Infant CPAP Machine

Final Report

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Abstract

Respiratory Distress Syndrome (RDS) is a condition characterized by a lack of surfactant production on lungs. RDS occurs in infants whose lungs have not fully developed and is one of the leading causes for preterm death, especially in developing countries where health care is severely limited. Continuous Positive Airway Pressure (CPAP) machines are commonly used to assist preterm infants in breathing by providing a continuous air flow to the infant. Our goal this semester is to design and fabricate a CPAP machine that can be used in developing countries and at a cost significantly less than today's CPAP machines without sacrificing the safety, efficiency, and reliability of the machine.

Background

A CPAP machine is a commonly used medical instrument in the health industry that delivers pressurized air to a patient through the nose. The general components of a CPAP machine include a flow generator, a hose to connect to the flow generator, and a mask interface to fit on the patient's face. Many CPAP machines will also contain a humidifier, data logging, and exhalation relief for extra comfort and function. Although originally meant for sleep apnea patients, CPAP machines are now used to treat a variety of illnesses.

In today's world, a large number of pregnancies end with preterm birth. 9.6 percent of births in 2005 were preterm according to the World Health Organization or WHO [1]. A majority of these preterm births occur in developing countries with a large percentage occurring in African countries. Of the 115.3 million births recorded by WHO, 12.9 million were preterm births with 11.8 million occurring in African, Latin American, and Caribbean countries. Research also showed that 30 percent of preterm infants are born with RDS [1]. RDS is a condition where a newborn does not produce enough surfactant in their lungs [2]. Surfactant maintains the shape of the alveoli within the infant's lungs, which are responsible for allowing oxygen to enter the body [2]. Without enough surfactant, an infant's alveoli will not inflate enough for the infant to breathe normally (Figure 1) [2]. RDS can commonly cause rapid heartbeat and breathing in infants. In order to prevent the alveoli from collapsing, CPAP machines are used.

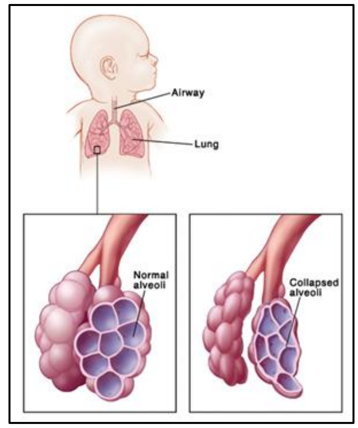

Figure 1. Effects of RDS

Infant CPAP machines are the most common treatment for RDS. A CPAP machine works by providing a steady flow of pressurized air to a patient. This air is also humidified and heated to improve the comfort of the patient using the CPAP. Infant CPAP machines are designed specifically to re-inflate the alveoli in an infant suffering from RDS. The pressurized air from the CPAP machine forces the alveoli to form into the proper shape to allow oxygen to enter the body easily. CPAP machines can be used to effectively treat patients in the United States where they are easily found, but this is not the case in many developing countries.

A large number of developing countries around the world lack formalized healthcare. These countries lack the materials and funds to obtain any type of modern-day medical technology. Because of this, many preterm infants suffering from RDS do not get the medical treatment they need which proves fatal.

Problem Statement

The goal for the this project is to design a CPAP that will be significantly less than current CPAPs and be able to be used in developing areas by untrained workers. The device needs to be made of resources that are found in the region that it is being implemented in or be easily accessible to those regions. It also needs to be reliable and user-friendly so that anyone can operate the machine.

Design Specifications

Our infant CPAP is designed for premature infants born 30 to 33 weeks after conception. These pre-mature infants are the most common infants born without sufficient surfactant to fully support their lungs. Targeting this range of premature infants optimizes the amount of premature infants our infant CPAP can save. For these infants certain physiological parameters are necessary to meet in order to save their lives.

It is vital that the pre-determined specifications of the air that is continuously pumped into the infant are under tight control. First, the infant CPAP must supply a continuous stream of air for up to 2 weeks. Infants born after 30-33 weeks after conception usually require a CPAP for 3 days to allow their lungs to recover. Anything longer than that is for precautionary measures. Air pressure from the infant CPAP must between 4-10 cmH_2O. Anything below 4 cm H_2O will not have an effect on the infant. Anything above 10 cm H_20 may do more harm to the infant than good since their lungs most likely won't support pressures this high. The infant CPAP must also be able to 100% humidify the air and heat it to 35°C. All of the specifications of the air entering the lungs must also be able to be regulated based on the circumstances of the birth.

Since we are designing this infant CPAP for developing countries the entire infant CPAP machine must be portable in case the infant CPAP needs to travel from village to village. The entire infant CPAP includes its own power supply. The goal for the sum of the cost of each of these components of this infant CPAP must be under $150. This goal was given to us by the EWH national organization.

Overview of Design

The design that is being modified to function in developing country environments is the Bubble CPAP (Figure 2). The Bubble CPAP operates in the same way as a traditional CPAP. A blower generates air flow that passes through a heater/humidifier [3]. This heats the air to the desired temperature and humidifies it to provide comfortable air to the patient and to prevent the nasal passages from drying out [3]. Once the air is heated and humidified, it passes by a temperature sensor which monitors the temperature of the air to determine if the heater is functioning properly. The air then travels into the patient via nasal prongs that are inserted into the infant's nose [3].

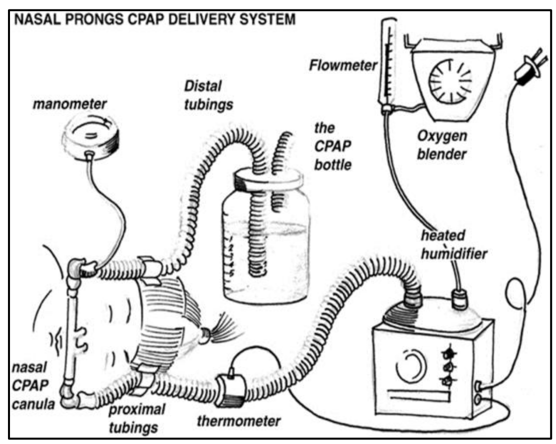

Figure 2. Bubble CPAP

When the infant exhales, the air travels through an exhalation tube whose end is submerged in a bottle filled with sanitized water [3]. This maintains the air pressure in the whole system. The pressure can be changed by moving the tubing deeper or shallower in the water [3]. A pressure sensor is attached to the exhalation tube to monitor the pressure of the air in the system. A one way exit valve is attached to the bottle to release pressure from the bottle along with water exit and entrance tubes to release or add water as needed [3].

This design was split into four different parts, with each group member taking the lead on a part. These parts were the blower, the heater/humidifier, the pressure sensor, and the power supply. Several designs were brainstormed for each part in order to determine the most effective, reliable, and cost-efficient design.

Designs

Blower

Two different fan designs to act as the blower in our infant CPAP machine were researched. The two designs were the centrifugal fan (Figure 3) and the axial fan (Figure 4). Centrifugal fans include a fan wheel and a housing unit [4]. Air is brought into the side of the fan wheel which rotates and blows a flow of air out of the housing unit [4]. An axial fan contains a group of blades attached to a rotating shaft [4]. An example of an axial fan is a basic household fan. The centrifugal fan costs $27.24 dollars which is slightly more than the axial which costs $21.21 dollars. In terms of portability, the centrifugal fan was much smaller than the axial: 39 cm^3 compared to 160 cm^3. Both fans are able to produce the required flow rate range of 20 to 60 liters per minute making them both good candidates, but the centrifugal fan's max output was much closer to the maximum output needed. We ultimately decided that the centrifugal fan was a better choice because of its lower volume.

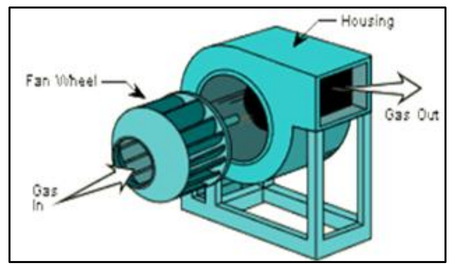

Figure 3. Centrifugal Fan

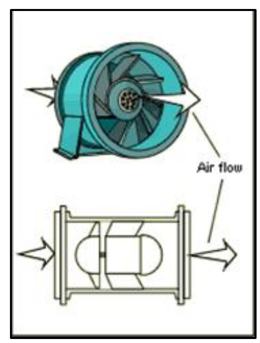

Figure 4. Axial Fan

Heater/Humidifier

Steam Humidifier

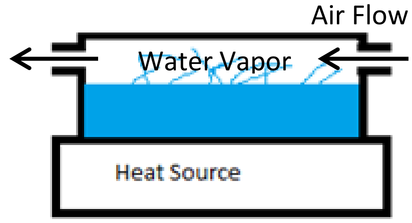

Figure 5. Steam Humidifier

The steam humidifier uses a heat source to heat up a container of water to produce water vapor (Figure 5) [5]. The air that is generated from the blower is humidified as it passes through the water vapor and this air is sent to the infant. The steam humidifier has many pros. It is very effective and it provides clean air for the infant. It also provides the user with control over the humidity of the air. Depending on the temperature of the heat source, the air will become more or less humid. It is also able to be used in developing countries as many of the materials that are needed can be found in developing countries. A con of the steam humidifier is its need for a heat source. Typically steam humidifiers use an electric hot plate to heat the water, but since that would not be applicable for a developing country, a different heat source will have to be designed.

Wick Humidifier


Figure 6. Wick Humidifier

The wick humidifier utilizes a water reservoir and a water absorbent material (Figure 6) [5]. Depending on the humidity outside, the water is absorbed into the wick from the reservoir [5]. The fan then blows air through the wet wick and this humidifies the air. This technique is beneficial as it is easy to set up and it requires no energy for it to operate. However the wick humidifier has bacteria concerns, lacks control over humidity, and is not very comfortable for the user. The wick absorbs water and will constantly be damp. This damp environment is great for bacteria to thrive and the bacteria would be picked up by the air and flow into the infant. The wick would have to be changed periodically to prevent these harmful bacteria concerns. The wick also self-regulates itself, meaning depending on the humidity of its surroundings it makes the air more or less humid. If the air outside is very humid the wick will absorb less water making the air that flows into the infant not that humid. Lastly, the wick is not comfortable for the user because it lacks warm air.

Pressure Sensor

Piezoresistive Sensor

A piezoresistive pressure sensor uses the piezoresistive effect of formed strain gages to detect strain due to applied pressure [6]. The strain gages, made of a semiconductor material, have a certain resistivity at a particular pressure. As the pressure induced on the strain gages increases or decreases, the resistivity of the strain gages increases or decreases respectively [6]. This change in resistivity affects the current passing through the circuit which in turn affects the total output voltage of the sensor. An increase or decrease in output voltage indicates an increase or decrease in pressure. The strain gages are arranged in a Wheatstone bridge to maximize the output of the sensor (Figure 7).

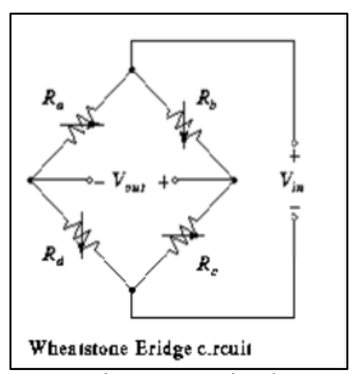

Figure 7. Wheatstone bridge circuit

Piezoresistive pressure sensors have many pros over the other pressure sensors. The first is that they have low power consumption. This is beneficial because allows the power supply to provide less voltage, which will increase the life of the power supply. They are also very accurate at low pressure operations and are commonly used in many biomedical applications. Piezoresistive pressure sensors are very cost-effective and because of their simple circuitry, they require a smaller area and can therefore be used in more applications. However piezoresistive pressure sensors are sensitive to environmental temperature changes and require Silicon to achieve high-performance.

Capacitive Pressure Sensor

A capacitive pressure sensor utilizes two parallel metal plates that are aligned facing each other to create a capacitor [6]. One plate is fixed to provide a reference pressure and the other plate is allowed to move freely back and forth. As the pressure on the free-moving plate increases or decreases, the plate moves closer or further away from the other plate which affects the capacitance of the circuit [6]. This change in capacitance affects the current flowing through the sensor which affects the output voltage of the circuit. An increase or decrease in output voltage indicates an increase or decrease in pressure.

Capacitive pressure sensors have many pros. They are very accurate and are not as affected by temperature change as piezoresistive sensors. They are most commonly used in low pressure environments because of their sensitivity. Although they are more expensive than piezoresistive sensors, they still are relatively cost-efficient. They also are made of simpler materials than the other pressure sensors. However capacitive pressure sensors are relatively larger than other pressure sensors, sensitive to electromagnetic fields, sensitive to particles and humidity, and have more complex circuitry.

Potentiometric Pressure Sensor

Potentiometric pressure sensors utilize a Bourdon tube, capsule, or bellows to drive a wiper arm along a resistive element (Figure 8) [6]. As the pressure on the wiper arm increases or decreases, the wiper arm is raised or lowered along the resistive element [6]. The resistance of the element is dependent on where the wiper arm is located. The higher up the arm is the more resistive the element is and vice versa [6]. The change in resistance affects the current flowing through the circuit which affects the output voltage of the circuit. An increase or decrease in the output voltage indicates an increase or decrease in pressure.

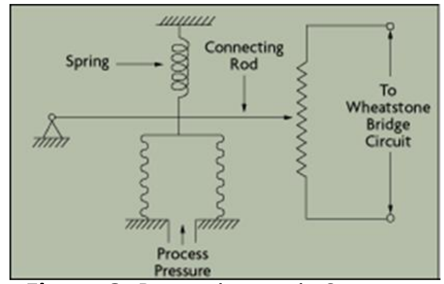

Figure 8. Potentiometric Sensor

The pros of potentiometric pressure sensors are that they are very low cost, can be small, and are relatively simple. However in order to obtain a reliable operation, the wiper arm must bear on the resistive element with some force, which leads to repeatability and hysteresis errors. They are also prone to mechanical wear which makes them unreliable over long periods of time. Overall, we decided that the piezoresistive pressure sensor was the best option to implement in our system because of their accuracy and their low power consumption.

Power Supply

The design of the infant CPAP requires four main components to be powered: a blower, temperature sensor, heating element and pressure sensor. Through research and operation of CPAPs currently on the market the goal is to achieve 100 W supplied. Our infant CPAP most likely requires less wattage. Once each component of the infant CPAP is determined, the resistance of each one will be calculated. From here, the wattage of which it runs at will be determined.

In order for the infant CPAP to run for a couple weeks the power supply must deliver 100 W continuously. Many power sources were taken into account. Solar panels and wind turbines are very expensive, and water turbines are unreliable. All these ideas also depend on factors that may not be available in a certain region. Deep cycle marine batteries work the best for our design (Figure 9). Deep cycle marine batteries are designed to be discharged down as much as 80% time after time [8]. They are designed to supply a constant supply of voltage and current and made to last longer than car batteries. However, for the infant CPAP to run continuously for 2 weeks, these batteries must still be recharged after a certain amount of time.

Figure 9. Deep cycle marine battery

Recharging the marine batteries efficiently is the largest problem associated with this design. Some ideas to recharge these batteries is to use a Stirling motor with a hand crank generator, man or animal power to constantly turn a hand crank generator or solar, wind and water power to recharge them. In order to charge a deep cycle marine battery, the voltage delivered to the battery must be more, about 15 V, than the voltage the battery produces, 12 V. More tests need to be conducted to determine which method is the most efficient to charge a deep cycle marine battery.

Final Design

The first design for a blower utilized an axial fan design. Unfortunately, the axial fan failed because too much air was lost through the fan itself so a different design was needed. Later on in the design process, a centrifugal fan was fabricated and experimented with. It was found that this was much more effective at moving air through the CPAP machine. The centrifugal fan was made from a small axial fan that had been found. The fan blades were replaced from the axial fan with a centrifugal fan wheel and the centrifugal fan was then housed in a metal cylinder with a hole drilled in the side to allow air to flow out of the fan into the tubing (Figure 10).

Figure 10: Air input system

The fan, ran at 5V, generates air that travels into the humidifier and then to the infant. A 6” piece of 3/4” ID x 1” OD vinyl tubing was used to connect the blower to the mouth of the humidifier. Plumber’s putty was placed around the mouth of the bottle to create a seal to prevent air from escaping the humidifier. A 4’ piece of 3/8” ID and 1/2” OD vinyl tubing was connected to the output hole in the humidifier. This tubing runs from the humidifier to the bubble CPAP, maintaining the pressure in the entire system.

The humidifier had to have parts that could be found all over the world. This decreased the cost of the overall product and ensured it could be replicated anywhere. The humidifier uses a cleaned stainless steel water bottle as its container. This was chosen for its ability to be heated easily. This means that the heat source does not have to reach an extremely high temperature in order to heat the water to the correct temperature.

Once the container had been chosen, it needed to be attached to the tubing to direct the air flow to the patient. To accomplish this, a hole was drilled into the side of the water bottle. This drilled hole became the output hole and the mouth of the water bottle became the hole for the input of air.

For our CPAP to function properly a heating element needed to be created to heat the water up to humidify the air. Nichrome wire was used to heat up the water bottle. This was a simple solution since only a constant flow of energy needed to be provided to the nichrome wire in order for it to heat the water. We used two plates from a coffee maker to house the nichrome heating element (Figure 11).

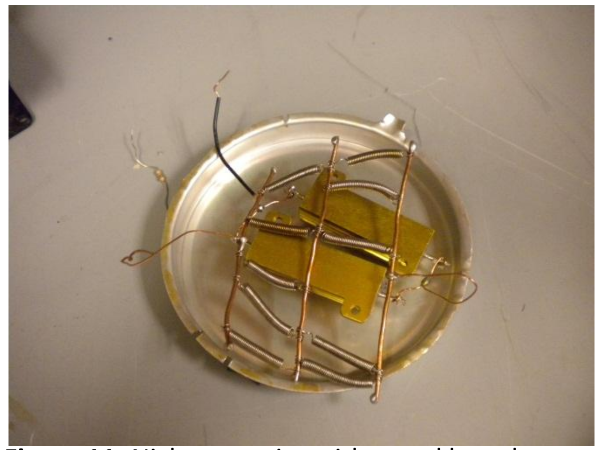

Figure 11: Nichrome wire with metal hot plate

Nasal prongs were placed on the outside of the output tube to accomplish this. The nasal prongs, which are placed in the patient's nose to deliver the pressurized and humidified air, were placed halfway between the humidifier and the bubble CPAP. The prongs were cut from the original tubing they were connected to in order to attach them to the tubing that we needed. Two holes were made in the output tubing in order to allow the air to flow from the tubing and out of the nasal prongs. Using electrical tape and glue we attached the nasal prongs to the output tube (Figure 12). Also, two sections of insulation tubing were then placed between the nasal prongs and the humidifier and

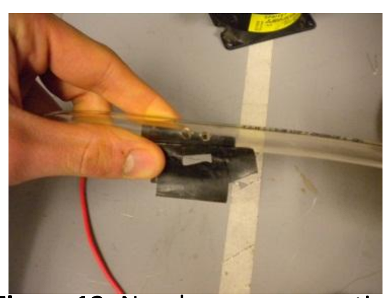

Figure 12: Nasal prong connection

between the nasal prongs and the bubble CPAP. This was included to try and reduce the heat lost as the air moves through the CPAP machine.

In order for our CPAP machine to function properly careful consideration in the materials used was taken. The vinyl tubing could not be too small otherwise the air would not be able to flow through quickly enough. The tubing could not be very large or the air would not flow through enough. The humidifier needed to be able to easily transfer heat which is why we used a stainless steel water bottle. The location of the nasal prongs at halfway between the humidifier and the bubble CPAP was chosen to allow the infant to be able to move somewhat freely and to ensure that the infant will be situated far enough away from the heating source.

Pressure Sensor

The pressure sensor that is implemented in our prototype was the 26PC SMT. The 26PC SMT is a differential sensor, meaning it calculates the difference between the applied pressure and atmospheric pressure. Unlike some pressure sensors though, the 26PC SMT doesn't have an op-amp built in so a circuit was needed to amplify the signal.

The sensor requires a 5V supply voltage and can be operated in between -40 to 80 °C environment. Because the sensor didn't have an op-amp built in, a circuit needed to be created that would amplify the output voltage to a range where the changes in output voltage due to changes in pressure could be easily seen (Figure 13).

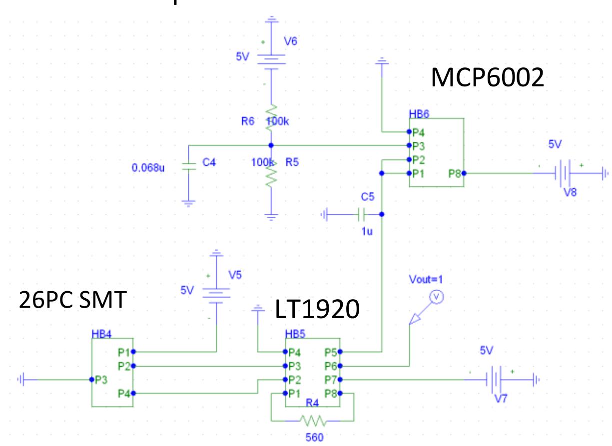

Figure 13: Pressure Sensor Circuit

In the system, the pressure sensor will be attached using a T-joint located between the humidifier and the nasal prongs. This is because the pressure of the air needs to be calculated before it reaches the infant to ensure safety in the applied air pressure. The resulting output voltage will be fed to the arduino where blinking LEDs will indicate whether the pressure is in the correct range or not.

Arduino

In order to regulate the temperature and pressure going to the patient an Arduino circuit is utilized. The Arduino Duemilanove ATmega328 powers and takes in readings from two thermistors and a differential pressure and informs the user whether they are reading the correct value. A custom made code made in C+ programing was developed and is given in Table 1.

Thermistors change resistance based on the temperature that are exposed to. This change in resistance sensed by the arduino board and converted into temperature based on the equation provided in the code. The 10 k Ohm thermistor

```
const int ledPin = 11;
const int ledPinP = 10;
int Pval = 0;
#include <math.h>
double Thermister(int RawADC) {
 double Temp;
 Temp = log(((10240000/RawADC)-10000));
 Temp = 1/(.001129148 + (.000234125 *
Temp) + (.0000000876741 *
Temp*Temp*Temp));
 Temp = Temp - 273.15;
 return Temp;
}

void setup() {
 Serial.begin(115200);
 pinMode(ledPin, OUTPUT);
 pinMode(ledPinP, OUTPUT);
}
 double temp;
void loop() {
 Pval = analogRead(5);
 float Pvol = Pval*0.0049;
 Serial.print("Vol = ");
 Serial.println(Pvol);

 float Pval1= (((Pvol)- 2.5477)/-.0669);
//mmHg
 Serial.print("Pressure = ");
 Serial.println(Pval1);
 if(Pval1<=2.986) {
  digitalWrite(ledPinP, HIGH);}
 else if (Pval1>=7.2792) {
  digitalWrite(ledPinP, HIGH);}
 else
  digitalWrite(ledPinP, LOW);

 Serial.print("Temp = ");

Serial.println(int(Thermister(analogRead(0))));
 if (int(Thermister(analogRead(0))) <= 34) {
     digitalWrite(ledPin, HIGH);}
 else if (int(Thermister(analogRead(0))) >= 40)
{
     digitalWrite(ledPin, HIGH);}
 else
     digitalWrite(ledPin, LOW);
delay(2000);
}
```

Table 1: Code for adruino

provided to us by arduino burnt out while testing so two 20 k Ohm resistors are in parallel to act like a 10 k Ohm thermistor. These thermistors are going to analog input 0. Based on the temperature read, digital output 10 will turn a red LED on if the temperature in below 34 or about 40 degrees Celsius. From here the user can adjust the resistance of the humidifier to change the temperature of the entire CPAP.

The output differential pressure sensor was calibrated and line of best fit for the linear relationship between the voltage of the sensor and pressure. Arduino takes in the drop in voltage from the differential pressure sensor in analog input 5. Based on the code this voltage is translated into pressure (mmHg). If the pressure falls below 2 mmHg or goes about 7 mmHg then a yellow LED will light up. This will inform the user to adjust the fan speed with the potentiometers.

Testing

The sensor first had to be calibrated to determine what voltage outputs would occur in the pressure range that we were operating in. This was done by hooking up a blood pressure cuff and scale to the sensor using a T-joint.

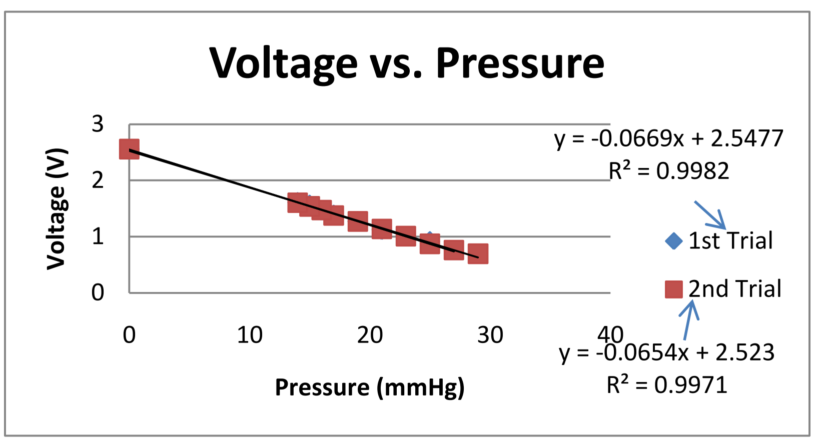

Figure 14: Calibration graphs for pressure sensor

The cuff was wrapped around a roll of paper towel and was pumped to a pressure of 35mmHg using the scale. The resulting output voltage was observed on an oscilloscope. This was done in decreasing increments of 2mmHg until 16mmHg. A graph was made using the data and a line of best fit was calculated (Figure 14). The equation of the line was used to determine the output voltages at the min and max of our pressure range, 4 and 10cm H_2O. This test was repeated a second time. The results were programmed into the Arduino so that LEDs could be used to provide a visual aid to indicate if the pressure is in the correct range or not.

Thermometer values (Celsius)	**Thermistor values (Celsius)**
22	20
23	20
24	21

Table 2: Thermistor testing

Testing the thermistors for accuracy involved using the blower, heating element, arduino circuit and a thermometer. Both the thermometer and thermistors were placed together right before the nasal prongs for testing. The thermometer value and thermistor values were recorded regularly and are presented in table 2. The values of the thermistors are little low so some adjusting of the arduino code may need to be done. However a statistical t-test of the averages needs to be conducted before any code changing.

Testing and calculations on the heating element were done as well. It was necessary to determine if the heating element was capable of achieving the desired air temperatures. The humidifier was placed on top of the heating element and the temperature was recorded every five minutes (Table 3). It was found that the heating element worked, but at a cost. It took 22 minutes to reach the desired temperature, but it was running on 6V and had 4.29 Amps running through it. The large amount of current would quickly drain the battery and was found to be very inefficient.

It had to be determined if the heating coil would still be effective with lower current. Multiple equations were used in order to calculate what amount of current is needed to heat water for a period of time. The equations $Q = mC\Delta T$ and $P = I^2R$ were used to determine this. The heat energy, Q, was calculated for heating 1000 mL fifteen degrees Celsius. Q was

found to equal 62715 J. That number was divided by seconds in order to be able to compare it with power. P was found to equal $3600I^2R$ in J/hr (3600 comes from wanting it in hours rather than seconds). Plugging in 2.25 Ohms for R and 62715 J/S for P, I was found to equal 2.78 Amps/hr. This means that with 2.78 Amps over one hour the temperature of the water will increase by 15 degrees Celsius. This means it can still heat with low current, but it will take a long time. This equation doesn't take into account the fact that a lot of the heat is lost so this heating coil is even more inefficient. Despite its inefficiencies, the heating coil was still used. It will take a long time to achieve the desired temperature. That won't be a problem because the infant will be on the CPAP for a long period of time so a few hours won't be that big of a deal.

Time (min)	**Temperature (Celsius)**
0	25
5	27
10	30
15	34
20	38
22	40
25	42
30	46
35	50

Table 3: Heater Testing

Future Work

Although lots of progress has been made on the project, there is still some work that needs to be done in the future. The biggest problem is coming up with a way to recharge the car battery. Because electricity is not a reliable luxury, a different approach will have to be taken to recharge our car battery. The EWH-Madison Chapter has been working on coming up with an effective way to power devices in developing countries without the use of electricity. Some of the ideas have included a Stirling motor, an inductor, and the use of solar and wind energy. The design that is being pursued utilizes a solar panel to collect sunlight and multiple fans connected to a single turbine to collect wind energy. This dual design will allow the battery to be recharged in multiple weather conditions.

Another area of future work is water purification. Because many developing countries don't have access to clean water, a design is needed to purify it to ensure that only clean water is being used in our system. Contaminated water could lead to contaminated air in the humidifier which would be harmful to the infant. EWH-Madison Chapter has been working on coming up with an effective way to purify water in developing countries. The most promising idea has been the use of plastic bottles that are coated with a special type of oxidized coating. As sunlight hits the bottle, it oxidizes the coating which purifies the water inside. This process takes several hours, but has been proven effective. More research and testing are needed in order to make an analysis.

The issue of condensation in the tubing is another area that needs to be addressed. As the humidified air left the humidifier and traveled to the nasal prongs, the heated air cooled and condensed in the tubing creating liquid water. The use of pipe foam was implemented in order to prevent this process, but it proved to be not an absolute method. A drainage tube of some sort is needed to have the water leave the tubing before reaching the infant.

Air filters are another part that would be implemented into the design in the future. Because the conditions in developing countries can be dusty or have other particles in the air, filters are needed to ensure that the air is clean and safe for the infant. The filter would be placed in the tubing before it enters the humidifier.

Given more time, a more efficient heating element could be figured out. Having a proper container for the heating coil would make it more efficient and allow for more accurate tests. The container needs to be a nonconductive material that can get very hot. Such materials are either too expensive or hard to come across. Further work on the heating element is necessary to determine its value for the design.

Having tubing that is flexible and the same size would be desirable. Having flexible tubing makes things more comfortable for infants. Having the same size tubing would also reduce our problem with the pressure in our system. A design for attaching the interface securely to the infant is also needed so that the nasal prongs remain in the nostrils.

The fan should also be made more powerful and effective. Having a more powerful fan would increase the flow rate in the tubing and make the pressure in the system within the desired range. Also, the fan we currently have was put together in a day and given more time could become more stable and efficient with the right time and equipment.

Heating the humidifier becomes a large problem when there is no energy supplied. Possible heat sources include nichrome wiring, any DC heat source one could come across or a very controlled fire. If there is a consistent supply of energy then a hot plate would be very effective at heating the container to the correct temperature. Nichrome wire can be found in some house hold appliances such as, hair dryers, toasters and in old guitars. If nichrome wire is used it would have to be created and fitted to the correct size of the container.

A final future work would be using the MPXV7025DP pressure sensor instead of the 26PC SMT because it already has the op-amp circuit built into it. This would simplify the design and also limit the amount of problems that could occur. Also, the MPXV7025DP is designed for respiratory pressures and is more sensitive to changes in pressure than the 26PC SMT.

Materials List

Name of material	Actual cost per unit	Cost of similar product if actual cost is not known	Cost of materials used
1/2” x 5/8” x 3’ Pipe Insulation	$3.29	-	$3.29
.4 L stainless steel water bottle	N/A	$13.95	N/A
Arduino starter kit	$66.10	-	$66.10
3/4” I.D. x 1” O.D. Vinyl Tubing	N/A	$72.00 per 50 foot pack	N/A
3/8” I.D. x ½” O.D. Vinyl Tubing	N/A	$19.25 per 50 foot pack	N/A
Nasal Prongs (x3)	$3.50	-	$11.50
MPXV7025DP: Pressure Sensor	$5.99	-	$5.99
Interstate Marine/RV 12V Premium Battery 24M-RD 5965	N/A	$72.95	N/A
1939K17 12V Fan	N/A	$15.32	N/A
		Total cost of materials purchased	$86.88

Materials without an actual cost were found by group members

Material Citations

"Amazon.com: Camelbak Stainless Steel Kids Bottle - .4L: Sports & Outdoors." Web. 08 Dec. 2010. <http://www.amazon.com/Camelbak-Stainless-Steel-Kids-Bottle/dp/B002WV90OW/ref=sr_1_6?ie=UTF8&s=sporting-goods&qid=1291778913&sr=8-6>.

"Amazon.com: Nasal Micro Cannula, 7 Ft, Infant: Health & Personal Care." Web. 08 Dec. 2010. <http://www.amazon.com/Legend-M-D-Nasal-Cannula-infant/dp/B000WLFZKC/ref=sr_1_1?ie=UTF8&s=hpc&qid=1291787652&sr=8-1>.

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<http://www.windsun.com/Batteries/Battery_FAQ.htm>.

Appendix

Product Design Specifications: Infant CPAP Machine

Team Roles:
Team Leader: Nick Shiley
Communicator: Drew Pierce
BSAC: Brad Lindevig
BWIG: Mike Kapitz
Last Update: December 8, 2010

Function: Preterm Infants are generally born with less surfactant in their lungs than full-term infants, resulting in more difficulty in keeping their lungs expanded. This can lead to chronic lung diseases which are often fatal for the infants, especially in developing countries where health care is severely limited. Continuous Positive Airway Pressure (CPAP) machines are commonly used to assist preterm infants in breathing, giving them a chance at a normal life. Our goal is to design and fabricate a CPAP machine that can be used in developing countries and at a cost significantly less than today's CPAP machines.

Client Requirements:

- Must cost no more than $150
- Must provide a continuous power supply for up to two weeks
- Must provide continuous pressurized air (4-10cmH_2O)
- Must supply 100W to system
- Must have a heater/humidifier to create safe air for the infant to breathe
- Must have a temperature and pressure sensor to measure values during treatment
- Must provide air at 36-37°C

Design Requirements:

1. **Physical and Operational Characteristics**

a. **Performance Requirements:** The CPAP machine must provide continuous pressurized air and continuous power supply of 100W for up to two weeks.
b. **Safety:** It must provide air that is at the correct pressure for the infant, at body temperature, humidified and filtered; otherwise the machine may be fatal.

c. **Accuracy and Reliability:** The air temperature must be measured continuously and be between 36-37°C. The air pressure must be measured continuously and be between 4-10cmH_2O.
d. **Life in Service:** Power Supply must last for up to two weeks.
e. **Shelf Life:** Storing the product will have no effect on its ability to perform.
f. **Operating Environment:** This device will be used in developing countries around the world, mostly in Africa and South America. It should be operable in any environment, including patients' homes.
g. **Ergonomics:** The device should be able to be operated by an untrained adult, but settings should be determined by a professional.
h. **Size:** The device should be compact and easily portable. The Bi-Nasal prongs should have a diameter between 2mm-3.5mm and separated between 6mm-7mm.
i. **Weight:** The device should be light enough to be lifted by an adolescent.
j. **Materials:** The device should utilize materials that can be found in the area it is used in or be combined into a kit that can be used anywhere in the world.
k. **Aesthetics, Appearance, and Finish:** Not applicable.

2. **Production Characteristics**

a. **Quantity:** Our team will be developing one CPAP.
b. **Target Product Cost:** The cost should be significantly less than current CPAPs. Our device should cost $150 as compared to $500.

3. **Miscellaneous**

a. **Standards and Specifications:** The device should utilize the same concept as current CPAPs, but with cheaper material.
b. **Customer:** The client wants the design to cost significantly less than current devices and utilize rechargeable batteries, making it operable in any environment.
c. **Patient-related concerns:** The device should be sterilized when switching patients. The device should be comfortable for the patient. Pressure and temperature readings should be carefully monitored.
d. **Competition:** CPAPs are a common instrument used in developed countries, but not where health care is severely limited. Our device will be able to be used anywhere.