Aquamatic Technologies

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April 18, 2010

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

Re: ENSC 440 Project Post-Mortem for a total spa system

Dear Dr. Rawicz,

Attached is a copy of our post-mortem for the *Spa Commander.* This spa system will allow users to easily check the cleanliness and safety of the water before enjoying a dip, without the hassle of handling messy chemicals and doing tricky mathematical equations to determine safe amounts. This document summarizes our project and outlines problems encountered as well as future plans for our spa system. Each team member's experiences during the three months of development and implementation are included in the report.

If after perusing the post-mortem, you have any questions, comments or concerns, please contact Matt Bergsma – our company contact – at his email address (mjb4@sfu.ca)

Sincerely,

the Aquamatic Team

Enclosed: Post-mortem for the *Spa Commander*

Aquamatic Technologies

Project Team:

Matt Bergsma
Ken Chou
Dan Latuszek
Michelle Ochitwa
Sulien Wong

Contact:

Matt Bergsma at mjb4@sfu.ca

Submitted To:

Dr. Andrew Rawicz – ENSC 440
Steve Whitmore – ENSC 305
School of Engineering Science
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Executive Summary

The details for designing and developing our spa maintenance system are outlined in the design specifications (this includes only our proof-of-concept model). The specifications of the *Spa Commander* include, but are not limited to, the intake of spa water, the correct and continual testing of this water for pH levels and contaminants, and the administering of chemicals back into the spa. Possible problems and design improvements for future iterations of the *Spa Commander* are not discussed in this document.

Each chemical, pH Plus, pH Minus, Chlorine/Bromine, will be administered from the hoppers by DC motors driving gate valves. A PIC will control this function as described below and general software program process flow is also included. These chemical adjustments will then be pumped back into the spa to maintain clean and clear water at all times. The plumbing design is fully described in the document. The display panel will allow the user at-a-glance information about the pool water and chemical levels. Three LEDs (one for each chemical hopper) will turn on when the chemicals are running low, two LEDs will show if pH or Chlorine/Bromine is imbalanced, and one LED will turn on when the pool is safe for use. There will also be an LED to indicate power. The *Spa Commander* will need detailed testing, and a description of this test plan (for the system and the system components) is provided at the end of the design specification.

Since our team is having troubles obtaining a cost effective sensor for chlorine, and the one we ordered (analog) may not arrive in a timely fashion. We will leave the design option open for possible use of an ORP sensor – digital or otherwise. This possible change will not affect our design, outlined below, significantly.

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Introduction:

Over the past three months the Aquamatic team has designed and nearly completed a working proof-of-concept model for the *Spa Commander,* an automated spa chemical testing and distributing system. The system intakes water and senses concentrations of bromine or chlorine and pH levels, then the control system pumps small amounts of chemicals (Br/Cl, pH plus and pH minus) back into the spa to balance the water. This model is repeated until the spa water is safe. The *Spa Commander* is marketed for residential use as a cost effect way of eliminating hand testing and chemical additions.

Proposed Project:

These days many people own home pools and spas, but no viable, inexpensive, automated chemical testing and dispensing system is commercially available to them. Seeing this uncaptured market niche Aquamatic Technologies Inc. began to develop the *Spa Commander,* this system will first take in water from the source are test it for pH levels and available chlorine/bromine. Then the 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. With thoughts foremost on safety the *Spa Commander* will conform to all pertinent standards and guidelines, including those of the CSA. What sets our system apart from the competition is that it supplies the spa owner with a cheap, compact solution for maintaining water cleanliness and safety.

Figure 1 is a flowchart of how the proposed system will work. We followed this quite closely throughout the project and ended up with a system that actually closely follows this design.

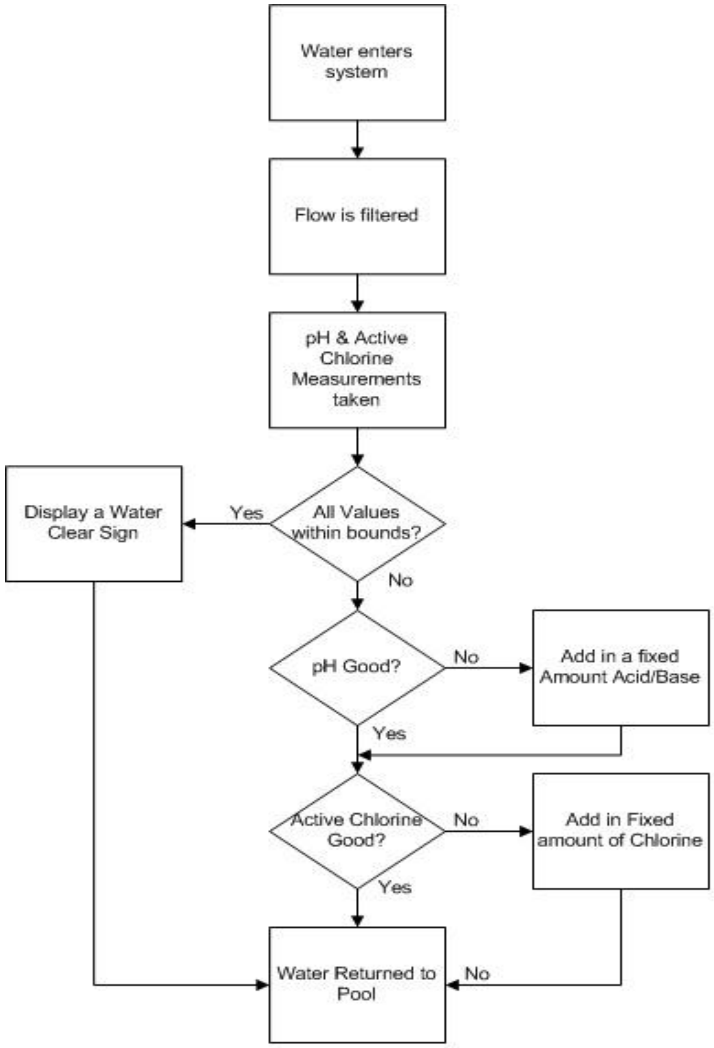

Figure 1 : System flow chart

Modifications to the Proposed Project:

There where a few small modifications as well as simplifications made to ensure our model was inexpensive and easy to implement in the short amount of time available. Also, many parts used where off the shelf to cut down on cost and shipping times. The adverse effects to such changes were things like a lower success rate with the cheaper sensors as well as a larger total unit and less functionality. Finding a golden mean between cost and reliability was an important lesson learned by the whole team.

By using an old computer power source we saved money, but modification took up time that was allotted to testing the system. Another feature we chose to save money on was the sensors. These cheap electrolytic sensors work in a similar way to the ORP sensors that we originally chose for our system, but we had many problems integrating them into our design. We also chose a submersible pump, which worked great and saved time, but made product larger then we originally wanted. This trade off, however, let us forgo the cost of an inline pump which are typically much more expensive.

Some early thoughts about functionality of the system included detection and changing concentrations of calcium hardness and total alkalinity in addition to pH and bromine/chlorine concentration. We had also originally wanted a user interface which would allow one to see trends in chemical usage and modifications made by the system.

Electronic Issues Encountered:

We specifically chose the PIC16F690 microcontroller as we found it to meet our requirements including number of I/O pins, A/D conversion, memory, and economic cost in comparison to fully featured microprocessors. Our microcontroller was driving our entire logic flow based on inputs and controlling different outputs through A/D conversion and an internal timer to control the servo motors via pulse width modulation signals. Although we ran into a problem by running out of analog input pins after we found out that the chlorine sensor required the difference between two inputs not one input. This could have been solved by creating a difference amplifier however we found that computing the difference via code was more accurate. Therefore, we moved an existing non-critical analog input and converted it to be a digital input instead as it did not affect the performance noticeably.

Other issues we came across were due to the varying internal resistance of the PIC which caused voltage fluctuations in our circuit that alters the accuracy of the input readings for both chlorine and pH sensors. However, we decreased the fluctuations by adding some capacitors thus minimizing our accuracy offset.

Future Plans:

There is lots of room for potential growth with the Spa Commander. Along with ideas to make our current model more effective there are features we could add to the design for future models as well. Making changes to improve aesthetics, usability, and production are our focus.

To make our product more marketable we would reduce the chassis size and improve the aesthetics of our overall design. Our proof of concept model has lots of unused space in the chassis that could be easily compacted. Using an inline pump would also decrease the size of the *Spa Commander*, and would appeal to the users. Also, our user interface could use some tweaking. A small LCD for the pH and Br/Cl readings would be very effective along with our LED display.

Production and safety features will also need improvement before we would sell our product. Our system would need total waterproofing for use outdoors in all sorts of weather. Making a fail-safe for our design would make sure all chemical tanks are closed in case of loss of power when a gate valve is open and dispensing chemicals. Improving sensor performance is a must. We would invest in the higher quality ORP sensors for our product to increase reliability.

Adding features to our future models is another idea. We would like to implement a "shocking" feature to allow the user to quickly balance a freshly filled spa. In addition it would be beneficial to test and control the calcium hardness and total alkalinity in addition to pH and bromine/chlorine concentrations.

Financial considerations:

We have compared our estimated costs for the Spa Commander with the actual costs (see table 1 below)

Equipment	Proposed Price (CAD)	Actual Price (CAD) (costs rounded)
Pump	$250.00	$40.00
Chlorine Sensor	$100.00	$20.00
pH Sensor	$50.00	$0.00
Thermometer	$10.00	N/A
Chemicals & Test strips	$40.00	$16.00
Gate valve	$40.00	$5.00
Electrical components (including motors, power supply, PICs etc.)	$50.00	$135.00
Plumbing	$50.00	$80.00
miscellaneous	$10.00	$80.00
Total Cost	$600.00	$376.00

Table 1: Proposed Costs vs. Actual Costs

Looking at table 1 we can see that we saved over $200.00 CAD on our system. Most of the cost savings where in the pump (we chose a submersible pump instead of a more expensive inline pump) also using the cheaper electrolytic sensors instead of the OPR sensors. However electrical components cost more then we budgeted for. We did not expect to spend $30.00 CAD on each of the 3 servo motors – but we did save money on using Matt's old computer power supply.

Time-line:

Given that we only had about 3 months to devote to the project, we outlined a dense time-line for completing key tasks throughout the semester using a Gantt chart. The time-line in Figure 2 shows the proposed time-line we gave in our project proposal overlaid with the actual time-line followed throughout the semester.

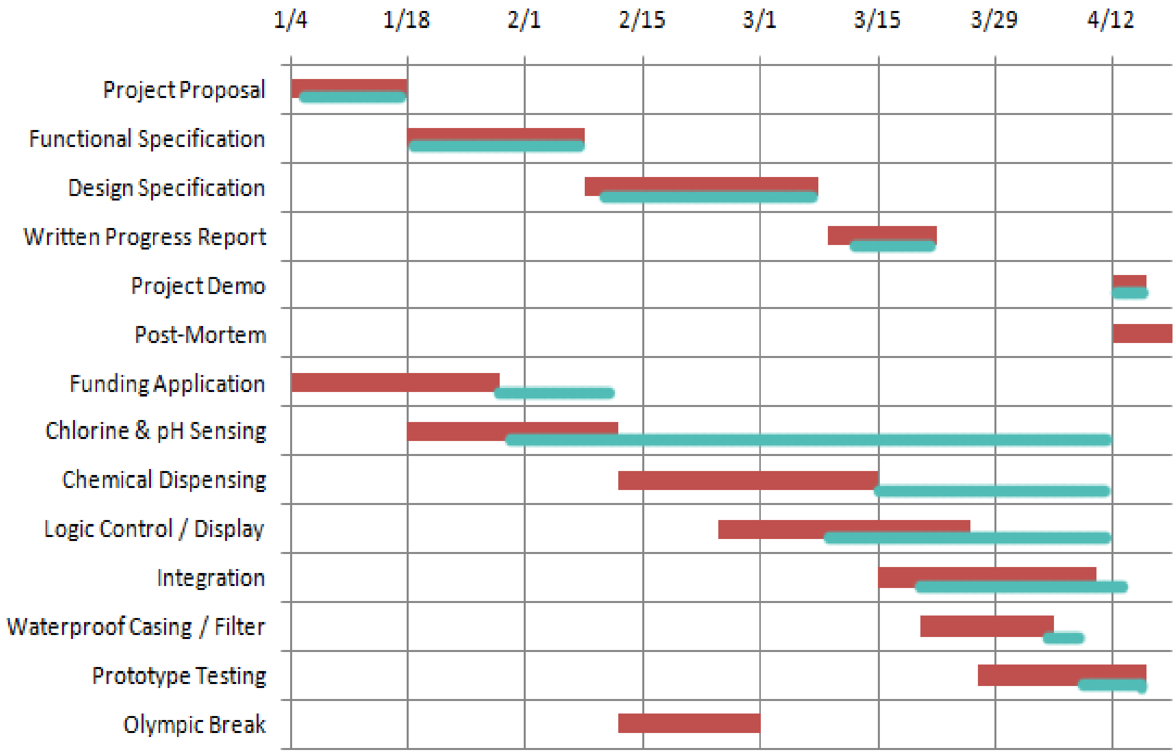

Figure 2 : Gantt chart for proposed and actual timelines

From figure 2 the red timeline is the proposed timeline and the blue is the actual timeline. As you can see the Cl and pH sensing took up a lot of time due to the choice of sensors and subsequently integration and testing where pushed back allowing only a small amount of time for those items. Our project turned out to be bottom heavy since we did not allow enough time for shipment of parts and of course procrastination.

Personal Experiences

Each member of Aquamatic Technologies Inc. has included a summary of his or her 305/440 experiences.

Michelle Ochitwa

ENSC 305/440 was invaluable to my engineering degree. This course was the only one where all aspects of engineering come together along with our own creativity and team dynamics. Since I own a spa and have worked as a lifeguard for over six years I have done more water tests then I can count (the public pool requires water testing 4 times daily to confirm the automated readings). Doing this project was an idea of mine years ago, but one I thought someone would come up with one day. It was great getting a chance to try out the idea in a group and actually have something to show for it in the end.

I worked on sourcing and procuring many of the parts for our proof-of-concept model, finding a happy medium between costly parts and reliability/functionality was a challenge and in the end realized that the cheaper sensors may have been more trouble then they were worth. The mechanical side of the project was more hands on. Work on many of my level sensing ideas seemed to become mostly trial and error as time went on. A main problem was that the pH chemicals and the bromine where both different textures and each would “flow” in the tanks in a different way. In the end I came up with a “brush” technique to complete the circuit but not allow chemical to become trapped in-between and hold an open circuit when chemical needed replacing. Pumping water through the system was another source of frustration. Using the cheaper submersible pump seemed to be our best option, but it presented some difficulties with water pressure. Finally Matt suggested “taping” the intake to minimize the flow- thus not allowing water to penetrate the chemical tanks.

Other soft skills were learned on the fly when dealing with five different personalities. Working for 3 months as the only female had it's challenges but was a good experience - as this is bound to happen in the workplace. Coops aside (it is very different working with men as a subordinate with a narrow job description) sometimes I found myself trying only to mediate the group or having a hard time getting a point across - especially among team members that I hadn't worked with in the past. Splitting off into smaller groups for the hardware portion of the design made it easier communicate and not get lost in the “crowd”.

I think our group was very successful in the end, and we may just have a great idea in the *Spa Commander* for a future business venture. I find this course a bitter sweet end to my undergraduate degree. I enjoyed this course immensely and have made some close friends in the process, but am exceedingly happy to forgo the stress that goes along with a giant project like this one.

Matt Bergsma

I’ve thoroughly enjoyed my time this semester spent on ENSC 305/440W. Over the course of this project I was able to further develop and stretch many different skills I have developed over the years. My team-working skills developed in the work place, I found to be an asset and through some minor internal conflict further developed which will be a benefit for me when I seek my last co-op job and jobs down the road. As well, I was able to utilize skills and knowledge that I haven’t used since graduating from BCIT and from experiences I had prior to coming to SFU, such as piping layout and chemical/process design.

More specifically I found reverse engineering the Chemical Sensor we had used to be a bit harder than it originally seemed to be, due issues with the quantities of chemicals present in our sample solutions and the effect their small size had when trying to keep a sample stable over short periods of time. The interaction between pH and chlorine also posed some problems, since our sample solutions would rapidly lose chlorine to evaporation which would shift the chemical balance of the chemical equilibrium, which I had expected would have a minimal effect on the pH of the solution, was unfortunately not the case, as confirmed by what happens in real pools and spas.

The development of the custom gate valves used for the chemical tanks was also an interesting problem, which thankfully I was able to fix with help from my dad, due to his experience with industrial valves and control system (due to his work as a ticketed millwright the last 10 years, and 15 years of experience as an operator on a pulp and paper machine before that). Once both of the problems were solved, or at least to the best of our ability, the system also ended up being much more sensitive to both water depth of the intake pump, as well as the height of the outlet valve, which was a simple fix, simply shortening the length of the outlet pipe to decrease the pressure drop over it.

On the personal side of the project, I found for the most part we worked very well as a team, most small conflicts that would developed would typically be talked out as a group before it became a massive issue. Our time management in retrospect was lacking a bit, which resulted in us having much less time to build, integrate and test our final product, but as a team we did pull together and the resultant product was fairly good, even given the issues with the sensors in the final demo. The largest conflicts seemed to happen between Dan and I because we are both fairly dominant personalities, and varied in occasion on how to get things done, and when to do them, as well as how often to hold meetings, but those issues rarely became an issue, as both of us where willing to compromise on a solution that would work best for the team. When we where building the demo unit itself, there was some conflict due to the way it was split into mechanical and electrical components, and the appearance of lack of work and effort by the mechanical team (Michelle and I) to the electrical team, due to the fact the electrical team spent many a long day and night in the lab, while the bulk of the mechanical work was done outside of the school. When the issue was brought up, it was explained to the electrical team about how much work had gone into the mechanical side and that coupled with the fact that integration started to occur soon after, seemed to satisfy the electrical team's complaint about lack of effort.

In retrospect, this project I feel was quite successful, and that the only changes that I think would have been needed to make it more successful, would be to increase transparency of meeting times and what is being accomplished when we split into the two different teams; as well, we should have started the development and ordering parts much sooner than we had, so that the long days and nights that occurred during the last bit of the project could have been mitigated slightly by a more sustained effort throughout the course of this project.

Ken Chou

My main technical contributions towards the project were in electrical design and microprocessor programming with Dan and Sulien. I played a role in solving the numerous problems associated with sensors and actuators, electronic design, and control. What started as a methodical approach ended up requiring guessing and testing due to the unpredictability when trying to interface analog with digital circuits. The same went for programming the PIC16F690 microprocessor because of limitations with the compiler and the fact that all debugging had to be done in-circuit. This eventually led to the mutilation of multiple microprocessors by means of breaking pins and overvoltage. We quickly learned the importance of buying spare parts as we needed more than what we originally purchased. Construction of the sensor circuitry and eventual debugging taught me about the specificity of chemical sensors and not to be overly optimistic and never to put all your eggs into one basket. Much of our problems were a direct consequence of the extremely low budget we enforced upon ourselves compared to other teams. However, this ordeal has given me a new found respect for successful start-up companies.

Another aspect of the project I was responsible for was the design and construction of the chassis. For this part, I must thank 510 Innovations for their enormous help with acquiring materials and helping me with laser cutting. Without them, I would not have been able to construct a case anywhere as good as the one we did for the price we did. This in itself was another learning experience, one that taught me the importance of networking and external aid.

The team itself possessed its fair share of conflicts and I sensed a divide between the mechanical team and the electrical and programming team. Interdepartmental conflicts, I can only speak for the electrical team, started the moment problems arose and ended the moment they were solved. Towards the end when we were going home at midnight on a regular basis, I started to feel more and more like Sisyphus. Emotions ran strong during the final days. I think they were spawned from my frustration towards the project rather than animosity towards others. My happiest moments during the project were drawing the chassis schematics in CorelDraw and soldering the interface LEDs onto a component board. I felt like I finally found sanctuary during what felt like an eternity of fiddling with voltages and C code. I only wish these parts were bigger so I could have shared them with Dan and Sulien, I think they would have enjoyed the change in scenery.

The realization of the Spa Commander is my first experience in seeing a project through from beginning to end, and I found this to be an invaluable experience. Looking back, I value the process as much as the result as it reinforced and taught me ways of working with people. The completion of this project is one of the most fulfilling experiences in my life. The feeling of an immense weight finally off your shoulders and the sight of cherry blossoms on a warm sunny spring day make the entire process worth going through again.

Dan Latuszek

This engineering science capstone project course has been a valuable experience both technically and personally. As CEO of Aquamatic Technologies, the start-to-finish project flow including proposal, design, and construction gave me insight leading to a greater respect for deploying products and organizing an engineering team.

On the technical aspect of the project I was involved in creating the electronic control circuitry for the Spa Commander along with Ken Chou and Sulien Wong. This included the learning process of microcontrollers in embedded systems and many late nights testing and debugging the written code for the microcontroller. Although the three of us have worked on the entire circuit together, we found that individually we focused on different aspects which worked out very well. I found myself focusing on the PIC programming and circuit integration portion.

Technical issues that did arise were very well handled by myself and the electronics team even if we didn’t always exactly understand what was happening. The communication between us was excellent as we all knew what each of us was working on and our accomplishments. The main source of conflicts within the team originated when we initially split the team having Sulien, Ken and I focusing on the electronic aspects and Michelle and Matt focusing on the mechanical aspects. This occurred when attempting to assign tasks while waiting for parts to be shipped including the PIC’s and sensors. However, this only spread us apart and the communication between the now divided teams was not very effective. As CEO, I attempted to reunite the group by having weekly meetings but the division seemed to stay until we started integration.

In the end, the process of creating the Spa Commander I gained some technical knowledge but most importantly it has taught me project management and team dynamics. I am happy with the results and it has been a pleasure bonding and solving both technical and personal issues with my fellow teammates. This was a great course and I only wish we could have more team project experiences like this one in engineering science at SFU.

Sulien Wong

This course has been a great experience is all aspects of engineering. I've learned how ideas are turned into products through stages of design, implementation, testing, and marketing. I've experienced how valuable communication and proper group dynamics can affect the success of the product. I've also discovered that it takes a lot of time, effort, and cost to develop and market a simple product such as ours.

My contributions to this project mainly focused on designing the electric circuit and programming the microprocessor with Dan and Ken. We spent countless hours implementing, debugging, testing and retesting ideas that didn't always work out. When we finally found something that worked, we found out that it broke something else, and we had to start all over. Even though it was a painstaking process I still enjoyed it because I could see what our efforts were producing and it motivated me to work until the project performed as we had designed it.

We split our group into two covering the mechanical and electrical aspects of the project. This decision worked out for the most part but near the end we ran into arguments when time was critical and we still had a lot to finish. However, this only strengthened our group and in the end, we all pulled together to deliver a finished product. I learned a lot from working with my team members in general, but my experience as part the electrical team will be one of the most memorable at SFU.

Throughout the term, I've had to worry about the project and how it will perform, but it was a pleasure seeing it completed and functioning. I'm glad that I had the opportunity to be part of this project and all the experiences involved.

Conclusion:

Looking back on the past 3 months we believe our overall project was a success. Our final proof of concept model was very close to what we projected at the beginning of this journey. We had our problems with time management as well as team dynamics, but it was all part of the learning process. Seeing our *Spa Commander* take shape was a great feeling for all of us and imagining future work on the system is an exciting prospect. Working in the group of 5 engineering students was a roller coaster ride with everyone bringing their unique outlooks and skills to the project. We would like to send out a special thanks to Dr. Andrew Rawicz, Steve Whitmore and our TA's Duncan Chan, Ali Ostafar, Sara Mogahddamjoo for all their hard work in making this course and our project possible.