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Designing a Micro-Hydro Powered Automatic Flush System

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ABSTRACT

With the detrimental effects of global warming becoming increasing visible, the desire to conserve energy has become a primary concern for the public. Companies such as BC Hydro are now marketing the awareness of conserving electricity and promoting sustainable energy practices. The idea for this project was to create a micro-hydro power generator to power an automatic hand-wash unit (AHU). This design would be self sufficient and eliminate the need of external electrical power. To find out the operational requirements of an AHU, voltage and current tests were conducted. Various load tests were performed on a modified water meter generator at different flow rates to measure voltage, current, and power output. Through testing we found that the motor chosen for the design is not suitable for the successful creation of our design concept. The generator chosen for this project was not sufficient to power an automatic flush unit. Efficiency of the generator was found to be too low with not enough current and power output. The design concept is still conceptually feasible; however, future development would require research into designing a suitable micro-hydro turbine and generator for powering an AHU.

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LIST OF ABBREVIATIONS

AC – Alternating Current

AHU – Automatic Hand-Wash Unit

DC – Direct Current

L/s – Liters per second

IC – Integrated Circuit

kPa – kilopascal

mA – Milli-amp

mW – Milli-watt

NiCd – Nickel Cadmium

Ω – Ohm

PSI – Pounds per square inch

RPM – Revolutions per minute

s/ 1L– Seconds per one liter

SEEDS – Social, Ecological, Economic, Development Studies

V – Volts

VDC – Volts Direct Current

UBC – University of British Columbia

1.0 INTRODUCTION

This project involves modifying an AHU to operate on a micro-hydro power system. My overall objective during this project is to understand if it is possible to extract enough power from flowing water to power an AHU.

The effects of global warming on our environment are increasingly visible and companies such as BC Hydro are now marketing the awareness of conserving electricity and promoting sustainable energy practices. My initial idea was to develop a way to utilize clean water under pressure. Before water enters your home there is a pressure drop from 200psi to 65psi. This is a significant drop in pressure and my group member, Narvir Patrola, and I postulated that the drop in pressure could be utilized to turn a micro-hydro turbine to power a small generator to create electricity. This electricity could then be used by the home or be wired back into the main electrical grid. However, taking on such a project would require resources and time greater than the scope of this course. Therefore, we were advised by our technical supervisor, Dr. William Dunford, that we should start with a smaller goal which utilizes the same idea. We looked into modifying AHU's, which are installed in most modern washrooms. AHU's reduce water consumption and increase washroom sanitation when compared to conventional manual hand-wash facets. However, AHU's use electrical power for operation. This creates a problem of whether it is more important to reduce water or electricity consumption. Therefore, to reduce electricity consumption as well, we decided to investigate into a design of a micro-hydro power system to power an AHU. This would make an AHU self powered instead of being powered from the main electrical grid.

In this report, all the information we have gathered from research and performing tests is included, there is no information left out. There were many constraints involved with this project. It was very difficult in the beginning for us to find the necessary information regarding how much power an AHU consumed. Also, purchasing the required equipment and parts for this project were very costly. Therefore, it took us a long time to find a way to have what we needed for this project donated. We thank UBC Facilities and UBC SEEDS for their contributions to our project.

This report divides into five major sections. First our design concept for the project is explained. Then the parts used and modified for this project are discussed. Thereafter, the experiments performed during the project are explained. Finally, the overall results are presented followed by a discussion and concluding thoughts.

2.0 METHODOLOGY

This section presents the methodology behind creating a self powered AHU and outlines the specific parts used.

2.1 The Design Concept of a Self Powered AHU

The concept for this project is to design a self powered AHU that would not require any external electrical energy. Figure 1 below is a flow chart for a self sufficient AHU. The AHU is continuously active but only turns water on when it detects a human near the vanity. The AHU will remain on until the user leaves. The energy for this design is harnessed by the use of a micro-hydro turbine. The micro-hydro turbine is connected before the clean water input of the AHU. When the AHU is triggered, water will have to flow through the micro-hydro turbine which will rotate a shaft coupled to a DC generator to produce electrical energy. A battery will then store the electrical energy which will be readily available to the AHU. To monitor the overall charge of the battery, control circuitry would be needed. The control circuitry will also ensure that there is enough power stored for one cycle of usage. If the control circuitry determines that the battery level is less than what is required for one cycle of usage, it will send a signal to the AHU unit to open the solenoid water valve. This would occur regardless of whether a human is in close proximity to the sensor or not. Once the control circuitry determines that the battery is sufficiently charged, it will send a second signal to the AHU to close the water valve. Figure 2 is a flow chart summarizing the control circuitry.

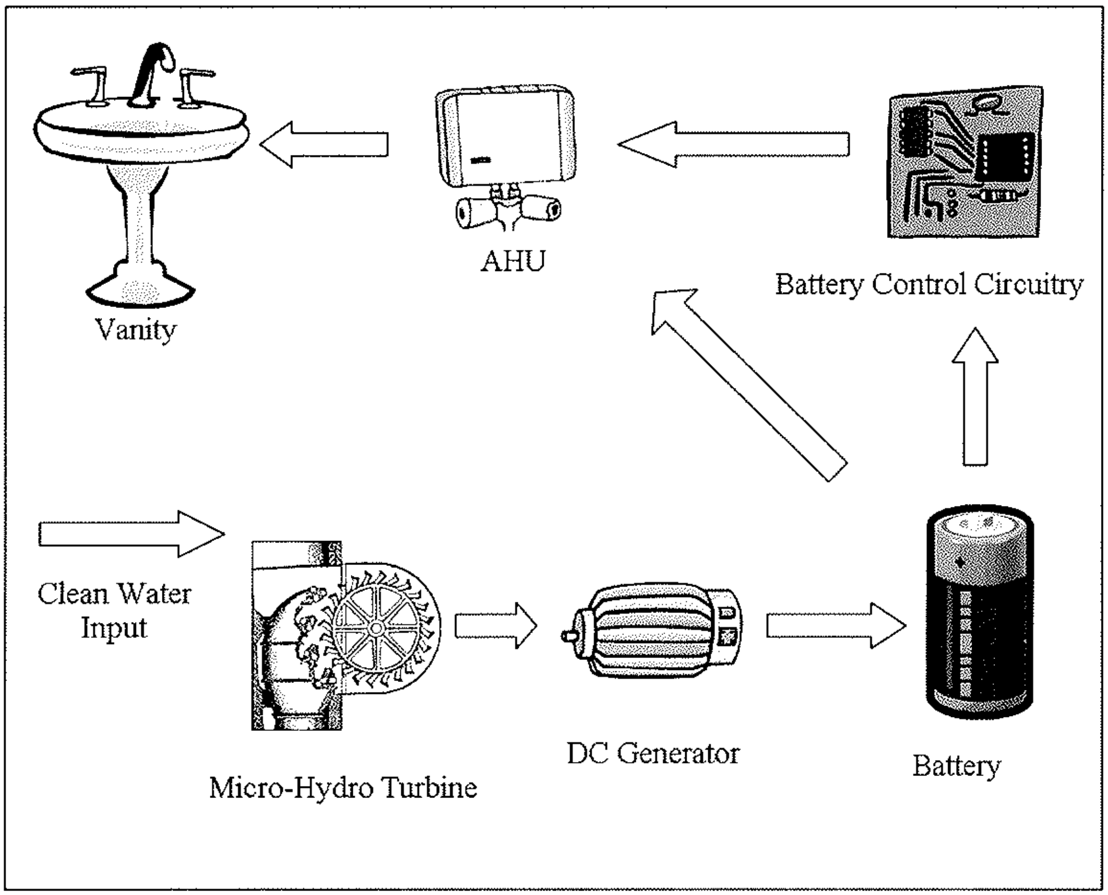

Figure 1: Design Concept for a Self Powered AHU

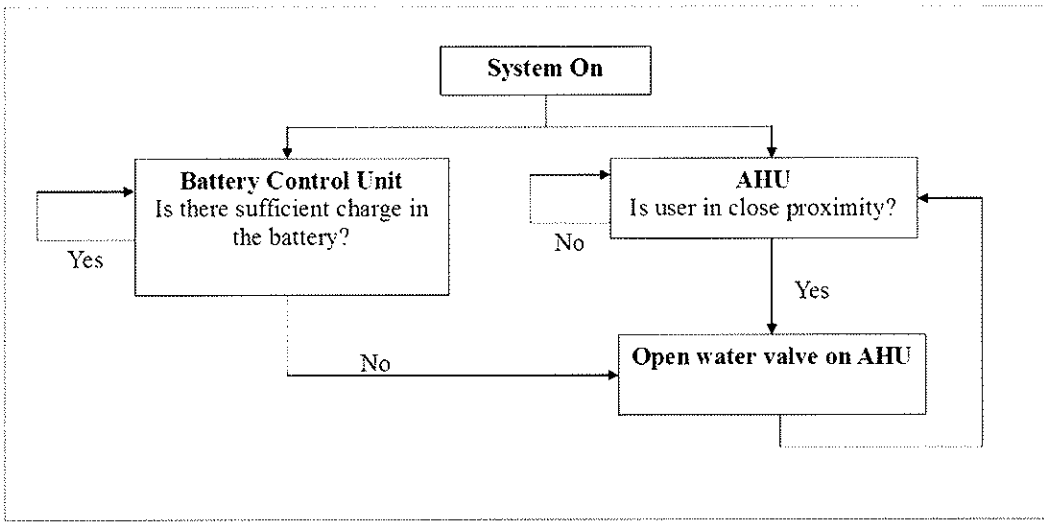

Figure 2: Control Circuitry Flow Chart

2.2 Parts Used In the Design

The parts that will be used in our design consist of the following: a vanity, a micro-hydro turbine, DC generator, battery, control circuitry, and an AHU.

2.2.1 The Vanity

The vanity can be a residential or commercial unit but must contain a sink or hand wash station. To ensure proper operation, the AHU will mount directly to the vanity in close proximity to the sink.

2.2.2 Micro-Hydro Turbine

For our design, we will be modifying a water meter into a micro-hydro turbine. The water meter is a Neptune T-10 water meter. In correlation with the UBC SEEDS Department, the water meter was donated for our research on June 13, 2008 by Mr. Len Sobo, the project manager for UBC Land and Building Services.

2.2.3 DC Generator

The DC generator that we are using for our design will be from a 5V hand crank radio. The DC generator has 10 poles and came assembled with a gear box. The gear ratio of the gear box is 1:20. The DC generator also has a full bridge diode rectifier which will smooth out any voltage ripples that could be caused by variations in rotation speed. Refer to Figure 3 for a picture of the DC generator.

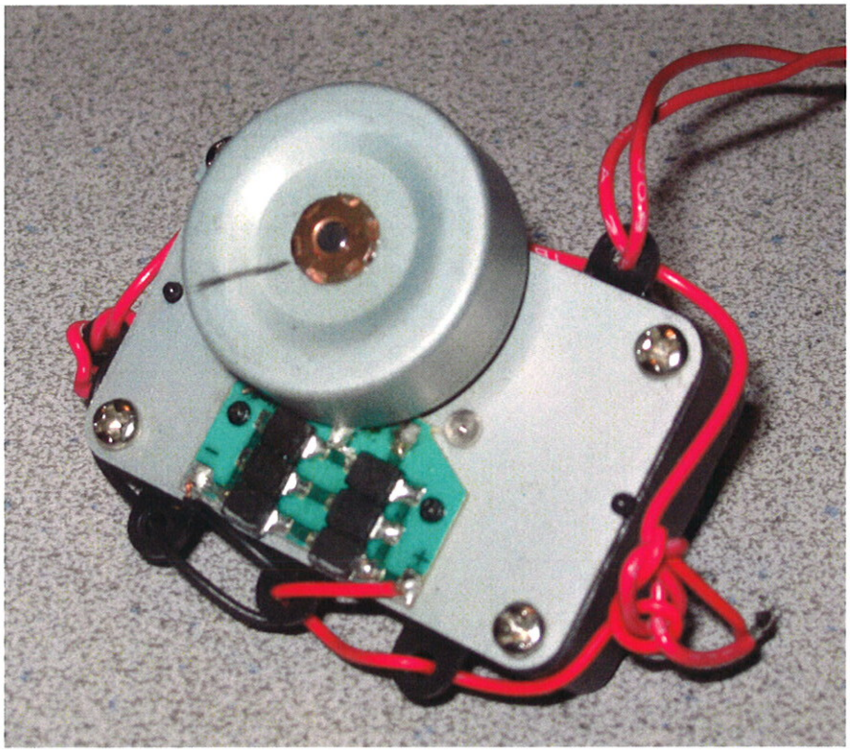

Figure 3: DC Generator

2.2.4 Battery

We do not currently have a battery pack for our design. However, we intend to use NiCd batteries. We feel that this type of battery will be sufficient for our design because of the following advantages: low internal resistance, good charging efficiency, and consistent terminal voltage.

2.2.5 Control Circuitry

The control circuitry we intend to design will be able to monitor the charge of the NiCd batteries. We intend to measure the battery voltage at regular intervals. If the battery charge drops below a predetermined critical range, the designed control circuitry will be able to send a signal to turn on the AHU for charging.

2.2.6 AHU

The AHU we will be using is a Nepitek H-6000CB electronic faucet. The AHU was donated us on June 12th, 2008 by Mr. Jim Ramsay, Facilities Manager at UBC. The Nepitek AHU came completely assembled with: an infrared sensor, a control module, a 12V AC to DC adapter, and a goose neck faucet. The Nepitek AHU goose neck faucet is shown in Figure 4.

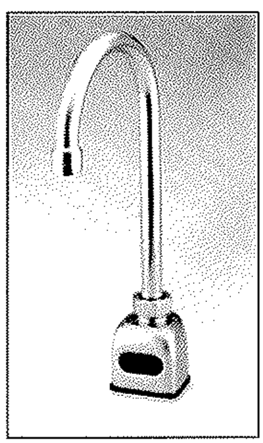

Figure 4: Nepitek H-6000CB AHU [1]

3.0 WATER METER MODIFICATION

As donated, the Neptune T-10 water meter was not suitable for our project. However, the internal mechanics of the water meter were ideal to a water turbine. Therefore, we modified the water meter. We had a metal shaft machined and attached to the water meter for the purpose of mounting a DC generator. The before and after modification of the water meter can be viewed in Figure 5.

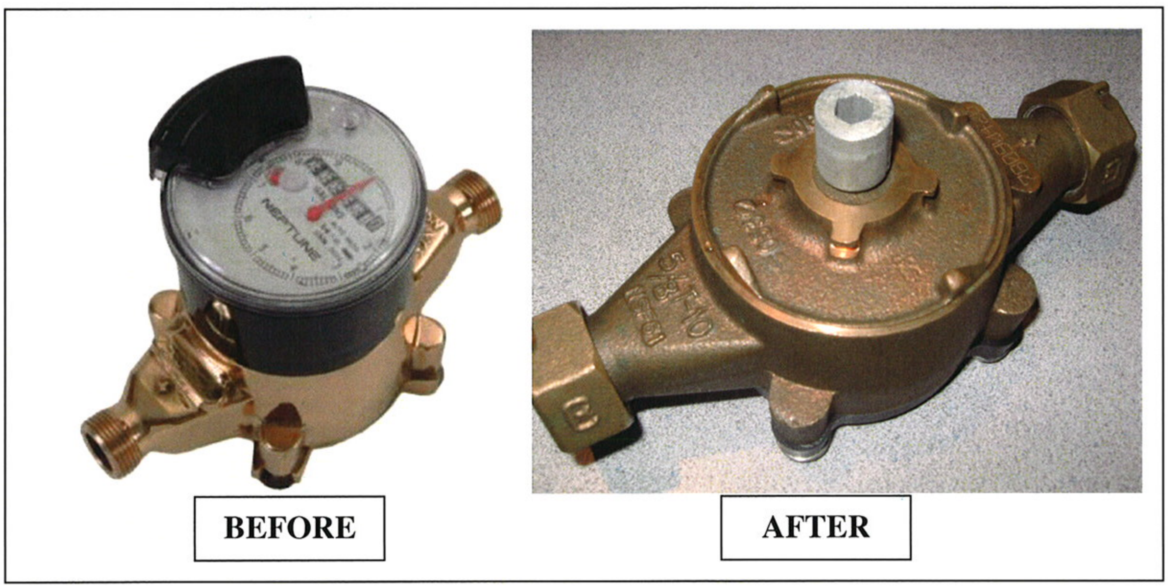

Figure 5: Modification of the Water Meter [2]

4.0 EXPERIMENTS

This section discusses the experiments performed for this project. First, how current and voltage requirements were measured for an AHU is explained. Then, how voltage output from the DC generator was measured is explained.

4.1 Understanding AHU Requirements

It was very difficult for us to find the necessary information regarding the electrical and mechanical operations of an AHU from data sheets available from manufacturers. Therefore, it was imperative that we had an actual AHU to further progress in our project. The information we required was the following: how much current is drawn by an AHU during operation and how much voltage is required to turn on an AHU for operation.

4.1.1 Current

We performed the following list of steps to measure the current drawn by an AHU during operation.

Step 1.	We set the multi-meter to measure current.
Step 2.	We attached the leads of the multi-meter in series between the positive input of the AHU and positive output of the 120VAC to 12VDC adaptor.
Step 3.	We plugged the AC to DC adaptor into a 120V AC wall outlet to turn on the AHU.
Step 4.	We recorded the current value on the multi-meter when the AHU was in standby mode.
Step 5.	We recorded the current value on the multi-meter when the AHU sensor was activated to open the solenoid water valve.
Step 6.	We recorded the current value on the multi-meter when the solenoid water valve closed to return the AHU back to standby mode.

Measured values can be viewed in Table 1 in Section 5.2.1.

4.1.2. Voltage

The AHU we were donated was rated to have a 12V DC input at 800mA. We wanted to know if the AHU could operate at lower voltages. The list of steps we performed for this test are listed below.

Step 1. We attached the power inputs of the AHU to a variable power supply.

Step 2. We turned on the power supply and varied the output voltage from 12V DC to a lower voltage until the AHU turned off.

Step 3. We recorded the lowest voltage that the AHU operated at.

The recorded value is reported in Section 5.2.1.

4.2. Generator Power Output

As in Figure 6, we mounted a 5V DC generator on our modified water meter. The two tests we performed to measure the voltage output from the DC generator are listed below. The voltage was measured using a multi-meter.

Test 1.	We measured the voltage output from the generator at different flow-rates with no load.
Test 2.	We measured the voltage output from the generator at different flow-rates with a 50, 100, 300, and 680 ohm load, respectively.

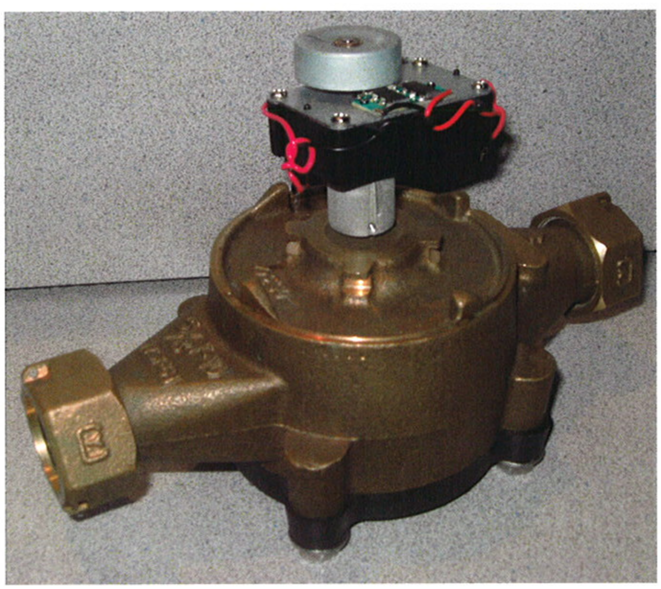

Figure 6: DC Generator Mounted on the Modified Water Meter

5.0 RESULTS

In this section our results for the project presented. It will begin with an overview of the performance of our modified water meter, followed by the results recorded for the experiments explained in section 4.0.

5.1 Water Meter

We had the modified water meter attached to the output of a garden hose for testing. We were impressed to see that the modified water meter performed accordingly to our intended purpose. As water flowed through the modified water meter, the metal shaft rotated. Although we were not able to calculate, we did observe the metal shaft to have a sufficient amount of rotational torque. Furthermore, there was a drawback to our modification. There was water leakage around the metal shaft.

5.2 AHU Operation Requirements

This section presents the results from the experiments performed on the AHU.

5.2.1 Voltage and Current

The AHU was observed to operate between 7.5VDC to 12VDC. The current and power measurements at 12VDC can be viewed in Table 1.

ACTION	CURRENT (mA)	POWER (mW)
Standby	7.21	86.52
Opening Solenoid Valve	44.53	534.36
Closing Solenoid Valve	43.89	526.68

Table 1: AHU Current and Power requirements

5.3 Generator

The following sections are the results to the various load tests performed to measure the power output from the generator. First the results from the no load test are presented, followed by the results from the various load tests. The loads used for the various load tests were resistors with the flowing resistance values: 50Ω, 100Ω, 300Ω, and 680Ω.

Theoretical power output was calculated by the formula below.

Power = Pressure X Flow Rate

Pressure = 65 psi = 448.15922 kPa

Flow Rate = as listed on tables, L/s

To calculate efficiency, we compared the theoretical power output to the actual power output. We noticed that our efficiency was very low and that the DC motor we chose as our generator cannot produce the required voltage and current to operate our AHU. However, it gave us an understanding of whether there will be enough power to operate our AHU if a larger and more efficient DC generator was used.

5.3.1 No Load Test

The measured voltage at different flow rates with no load can be viewed in Table 2. The theoretical power output is also calculated. Figure 7 is a graph of the relationship between voltage output from the DC generator and flow rate. A best fit line is drawn on the graph to represent that there is a linear relationship.

NO LOAD			
FLOW RATE		VOLTAGE	Theoretical Power
(s/ 1 L)	(L/s)	(V)	(mW)
12.9	0.0775	2.75	34.7410
10.1	0.0990	3.52	44.3722
9.7	0.1031	4.12	46.2020
8.2	0.1220	5.36	54.6536
5.7	0.1754	8.85	78.6244
5.3	0.1887	11.38	84.5583

Table 2: No Load Test Results

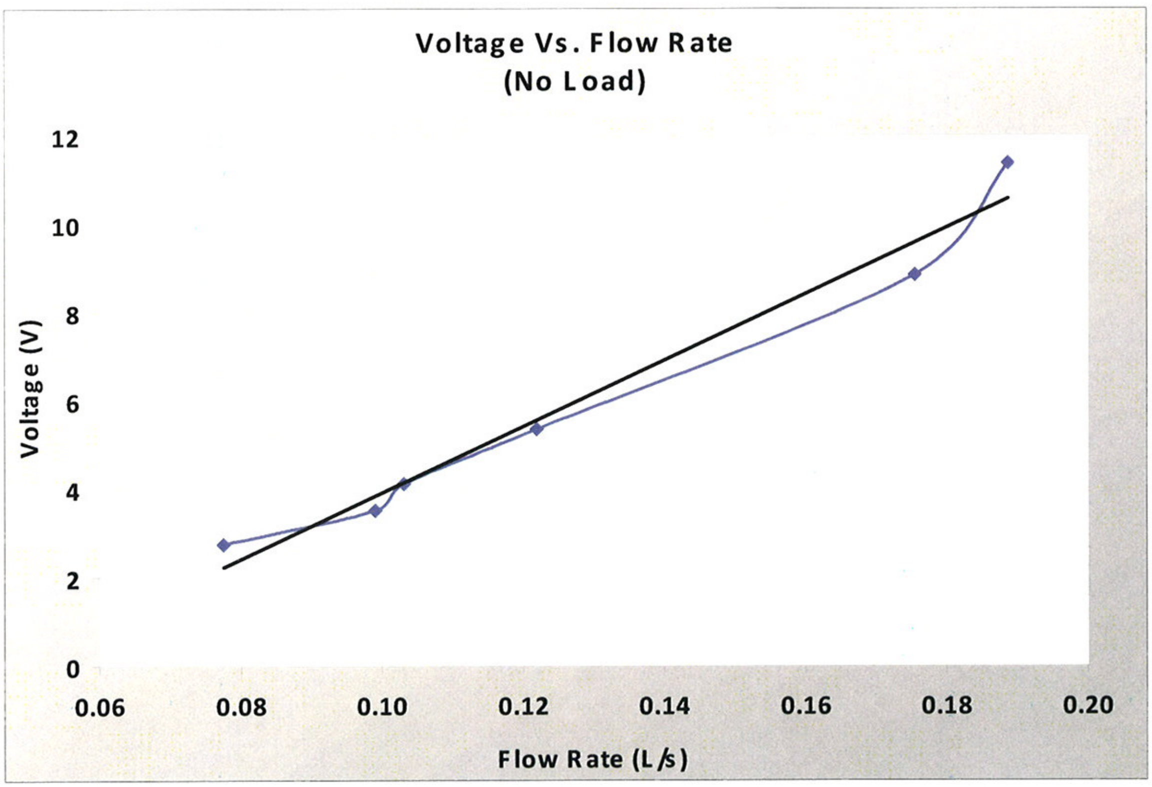

Figure 7: No Load Test Results

5.3.2 50 Ohm Load Test

We noticed the flow rate to decrease when we tested using a 50Ω load. As shown in Table 3, the maximum power output was 9.527mW.

50 Ohm Load		Measured Resistance: 48.52 Ohm				
FLOW RATE		VOLTAGE (Across Load)	CURRENT	Actual POWER	Theoretical POWER	POWER Efficiency
(s/ 1L)	(L/s)	(V)	(mA)	(mW)	(mW)	(%)
13.6	0.0735	1.11	2.2877	2.5394	32.9529	7.7
12.9	0.0775	1.23	2.5350	3.1181	34.7410	9.0
9.8	0.1020	2.15	4.4312	9.5270	45.7305	20.8

Table 3: 50 Ohm Load Test Results

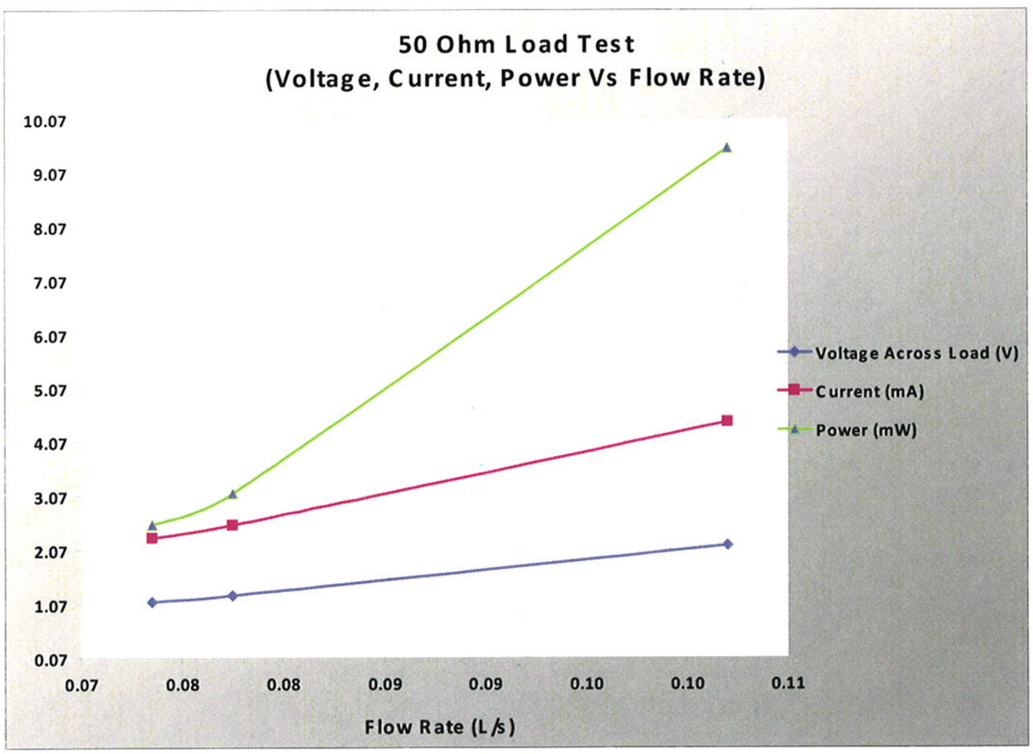

Figure 8: 50 Ohm Load Test Results

5.3.3 100 Ohm Load Test

Using a 100 Ω Load, we had improved results. As shown in Table 4, the flow rates were similar to the no load test and we had the maximum measured results for both power and current output. However, the current output is not sufficient enough to operate our AHU since the generator would have to run continuously at full speed to keep the AHU powered on.

100 Ohm Load, Measured Resistance: 92.56 Ohm						
FLOW RATE		VOLTAGE (Across Load)	CURRENT	Actual POWER	Theoretical POWER	POWER Efficiency
(s/ 1L)	(L/s)	(V)	(mA)	(mW)	(mW)	(%)
10.2	0.0980	2.63	2.8414	7.4729	43.9372	17.0
8.6	0.1163	2.57	2.7766	7.1358	52.1115	13.7
6.2	0.1613	6.4	6.9144	44.2524	72.2837	61.2
5.8	0.1724	6.78	7.3250	49.6634	77.2688	64.3

Table 4: 100 Ohm Load Test Results

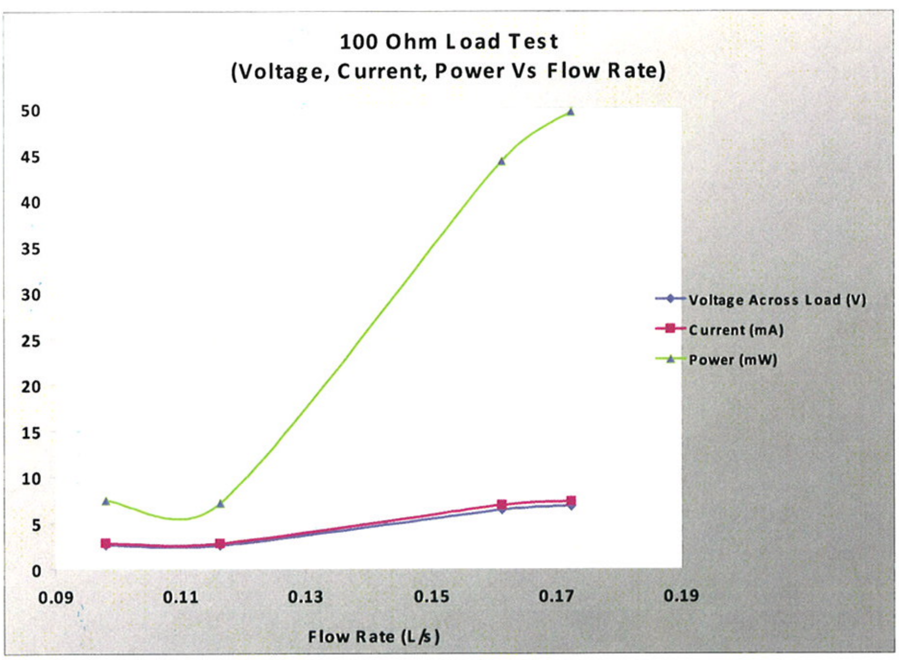

Figure 9: 100 Ohm Load Test Results

5.3.4 300 Ohm Load Test

In Table 5, it can be noted that the flow rate increased when we used a 300 Ω load. However, the power and current outputs were less than what were measured with a 100 Ω load.

300 Ohm Load, Measured Resistance: 297.45 Ohm						
FLOW RATE		VOLTAGE (Across Load)	CURRENT	Actual POWER	Theoretical POWER	POWER Efficiency
(s/ 1L)	(L/s)	(V)	(mA)	(mW)	(mW)	(%)
10.4	0.0962	2.89	0.9716	2.8079	43.0922	6.5
8.5	0.1176	3.1	1.0422	3.2308	52.7246	6.1
5.9	0.1695	7.4	2.4878	18.4098	75.9592	24.2
5.1	0.1961	8.9	2.9921	26.6297	87.8744	30.3

Table 5: 300 Ohm Load Test Results

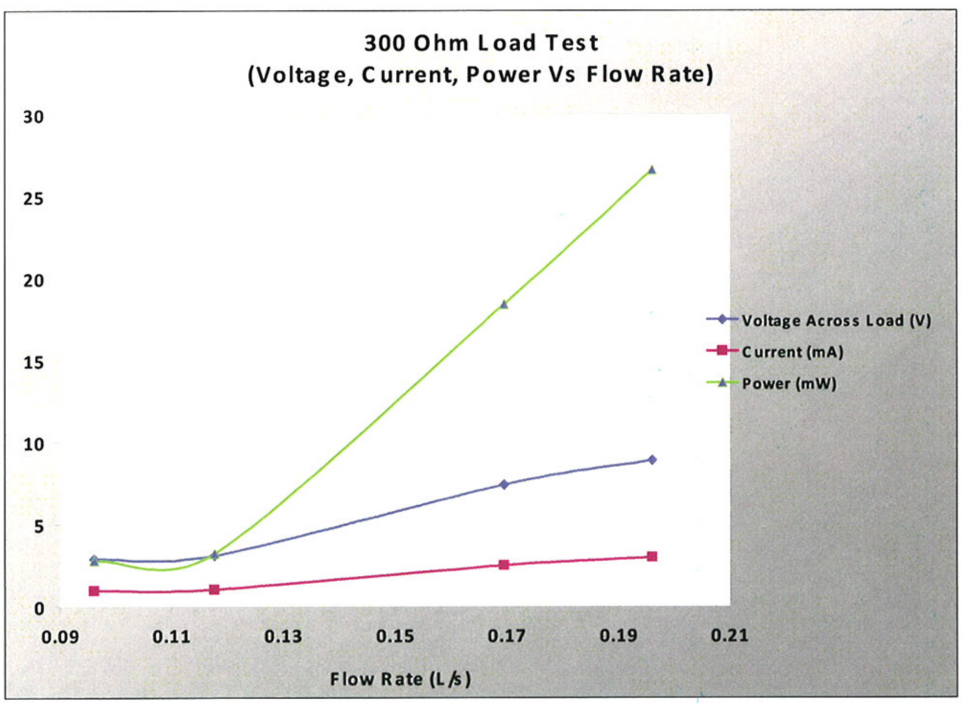

Figure 10: 300 Ohm Load Test Results

5.3.5 680 Ohm Load Test

With a 680 Ω load, we had the worst performance from the generator. In Table 6, it can be seen that the current output was than the 50 Ω load test, while the power output was merely higher. The flow rate was measured to be the highest when compared to the other load test. However, when comparing the theoretical power to the actual power measured, efficiency is very little.

680 Ohm Load, Measured Resistance: 675.38 Ohm						
FLOW RATE		VOLTAGE (Across Load)	CURRENT	Actual POWER	Theoretical POWER	POWER Efficiency
(s/ 1L)	(L/s)	(V)	(mA)	(mW)	(mW)	(%)
12	0.0833	3.52	0.5212	1.8346	37.3466	4.9
8.9	0.1124	5.28	0.7818	4.1278	50.3550	8.2
6.1	0.1639	8.8	1.3030	11.4661	73.4687	15.6
4.9	0.2041	9.85	1.4584	14.3656	91.4611	15.7

Table 6: 680 Ohm Load Test Results

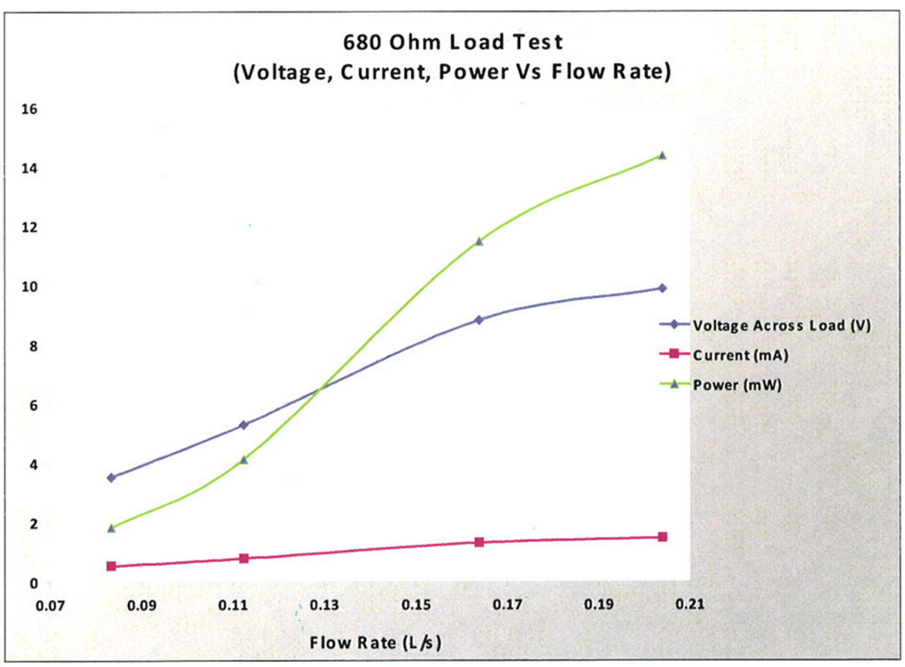

Figure 11: 680 Ohm Load Test Results

6.0 DISCUSSION

From the results of the experiments we performed, our goal of designing a micro-turbine powered AHU cannot be accomplished. The generator we chose for the project is not sufficient enough to provide the necessary voltage and current for adequate power to run our AHU. However, from our efficiency calculations, we learned that we are experiencing a lot of power output losses. We have postulated that this is due to the type of generator we chose and the design of our water turbine. Using a modified water meter as our water meter was a good approach to harnessing the power from flowing water, however, it is not the best. We had to deal with water leakage which is another reason for low power output efficiency. Furthermore, from the theoretical calculations of what power we could potentially harness, there may still be the possibility of designing a micro-turbine powered AHU

7.0 CONCLUSION

The idea for our project was to design a self powered AHU that would not require any external electrical energy. The overall objective during this project was to understand if it is possible to extract enough power from flowing water to power an AHU. Theoretically we postulated that the energy for this design would be harnessed by the use of a micro-hydro turbine. The turbine would connect before the clean water input of the AHU. When the AHU is triggered, water would flow through the micro-hydro turbine which will rotate a shaft coupled to a DC generator to produce electrical energy. Finally the battery would store the electrical energy which will be readily available to the AHU.

To achieve our objective we modified a Neptune T-10 water meter to operate as a micro-hydro turbine. A metal shaft was machined and attached to the water meter for the purpose of mounting a DC generator. With our modified water meter we conducted various tests to understand the feasibility of achieving our objective. The successful completion of our design was dependent on understanding the AHU unit in operation. Through testing we successfully found out the voltage required to operate the AHU and how much current is drawn by the AHU. To measure the output of the generator we measured power and current output at different flow rates and calculated efficiency. Comparing the theoretical power output to our measured results we noticed that our efficiency was quite low. Furthermore, the DC motor we chose as our generator could not produce the required voltage and current required to operate the AHU.

Using a modified water meter as our micro-hydro turbine was a good approach to harnessing the power from flowing water. However, we encountered water leakage with our design. Overall, this project was a success because we gained a theoretical understanding of the requirements in constructing a micro-turbine powered AHU. The DC generator we chose was not suitable for our design; however, with a larger and more efficient DC generator we are confident that our project design could be successfully created.

REFERENCES

[1] (2008, Jun.). Nepitek. [Online]. Available: http://www.nepitek.com/faucets.html

[2] (2008, Jun.). Neptune T-10 Water Meter. [Online]. Available: http://www.neptunetg.com/uploadedFiles/NTG240%20PS%20T10SMALL%2004.06.pdf