Aquamatic Technologies

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January 18, 2010

Dr. Andrew Rawicz
School of Engineering Science
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Re: ENSC 440 Functional Specifications for the Spa Commander

Dear Dr. Rawicz,

Attached is a copy of our Functional Specifications for the *Spa Commander*. The document briefly outlines all the technically relevant information pertaining to the spa chemical testing and delivery system. Our system captures a market niche for affordable and portable water cleansing in residential spas. This spa system will test the water for available chlorine and pH levels - and adjust the amounts of chemicals necessary to keep the water safe and clean.

The high level requirements of the *Spa Commander* are outlined in the enclosed document for the proof-of-concept design, as well as final additional requirements for final production. Our engineering team will be responsible for developing the proof-of-concept product based on the requirements listed in attached functional specifications documents. The team members will use this document to meet product goals as well as a guideline for functionality testing.

Our company, Aquamatic Technologies Ltd. consists of five senior undergraduate engineering students- Matt Bergsma, Ken Chou, Dan Latuszek, Michelle Ochitwa and Sulien Wong. If you have any questions, comments or concerns, please contact Matt Bergsma – our company contact – at his email address (mjb4@sfu.ca)

Sincerely,

Dan Latuszek, CEO
Aquamatic Technologies

Enclosure: Functional Specification for the *Spa Commander*

Aquamatic Technologies

Functional Specification for the Spa Commander

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Submitted To:

Dr. Andrew Rawicz – ENSC 440

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Executive Summary

Today, as more and more people own home spas and hot tubs the need for an automated chemical testing and dispensing system has become apparent. Many people have spas located at their weekend getaways and are just too busy to continuously maintain the water, although proper chlorination and pH is essential in inhibiting the growth of bacteria while preventing unnecessary skin and eye irritation. The *Spa Commander* takes advantages of this fact and supplies the spa owner with a cheap, compact solution for maintaining water cleanliness and safety as there are very few viable automatic calibration systems on the market for home use from both a cost and implementation perspective.

The Aquamatic team will begin development of the *Spa Commander* with thoughts foremost on safety requirements. The other high level requirements for the system's functionality and proof of concept are important as well and are outlined in the functional specification.

Our system will first take in water from the source and test it for pH levels and available chlorine. Then our control system will dispense the required amount of chemicals into the spa water to make it safe. Constant rechecking of water cleanliness and safety will allow our system to maintain a spa's water in an optimal range. As such, the *Spa Commander* will conform to all pertinent standards and guidelines, including those of the CSA.

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Glossary

Chemistry:

[x] – concentration of x

pH – measure of the acidity or alkalinity of a solution. It is equal to p[H], the negative logarithm (base 10) of the molar concentration of dissolved hydrogen ions (H+).

Cl – chlorine (an element, atomic number 17), Cl- refers strictly to chlorine ion(s)

Br – bromine (an element, atomic number 35), Br- refers to bromine ion(s)
ORP – oxidation reduction potential, the oxidation capacity of a solution

Electrical and Electronics:

AD – analog-to-digital

DA – digital-to-analog

DC – direct current

VAC – Volts Alternating Current

P&ID - process and implementation diagram

PIC – programmable integrated chip, a type micro-controller

MOSFET – Metal Oxide Semiconductor Field Effect Transistor

Associations:

CSA – Canadian Standards Association

ANSI – American National Standards Institute

NSF - National Sanitation Foundation

Miscellaneous:

CAD – Canadian dollars

Introduction

When designing our *Spa Commander,* Aquamatic realized that safety requirements are especially paramount for an electrical product around water. The system must also be usable for an average residential spa owner and cost effective. These requirements and more are outlined in the text below.

The product, once mounted on the spa, will check chemical levels (pH and free chlorine) and adjust the water to the recommended standards for cleanliness and safety. The *Spa Commander's* display will allow the owner to see at a glance if the hot tub is safe for use, or if chemicals need to be refilled. Chemical refilling will happen infrequently, as the chemical hoppers will be large enough to maintain any standard home spa for months at a time.
Aquamatic's functional specification provides all of the high-level requirements for our system's development. Both proof-of-concept and production functionality requirements are outlined.

1.1. Scope

The functional specification outlines the design of our chemical testing/delivery system. This document briefly touches on all aspects of the Spa Commander's technical requirements and describes the testing approach for our prototype unit. It will serve as an outline for our detailed design specification and ultimately for building our proof-of-concept model.

1.2. Intended Audience

This document will be used by the Aquamatic Technologies team to decide on our design specifications and ultimately create our Spa Commander. The functional specification is intended for use as a guideline to ensure that no requirements are left out of our design specification, and it will be used to familiarize the ENSC 305/440 markers with our product.

Classification

The following convention is used in order to identify and classify all functional requirements throughout this document.

[Rn] A functional requirement. **x**

Where 'n' denotes the functional requirement number and 'x' specifies the development category of the requirement which is one of the following two:

I – Requirement present in proof -of-concept and final production.
II – Requirement present in the final production only.

System Overview

The high level block diagram of the operation of the Spa Commander is illustrated below in Figure 1:

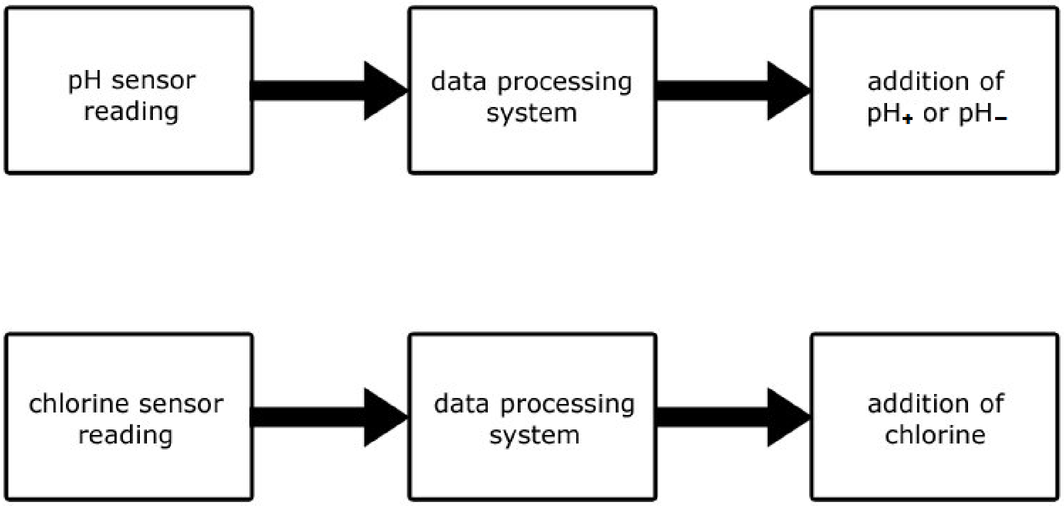

Figure 1 – System functional block diagram

The device is completely automated to reduce the incident of end user caused errors often induced by the end user playing with settings and incorrect inputs. Given the possible damages inflicted by overly high or low pH levels and high chlorine levels, it is safer to automate the entire system. As long as the system is properly automated and reliable, the Aquamatic team believes that this is the safest implementation.

Upon adjustment of chemical levels, a water safety indicator LED will turn on. LEDs will also be implemented to indicate whether chemicals need to be refilled. One limitation of the Spa Commander is that it will only accept powdered chemicals due to the delivery mechanism in place. However, one advantage of using powders over tablets, pills, or other bulk release mediums is that it allows us to control chemical levels more precisely, this is especially important in small bodies of water.

The model below presents the system with all of the major components: pH/Chlorine Sensors, Pump, Chemical Containers, Valve, LED Display, and Casing.

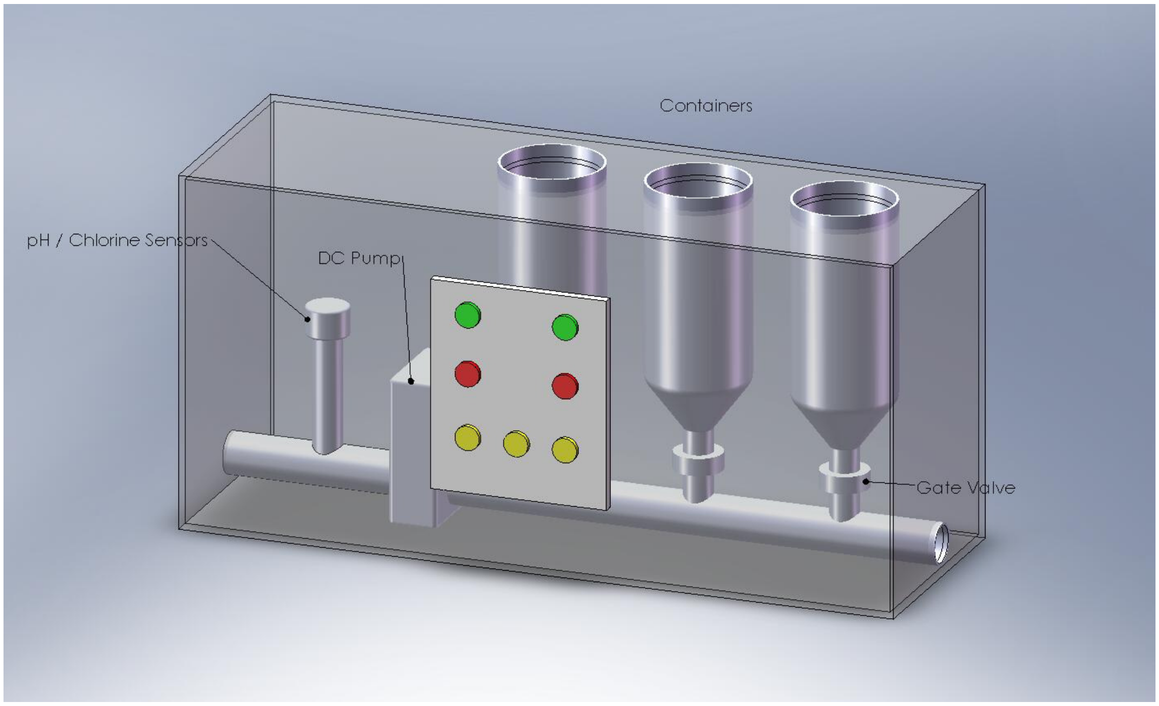

Figure 2 - Model of the system

System Requirements

3.1. General Requirements

[R1]	The initial proof-of-concept model will cost no more then $500CAD and considering the amount of units made during manufacturing and time to order parts from a cheap source, the retail cost of the system will be under $80CAD	I
[R2]	The system will be portable to allow the spa owner the freedom to set the unit up themselves and move it at will	I
[R3]	The system will be minimally intrusive to the user so it can continue to check and maintain chemical balance even when users are enjoying the spa	I

3.2. Physical Requirements

[R4]	The system will be waterproof	**I**
[R5]	The system will weigh less than 5 kg	**I**
[R6]	The system will be compact so that it can be easily stored when not in use	**I**
[R7]	The system will be designed to stand next to the spa with hoses going into the spa water to collect water samples and dispense chemicals	**I**

3.3. Electrical Requirements

[R8]	The system will be powered by North American electrical outlets 120 VAC, 60 Hz. (http://en.wikipedia.org/wiki/AC_power_plugs_and_sockets)	**I**
[R9]	The system will require a DC adaptor	**I**
[R10]	The power cord will be a minimum of 3 meters long, this length should reach an outdoor outlet, though an extension cord may be needed in some cases	**I**
[R11]	The system will enter a low power state once the ideal water condition has been achieved, to save on energy costs	**II**

3.4. Environmental Requirements

[R12]	The system will be suitable for indoor and outdoor use	**II**
[R13]	The system will operate at temperatures between -10 and 60 °C	**II**
[R14]	The system will operate under all levels of humidity (0 - 100%)	**II**
[R15]	The system will operate at altitudes between 0 and 2000 m above sea level	**II**
[R16]	The system will be able to withstand normal weather conditions such as rain, snow, wind etc	**I**
[R17]	The system will operate with a sound level less than 50 dB	**II**

3.5. Standards

[R18]	The system will meet all appropriate CSA requirements (http://www.csa.ca/cm/ca/en/standards/products/electrical)	**I**
[R19]	The system will meet pool/spa water guidelines – having a pH 7.2-7.6 and a free chlorine of 1.0-3.0 ppm (http://www.waterandhealth.org/pool_spa/guidelines.html)	**I**

3.6. Reliability and Durability

[R20]	The system will be able to maintain continuous usage for a minimum of 3 year, and will not need refilling more then once a month	**II**
[R21]	The system will not degrade in performance from normal use	**II**
[R22]	The system will be serviceable by a trained technician	**II**
[R23]	The system will be resistant to shock and vibrations	**I**

3.7. Safety Requirements

[R24]	All electrical and mechanical components of the system will be enclosed and inaccessible by the user	**I**
[R25]	The system will be electrically safe and well protected from water	**I**
[R26]	The system will have automatic shutdown and error indication in case of electrical or mechanical failure	**I**
[R27]	The system will have fail-safe mechanisms for dispensing chemicals	**I**

3.8. Performance Requirements

[R28]	The system continuously checks chemical levels in water and the user will see a change in water cleanliness in less	**I**

	than 5 min	
[R29]	The system will be able to maintain ideal water conditions with minimal fluctuations and overshoot	I
[R30]	The system will be used for spas and hot tubs with a capacity that is less than 2000 L	II

3.9. Usability Requirements

[R31]	The system will be simple and intuitive to use	I
[R32]	The system will be used for maintaining water conditions and not treating water	I
[R33]	The system will be operable by one person	I
[R34]	The system will not require regular cleaning or maintenance	I

Sensors

For this system, the sensors need to be able to detect active chlorine and pH levels. Having them experience little drift over their lifetime will be a benefit, in addition to a roughly linear response to keep amplifier costs down. These sensors will form the backbone of our system.

[R35]	The system will have two sensor outputs	I
[R36]	The sensors will measure chlorine in ppm	I
	Sensitivity of the Cl sensors themselves will be less then +/- 0.1ppm	I
[R37]	The pH sensor will read a direct measure of pH	I
[R38]	Sensitivity of the pH sensors will be less then +/- 0.1 pH	I
[R39]	Output will be in standard form of 1-5V or 4-20mA to maintain simplicity	I
[R40]	If output is not in standard form, it will be easily converted to standard form	I
[R41]	The sensors will require no calibration past factory calibration to make final product usable for the average person	I
[R42]	Sensors will be able to last over a year of constant use with little drift or wear – but be low in cost- this will keep system reliable	I
[R43]	Drift will be less then .01 of input / year so the system will not have to be replaced for several years of continuous use	I
[R44]	Size will be under 1 cubic inch for each sensor to maintain a small, portable system	I
[R45]	Senors will require under 1mA of power per sensor.	I
[R46]	Sensors will be fast to respond, under 100 ms for a change in measured variable	I
[R47]	Sensors will be continuously acting	I

Chemicals

This system will focus on chlorine and pH adjustment, since chlorine is one of the more common disinfectant chemicals. These chemicals will have to be stored in such a way that they are kept relatively dry, in well marked containers, as well as separated to avoid any dangerous reactions between chemicals. These chemicals will be fed into the water via a custom gravity fed system for simplicity. Also since typical usage will be around 30-40g/week of disinfectant (http://www.waterandhealth.org/pool_spa/guidelines.html) depending of the size and usage of the consumer's spa, it must have sufficient storage to go a couple months without refilling.

5.1. General Requirements

[R48]	Chemicals required will be in powder form.	I
[R49]	“pH Minus”, a typical commercially available spa chemical, will be used to lower the pH	I
[R50]	“pH minus” being Soda Ash (Na_2CO_3)	I
[R51]	“pH Plus”, a typical commercially available spa chemical, will be used to raise the pH	I
[R52]	“pH Plus” being Sodium Hydrogen Sulfate ($NaHSO_3$)	I
[R53]	Chlorine control will be done using granular chlorine	I
[R54]	Typically granular chlorine will be DiChlor (Sodium Dichloro-S-Triazinetrione) or Calcium Hypochlorite ($Ca(HClO)_2$)	I

5.2. Physical Requirements

[R55]	Supply of all chemicals will be around a 3 month supply depending of spa size and usage	I
[R56]	“pH Plus” and “pH Minus” tanks will hold 200g each	I
[R57]	Chlorine tank will hold 500g of chemical	I
[R58]	Tanks will be of cylindrical shape with tapered bottoms about 5 cm in diameter and 13 cm in height	I
[R59]	For prototype, tanks may be implemented to support a full container, or of other shape for proof of concept purposes	I
[R60]	Tanks will have some seal on the top surface to prevent contamination by air and moisture	I

[R61]	Tank tops will be clearly labelled to prevent cross contamination of chemicals	I

5.3. Usability Requirements

[R62]	Tank tops will be easily accessible for refilling	I
[R63]	Clear markings and logical placement of tank tops, will reduce risk of mixing chemicals	I
[R64]	All valves used will be of the “Fail Close” variety (This is done to prevent excess chemicals filling the lines when the system is without power)	I
[R65]	Valves will be long lasting, they will not degrade with regular usage and should certainly last throughout the system’s lifetime	I
[R66]	The system will be implemented using Gate Valves	I
[R67]	Valves will be electronically actuated, using 4-20mA or 1-5V input signal preferable	I
[R68]	Chemicals should be dispensed at such a rate that a 150gal spa, will be under control in under 30min	I

Pump

A small DC pump is required to keep water flowing through the SPA Commander for measurements and dispensing chemicals. The purpose of the pump is not to completely mix the spa water but to provide sufficient water flow allowing diffusion and time to mix the chemicals fully.

6.1. General Requirements

[R69]	The pump will be quite giving low noise	I
[R70]	The pump motor will be a brush-less dc motor	I
[R71]	The pump will consume low power	I
[R72]	The pump will be reliable and durable	II
[R73]	The pump will have a life-time of at least one year	II
[R74]	The pump will dissipate little heat during operation	I

6.2. Physical Requirements

[R75]	The pump will be reasonably sized to maintain a small portable system	**I**
[R76]	The pump will weigh under 600 g	**I**
[R77]	The attached hose to pump will contain a movable protective casing to prevent damage from environment	**II**

6.3. Electrical Requirements

[R78]	The pump will be as low power as possible	**I**
[R79]	The pump will have a nominal operating voltage of 12 V DC	**I**
[R80]	The pump will have a nominal power of maximum 8 W	**I**

6.4. Standards

[R81]	The pump will meet appropriate CSA requirements (http://www.csa.ca/cm/ca/en/standards/products/electrical)	**I**
[R82]	The pump will meet appropriate NSF International requirements (http://www.nsf.org/business/pool_and_spa/index.asp?program=PoolsSpasHot)	**I**
[R83]	The pump will meet appropriate ANSI requirements (http://webstore.ansi.org/RecordDetail.aspx?sku=DIN+EN+13451-1%3A2001)	**I**

6.5. Performance Requirements

[R84]	The pump will have a minimum discharge flow rate of 2 L per minute	**I**
[R85]	The pump will be operational with liquid temperatures up to 60 °C	**I**
[R86]	The pump will have a quick response time to reach full speed (under 1 second)	**I**

6.6. Reliability Requirements

[R87]	The pump will not require cleaning or maintenance	**I**
[R88]	The pump will replaceable by a trained technician	**II**
[R89]	The pump will maintain continuous usage for a minimum of 3 years	**I**
[R90]	The pump will be resistant to the system's chemicals	**I**

Display

The system will contain a display unit in order to provide notification to the user of the following information:

- Power On
- "pH plus" chemical level low
- "pH minus" chemical level low
- Chlorine chemical level low
- Water pH level OK
- Water pH level not OK
- Water chlorine level OK
- Water chlorine level not OK

7.1. General Requirements

[R91]	The display interface will be easy to read and understand	**I**
[R92]	The results on the display will be easy interpreted from a distance of 2 meters	**II**
[R93]	The notifications will be displayed by the use of LEDs	**I**

7.2. Physical Requirements

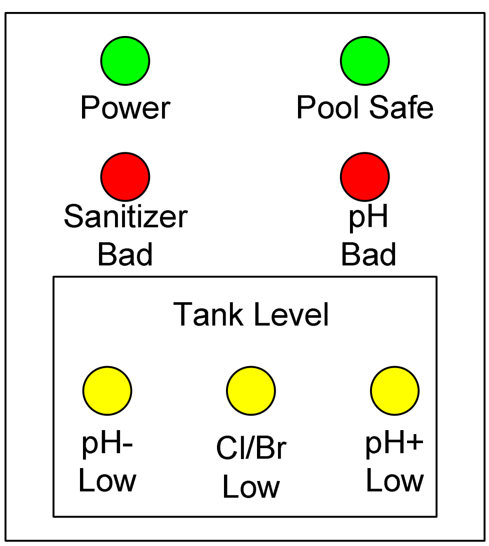

Figure 3- *Spa Commander* Faceplate Design

[R94]	The display panel will be placed on the front surface	I
[R95]	The LEDs will be large and bright to notice from a distance of at least 5 meters	I
[R96]	The display panel will be waterproof, this will block out the humidity, rain, vapour, splashed water from interfering with the electronics	I

7.3. Usability Requirements

[R97]	The display will be clearly labelled and simple to read	I
[R98]	The LEDs will be coloured differently for signifying levels that are good vs. bad	I

7.4. Performance Requirements

[R99]	The LEDs will be bright and viewable from a wide angle	I
[R100]	The LEDs will be operable under all conditions	I

System Test Plan

There will be two stages of functional testing for the Spa Commander, open box and black box testing. Initial testing will be open box, dividing the system into smaller blocks that can be tested individually to verify the low level operation. Upon completion of open box testing, the Spa Commander will undergo black box testing, exposing it to common use case scenarios and corner cases to gain an understanding of the limitations of the implementation and identify any problems. Three key test cases are: beginning operation in untreated water, beginning operation in partially treated water, and beginning operation in treated water.

The functional specification document, pending revision, will serve as the guideline for testing. The Spa Commander will be tested against each requirement listed and issued a pass or fail. For each failed test case, the team will assess the necessity of the feature and the cost of repair to determine whether the problem should be addressed. A lower level test plan will be developed once the design becomes more mature. The lower level test plan will outline the electrical and mechanical requirements that need to be met such as maximum power consumption. Key components and components with low reliability will also be given more attention in the test plan.

Black box testing will begin with a low volume of water, possibly 10 gallons, and increase incrementally. The performance of the system will be assessed by taking hand measurements of pH and chlorine levels once the Spa Commander has completed operation and charting the values against recommended levels for the particular operating environment. Completion of operation will be indicated by when the system identifies the water as “safe”.

Upon completion of functional testing, the Spa Commander will be tested for compliance to standards that need or want to be met. The specific compliance tests that need to be done will be determined once the design becomes more mature, CSA and ANSI are likely candidates.

Conclusion

The *Spa Commander* is a total solution for maintaining a home spa. The system balances the water chemistry automatically to make sure it is safe and clean with no hassle to an owner. One can see at a glance if the spa is usable and if there are enough chemicals in the hoppers to maintain it thus.

Functionality of the system was outlined in the above document, with special consideration for safety and usability features. This document will serve Aquamatic Technologies' engineers as a guide for production of the *Spa Commander.*

References

NSF International: Pool, Spa, and Recreational Water Products, 2004
http://www.nsf.org/business/pool_and_spa/index.asp?program=PoolsSpasHot
Accessed: January 2010

NSF International: Electrical Safety: Pool and Spa, 2004
http://www.nsf.org/business/electrical_safety/pool_spa.asp?program=ElectricalSaf
Accessed: January 2010

ANSI Swimming pool equipment – Part I: General safety requirements and test methods, 2001
http://webstore.ansi.org/RecordDetail.aspx?sku=DIN+EN+13451-1%3A2001
Accessed: January 2010

CSA Electrical Standards, 2009
http://www.csa.ca/cm/ca/en/standards/products/electrical
Accessed: January 2010

AC power plugs and sockets, 2009
http://en.wikipedia.org/wiki/AC_power_plugs_and_sockets
Accessed: March 12, 2010

pool chemical guidelines, 2009
http://www.waterandhealth.org/pool_spa/guidelines.html
Accessed March 12, 2010