Solar Autoclave for Rural Areas

By:
Blake Lawrence, Eric Brettner, Yuchen Liu, Kyle Godwin,
and Adam Compton

Team 6

Progress Report

Document

Submitted towards partial fulfillment of the requirements for
Mechanical Engineering Design – Spring 2013

Department of Mechanical Engineering
Northern Arizona University
Flagstaff, AZ 86011

Table of Contents

Executive Summary (Adam Compton)

Many developing countries in the world lack the resources to sterilize medical equipment after use. Traditional autoclaves, a medical sanitation machine, require expensive repairs and electricity to operate, often unavailable in these countries. Lacking the means to sanitize medical equipment on site leads doctors and nurses to use contaminated medical equipment or put off crucial operations until sterilized equipment arrives. A solar autoclave provides sterilized medical equipment without the use of electricity and provides easier replacement of parts if the device breaks down. Our goal is to create this device to be affordable, safe, and easy to repair and operate.

Introduction to Medical Sanitation

While there are many sterilization techniques available, the preferred method is steam sterilization. In this process, water is pressurized to raise its boiling point. When this occurs, steam will be created at a temperature higher than 100^{o}C. In fact, in order to fully eliminate all prions and bacteria associated with disease, saturated steam needs to be at least 121^{o}C when in contact with the equipment being sterilized.

Final Design (Eric Brettner)

The final design harnesses the power of the sun using a trough, shaped from sheet metal, to collect the energy and focus that energy along a pipe or boiler. The reflectivity of the surface facing the boiler is extremely important. To improve this, the surface will be lined with Mylar. This boiler then heats the water while simultaneously raising the pressure. The boiler will be both handling high pressure and temperature so corrosion is a large factor, especially when water is a main component of this system. For these reasons, schedule 40 galvanized steel was chosen for the material of the pipe, because it is both strong and resists corrosion. A spring pressure valve, located at the top of the inclined boiler, regulates the pressure within the boiler while allowing steam to pass through the hose to the secondary chamber containing the medical equipment. The steam, being less dense than the air within the chamber, slowly pushes the air out of the valve located at the bottom of the chamber. Evacuating the air creates a better environment to sanitize the equipment. The valve should be closed once it begins discharging steam. After the valve is closed, the secondary chamber and the boiler will slowly equalize pressure. This is because the boiler must exceed the force behind the spring valve and the force from the pressure within the secondary chamber after the valve is closed. The pressure and temperature will continue to rise in the boiler because of the increasing force from the opposite side of the valve, allowing increasingly hotter steam to flow into the secondary chamber. This process will continue for at least 15-30 minutes until the equipment is safe for medical purposes.

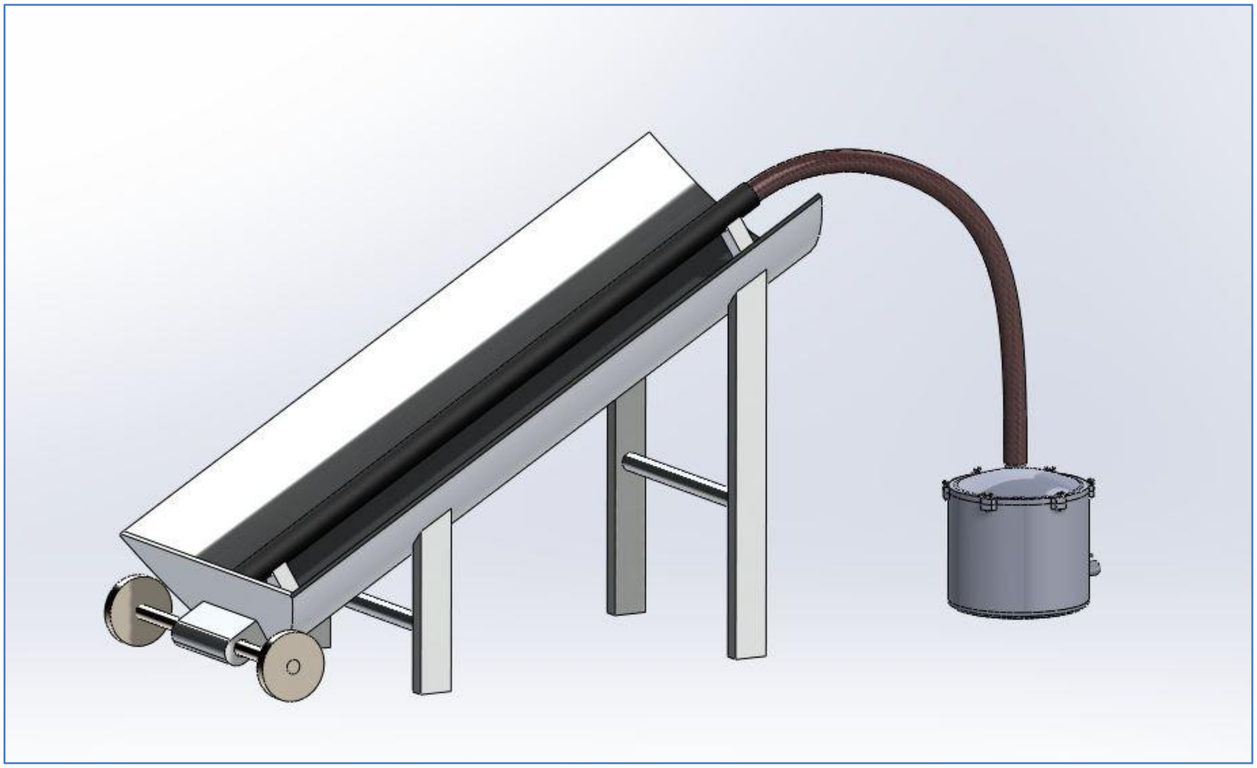

Figure 1 – Final Design

As one can see from Figure 1, the Solar Autoclave Prototype, nicknamed "Troughdor", has several parts that involve its working process. The water is placed in the boiler pipe, directly at the focal point of the trough. The pipe is held in place by two stands protruding off the bottom of the trough. The capped end of the pipe slides into place via a pocket at the end of the trough design. A closer look at the placing of the pipe can be seen in the appendix, which gives an auxiliary view of the autoclave with the pipe suppressed. Since this design is only a prototype, it was decided that a lowering and raising mechanism was not necessary in this design. Therefore, the trough is held in place at a 30 degree angle by four stands. However, mobility of the prototype is essential at this stage. The prototype carries a ‘wheelbarrow’ design with two wheels hanging on the end of the trough design.

Manufacturing:

Trough Design (Kyle Godwin)

The key component to our solar autoclave is the thermal capture. Common methods of thermal capture include the use of a parabolic dish, a parabolic trough or a Fresnel lens. After arduous debate in the fall, our team decided that the best design to capture the irradiation from the sun is the use of a parabolic trough. Using an approximation for the radiation being emitted from the sun, we were able to formulate a final design for our trough to be used for the solar autoclave.

Design Dimensions

The physical design of the trough is fairly straightforward. Using the assumption that the irradiation from the sun will be approximately $850\ \frac{W}{m^2}$, we were able to calculate a projected area of $0.528\ m^2$, which allowed us to make final design measurements as shown in Figure 2, below:

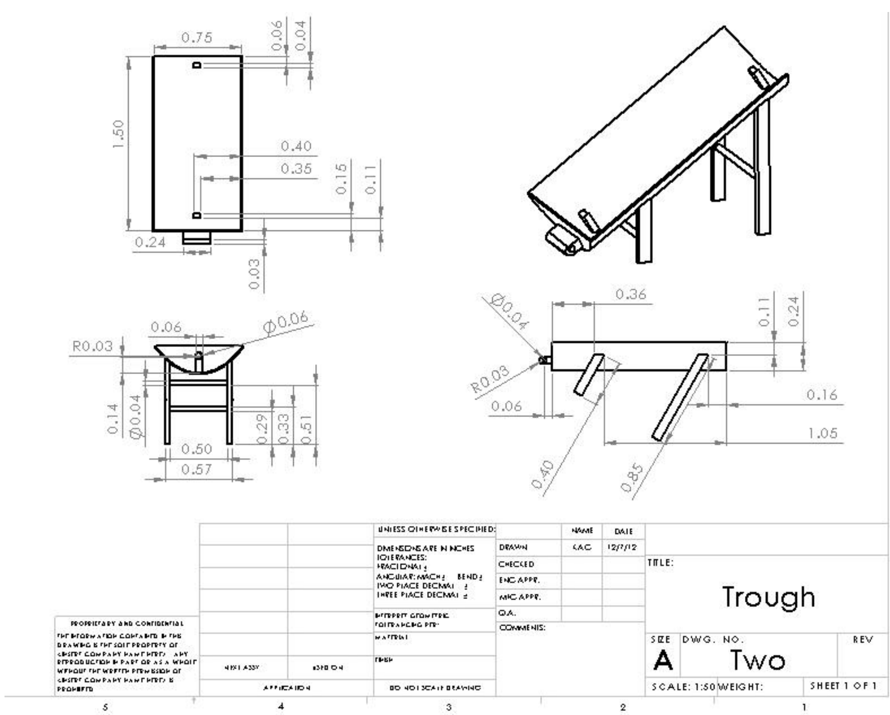

Figure 2 – Trough Dimensions

As seen from the figure, the overall dimensions of the trough will be 1.5 meters long and 0.75 meters wide. The boiler rests at the focal point 0.14 meters above the lowest point on the trough, which was calculated using the equation of $y = \frac{x^2}{4f}$ and the depth of the trough being 0.234 meters.

Manufacturing Specifications

The manufacturing of the trough is an extremely tedious process; however it will be the very first section of the design to be manufactured due to the fact that we cannot focus on the rest of our design until we have achieved a successful method of thermal capture. We will begin with a large piece of sheet metal approximately one meter wide by two meters long. (The extra length is added to allow for mistakes and trimming of the material after we achieve the desired parabolic shape.) Next, we will acquire an even larger piece of thick wood to be carved precisely into the desired parabolic shape. Once the shape of the wood is made perfect, the sheet metal will be bolted down to the wood so that it forms the same shape of the wood after an extended period of time. The advantages of using wood for the shape of the trough are the low cost factor and the fact that wood can be carved very easily to exact formation. Once the shape of the trough is formed and the desired dimensions of the trough are acquired, the next step is to create and enhance the reflectivity of the material.

Reflectivity Enhancement

As previously decided on in the fall, the trough will be covered using Mylar in an attempt to drastically increase the reflectivity of the material and produce the largest amount of heat transfer into the boiler. Mylar is an excellent choice for this project due to the fact that it is inexpensive and in the event of a tear or rip, a small knife can be used to cut out the damage and replace The Mylar will be placed onto the trough with extreme caution and precision, as the material must be perfectly adhered to the trough in order to achieve the greatest efficiency of the trough. An extremely strong adhesive will be used to bond the Mylar to the sheet metal and laid out flat with a soft, flat surface. This section of the design will be performed by two or more team members.

Design Objective

In conclusion of this section of the report, the parabolic trough will be our primary use of thermal capture in our solar autoclave project. We will be forming the shape of the trough using a wood cutout of the trough, forming our desired shape and size then coating the trough with Mylar for maximum heat transfer into the boiler in order to Our team plans to have a fully-functional parabolic trough for use in thermal capture by no later than February 15th, 2013. The projected final design of the trough can be seen in Figure 3, below:

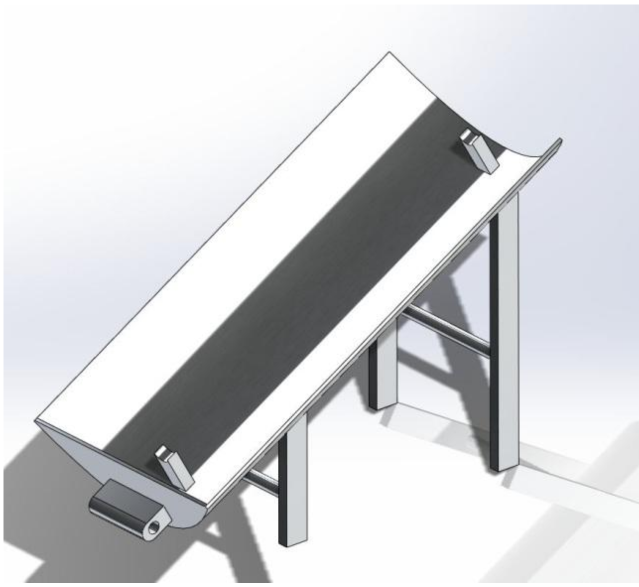

Figure 3 – Isometric View of the Trough

As seen in the figure, the trough is supported by a frame, a stand for the boiler and a place for the wheels to attach at the bottom. All three of these portions will not be constructed or added on until the rest of the project is complete so that we may allow for user-interface prototyping later on.

Boiler Design (Eric Brettner)

Design Objective

The boilers purpose is to heat the water while simultaneously raising the boiling point of the water to 121˚C. This will be achieved by placing the boiler at the focal point of the trough to collect the solar energy. While the temperature rises, so will the pressure. To contain the pressure the boiler will use a pressure valve illustrated in Figure 4 and explained in greater detail in the manufacturing specifications.

Manufacturing Specifications

The manufacturing of the boiler will be accomplished in four steps. First, the materials will be ordered through Northern Arizona University. The next step will be to complete a detailed Solidworks drawing to ensure it is assembled safely and properly at the machine shop. The following step will begin the actual assembly, starting with the bottom of the boiler. Finally, the most key element in the boiler, the top portion, will be manufactured. This is where the pressure valve is located. This valve regulates the pressure, and therefore the temperature, which is important for the sanitation process.

The body of the boiler will be made of Schedule 40 Galvanized pipe that is the length of the trough at 1.5 meters. This pipe will be large enough to contain the required amount of liquid, which is approximately 1 Liter. The galvanized coating will protect from both our application and weather conditions. The bottom of the boiler will need to be sealed by one of two ways. The first option is to weld a suitable material to the bottom of the pipe. Or another option would be to thread a cap onto the end of the pipe. The top of the boiler, shown in Figure 4, will be the last step in building the boiler. The pressure valve is going to be custom made; either by recycled goods, such as a radiator cap, or by purchasing the spring, plug, and cap to assemble the design ourselves. The plug, along with the pressure from the spring, will keep the water tight seal by being tightly pressed against a donut shaped stopper either welded or press fit at the end of the pipe. The assembly housing the spring and plug will be made from the same material as the pipe. The cap on the right of the picture will be threaded into place so the spring assembly is removable. Finally, a hole will be cut on the side of the spring housing to make the “T” shape in Figure 4. This will be a stem for the radiator hose to attach and allow steam to travel to the pressure vessel for sanitation.

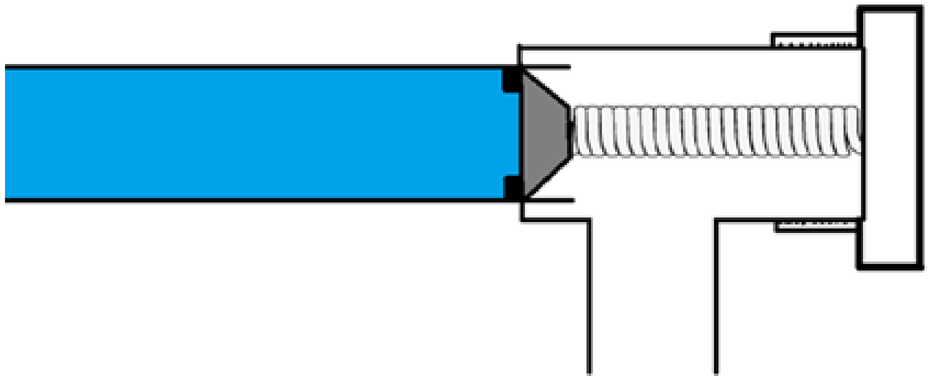

Figure 4 – Top Portion of the Boiler

Pressure Vessel Design (Blake Lawrence)

Another essential part of the solar autoclave is the secondary chamber, or the pressure vessel. This is where the medical equipment will be held during the sterilization process. Initially, the team was considering using a modified pressure cooker. This would be ideal because a pressure cooker is designed to contain large amounts of pressure and comes manufactured with a rubber gasket, a lid able to be screwed or clamped down, and gauges to determine the internal pressure. However, after further discussion with our sponsor and client, the team decided to manufacture a pressure vessel using modified cooking pots. The reason for this is to make the pressure vessel easily replaceable in a developing country. If the design were to fail, it would be much easier to replace a cooking pot than a $200 pressure cooker.

Manufacturing Specifications

The pressure vessel will need to be machined in order to work properly. Currently, the team plans to begin construction for the secondary chamber around mid-February, leaving enough time to be finished by March 12, 2013 for our first hardware review. The modifications that need to be made for this pressure vessel include drilling fittings for the attachment of the radiator hose, installing a valve at the bottom of the vessel, and machining the lid so that it can be clamped down. Figure 5 below shows the current design of the pressure vessel.

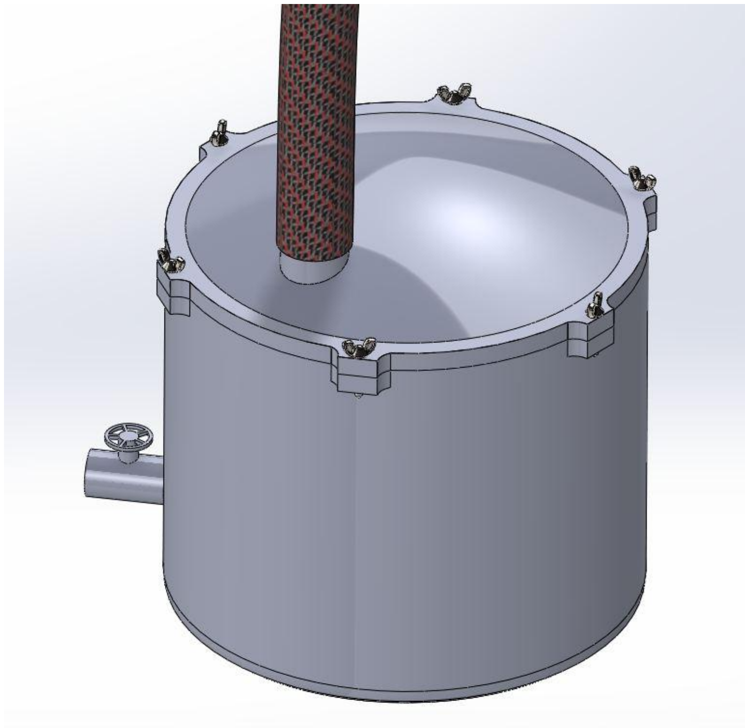

Figure 5 – Current Design for Pressure Vessel

In addition to this design, an emergency pressure release valve may be added to the lid as well as gauges to help determine the internal temperature and pressure. However, these additions are not necessary for the functionality of this chamber.

Design Dimensions

The secondary chamber must be large enough to hold a substantial amount of medical equipment. Figure 6 below shows the current dimensions for the pressure vessel.

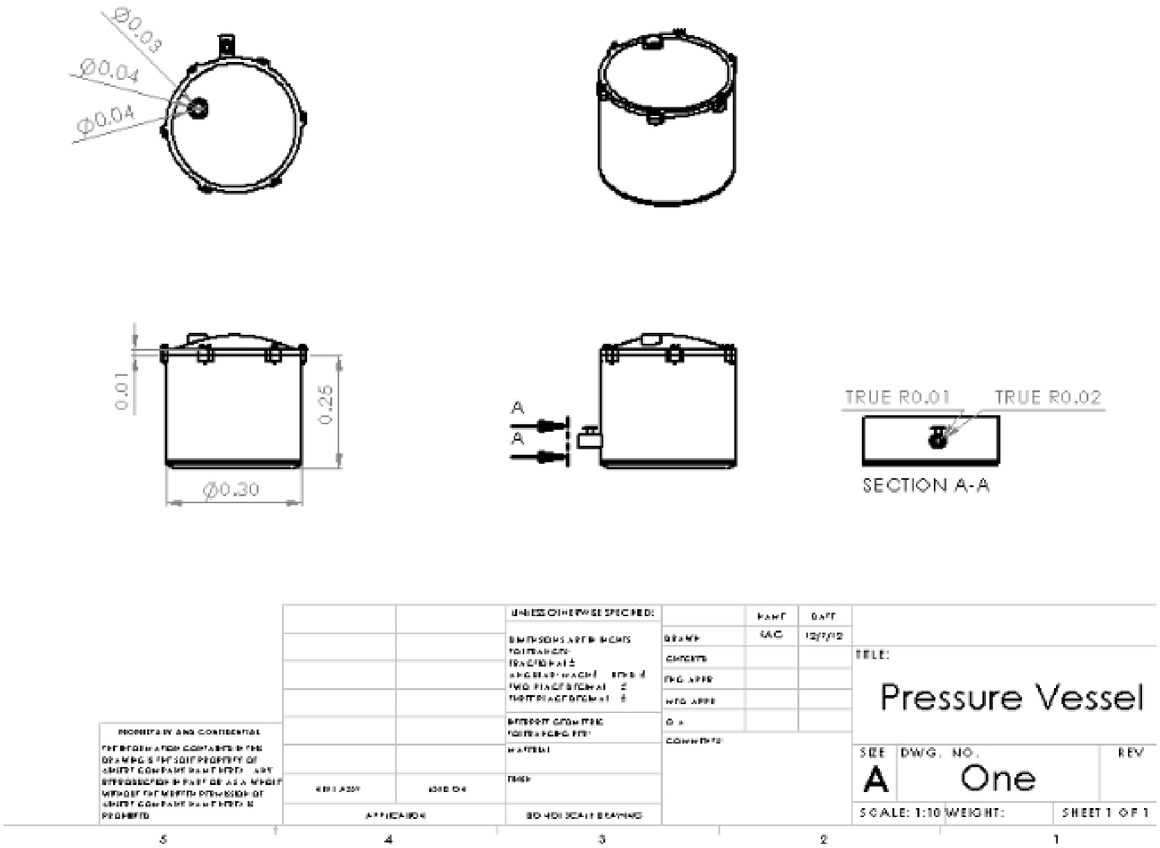

Figure 6 – Dimensions of Pressure Vessel

The outer diameter of the vessel will be 0.3 meters, and the height excluding the lid will be 0.25 meters. These dimensions are subject to change based on the materials we find to build the vessel.

User Interface (Adam Compton)

This solar autoclave will operate under high pressures and high temperatures thus safety must be considered in its design. Typical users will know where the hot and pressurized parts of the system are, but not all users; this is the purpose of a simple but effective user interface.

To test where users will grab to move parts, the whole system and change fluids a prototype design made of PVC piping and miscellaneous materials will be made as a nonfunctioning replica of the system. Our team will use this prototype on students, particularly non engineering, to identify errors within the instructions given and where extra caution in design is needed to ensure the safety of the user. Several solutions have already been identified with possible problems. These issues along with solutions are listed below in Table 1.

Table 1 – Issue Correction Figure

Issue	Correction
Making contact with hot components of the system	Update user manual high temperature section, warning labels or stickers
Disposing of hot liquid	Update user manual high temperature section, warning labels or stickers
Opening pressurized system	Update user manual pressure section, warning labels or stickers
Unexpected broken part	update list of materials in user manual
Unclear instructions	Update user manual

By testing this prototype multiple times with a variety of students, we hope to eliminate all potential operating hazards to the user. As mentioned above in Table 1, we will also be compiling a user manual to provide instructions on how to assemble, operate, and disassemble the autoclave. The manual and the prototype autoclave will be tested and revised several times until the testing subjects can operate without injury. The purpose of this device is to provide safe medical equipment to protect the users from hazardous biomaterials; if the device is dangerous itself then we are not meeting the needs of our clients.

Conclusion (Yuchen Liu)

In summary, our task for this project is to develop a solar autoclave for rural areas that uses the energy of the sun to satisfy the sterilization requirements. The design should be flexible from location to location, the materials used should be readily available, and the parts in the design should be able to repaired or replaced from local materials. After performing further research and making modifications on former designs, our team has developed the parabolic trough prototype as the final design, selected materials for each section, and determined the manufacturing specifications. The final design mainly consists of three parts: a boiler, a trough and a pressure vessel. A brief and revised plan has been made in order to accomplish the building of the solar autoclave efficiently. Applying all the manufacturing methods detailed above, the next step is to gather appropriate materials for the design. After collecting most of the essential materials we need, we are going to start with the construction of the trough first within the first two weeks in February, following by the construction of boiler, pressure vessel, and frame. We expected to finish the manufacturing and collaboration by the first week in March, 2013. Considered that the design can be safely used by all users, we would like to develop the user interface during March, accompany with testing and evaluation stage. It is important to keep on track to ensure the full completion of the solar autoclave by the beginning of April 2013. Figure 7 below shows the timeline for the spring semester.

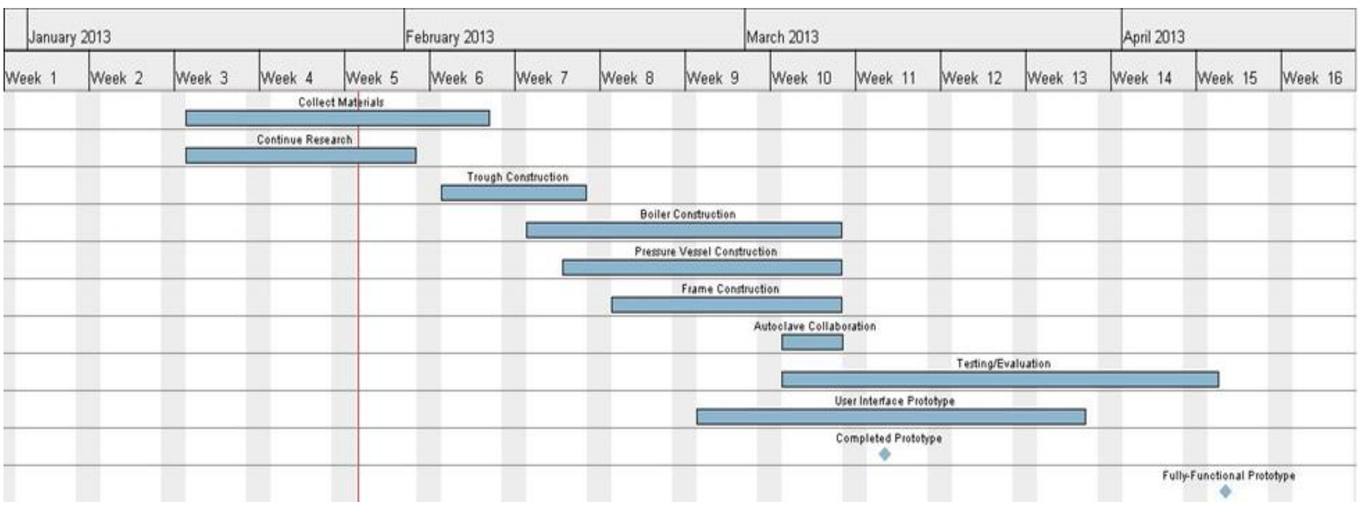

Figure 7 – Gantt Chart for Spring 2013

References

Books:

[1]. N. Shapiro, Howard and Michael J. Moran. *Fundamentals of Engineering Thermodynamics*. 6th. Print.

[2]. Richard Budynas and Keith Nisbett. Shigley's Mechanical Engineering Design 9th. 2010. Print.

Journal Publications:

[3]. "Global Challenge." *MIT Ideas Global Challenge*. N.p.. Web. 27 Oct 2012. http://globalchallenge.mit.edu/teams/view/171.

[4]. Web. 27 Oct. 2012. http://www.solare-bruecke.org/projekte-Dateien/Solarsterilisator/summary english.html.

[5]. United States. U.S. Department of State. Web. http://www.travel.state.gov/.

Websites and Images:

[6]. Centers for Disease Control and Prevention. Web. 1 October 2012. URL: http://www.cdc.gov/

[7]. World Health Organization. Web. 1 October 2012. URL: http://www.who.int/en/

[8].*Western Design Autoclave*. N.d. n.p. Web. 27 Oct 2012. http://www.sciencedirect.com/science/article/pii/S0195670112000230.

[9]. *Mosaic Glass Solar Panel*. N.d. n.p. Web. 27 Oct 2012. <http://inhabitat.com/19-year-old-teenager-makes-homemade-solar-death-ray/solarray2/ >.WN: http://article.wn.com/view/2008/01/16/Fresnel_lens_sheet_rear_projection_screen_and_rear_projectio/

[10]. *Trough Panel*. N.d. n.p. Web. 27 Oct 2012. http://techbells.blogspot.com/2012/07/working-of-csp-parabolic-trough.html.

[11]. *Fresnel Lens.* N.d. n.p. Web. 27 Oct 2012. http://article.wn.com/view/2008/01/16/Fresnel_lens_sheet_rear_projection_screen_and_rear_projectio/.

[12]. *Fin Array*. N.d. n.p. Web. 27 Oct 2012. http://www.hellotrade.com/peninsula-components/forged-fin-heat-sinks.html.

[13]. *Metal Clamp.* N.d. n.p. Web. 27 Oct 2012. http://www.electriduct.com/Arlington-Industries-Steel-and-Iron-Beam-Clamps.html.

[14]. *Pressure Cooker*. N.d. n.p. Web. 27 Oct 2012. http://www.pressurecookersbest.com/all-american-15-12-quart-pressure-cooker.html.

[15]. *Thermablok*. N.d. n.p. Web. 27 Oct 2012. http://www.thermablok.com/thermal-insulation/thermablok-contact-form.htm.

[16]. *Insulation 1*. N.d. n.p. Web. 27 Oct 2012. http://www.alibaba.com/product-tp/12283858/FiberGlass_wool_Insulation.

[17]. *Insulation 2*. N.d. n.p. Web. 27 Oct 2012. http://www.thermafiber.com/InsulationProducts/CommercialInsulation.

Project Website:

[18]. http://www.cefns.nau.edu/interdisciplinary/d4p/EGR486/ME/13-Projects/SolarAutoclave/

Sponsor:

[19]. Dr. Brent Nelson. Email: Brent.Nelson@nau.edu

Additional Resources:

[20]. Program OrCAD Capture 9.1, Version 2.0, Build 28, Feb 18 2000, OrCAD, Inc.