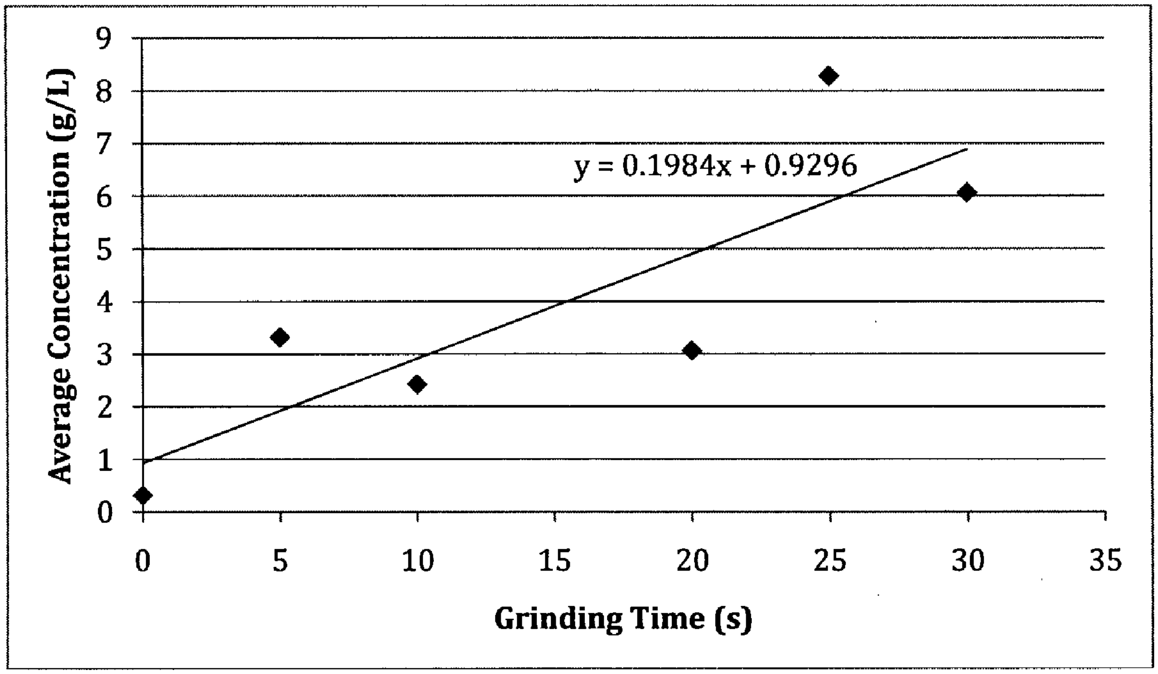


Figure A: Concentration vs. Grinding Time: Shows the concentration of the coffee related to the time the coffee beans were ground.

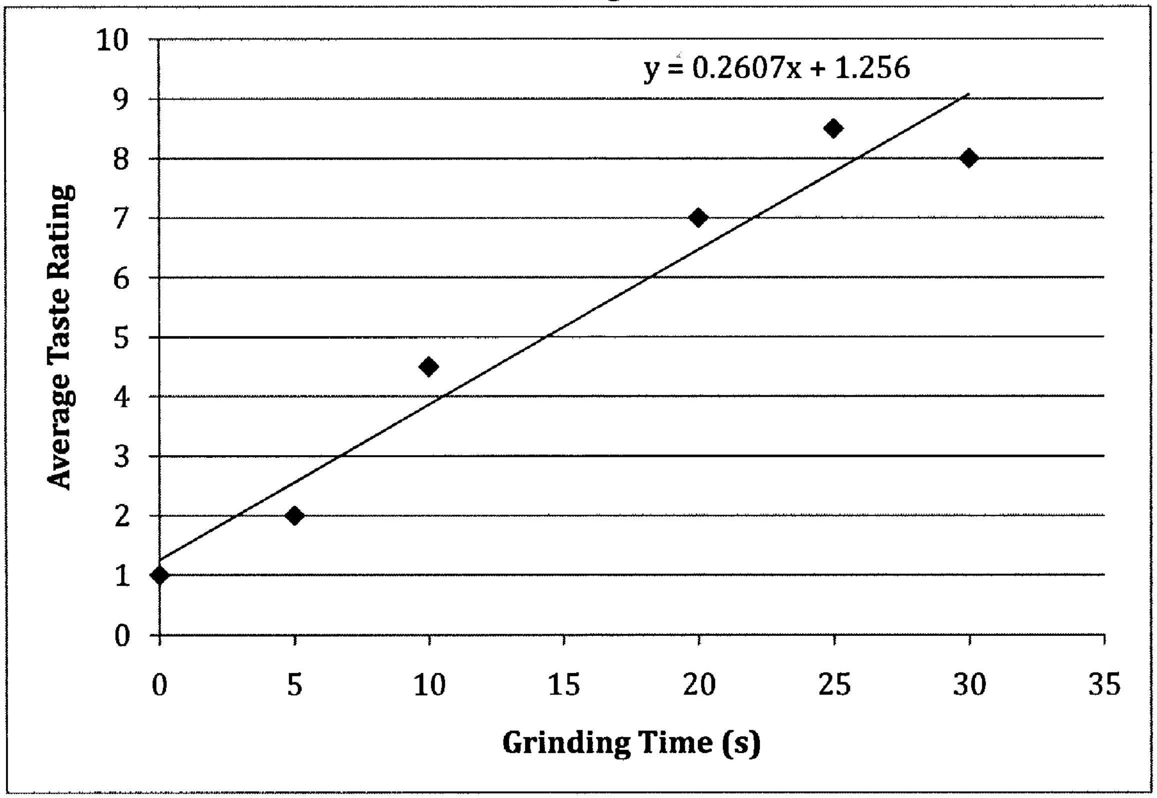


Figure B: Taste vs. Grinding Time: Shows the taste rating compared to the grinding time of the coffee beans.

Abstract

This study was conducted in order to gain a clearer understanding of how coffee machines work. It is designed to investigate the factors that affect the taste of coffee, and explore some of the engineering and scientific principles that enable a coffee machine to work. The grinding time of coffee beans has the largest impact on taste. Finer grounds promote a higher absorbance of bean during the brew process. This then increases the concentration of coffee, and strength of its taste. The electrical components of the machine enable heat transfer during brewing. A slower input water flow into the machine will decrease the amount of power the machine needs. These findings are extremely useful in the prosperous coffee industry. Understanding how to conserve energy and alter the taste of coffee to accommodate varying preferences will not only maximize profit in the industry, but also provide more enjoyment to the consumer.

Introduction

In America, the popularity of coffee has been on the rise. Nearly 56% of adults in the United States drank coffee every day in 2006, which is 7% higher than in 2004 (Moore 1). Of these regular coffee drinkers, many consume about three cups a day (Moore 2). This demand for coffee has resulted in a very profitable industry. Americans alone spent over 18 billion dollars on coffee in 2006 (Moore 3). Starbucks, a company famous for coffee, had fiscal revenue of 10.3 billion in 2008 (Daumeyer). The importance of coffee in the modern world is apparent based on these overwhelming statistics. It is equally important to understand the concepts behind coffee machines. These devices are

Introduction

Coffee maker manufacturers give instructions alongside their machines in order to brew a cup of coffee. Most people who drink coffee follow the instructions to brew coffee and that method that they use is of upmost importance. The intention of using a coffee maker is to make the ideal cup of coffee and many factors are involved in making this ideal cup of coffee. If the factors involved in brewing coffee aren't close to the intended amount then the coffee that is made will have bad taste.

Ideal pot of coffee is defined coffee that has the highest concentration of coffee while maintaining uniformity at that highest concentration while at a temperature that is not too cold and one that is not too hot. The primary factors involved in coffee brewing are absorbance, concentration, temperature, and time. The purpose of this study is to discover the method necessary to brew the ideal cup of coffee.

The factors will all have an effect on the resulting taste. The intention is to have a perfect balance of each factor; factors like absorbance, concentration and time are connected and will have a heavy result on the taste. Temperature also has an effect on taste, but not in connection with the other factors. By the end of the study the method for brewing an ideal cup of coffee should be discovered.

Background and Theory

Coffee is a caffeinated drink brewed from coffee beans, which are seeds of the coffee plant. Coffee beans off of the plant go through several processes and then are roasted for use in to make coffee. Coffee makers are household appliances developed for the purpose of boiling hot water in the same appliance as coffee beans are used to make the coffee drink. During the process of making coffee the factors that affect taste come into play. Absorbance of coffee is determined by the use of a spectrometer. The thing effects absorbance is the surface area of ground coffee beans exposed to the hot water that is absorbing it. Concentration of the coffee can be determined taking absorbance and multiplying it by 16.8g/L (grams per liter).

C=(16.8g/L)*A

where C is concentration (g/L), A is absorbance (no units), and 16.8(g/L) is the constant. The (16.8g/L)*A is derived from the equation C=(m(i)-m(f))/V where m(i) is dry un-brewed coffee bean mass(g), m(f) is wet brewed coffee bean mass(g), and V is volume of water(L).

Time for all of the study is measured using tools that can accurately do the measuring, as are volume, object masses, flow rate (for the tubular heat experiment), and temperature.

For some parts of temperature and heat, the heat required, heat lost and efficiency must be solved. To find the heat required the density (a constant: 1000kg/m^3) must be multiplied by the flow rate (found using a flow rate meter), then multiplied by the heat capacity of water (a constant: 4182J/kg*deg C), then multiplied by the difference of the measured temperature out and the measured temperature in:

q(required)=p*F*Cp*(T(out)-T(in))

Where p is density (kg/M^3), F is flow rate (m^3/s), Cp is heat capacity (J/kg*deg C), T(out)/T(in) is Temperature (deg C), and q(required) is the work required to change the initial temperature to the final temperature (J/s).

Heat lost is found by taking the heat of the heater and subtracting the heat required:

q(losses)=q(heater)-q(required)

Where all q's are measured in work (J/s).

The net efficiency of the heater is found by dividing the required heat by the heat of the heater:

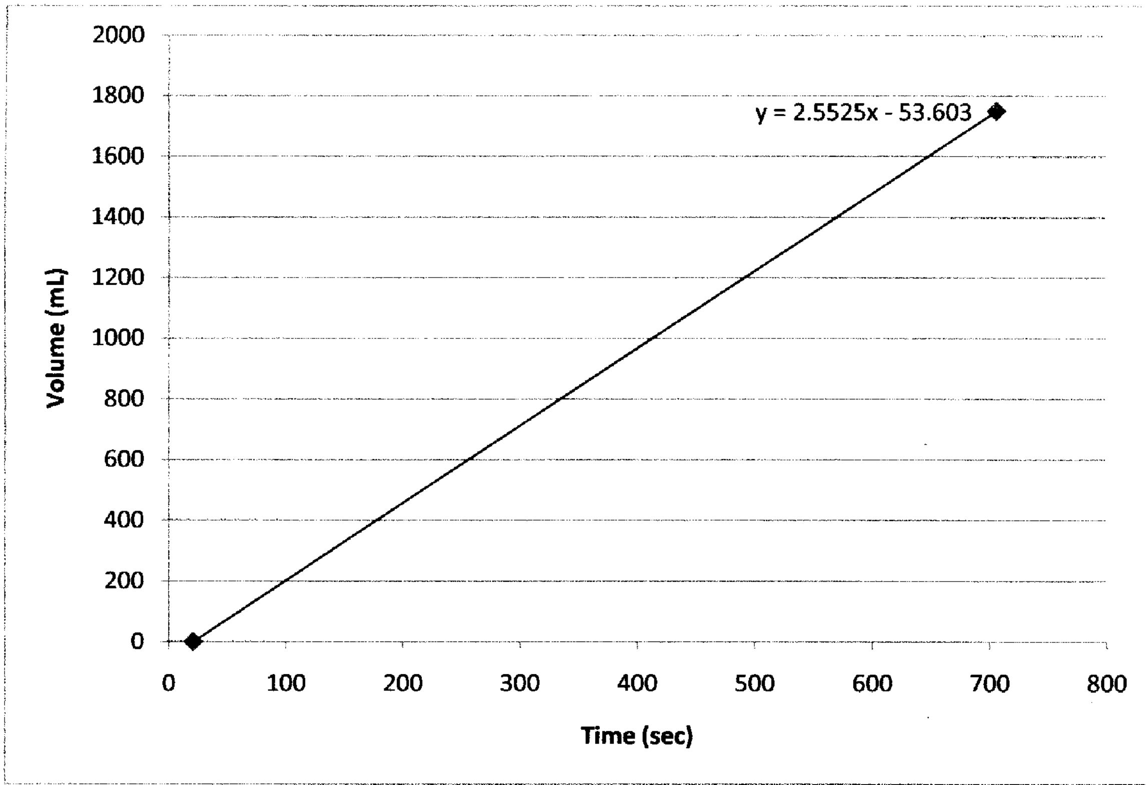


Figure 6. Shows the Linear Rate of increasing Volume from when Water Start to drip to when there was two seconds between the drips in the coffee maker. This Graph shows that there was a flow rate of 2.55 mL/min. The data was obtained by timing from the turning on the coffee maker to when the drips started to appear to when there was two seconds between the drops.

The Data Presented in these experiments presents more insight into how the coffee machine operates. This Data shows that the coffee maker uses around 900 watts of energy while brewing, cuts off power when brewing is down and powers up the heater for 10 seconds for every 100 seconds after the brewing process to heat up the hot plate on the coffee maker. This fluctuation in energy helps reduce energy costs while maintaining a constant heat source to heat up the water and to keep the coffee warm. The data also present itself with the fact that the coffee maker for the most part maintains a constant temperature at around 80°C. This constant

Appendix E

Trial #	Electrical input (J/s)	Rotameter Setting (Cole Parmer)	Flow Rate		Temp (deg C)		Energy Required (J/s)	Energy Lost (J/s)	Efficiency
			mL/min	m^3/s	Final	change			
1	913	80	678.4	1.131E-05	34	18	851.1	61.9	93.22%
2	907	70	588.2	9.803E-06	37	21	860.9	46.1	94.92%
3	912	60	498	8.300E-06	42	26	902.5	9.5	98.96%
4	939	50	407.8	6.797E-06	49	33	938.0	1.0	99.89%
5	941	37	290.5	4.842E-06	61	45	911.2	29.8	96.83%