November 14th, 2010

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
8888 University Drive
Burnaby, British Columbia
V5A 1S6

Re: Design Specification for the Portable Filtering System

Dear Dr. Rawicz,

The document presented here outlines the design specifications for our Portable Filtering System (PFS).The PFS is a reusable, durable and easy-to-use solution to the ever-present problem of clean water in rural areas of developing countries.

The design specifications described here within provide details of how we plan to reach the design goals laid out in our previous document, Functional Specification for the Portable Filtering System, submitted on October 14th. However, we will only be discussing the design implementation of the features in our Proof-Of-Concept model. Functions not found in the POC model will not be discussed in detail.

The AquaQuick team, which is comprised of Vaibhav Mal, Shivam Mathur, Adam Tanabouz and Jie Gu, can be contacted via the email address or phone number listed below and are more than happy to answer any questions you may have.

Regards,

Vaibhav Mal

Vaibhav Mal
President and CEO
Email: vvm@sfu.ca
Phone: 778.389.9401
AquaQuick Solutions

Design Specification for Portable Filtering System

Project Team: Vaibhav Mal
Shivam Mathur
Jie Gu
Adam Tanbouz

Contact Person: Vaibhav Mal
vvm@sfu.ca

Submitted to: Dr. Andrew Rawicz – ENSC 440
Michael Sjoerdsma – ENSC 305

Issued Date: November 14th, 2010

Executive Summary

The design specification for the Portable Filtering System (PFS) will detail our plans for the design, development and implementation for our Proof-Of-Concept model. It must be noted at this point, that these plans are for the POC model only i.e for functional specifications marked either A or B in the Functional Specification for the Portable Filtering System submitted previously.

This document gives an insight to our design ideas and the reasoning behind the chosen methods of implementation. The main water carrying container will be mounted on a cart with ergonomically placed handles to allow the user to either to pull the PFS. The cart will also have a recommended line upto which the water should be filled, this line ensures free space in the container which causes the water inside the container to move around which expedites the filtering. The wheels of the cart are attached via a gear system, implemented using a pulley belt, to the power supply and will be the source of the generation of energy due to their rotation. The PFS will be powered by a generator, housed in a cabinet below the container, along with a battery. The battery is to ensure that while the output of the generator may vary according to the speed with which the user is travelling the input into the UV bulbs remains constant at 12 V[i] . This is accomplished by the battery using the excess voltage to charge itself while outputting only a constant 12 V [i][ii]. The UV bulbs will be housed within the container itself in a clear water proof pocket. This placement ensured that the light from the bulbs covered maximum area thus allowing us to purify more water. Since the effect of the UV lights is almost instantaneous[iii], the only factor is ensuring that it reaches everywhere in our container. To ensure this, the inside surface of the container will be either lined with a reflective material or be polished to ensure increased reflectivity. We are currently also testing a container with a window and reflective wings on the outside to make use of the UV rays in the natural sunlight. If the effect of the sunlight is greater than the loss of the reflective surface due to the presence of a window, we will implement this in the final production run, if not in the POC model.

[i] – Though we use the term constant, an error fluctuation of ± 1-2% is acceptable as long as the fluctuation is centred around 12 V.

[ii] – Even though the battery is used in our extreme case of powering the PFS in case of a unexpected stoppage, it's main purpose is to act as a buffer and provide constant voltage and should not be expected to power the PFS for extended periods of time (> 30 min).

[iii] – The effect of the UV lights is instantaneous if the absolute perfect conditions are met in regards to water circulation, temperature and the type of bacteria being targeted. This is why we recommend the UV lights being on for the entire journey.

Table of Contents

List of Figures

Glossary

User	Any person pulling the PFS is the user of the PFS. If the person pulling switches, the user has switched as well. If someone was to use any other means, such as an animal, to pull the PFS that would be considered the current user.
Forward	The direction the PFS is moving while being pulled via its handles.
Backward	The direction the PFS is moving while being pushed via its handles.
Developing Countries/ Rural Areas	Any place where running water is not a norm and people have to walk to a source of water either man made or natural to acquire water
UV	Ultraviolet Light used to kill bacteria and filter the water
DNA	Deoxyribonucleic acid contains the genetic instructions used in development and functioning of living organisms
RPM	Revolutions per minute is the number of full rotations completed in one minute around a fixed axis.
EPA	U.S. Environmental Protection Agency
POC	Proof-Of-Concept

Introduction

The PFS is a filtering device for users specifically for people who have to walk large distances in order to access water. The PFS allows the user greater ease while transporting the water due to being on wheels and also filters the water while it is being transported. Being powered by its own motion it saves energy and is a perfect fit for developing countries. This document provides the requirements for the PFS.

1.1 SCOPE

This document describes the design of the PFS and explains how they meet and are consistent with the functional requirements of the PFS. We will focus on all features that will be found in the Proof-Of-Concept model and briefly talk about any additional ones in the production device.

1.2 INTENDED AUDIENCE

The guidelines and specifications detailed here within are for use by all members of AquaQuick. It gives the design engineers a map of what all needs to be implemented and it also gives the test engineers a list of functions to test/check once that stage arises.

System Overview

This section covers a complete overview of the system as a whole and will cover the high level design. Subsequent sections will cover individual design components. All of the sections will discuss proof-of-concept design and the justifications for the design choices.

The following figure shows the overview of how the system works and the key components. Each color signifies a sub-component. Green backgrounds are the inputs and outputs of the system. Blue signifies the filtration component and purple signifies energy generation component. Detailed designs considerations for these sub systems will be covered later in this document.

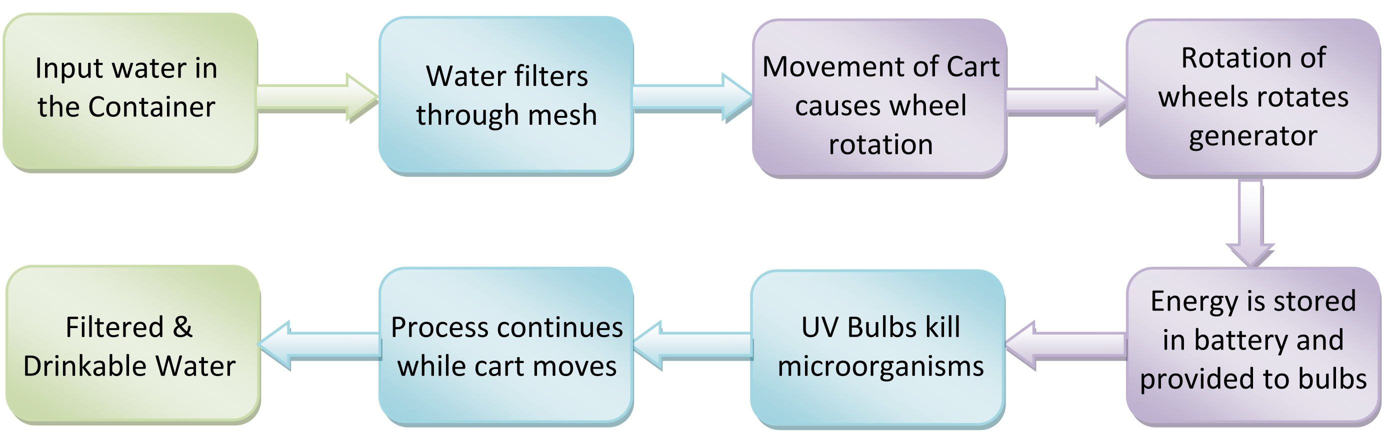

Figure 1 Overview of the system and its sub components

After careful thought, we came up with the final physical design for the system. We wanted it to be simple to build, yet sturdy and reliable in the usage environment. Specific design choices will be discussed later, however figure 2 shows the complete overview of our PFS.

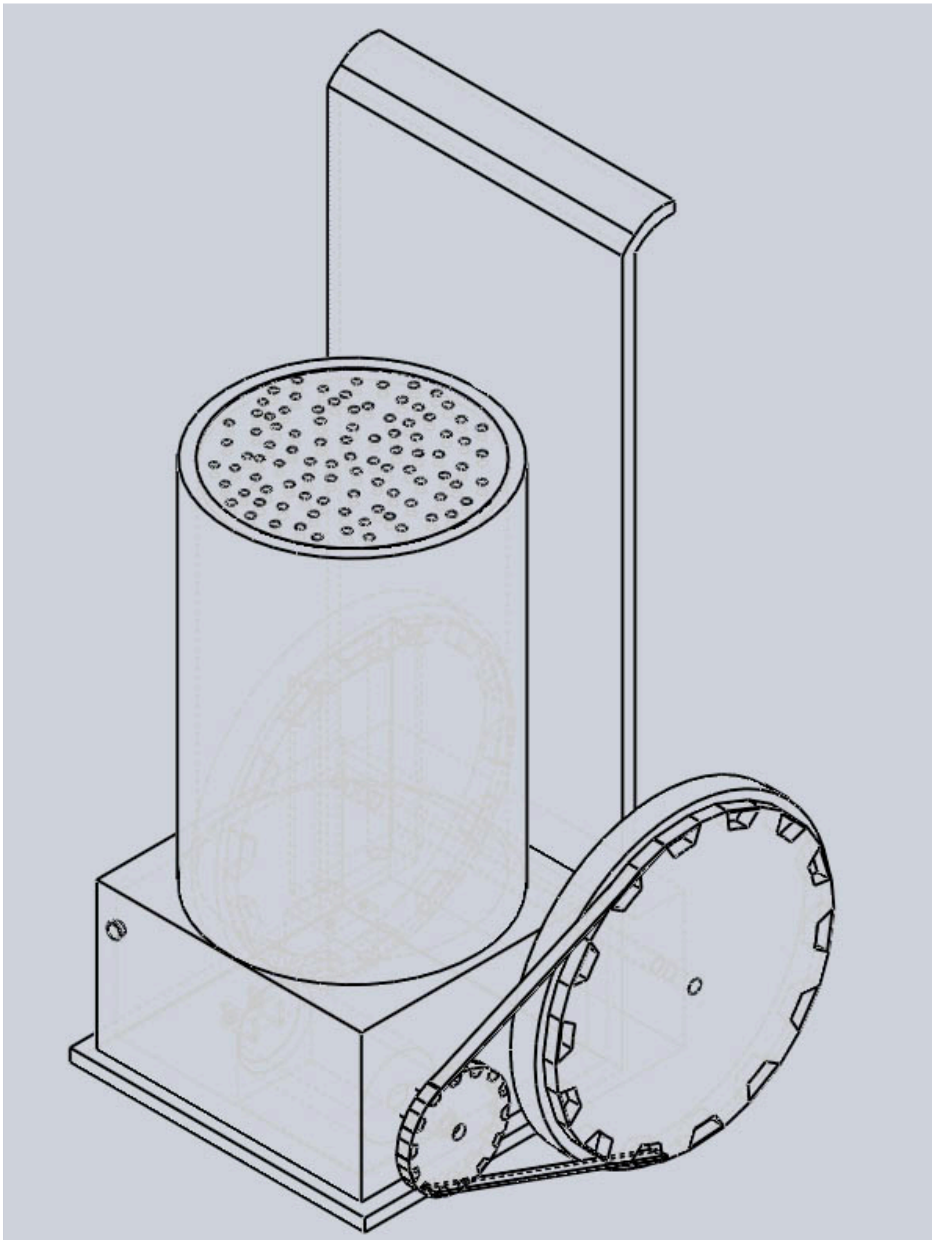

Figure 2: Overview of the PFS Cart.

Physical Design

3.1. Cart Structure

Figure 3 shows the two wheeled steel cart which can be dragged by hand. The metal cabinet is located in the lower part of the cart below the metal container. The length of the cart is 1.2 m, 45 cm width and 55 cm depth. This type of cart was chosen because it is more comfortable for the user and can be controlled easier. The user tilts it at an angle then drags it while walking comfortably. It is handier for rough ground with relatively large wheels to overcome the bumps and ditches in the way. All parts of the cart are made from metal to give it strength and reliability for everyday use and for longevity. More than that, metal is safer and better for heat dissipation of the electrical circuit. The cylindrical water container is located above the cabinet and is fixed to the cart's handle bars by two metal thick rods.

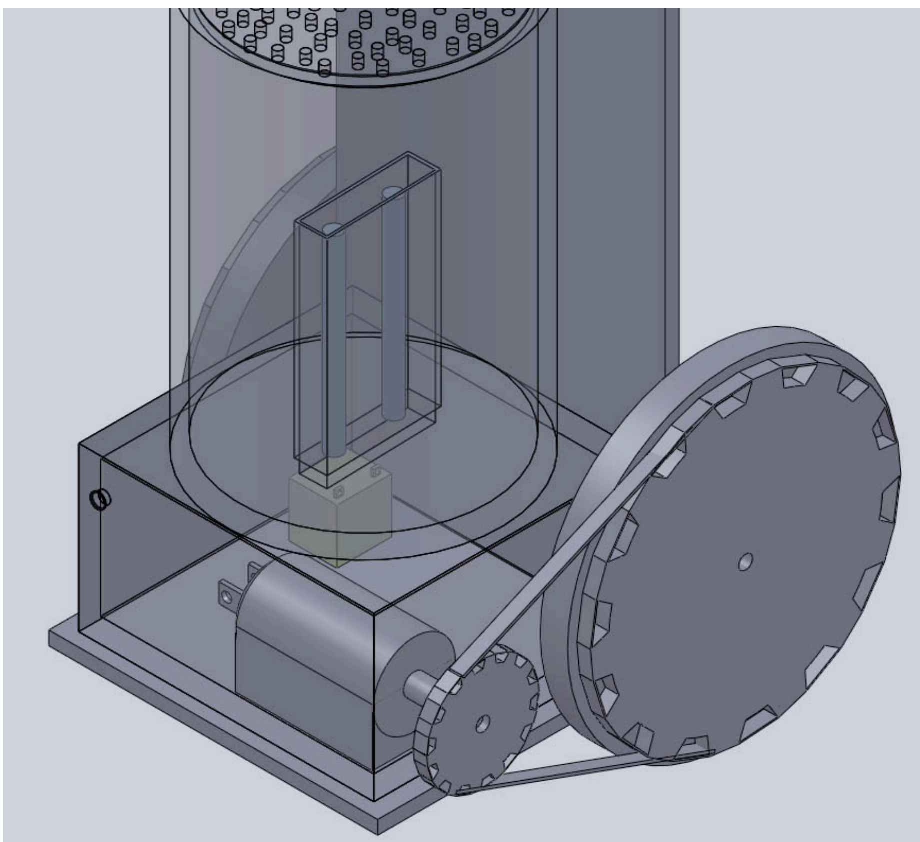

Figure 3: Mechanical and Electrical components

3.2. The Base Cabinet

The cabinet is made of metal and is 45 cm in length, 35 cm in width, and 30 cm in depth. It is located under the container to protect and preserve the electrical circuit from weather conditions. Also, it makes it is safer for the user due to the isolation of wires and all electrical connections away from where they maybe accidentally harmful. All electrical parts are located inside the cabinet (the generator, the battery and the bulb's circuit). And can be easily accessed via a panel for maintenance and replacement. The voltages inside the cabinet are 12 to 14.5 V DC.

3.3. The Container

The container volume is 22 L with 35 cm diameter and 45 cm length, the container has tight cover and it contains the filter and ultra violet bulbs which are fixed inside the container and can be replaced if need be. The inside of the container will be polished brightly to encourage maximum reflection of the UV rays. Currently we are also testing a transparent windows on the container to let the sun rays hit the water inside along with sun reflectors beside transparent windows at both sides of the container to help for reflecting the suns rays to the water inside the container. If these prove to positively effect the filtration process they will be added to the POC model. In addition, there will be a tap at the bottom of the container to collect the disinfected water.

aquaQuick Filtering Solutions

Power Generation Design

4.1. Gear System

The function of the gear system of the cart is to transmit the rotation of the wheels to the rotor of the generator. Also, it is so important to increase the RPM of the generator to the required rotation speed. By changing the diameter ratio of gears, we can change the generator speed which will increase the amount of the generated voltage and current.

The gear ratio was calculated using the following formula:

$$\frac{W_d}{G_d} = \frac{RPM_g}{RPM_w}$$

W_d = diameter of the wheel G_d = diameter of the generator's wheel

$RPM_{g/w}$ = RPM of the gear/wheel

By dividing the rpm of the generator's gear (40 to 55 rpm) by the wheel shaft's gear (40 rpm), we found that the ratio average is 1.25. Using 10 cm diameter for the wheel shaft's gear means that we need 10/1.25=8 cm for the generator's gear diameter.

As mentioned in the generator section, we need the gear system to ensure that the generator rotates in one direction only. We found that the bicycles have this feature for the rear wheel and modeled the gear using that as a model and the system consists of two gears connected together by chain.

4.2. Generator

The generator rotation is achieved via the rotation of the wheel through the gear system. The faster the wheels rotate, the more the potential energy we get from the generator. The generator is a DC permanent magnet motor. It is more powerful than the generators that have DC excitation for rotor coil. It generates higher voltage and current at low RPM which makes it ideal for the cart that rotates at low rpm but needs to output relatively high voltage .The generator we used is capable of producing12 to 24 V DC 80 Watt. It is due to this wide range that we use the battery to act as a buffer and to ensure that despite any fluctuation we

only deliver around 12 V DC to the bulbs so as to ensure the most efficient usage of the bulbs.
The generator is mounted on an L- shape metal plane fixed near the wheel shaft at the right side of the cart. The generator rotates in one direction because of the nature of the gear that is built in with the rotor's shaft of the generator. So, to avoid damaging the generator, the gear system is designed to rotate in one direction despite the wheels rotating in both directions.

4.3. The Circuit

Figure 4 shows the electric circuit that is connected to the output of the generator to feed the battery and the ultraviolet bulbs. The output of the generator is 12 to 14.5 V DC and is connected to 12 V sealed lead battery through 6A blocking diode and 6A fuse. Blocking diode is used to prevent the current to return to generator from the battery. The fuse is used to protect the battery and bulbs from high current.

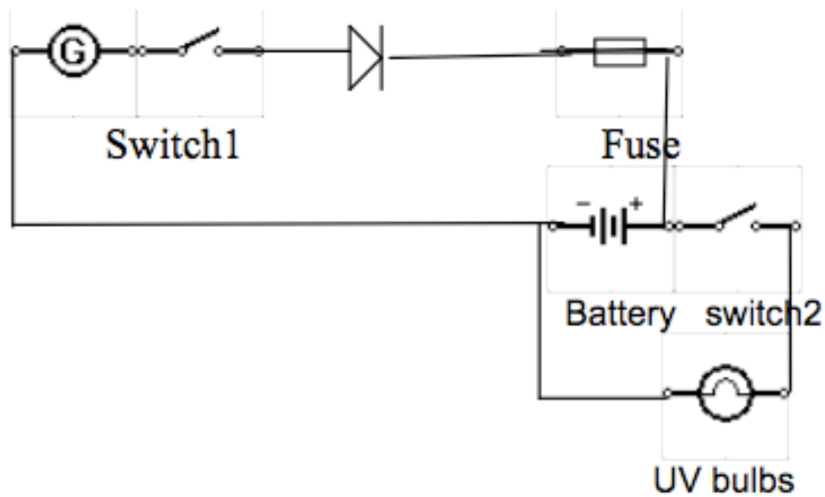

Figure 4 Circuit showing internal connections

Switch1 in the figure is used to isolate the battery and bulbs from the generator. Switch2 is used to isolate the bulbs from the circuit; in this case, the generated voltage will only be used to charge the battery. This case is useful to charge the battery during the journey from home to the source of the polluted water. When the cart is loaded with polluted water, the switch1 and 2 must be on to light the ultra violet bulbs which will disinfect water. The battery is 12 V 50 Watt Lead sealed battery, it is maintenance free, light weight 1.59 KG.

From figure, the battery and the UV bulbs are connected in parallel at the output of the generator. According to tests that have been done, it has shown that whatever the generated voltage is the value that reaches the bulbs always stays at 12 V DC. However, to start charging the battery, the generated voltage should be higher than voltage of the battery. When both switches is OFF, there will be no loads connected to the generator. In this case, no current will be in the circuit and the wattage we get from the generator is zero. When there is no load; when you drag the cart, you will not feel any resistance on the wheels. But when a load like battery or bulbs is connected to the generator you will feel resistance at the generator's gear. When the generated voltage is 14.5 VDC, there will be a drop to12 v DC at the load. For our circuit we implemented some tests to check the rotation torque needed when the battery and UV are connected. We found that there was resistance at the initial rotation but it disappears after overcoming this initial rotation torque. In general, the torque rotation was not large and we further reduced it using the larger diameters for wheels and gears.

Filteration Design

Our filtration design will consist of the two following parts:

- A physical mesh filter to catch the bigger impurities and particles
- A self powered UV light based filtering system to kill bacteria/viruses

5.1 Ultra Violet

Ultra violet bulbs will be used to disinfect water. UV filters water by attacking micro organisms and altering their DNA and hence preventing them from becoming pathogens and also from reproducing. UV is effective for all types of microorganisms including certain cryptosporidium, viruses, giardia that are resistant to other disinfectants like chlorine[6]. UV is safe and not harmful for environment. In addition, UV has no impact on taste, odour, and color of the water. To kill microorganisms, the UV energy penetrates the cell, and disrupts its DNA, preventing reproduction (a micro organism that cannot reproduce cannot infect a host). Then, after disinfecting the Water using UV, the water can be used directly.

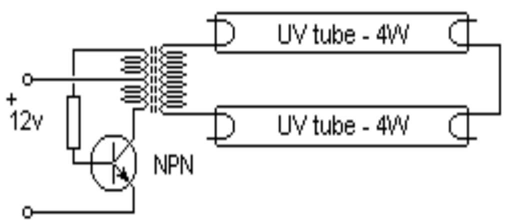

Figure 4: Ultra Violet Tubes System

The UV tubes are white in color and deliver light with 254nm wavelength which is the specified wavelength used for killing bacteria and viruses. The transistor is an NPN transistor which can deliver 15 watts. The resistor is value that will cause the tubes to strike when cold with 12 volts applied to the circuit. The transformer is about 3cm diameter. We also have about 30 SWG wire for the primary.

NOTE: To ensure that UV will be enough to cover the water in our container we will use the following formula provided by the EPA[5]:

$UVT\ \% = 100 * 10^{-A}$

UVT% = percentage of UV that can pass through material
A = constant depending on material[7].
For water we find that 99.7 % of all UV passes through it until a distance of 10m. We still go with 2 bulbs as a fail safe.

5.2 Mesh Filtering

We have a mesh filter on the top of the container that is flat and will filter up to 20 micrometers (sand, dust, bigger particles). The diameter of the mesh could have been smaller but since we want to the water flowing through the mesh to flow into the container at a reasonable speed so as to not keep the user waiting, we have chosen 20 micrometers as that provides us the perfect balance between quality of filtering and the speed with which the filtering occurs. As a comparison, the average diameter of a grain of sand varies from 62.5 micrometers to 2 millimeters.

System Test Plan

The individual part of AquaQuick will be tested first. After that, the ideal operation and function of whole device is examined as well as other normal and extreme cases.

6.1. Unit Testing

Before integrating individual components to the system, each component will be individually tested to ensure that it is not faulty or damaged.

6.1.1 Generator Test

The generator used to convert mechanical energy to electrical energy will be tested by manually rotating the mechanical side to ensure rotating is smooth and measuring the voltage using digital multi-metre to ensure the expected voltage output is produced.

6.1.2 Battery Test

The battery will be tested by being plugged into the outlet and then use digital multi-metre to test whether it's charged. After it is charged fully, the time it takes to discharge will be compared the expected time. We will then use the digital multi-metre to ensure the expected output (around 12V) is produced.

6.1.3 Wheels and Gear Test

Before integrating the gear system and the wheels to the system, first of all, we will check each gear to ensure there is no breakage . After that, we will ensure the gear ratio is within the expected limits. This will be done using a Tachometer to measure RPMs on the small gear and the RPMs of the wheel and using those values to calculate their ratio.

6.1.4 UV Bulbs

Each UV bulb will be tested individually. This will be done by simply putting the bulb in a simple circuit with a 12V source and visually ensure that the bulb will light up and then using each bulb on a small sample of impure water.

6.1.5 Sand Filter Testing

This is the first component where water is filtered initially to filter the larger impurities in water. This will be done by physically passing relatively dirty water and visually inspecting the water on the other side for clarity.

6.2. Integrated Testing

In addition to the testing of individual components, a recursive integration testing will be done after completion of assembly. A complete simulation of the product will be done to ensure product does what it is intended to. Each complete system with wheels will be simulated on a belt while the top is held so only the wheels rotate.

Firstly, impure water will be tested using a water testing device to ensure bacteria are present in water. Water will be poured into the containers through the sand filter and will be visually inspected that larger impurities are removed. Once the container is filled, the belt will start rotating the wheels which will go through the generator and charge the battery. Within minutes, all the UV bulbs will be visually inspected to see if they are lit up. After the cart has "travelled" enough distance (calculated using wheel's RPMs and time), water will be tested using the same water testing device to ensure that bacteria and other microorganisms have been killed.

In addition, we will also do sub component testing of the generator and the battery to ensure they work together and are producing the expected energy.

6.3. Water Testing

After water treatment has been done, we want to test whether the water reaches the standard for drinking. We may use microscopy to ensure that the microorganisms have not multiplied. However dead bacteria look the same as living bacteria (the dead bacteria are safe for consumption due to their inability to replicate).To ensure the leftover bacteria are dead, culturing can be used. The SFU microbiology lab has been extremely helpful and agreed to help us set up experiments, take samples, and get the results via culturing. These however take one day to see results.

6.4. Normal Case 1

User Input: The user pulls the cart forward with normal speed (5km/h)

Conditions: The user is pulling the cart forward with water to be filtered in the container. The user has already switched on the UV lights and the battery has been already ready to be charged.

Expected Output: The generator will start to work, and the battery will be charged and give a constant output voltage with 12V to feed the UV lights.

UV lights will light on and start to filter the water.

6.5. Normal Case 2

User Input: The user stops the cart and takes a short break (< 10 mins)

Conditions: The user has already been pulling the cart forward with water to be filtered in the container; and the battery has been charged for a while.

Expected Output: The generator will stop working, but the battery will keep feeding the UV lights with constant 12V to ensure AquaQuick still filter the water.

6.6. Extreme Case

User Input: The user pulls the cart backward

Conditions: The user is pulling the cart backward with water to be filtered in the container. The user has already switched on the UV lights and the battery has been already ready to be charged.

Expected Output: The rotation of wheel will not bring on the rotation of gear system; since the generator is limited to rotating only one way, even though the cart can be dragged both ways it will only power up while moving forward.

Conclusion

This document presents the design specs that meet the functional specifications provided earlier. While the actual building of the POC model we will try and be as true to this document as possible. The tests mentioned in this document will also be used during the testing phase to ensure that all the mentioned features are present and function the way they are described and will help us build a very robust POC model.

References

[1](2003). *Ultraviolet Disinfection*. Retrieved October 12th, 2010, from Edstrom Web Site: http://www.edstrom.com/DocLib/MI4178.pdf

[2](2009). *Bike Generator – Generate Electricity While you Exercise*. Retrieved October 12th, 2010, from Buzzle Web Site: http://www.buzzle.com/articles/bike-generator-generate-electricity-while-you-exercise.html

[3](2008). *Simple 6V Fluorescent Light Circuit Diagram*. Retrieved November 11th, 2010, from Electronics Circuit Diagram Web Site: http://circuitzoo.com/2010/08/26/electronics/simple-6v-fluorescent-light-circuit-diagram

[4](2010). *DNA*. Retrieved November 14th, 2010, from Wikipedia Web site: http://en.wikipedia.org/wiki/DNA

[5](2006). *UV Disinfection Guidance Manual*, Retrieved November 4th, 2010, from EPA Web Site : http://www.epa.gov/safewater/disinfection/lt2/pdfs/guide_lt2_uvguidance.pdf

[6](2010). *Zoheir Bousmina – Metro Vancouver engineer*, Retrieved October 28th, 2010 from zohier.bousmina@metrovancouver.org

[7](2010). *Absorption Specta of Water,* Retrieved November 11th, 2010 from http://people.seas.harvard.edu/~jones/es151/gallery/images/absorp_water.html