Aquarium Control Suite

UCF Senior Design 2

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Abstract— **The saltwater aquarium industry is currently booming due to the amount of time, energy and money these owners put into these aquariums. The fauna within a saltwater tank can have an extremely high monetary worth. Saltwater aquarium owners are willing to expend large amounts of time and money toward maintaining their investments. Our group will attempt to automate the solutions to the problems saltwater aquarium owners face with our project, The Aquarium Control Suite.**

I. INTRODUCTION

The motivation towards this project comes from Ectis' and Segovia's fathers interest in aquariums. Our knowledge of our parents' hardships while dealing with our family's fish tanks allowed us to come with this idea. Often, remote monitoring of a saltwater fish tank, filled with expensive assets, is impossible if the owner is away or traveling. Many owners must rely on their neighbors to stop in and take care of the fish, or at the very least check on them. Not everyone who is left with this option is comfortable with their neighbors having access to their home while they are away. We looked up other consumers' troubles and discovered saltwater aquarium owners had the most complications compared to freshwater aquarium owners. The variety of problems included: regulating the pH of the water, maintaining the salinity and cleanliness of the water; managing the temperature of the water, maintaining mechanical components such as the of the heaters, pumps, filters, lights, radiators, and automated feeders, and supplying the fauna within the tank their necessary caloric intake and supplements.

II. EASE OF USE

A. Problem

Our project will alleviate the time requirements that a user spends maintaining their tank. The Aquarium Control Suite will also alleviate the stress that can form when taking precise measurements that will affect their living investing, as well as knowing immediately when the levels in the tank are off, not just when they decide to take a reading. Another justification for this project is the large amount of money saltwater tank owners are willing to invest into their saltwater tank. Some of the potential fauna that can be kept in a saltwater environment have a very high monetary worth. The ACS can introduce new fish tank owners to all the tasks required to run a healthy ecosystem without becoming overwhelmed and damaging the ecosystem or fauna.

Our group's main goal is to take some of these responsibilities from the consumer and make them more manageable, cheaper and less time consuming. The objectives of this project are to envelop the oxygen intake, heat, feeding, pH, and salinity into a single printed circuit board (PCB). Our group would research each parameter and obtain the electronic parts and components needed to meet these objectives. Research will mainly be conducted with the use of a breadboard to organize and connect small electrical parts and electronics. Later, these breadboard designs can be translated onto a PCB. Our microcontroller unit, the Arduino, is used to logically manage the features on the PCB. The functions of our project would include:

pH Sensor: Electronic device that measures the alkalinity or acidity of the water though the hydrogen-ion activity in the water being analyzed.
Salinometer: Electronic device that measures the salinity or salt to water ratio in the water analyzed.
Automatic Feeder: Electronic device that acknowledges the time of day to enable a motor to spin a canister filled with food.

Thermometer: Electronic device that measures the kinetic energy of the molecules within a surrounding medium. In this case, the thermometer will measure the thermal energy within a large enclosed volume of water.
Heater/Cooler: Electronic device that will respond to the thermometer reading and divert the water flow through a heating coil or through a radiator to bring the temperature back into an acceptable range.

B. *Maintaining the Integrity of the Requirement Specifications*

The following tables describe the basic requirements for the project. The first table describes the hardware requirements (what the physical components must be capable of in order to be successful), while the second table describes the software requirements (what the programs must accomplish). These requirements can all be tested and verified, in accordance with the definition of requirement specifications.

Hardware Requirements

1.0	The system must measure pH of the water.
1.1	The system must measure temperature of the water.
1.2	The system must measure salinity of the water.
1.3	The system must measure the clarity level of the water.
1.4	The system must have a display for all relevant measurements.
1.5	The system must have a method of heating and cooling water temperature.
1.6	The system must have a method of monitoring activity while the user is away.
1.7	The system must have a method of automatically feeding the fish.
1.8	The system must be water resistant.
1.9	The system must maintain water temperature between 75 and 78 degrees Fahrenheit.
1.10	The system must be able to be operated remotely.
1.11	The system must not take away from the visual aesthetic of the tank
1.12	The system must not disturb the aquatic creatures living within the tank.
1.13	The system will communicate with a mobile application.
1.14	The system must have a visual color display for pH.
1.15	The system will accurately measure temperature to +/- 3 degrees Celsius
1.16	The system will run in a low power mode when it is not sampling/regulating the tank.
1.17	The system must be able to send out an alert in the case of power outage.
1.18	The system will have a way of keeping track of the water level (too high, too low, normal)

Software Requirements

2.0	The system must automatically regulate temperature.
2.1	The system must automatically update the displayed measurements regularly.
2.2	The system must be able to automatically send an alert if an error occurs.
2.3	The system must be able to schedule automatic feeding.
2.4	The system must have an accompanying application.
2.5	The application must communicate with the system directly over a wireless network.
2.6	The application must be able to substitute for the main control/display when the user is away.
2.7	The system must be able to automatically and manually enter and wake from low power mode when not in use.
2.8	The application must be simple to use, organized, and not visually off putting. (user-friendly)

III. STANDARDS

The Software and Hardware of our program has to be planned out and implemented having certain standards. These Standards were recognized and placed in diagrams for the user to easily understand the mechanics of the Aquarium Control Suite.

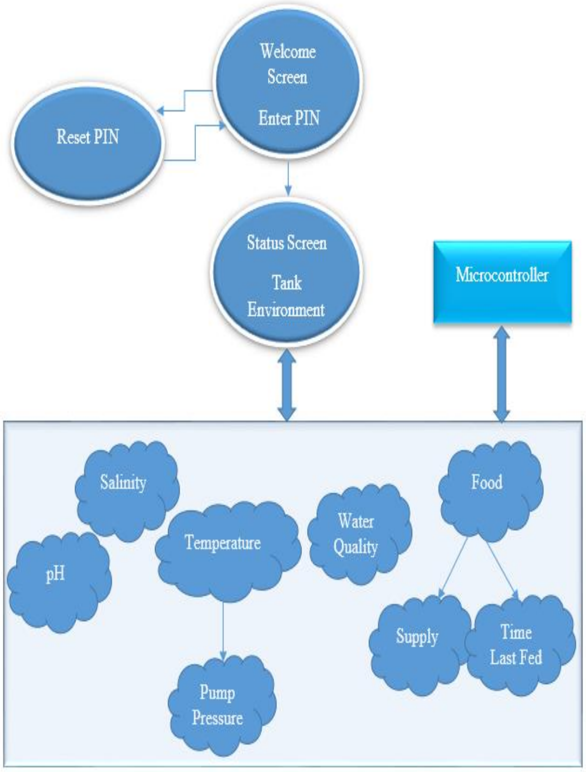
A. *Software Block Diagram*

The following figure is a block diagram model of what the software in question will be capable of. The basic premise is that the software will allow the user to access control and measurements of the tank that are pertinent to its stable operation. The microcontroller is the main component for the software, and it is able to run the automatic feeder as well as the automatic measurements. The user sees the welcome screen and the status screen, while behind the scenes the microcontroller operates the sensors and automatic feeder periodically in order to display accurate and recent results.

Wireless functionality from the microcontroller seeds indication monitor functions via software and sends them via packets to a domain name server. The domain name server is responsible for forwarding these packets to a machine host which will decode the information stored in the network packets. These packets contain a large host information, including which routing and addressing protocols are being used to transmit packets, as well as their sequence and acknowledgement numbers. These values are send directly from client to server and vice-versa and are invisible to the network programmer.

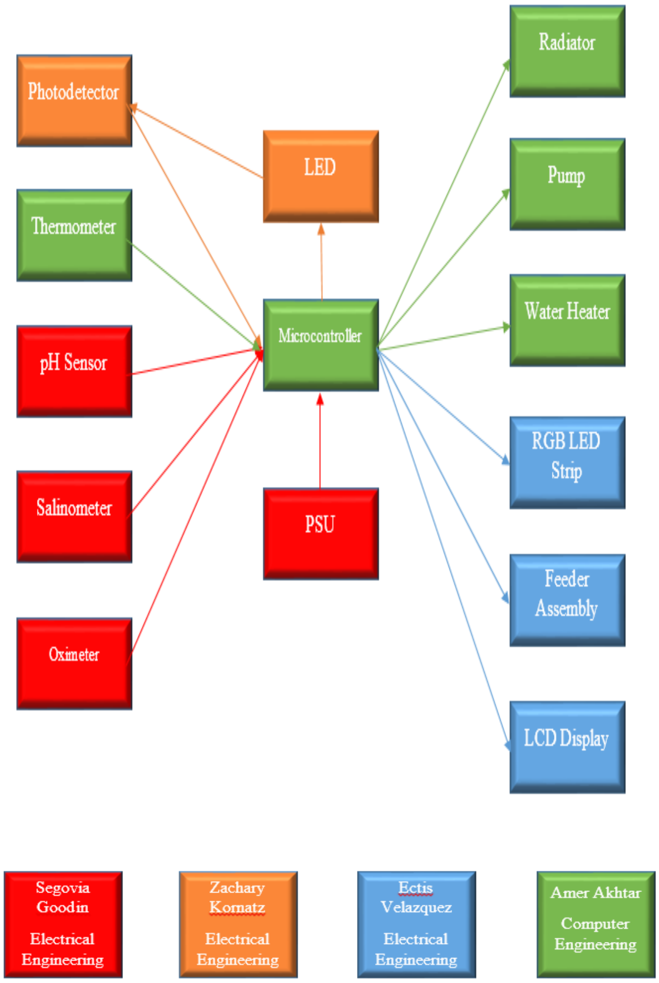
As such, the software is written simply to locate a wireless network, establish a connection to this network by asking permission, and then getting through network encryption via a WPA2 or WEP protocol secured connection. These steps are written in code simply to enact a connection to a network. Communication to the network at this stage is restricted to phantom data. When the client establishes a connection to a network, only then can information be routed by the network to the internet.

Transmitting data from the microcontroller to the networking interface is done by sending individual packets. The packets will contain data regarding the environmental parameters observed by the Aquatic Control Suite. Once these are sent to the domain name server, they are intercepted by host name written function which retrieve data. Data can be extracted by these functions through the use of a query-able database. Information passed from this database can be relayed and displayed onto a hypertext markup language form.



B. *Hardware Block Diagram*

The following figure shows a color-coded assignment of which team member is in charge of which component of the project. This project has many components, and this chart is not absolute. No team member was entirely on their own for the component that they were in charge of. The assignments were mutually agreed upon by all four of the members of the group and carried out diligently throughout with each team member offering and asking for assistance as necessary.



IV. RESEARCH

Our project started off with an idea. Our ability to thoroughly research our entire project allowed us to pick the correct components and implement them correctly. The main components we used in our project were: **pH Sensor**, **Salinometer**, **Automatic Feeder, Thermometer, Heater and Cooler**

A. *Ph Sensor*

A pH sensor is “a scientific instrument that measures the hydrogen-ion activity in water-based solutions, indicating its acidity or alkalinity expressed as ph.” pH is a measurement of acidity and alkalinity in a solution. It is a parameter that can be measured, but also be controlled thereafter. The pH stands for the value of hydrogen-ion concentration. The range of hydrogen-ion activity is between 1 to 10^{-14} gram equivalents per liter. Those ranges are then broken down into numbers between zero and fourteen to make it easier to read a pH reading. The low pH values of 0,1 or 2 have the ranges of 10, 10^{-1}, and 10^{-2} gram equivalents per liter. The high pH values of 12,13 and 14 have the ranges of 10^{-12},10^{-13},10^{-14} gram equivalents per liter. The median pH value of 7 indicates a neutral solution similar to water where the range is 0. The pH scale itself is logarithmic, which means that a solution with a pH of 6 has 10 times more acidic compound per unit volume of solute than a solution with a pH of 7.

The measurements of pH happen through a pH measurement loop. The pH measurement loop is made of three components. The three components consist of a pH sensor, which includes a measuring electrode, a reference electrode, and a temperature sensor; a preamplifier, and an analyser or transmitter. The pH Measurement loop uses the measuring electrode as a positive terminal of a battery while the reference electrode is the negative terminal of the battery. The measuring electrode stays similar to the hydrogen-ion activity of the solution and creates a potential voltage to match that. The reference electrode, does exactly what its ame explains, holds the reference voltage that he measuring electrodes voltage can be compared to.

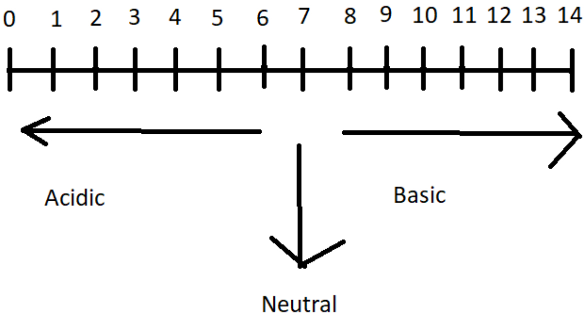
Once the electrodes are submerged in the solution to be measured the reference electrode will not change voltage. The circuit of the two electrodes are complete when the sample solution comes into contact with a solution inside the reference electrode and the measuring electrode. The temperature sensor is needed due to the output of the measuring electrode changing with temperature of the solution. The pH will stay similar throughout the temperature change, but the temperature sensor will communicate with the analyzer or transmitter software to correct the change in output.

The pH sensor components are most likely combined into one device and it is then called a combination pH electrode. The measuring electrode will be made out of glass although nowadays the electrode is replaced by more durable solid-state sensors. The preamplifier is there to take the high impedance signal from the electrodes and change it to a low impedance signal that the analyzer or transmitter can discern. The preamplifier can also isolate electrical noise from the signal by making it stronger and preserving the original signal.

Finally, the pH sensor's electrical signal can be displayed to the user. Usually the analyzer is a 120/240 Voltage AC-powered one and the transmitter is most likely a 24 Voltage DC loop-powered transmitter. These devices interact with the user and the settings corresponding to what the user is trying to set as a datum. The pH is controlled this way by calibrating the sensors and configuring outputs and alarms.

The ph Sensor is a system in itself and periodically needs to be cleaned and then calibrated. The system will use less controls and chemicals depending on the process conditions like the accuracy and stable pH measurements. The electrical characteristics of the pH sensor will get inaccurate over time. Buffers, calibration in known-value pH solutions, will correct some of the inaccuracy of the pH sensor, but not all of the issues will be corrected over time. To help the accuracy the measuring electrode, reference electrode, and the junction between them needs to be cleaned. The pH sensor will have to replaced eventually since the pH sensor is similar to a battery and all batteries have an expiration date.

The organisms held inside of an aquarium have different environments that their bodies can live in. For example, certain fish can only survive in a range of pH values and put out side of them will suffer from disease and die in a short span of time. The general pH values accepted in a basic saltwater aquarium is about 7.6 to 8.4 , but the saltwater aquariums should be kept in the higher pH values such as 8.0, 8.1, 8.2, 8.3 and 8.4. The pH needs to be so high due to a few sources in the tank such as excess carbon dioxide, nitric acid, and organic acids from metabolic wastes. One of the reasons the aquarium pH would go down is because of its buffers would go out. The buffers consist of several chemicals that also exist in the ocean such as bicarbonate, calcium, carbonate, borate and hydroxide.



If the pH starts to get acidic or starts to go lower in value, there are ways to alleviate this problem. One of the ways is to add some bicarbonate of soda like baking soda or an in store pH adjustment product. If the pH starts to get more caustic or starts to go higher in value, there are ways to alleviate this problem as well. One of the ways is to add some vinegar or lemon juice or a in store pH reduction product. On the other hand, to maintain the saltwater aquarium before it goes acidic or caustic is just to implement regular partial water changes. This process will refresh the natural buffers and restore the trace minerals in the aquarium's water. Another big tip is to figure out the cause of your pH dropping in the first place. The more expensive side of helping to maintain the pH balance is to get a Calcium reactor and it will control pH and alkalinity problems. A calcium reactor is a device that produces an acidic solution by putting carbon dioxide into a chamber with salt water calcium rich solution. The carbon dioxide will dissolve the calcium due to the solution being high in carbonic acid which will lower the pH of the aquarium.

We are applying a pH sensor to our senior design project. Due to the amount of problems that could go wrong when the consumer is not home. For example, if the power goes out the water may become acidic due to the buffers going out. The system will then alert the user and we could possibly have a system set up similar to a calcium reactor that could balance the pH until the user came home. In any case, the pH sensor would save all of the marine life in the aquarium or extend their lives until the problem can be alleviated.

The HAOSHI H-101 pH Electrode was chosen because it was the only long term option that could be continuously submerged in the aquarium and continue to take pH measurements. This is highly sought after requirement because the Aquarium Control Suite is meant to be accurate and relieve the user of many tasks to complete to smoothly operate an aquarium. A pH test is one of the

more cumbersome tasks any aquarium owner is tasked with. This pH meter runs the entire length of the pH scale, 0 – 14. As well as being operational between the temperatures of 0 and 80 degrees Celsius, which is plenty of range for an aquarium. This pH sensor is accurate to .01pH, which is far more accurate than any manual test an aquarium owner can perform with a physical test kit, which rely on the users judgement for where the ink stain matches the scale card.

*B. **Salinometer***

A salinometer is "a device designed to measure the salinity, or dissolved salt content, of a solution." It is basically a device that evaluates the purity of the water and the specific gravity. The device is usually made from an electrical conductivity meter or hydrometer and some way of converting these readings into a salinity reading. Measurement of salinity in a solution is usually measuring in parts per million. Solutes dissolved in water are quickly dispersed in a solvent such a water due to the high polarity of water. Water molecules are much higher in density when looking at a solution.

Oceanic conditions typically measure in at 35 parts per thousand, or 35,000 parts per million. Many saltwater wildlife species have adapted to this high salinity of the terrestrial oceans. This dynamic is reflected in saltwater lake species, such as those found in the Sargasso Sea off the coast of the Azores Islands.

Saltwater aquarium species have a wide variety of saltwater tolerances. These tolerances for a single community of aquarium inhabitants overlap. The responsibility for keeping saltwater wildlife is ultimately up to the owner of the tank, however it is also necessary that the Aquatic Control system give an accurate salinity reading of salinity such that the user can diagnose any variances in their aquarium. The Aquatic Control Suite is only designed to give an accurate reading of the salinity in an aquarium. It is vital that the salinity reading is correct, in order to ensure the health of the saltwater species in the aquarium. Should the Aquatic Control Suite be managed in a freshwater environment, the salinity reading should be in the single or double digits of parts per thousand.

Pure water is water that carries no electricity. The absence of salt is the definition of pure water. Pure water, distilled water or deionized water also has a high resistance due to their being nothing in it to conduct electricity. Truly distilled water has all the ions removed so there are basically no carriers for current. Salt water however has lots of ions that help conduct electricity even when it's only small amount of potassium or sodium mixed in. Typically tap water contains sodium, potassium, calcium, magnesium, chloride, and any number of other ionic species floating about in it. Sodium alone makes up about thirty percent of the mixture of tap water. All the ions are very mobile within the aqueous solution and give the solution a fairly high conductivity and low resistance.

An EC meter or Electrical Conductivity Meter is a device that will measure the amount of electrical current or conductance in a solution. As I said earlier conductivity or the ability of the water to carry electricity is the ability to know if the water is pure or not. Overall conductivity determines the health of a body of water. These meters are also used to monitor waste in water for certain procedures like water treatment plants. The most accurate and efficient electric conductivity meters are around two hundred and fifty dollars according to the EPA or Environmental Protection Agency. Common electrical conductivity meters are equipped with a probe and are handheld for going out in the field. First, the probe is to be placed into the solution to be checked. After inside of the device, there is two electrodes that voltage is applied to. The solution will cause a voltage drop due to the resistance of the ions in it. This voltage drop will be converted to milli- or micro- ohms to indicate the total dissolved solids.

A hydrometer or aerometer is "an instrument that measures the specific gravity if liquids—the ratio of the density of the liquid to the density of water." Commonly the hydrometer is made of glass and has a cylindrical stem and a bulb weighed down with mercury or lead to make the them float upright. To test the specific gravity a liquid will be placed in another container where the hydrometer is lowered into the liquid until its floating. The point where the liquid touches the surface of the hydrometer indicates the specific gravity. The scale will be imprinted on the side of the stem usually so that the user can easily get the readings. There is a variety of hydro meters made for specific liquids or solutions. The lactometer is a hydrometer made for measuring the density of the creaminess of milk. The saccharometer is a hydrometer made for measuring the density of sugar in a liquid. The alcoholometer is a hydrometer made for measuring higher levels of alcohol in spirits or alcohols like wine. The hydrometer is based off of Archimedes'' principle: "a solid suspended in a fluid is buoyed by a force equal to the weight of the fluid displaced by the submerged part of the suspended solid."

The salinometer detects the salinity through specific gravity. Specific gravity is "the ratio of the density of a substance to the density of a reference substance;" It is also referred to as the ratio of mass to another referenced mass for the same given volume. Specific gravity is mainly used in the industry due to the history of science working in terms of mass to volume. The units of specific gravity are dimensionless quantities because it is a ratio of densities. Specific gravity changes with pressure and temperature. For the specific gravity to be accurate in different environments you will have to compare the reference and the sample at the same temperature and the same pressure. The substance is buoyant in water if the specific gravity of a substance is one. The substances with specific gravity greater than one have a density greater than water and will sink when presented in water. The substances with a specific gravity less than one have a density less than water and will float on water.

Having done our research on the salinometer and its construction, we have decided to construct our own salinometer and probe modeling it after the circuit diagrams which we have studied. The potentiometer and amplifier circuit which we will construct will perform at the same level with an incredibly small fraction of the cost. The decision was made based on the relative simplicity of the design, its ability to interact with the Arduino microcontroller, and the incredibly low cost when

compared to the price of the salinometers we would be buying.

C. **Thermometer**

Thermometers have been around for over three hundred years but have recently started to change to keep up with our technological world. The first thermometers were made with a small amount of mercury metal confined in an air tight tube. Mercury is a special metal, in that it is liquid at room temperature, 23 ° Celsius. Like all metals, mercury is susceptible to thermal expansion. The high rate of thermal expansion mercury exhibits is exploited with an appropriate scale on the container to show temperature. Although mercury has these beneficial attributes, its main drawback is that is toxic when consumed (57). To combat this problem, alcohol, specifically ethanol and a dying agent to make it visible, has been used to replace mercury in modern thermometers (56). In even more recent years, digital thermometers have been introduced to the market. A digital thermometer usually comes in one of three variants; an infrared (IR) thermometer, a thermistor based circuit thermometer and a thermocouple (61). An IR thermometer works by detecting the blackbody radiation given off by an object. Blackbody radiation is the amount of infrared light given off by an object, as heat. Once the IR thermometer has been calibrated with the target object's emissivity, a value between 0.0 and 1.0 that describes how well an object emits infrared light, a temperature measurement can be approximated. A thermistor based circuit thermometer is one in which a special voltage divider circuit is implemented. To make the special voltage divider, a thermistor replaces one of the resistors in the circuit. A thermistor is a specially designed resistor that exploits the thermal effect of poorly made resistors (60). As the temperature of the resistor changes, its resistance value also changes. This change in resistance is designed to be predictable. As the temperature change causes the resistance change, the voltage coming from the voltage divider will subsequently change. This voltage change is measurable by a microcontroller and converted to a temperature approximation. The final type of thermometer is a thermocouple. A thermocouple works in a similar way as the thermistor. A thermocouple uses the thermoelectric effect to create a voltage potential between two specially designed conductors. The thermoelectric effect is a phenomenon where electrons flow from the hotter conductor to the colder conductor (61). This voltage potential is measurable by a microcontroller in the same way as the thermistor circuit. Each of these thermometer designs has its own benefits and drawbacks.

The DS18B20 is a Type T nickel-alloy thermocouple. This suits our projects needs because it covers a temperature range that is plenty wide enough for a fish tank and is accurate up to .5°C. The DS18B20 is rated for operating temperatures between -185°C and 300°C, but our specific model from DROK is rated for use between -55°C and 125°C because of the housing and cable sleeve that is used. Another benefit to the DS18B20 is that it utilizes the one-wire standard, which means it can easily be used in conjunction with other one-wire sensors or devices, such as O_2 sensors, water level sensors and calcium sensors that will be used in this project. The DS18B20 will receive 5-volt DC power from the Arduino's 5-volt pin and return a digital signal, through the data wire, to any of the input pins. The small fluctuations in voltage, on the order of millivolts, will be converted to temperature by an Arduino library provided by the manufacturer, Dallas Semiconductor. This library includes a function that will linearize the National Institute of Standards and Technology guidelines for how a Type T thermocouple performs, into usable data. This data will be calculated in degrees Celsius, to one decimal place. We will modify the function to return Fahrenheit values. These values will be displayed on the LCD display panel as well as on the app.

D. **Heater**

A heating coil will be added to the bottom of the aquarium to regulate the temperature when the microcontroller receives data from the thermocouple indicating that the water temperature has dropped below a certain temperature. An electronic relay will be added to the power cable of the heating coil to control whether the coil is on or off, as it is just a simple heating coil that begins to heat up immediately when it is plugged into a power source and will only cool down when the power is cut off from it. This heating coil is expected to run on several subroutines. The thermometer raises a flag if the temperature falls below the safe amount and then signals the heater to turn on. Once power is delivered to the heater it will run for a short time, after a delay the thermometer will once again check for the temperature and if it is acceptable the heater remains off and the flag is cleared. If the thermometer once again reads a below acceptable range temperature, then the heater is once again powered up for a short duration. The heating coil will be placed at the bottom of the aquarium to take advantage of convection currents within the water. As the heating coil heats up the cool water at the bottom of the tank, it will begin to rise to the top and more cool water will take its place. The heated water will rise to the top and the cold water will flow to the bottom in a cycle. As the cold water flows downward, that water becomes heated, and then rises once more. This is a faster process than having the heating coil at the top of the tank which requires the coil to get hot enough to heat the entire volume of water through conduction heating. In order to maintain the safety of the sea life within the tank, the coil will have to be housed in mesh wire casing to isolate it from the tank's fish and other living inhabitants. It is of importance to note that the heating coil circuitry (all parts other than the metal rod) cannot come into contact with the water. This has many potential impacts on the aquarium and the heater (danger of electrocution, or damage to the heater itself rendering it inoperable). High temperature silicon will be used on all open connections, to prevent water from seeping in, as well as not deteriorating due to the high heat.

The NORPRO Instant Immersion Heater is a small heating coil that requires 120 volts to begin heating up. This heater is implemented with a simple plug and play design, which for normal use is convenient, but will not work for this project. To circumvent this issue, relays will be used to create an electric on/ off switch controlled by the microcontroller. This heater is not rated to be completely submerged under the water, only the exposed metal heating coil portion. The body and cord are to remain dry. We will

apply silicon to all the openings in the body and where the cord attaches to the body to create a completely waterproof heater. Once this has been achieved, the heater is expected to be plenty sufficient to heat the tank as necessary. After some preliminary testing, it has been determined that one heating coil is enough to maintain a stable heating process.

E. **Cooler**

A radiator is a mechanical device designed to remove heat from its surroundings. As such, there are many types of radiators and many applications of it in modern industrial and residential systems, from a simple finned copper heatsink filled with eutectic fluid, to a steam generator in a nuclear power plant. The general definition of a radiator allows it to fit in multiple contexts as a heat exchanger. Radiators are powerful and important devices in the modern era, examples of which can be found in rural areas. They enable automations and electronics, reactors and buildings that by nature dispense enormous amounts of heat, to operate for a large period of time without overheating. Powerful radiators are required in the engines and turbos of cars, where waste heat is pumped through a radiator and recycled to spin a turbine and then exhausted. Should a radiator fail in an automobile, the engine would not be able to function for an extended period of time without overheating and destroying internal components. In mission-critical tasks such as electricity generation in nuclear reactors, large radiators encompassing tons of working fluid are designed to remove heat produced by the fissure of uranium nuclei. Should the heat exchange fail, critical overload of the system is achievable in a matter of minutes. Such a disaster would increase the pressure from the reactor to the coolant many-fold. Such was the occurrence in the Chernobyl Nuclear Disaster in 1986, whose reactor overload spilled a thick toxic haze over thousands of square kilometers of arable land. Thus, the function of a radiator is critical with respect to many performance-related applications.

The first modern radiator was patented in 1834 by an inventor by the name of Denison Olmsted. His invention was a rather crude heat stove that was used to concentrate heat and increase the temperature of buildings. A rather separate design was formed in 1855 by Franz San Gelli, which was a critical phase in the development of the modern heat radiator. These furnishings started out as appliances in buildings to exchange heat from hot water into the surrounding air via convection. As time went on, however, radiators began to make use of radiation as a means to exchange heat with a surrounding medium. When the temperature of the working fluid is not too far from the temperature of its surroundings, then a small amount of heat is exchanged via radiation. Radiators that rely on radiation and not convection are used in space satellites and extraterrestrial vehicles to dissipate the heat they generate, and the tremendous amount of heat that is absorbed from the Sun. Current radiators for spacecraft often use a classified working fluid solution not too dissimilar from ethylene glycol, which forms the basis of modern-day antifreeze.

In 1885, Karl Benz developed the first radiator designed for use in a vehicle. This radiator was different from previous household versions because it had a mechanism to prevent the working fluid from being completely evaporated within hours of being exposed to high engine temperatures. This solution allowed the radiator to expand past the realm of household heating, and permeate the market of automobiles and other machines.

In the mid-20th century the convection principle in radiators was used to develop the heatsink. This was a special type of heat exchanger that was created alongside the development of modern consumer electronics. It usually took the form of a finned copper-brass or aluminum finned block of metal that was hollow on the inside. The inside sometimes took up an eutectic fluid which was designed to expand when the surrounding electronics rose in temperature, and immediately dissipate the heat once the electronics cooled down. The high surface area of these devices allows it to absorb heat and then have many isolated zones to release it. Fans usually carry the ejected heat away from the heatsink and its associated systems. A heatsink can be found in nearly all modern electronics.

Several varieties of heatsink exist which can fulfill a logical means of disposing heat in the Aquarium Control Suite. Heat must be expelled in the cooling mechanisms of the Suite to lower the ambient temperature of the aquarium. Without the use of a heatsink, cooling would have to be done with fans mounted at the water's surface. A simple fan would be a brushless direct-current motor with a propeller head mounted onto the shaft. This motor would have to be brushless because brush direct-current motors cannot provide the angular speed and momentum required for cooling applications. Brush direct-current motors themselves produce some low-frequency whining in the motor which may disturb some sensitive aquatic species, such as delicate shrimp. Additional noise is created by the blades of the fan circulating large swathes of air over the surface of the water. They also remove heat from a localized area of aquarium, and do not have a large reach unless the fan uses an extremely large direct-current motor. Using such a large motor would exceed the noise and power constraints that are set depending on the aquatic life that is used to populate the aquarium. Fans would also produce currents in the water which would prevent aquatic life from feeding from the surface.

On the other hand, a static, or passive heatsink would not suffice for such large volume of water governed by the Aquatic Control Suite. A passive heatsink, at peak efficiency would only be able to remove enough heat from the tank to cool an aquarium to its surrounding room temperature outside the system. Some saltwater aquatic life requires cooler conditions that cannot be met by seasonal temperatures in many equatorial countries, such as Malaysia. Keeping cold water fish in an aquarium there during the summer is not possible given the average daily temperature for that country in the summer season. Therefore, a passive heatsink radiator arrangement is not a plausible arrangement for the cooling subsystem for the Aquatic Control Suite.

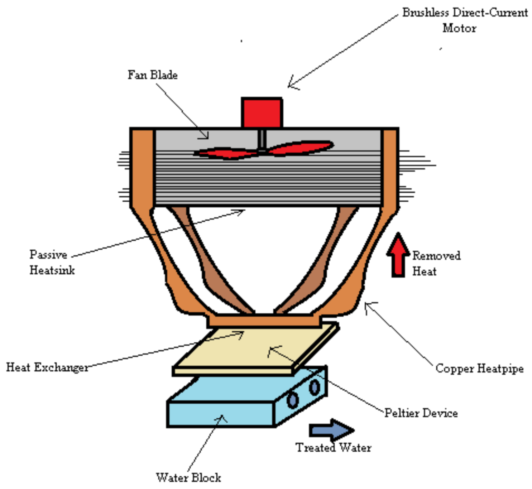
An alternative solution to the fan and the passive heatsink would be a combined module of both components. This would form what would be called an active heatsink. Heat is absorbed from the water by the heatsink and a fan powered by a brushless direct-current motor is then used to quickly expel this heat from the heatsink. This would form a more efficient system, where the heatsink is used to overcome the fan's inability to remove heat from a large surface area, and the fan is used to overcome the heatsink's inability to actively cool the water below ambient environmental temperature. Such a system would be mounted above the waterline, obstructing ay view of the water from above due to the large surface area of the heatsink. This would result in a significant decrease in aesthetics and hinder the ability to manually service the tank in the event of a power outage or disruption. This would result in poor customer satisfaction, as the aquarium is meant to be easily viewable and accessible from above the waterline. Although the active heatsink alone is sufficient in the cooling of the aquarium, it does not meet the constraints of the Aquatic Control Suite for the viability, maintainability, and ease of use of the system for the long run. Some aquatic species that rely on light for metabolic processes, such as kelp or phytoplankton, cannot survive by having outdoor light sources hindered by a large ray-finned passive heatsink above the waterline.

The next possible solution to removing heat from an aquarium we will look at is the Peltier device. The Peltier makes use of the Peltier Effect to generate thermoelectric cooling. Current is delivered between two semiconductors, where each conductor has a different level of n-type and p-type densities. The current flow diverges the heat transfer between the two materials, such that one side of the conductor loses the directional heat flow to the other side, making it very cool with respect to the outside temperature. The opposite side of the opposing conductor is a collecting point for all the heat in the system. The large amount of current flowing through the system, the higher rate of heat transfer in the Peltier device. Since the Peltier device is solid-state, just like a transistor, it has no mechanical parts and has a long-term reliability. It does not generate large currents in the water or a large amount of mechanical noise, as the brushless direct-current motor fan does. And, its small size will not obstruct the waterline's surface as a mounted heatsink would do. It is also a more time-efficient way to rapidly cool an environment below its outside ambient temperature. The Peltier Effect is used in many industrial beverage coolers and portable iceboxes, as opposed to the obstructive use of heatsinks and the noisy use of fans.

However, the Peltier itself requires a large amperage to operate, nominally at around 6 amperes. This is a large amount of current, and so a dedicated line from the power supply would be needed to supply the energy for the cooling that this valuable device provides. In addition, simply pumped water over the cool side of a Peltier device would not be that efficient. Because warmer water would transmit thermal energy to an area of the Peltier that is already being actively cooled, a negative feedback cycle would be formed on the cool side of the Peltier which would prevent the cool side from remaining cool, due to the thermal energy passed to it by the aquarium water.

So far we have explored to options of using fans, both passive and active heatsinks, and Peltiers alone to cool an aquatic system. None of these options alone would be sufficient in cooling an aquarium to a low temperature. When we combine all facets of these cooling methodologies, however, we get an efficient and modular water cooler. The Peltier itself a thermoelectric device that is the only one capable of removing large amounts of heat in a short period with budget and power constraints. To rid the Peltier of the negative feedback cycle induced by supplying heat to the cooler side of the Peltier, we have introduced an active heatsink to take heat away from the Peltier instead of the water in the aquarium itself. The active heatsink would need to be designed to accommodate the Peltier device and would need to integrate a brushless direct-current motor fan to quickly dissipate heat away from the Peltier device and the heatsink.

The Peltier is responsible for removing heat from the aquarium water, but it cannot be in direct contact with it or immersed in the water whatsoever because the water would short the large current flowing through the Peltier device. A current on the magnitude of several amperes would be enough to destroy all aquatic life in the aquarium, should this event occur. A water block would be required to interface the aquarium water with the Peltier device. A water block separates the surface of the Peltier from the water with a small conductive plate of copper. The copper separation prevents the shorting of the Peltier device with the water, but it will allow heat transfer of the water to the Peltier device to occur, due to the thermal properties of the conductive plate in the water block. This water block is responsible for the actual heat transfer from the water to the cooling apparatus: the Peltier in connection to the active heatsink.



The apparatus sketch and design can be seen in the infographic to the right. This apparatus was designed to make use of the best possible components available, using a high-current Peltier device, a custom water block designed to interface with the Peltier device and pure copper heatsink piping. These components are purchased at high prices normally befitted for a prototype model. Since the apparatus chosen has taken a design stage towards considering budget constraints, some elements have been scaled back, forcing the heat exchange capacities of the cooler apparatus to be reduced as well. This will result in a forced reduction of performance in the cooler, meaning temperatures the lowest achievable temperatures with the design sketch cannot be realistically contained given that the cost of the system would increase, resulting in a higher selling price for only a few degrees centigrade more of cooling ability, and more rapid cooling at that. Because the design of the aquarium is not focused on servicing the requirements of higher-end users who require very low temperatures for their aquariums, we have opted to befit regular saltwater tanks who require moderate cooling which is achievable with budget-constrained parts such as: copper-allow heatsinks, smaller surface area water blocks, low-voltage direct-current motor fans, and ray-finned passive heatsink.

In addition, the Peltier itself may be powered by a lower voltage and current than what it is rated for. Because the Peltier itself is solid state and does not rely on the delicate nature of mechanical parts, applying a voltage that it less than the maximum power rating of the Peltier would reduce cooling efficiency of the device itself, but would decrease the overall power requirements of the Peltier. Operating the Peltier at lower-than-peak voltage means that the maximum rate of heat exchange that the Peltier device is capable of will be reduced, which allows less heat to be transferred to the active heatsink cooling structure. The reduced amount of heat to be dissipated by the heatsink fan results in wasted fan efficiency should the fan be kept at the maximum rotary speed, which for an Intel stock LGA1155 heatsink, would be around 2500 revolutions per minute. The Peltier in combination with active heatsink chosen for this product form the radiator component for this system.

BIOGRAPHIES

Zachary Kornatz is 25-year-old graduating senior in Electrical Engineering. He moved to Orlando and transferred to UCF his junior year to complete his degree. He currently works for TLC Engineering for Architecture in their Orlando offices, as an Electrical Engineering Intern in their Health Care Operations division. He plans to continue working there as a Graduate Engineer after graduation.

Ectis Velazquez is a 21-year old graduating senior in Electrical Engineering. He moved to Orlando to attend UCF upon graduating high school to study electrical engineering after completing an advanced mathematics science and engineering magnet program. He plans on working in the field after graduating and continue to pursue a higher degree in the future.

Amer Akhtar is a 22-year old graduating senior in Computer Engineering. He attended UCF starting from his sophomore year and has worked on various software, database, and website projects. After graduation he hopes to pursue a career in software engineering.

Segovia Goodin is a 22-year old graduating senior in Electrical Engineering. He moved to Orlando after he finished an Advanced Placement program at Mosley High School in Lynn Haven, Florida. He currently works as a College Work Experience Student at UCF and contracts to Lockheed Martin. He plans on continuing work as a component or packaging engineer at Lockheed Martin Missile and Fire Control in Orlando, Florida after graduating.

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