# Design of a Personal Biomass Gasification Chamber for SynGas Production

MAE 4980 – Senior Capstone Design

Instructor:
Dr. Yuyi Lin, PE

Capstone Design Team Members:
Ryan Ott
Dan Childress
Doug Koch
Michael Koch

April 2, 2008

# TABLE OF CONTENTS

## Abstract

Today's economy suggests a need for renewable energy. There is a demand for a small scale biomass gasification chamber to produce inexpensive energy. The market for a personal biomass gasification chamber as a substitute for expensive fossil fuels remains untapped. The chamber will burn biomass logs to produce syngas. In order to produce syngas, the chamber needs to withstand temperatures exceeding 500 °C and a pressure of 30 psi. The chamber will be cylindrical in shape and made of AISI 309 annealed stainless steel. This material was chosen based on its price, corrosion resistance, high tensile strength, and maximum service temperature which was well above the required operating temperature of 500 °C. Our calculations show that a hot plate operating at 1000 W will meet the requirement of heating the biomass to a temperature of 585 °C.

# Introduction

## *Motivation*

Throughout the world, energy is becoming one of the most important issues in all facets of life. Be it political, social, economical or simply survival, the problems that the human race now face due to the limited supply of fossil fuel becomes more evident every day. The following paper will discuss the reasoning and need behind the research, design and building of a personal biomass gasification chamber, and the potential it holds for energy usage by persons around the world. Included in this paper are the design principals, schedule for completing review, research, engineering analysis and other related topics that went into our research process. This personal gasification chamber could be used in rural areas where biomass is abundant and logs could be made from agricultural waste as a byproduct of crops. This would make these logs very inexpensive to produce and gasify on sight and produce cost efficient energy. Similarly, reducing the use of fossil fuels is extremely important as issues of global warming seem to be cropping up everywhere. Since biomass is renewable it would eliminate the need to drill for fossil fuels, something that would significantly reduce the amount of greenhouse gases that are created by humans. Biomass is $CO_2$ neutral and thus immune to this problem.

## *Background Research*

Biomass gasification technology is a concept that has been around for over 100 years, but is now in steep demand due to several factors. Simply put, biomass gasification takes a dry, carbon-based fuel and turns it into a usable synthesis gas, or syngas, that can be used for various processes such as cooking or manufacturing. One of the prominent reasons biomass gasification is becoming important again is rising gas prices as well as United States dependence on foreign oil. These topics are now at the forefront of many American's minds. This biomass gasification chamber would give consumers an inexpensive alternative to expensive natural gas that now dominates the market. The effects of such a technology could have extensive implications on the economics of the oil markets, as well as the ability of people in third world countries to locally produce their own fuel.

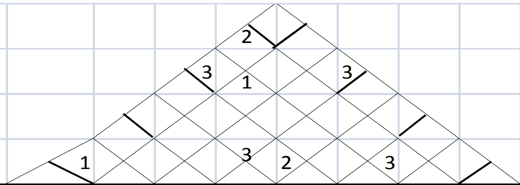
Similarly, this chamber would be using renewable energy because it is based on the gasification of biomass. Biomass is a broad term that essentially means any sort of carbon based material that can grow naturally and be used as fuel. In our case, we would be using biomass logs that would be gasified in the chamber. This process is much more environmental-friendly than simply burning the biomass because the gasification process has significantly less emissions. Also, the ash byproduct can be used as fertilizer for plants and crops. The fuel log will have much high energy density than loose, naturally available form so that it costs less to store and transport.

Through market research we were able to determine what gasifiers were currently being used today. Some of these gasifiers can be seen in Appendix C. As can be seen, these gasifiers are usually very large and expensive.  The only gasifier that is small does not capture the outputted syngas.

# Design

## *Qualify Function Deployment*

The parameters that govern our design have been chosen to gauge the functional performance of our product. The sales price must be kept to a minimum so that consumers will be encouraged to purchase the product. This is an important aspect of our design because most of the competitor's products are of a much larger scale and therefore much more expensive. The collectable syngas output is an important parameter because this syngas is the desired end result of our product. The physical size, like the price, is also an important parameter in our design because of our desire to market the product as a compact, household item. Our competitor's products are all of much larger scales and therefore not practical for average consumer usage. The insulation of the chamber directly correlates with the efficiency. Any energy loss through heat will reduce the efficiency of the unit. Being that this product will be marketed to the general public, it is important that the end result is as simple to assemble and operate as possible. It is important that the consumer be educated on the use of the product and its possible hazards. Safety is a top priority in the design of our product. We do not want our consumers to be at risk of injury while operating the product. The gasification efficiency is an important parameter because if the efficiency is too low, the product will be a failure. The resulting energy generated by the product will be too low to justify its use. Lastly, manufacturability is a crucial aspect of any product. Having a product that is easily manufactured is a key element to keeping costs low as well as maintenance of the product.




| Functional Performance | User | Manufacturer | Marketing | Maintenance | Cost ($) | Size (m^3) | Capturable Gas Output (KJ/s) | Heat Loss (%) | Efficiency (%) | # Of System Components | Degree of Manufacturing Difficulty (1-10) | Working Pressure (KPa) | Tom's Woodgas Stove | Biomax 15 | Crorey Biomass Gasifier |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sales Price | 6 | 1 | 8 | 1 | 5 | 1 | | | | 2 | 2 | | 7 | 4 | 2 |
| Capturable Syngas Output | 8 | 4 | 7 | 2 | | 3 | 5 | | 4 | | | 1 | 1 | 8 | 8 |
| Physical size | 4 | 5 | 5 | 5 | 1 | 5 | | | | | | | 8 | 2 | 7 |
| Insulation | 2 | 2 | 1 | 6 | | | | 5 | 1 | | | | 2 | 5 | 1 |
| Simplicity | 3 | 6 | 4 | 7 | 1 | 1 | | | | 4 | | | 5 | 1 | 6 |
| Safety | 7 | 7 | 6 | 8 | | | | 3 | | | | 5 | 6 | 6 | 5 |
| Gasification Efficiency | 5 | 3 | 3 | 4 | | | 4 | 1 | 5 | | | 1 | 3 | 7 | 3 |
| Manufacturability | 1 | 8 | 2 | 3 | 1 | 1 | | | | 4 | 5 | | 4 | 3 | 4 |
| Tom's Woodgas Stove | | | | | 55 | 0.004 | 0 | 100 | 40 | 1 | 1 | 0 | | | |
| Biomax 15 | | | | | 27,000 | (50) | 50 | 10 | 55-75 | 10 | 10 | 137 | | | |
| Crorey Biomass Gasifier | | | | | (50,000) | 15 | 150 | 20 | 65 | 7 | 8 | 0 | | | |
| Target | | | | | 800 | 1 | 2 | 15 | 60-70 | 2 | 3 | 70 | | | |

Fig. 1 – Quality Function Deployment Chart

There are eight important measurable design targets in our QFD chart. These are used to measure tangible results or goals. The first target is cost, which is to be measured in dollars. The next target is size. The size of the entire system will be measured in cubic meters. The capturable gas measurement is the amount of useful syngas energy per unit time that results from the gasification of the biomass. We chose to use Kilowatts as our units because most of the competitor's measure their output during a continuous biomass feed process. Because the biomass is continuously fed into the units, it is difficult to measure the instantaneous energy. The amount of energy lost through heat loss of the products is measured in a percentage. If all the energy is lost though heat loss the percentage will be 100%. The combined heat and power efficiency is also measured in percentage. This is the percentage of potential biomass energy that is converted into usable Syngas energy. The number of system components is measured because it shows the complexity of the total unit. The manufacturing difficulty will be measured on a scale from one to ten, ten being the most difficult to manufacture. This gives us a concrete idea of the range of difficulty between the competitor's designs and ours. The working pressure is measured in Pascals. This relates to safety because if the pressure exceeds a certain limit there could be an explosion.

We researched our competitor's websites to determine the products that are in the marketplace now that closely relate to our design. After narrowing the products down to three candidates, we researched them to acquire performance specifications. Being that biomass gasifiers are not used widely today, it was difficult to find much information about performance. Many of the performance values for the competitors had to be estimated. These estimates are denoted by parenthesis in the chart. Their performance was ranked from one to eight, eight being the most important parameter for that particular design.

### *Design Constraints*

Physical constraints are an essential part of every engineering design, however other real world constraints must be considered to better both society and the quality of life. Such constraints include environmental, social, and, health and safety. Renewable energy technology is in much demand now due to several factors. Two of the most prominent reasons for renewable energy are the rising gas prices and the United States' dependence on foreign oil. These topics are now at the forefront of many American's minds. This biomass gasification chamber would give consumers an alternative option to expensive natural gas that now dominates the market. The effects of such a technology could have extensive implications on the economics of the oil markets.

This chamber would be using renewable energy because it is based on the gasification of biomass. Biomass is a broad term that essentially means any sort of carbon based material that can be used as fuel. In our case, we would be using biomass logs that would be in turn gasified in the chamber. This process is much more environmental-friendly than simply burning the biomass because the gasification process has significantly less emissions. Also, the ash byproduct can be captured and used as fertilizer for plants and crops. Similarly, reducing the use of fossil fuels is extremely important as issues of global warming seem to be everywhere. Since biomass is renewable it would decrease the need to drill for fossil fuels, something that would significantly reduce the amount of greenhouse gases that are emitted by humans.

Through researching existing biomass gasifiers, we have discovered an open market for smaller, personal gasifiers. It is predicted that the future of biomass gasification is in small, in-house biomass gasifiers due to the high cost of storing and transporting the producer gases.

Due to safety concerns, warning labels and proper instructions should be clearly marked and readily available. A warning should be labeled that the system will be under pressure and operating at a high temperature. The warning should state that if the gasifier is punctured or improperly handled it will result in personal injury. Another warning should caution the user of the existence of carbon monoxide gas. Carbon monoxide is a colorless, odorless, and tasteless gas which is very hard to detect, but can be lethal. The warning should state that symptoms of mild poisoning include headaches and dizziness and start at concentrations less than 100 ppm.
For all of the above stated reasons, the biomass gasification chamber has many advantages and uses for people around the world.

## *Concept Generation*

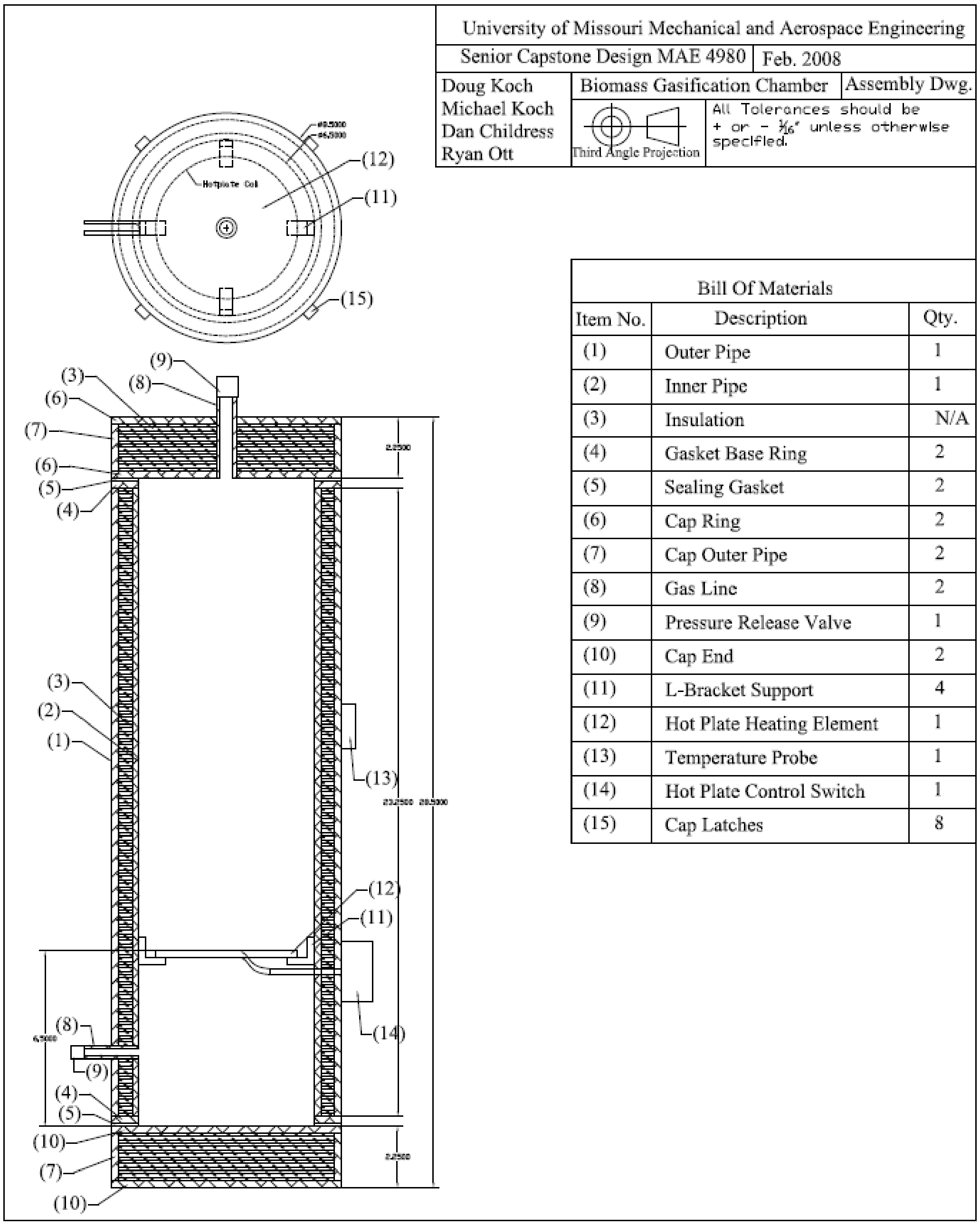
From this research, we were able to come up with several concept designs. As can be seen in the Decision Matrix below, our team was able to determine which design would be the most feasible based on a host of factors. CAD drawings of all three design concepts can be found in the Appendix.

| Criteria | Importance | Cone Design 1 | Alternatives CAD version Design 2 | Ashtray Bottom Design 3 |
|---|---|---|---|---|
| Price | 5 | - | | + |
| Capturable Syngas | 6 | + | | = |
| Physical size | 2 | = | | = |
| Insulation | 1 | = | | = |
| Simplicity | 3 | - | | - |
| Safety | 7 | = | | = |
| Manufacturability | 4 | - | | - |
| | Total Plus | 1 | | 1 |
| | Total Minus | 3 | | 2 |
| | Overall Total | -2 | | -1 |
| | **Weighted Total** | **-6** | **0** | **-2** |

Fig. 2 – Decision Matrix

## *Final Design*

The optimal design for our gasification chamber can be seen in Fig. 3. The gasifier consists of an inner and outer pipe, separated by insulation. Both ends of the pipes are sealed with insulated, removable end caps. There is an $O_2$ inlet port at the bottom of the gasifier to allow the introduction of $O_2$ to the process. There is a hotplate in the middle serving as the heat source. At the top of the gasifier there is an outlet for the capturing of the syngas produced. Detailed part drawings of the design from Pro/Engineer can be found in Appendix A.




| Bill Of Materials | | |
|---|---|---|
| Item No. | Description | Qty. |
| (1) | Outer Pipe | 1 |
| (2) | Inner Pipe | 1 |
| (3) | Insulation | N/A |
| (4) | Gasket Base Ring | 2 |
| (5) | Sealing Gasket | 2 |
| (6) | Cap Ring | 2 |
| (7) | Cap Outer Pipe | 2 |
| (8) | Gas Line | 2 |
| (9) | Pressure Release Valve | 1 |
| (10) | Cap End | 2 |
| (11) | L-Bracket Support | 4 |
| (12) | Hot Plate Heating Element | 1 |
| (13) | Temperature Probe | 1 |
| (14) | Hot Plate Control Switch | 1 |
| (15) | Cap Latches | 8 |

Fig. 3. AutoCAD drawing of final design

## Project Planning & Management

This section presents our schedule for completion of the project. The proposed research project culminates in a formal report that will be completed by May 9, 2008. To reach this goal, we will follow the schedule presented in Figure 3. These benchmarks have been preset by the MAE 4980 curriculum and will be met so that we complete our project on time.

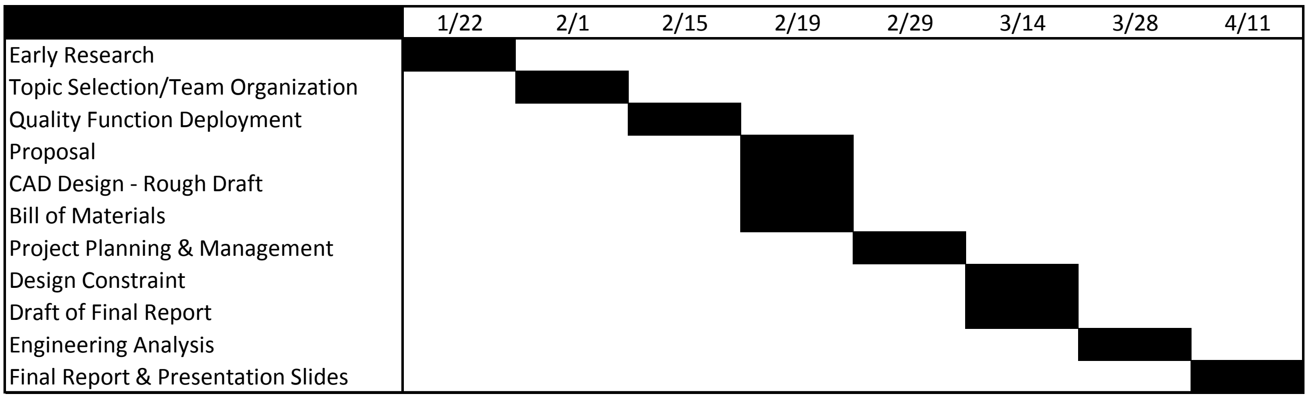


Fig 4. Gant Chart for project management

The above Gantt Chart outlines the benchmarks we plan on accomplishing on a bi-weekly basis.

During the first week, our group will be researching various topics to decide what type of project we are interested in working on. By looking at suggested topics as well as some of our own, our group should be able to get a basic idea about the scope of our pending projects. This will be completed by January 22nd by all group members.

Hours – 5 hrs

During the second week, our group will be working on selecting a topic based on the previous weeks preliminary research. This will mostly consist of looking at the basic technology behind biomass gasification, as well as getting a general idea behind the pros and cons. Also, we will complete our team organization at this time which will try to loosely place each member in a position based on their expertise. This work will be done by all members of the group and will be finished by February 1st.

Hours – 5 hrs

During the fourth week, the team will be working on creating a Quality Function Deployment chart or QFD. The QFD chart will allow our team to better gauge the results of our project by looking at goals and benchmarks in which to compare our product against other products on the market. This is very important because we will need to refine our product before we get too into the design process.

Hours – 4 hrs

During the sixth week, the work to be completed will consist of several parts. The first part is the proposal. This will outline why we need money for the project, as well as various justifications for why it is a worthwhile venture for the investor. The second part is the CAD designs. This will consist of the 3 designs we came up for as prototypes. Finally, we will make a Bill of Materials to outline all the parts we will need to construct our design.

Hours – 6 hrs

During the eighth week, we will be creating the project management plan in the form of the Gantt Chart. This can be found above, and outlines how exactly we are going to work through the project. This will ensure that we stay on time with all our obligations and do not miss any deadlines.

Hours – 4 hrs

During the tenth week, we will outline the structure of the final report. This will consist of laying out the basic architecture for the report, including chapters and appendices. Also, we will be looking at the design constraints we need to implement on our final project design. This is important so that we end up with a design that is realistic to build manufacture.

Hours – 6 hrs

During the twelfth week, our team will be doing the engineering analysis section of the report. This will consist of using FEA software to analyze the stresses. Also, dynamic analysis should be looked at as well. This will completed by all the members of the group.

Hours – 4 hrs

# Engineering Analysis

## *Hotplate Temperature Analysis*

Our decision to use an electric hot plate coil came from first doing a heat transfer analysis on the coil to be confident that it would reach a steady state temperature high enough to begin the gasification reaction on the compressed biomass logs. After some research it was found that the temperature needed for gasification to begin was between 220°C and 365°C depending on what type of biomass was being used (Ingentaconnect, Doctorfire). The analysis was done based on the electrical power added to the heating element with a 25% loss of energy to be conservative. A Matlab M-file was set up using some geometrical and material information about the hotplate heating element. This M-File can be found in the Appendix under *function Watts*. After calculating the temperatures of available hotplates we found that a 1,000 Watt hotplate would theoretically reach a steady state temperature of 585°C. Since this was a temperature sufficient enough for the requirements one was purchased and tested to verify the analysis. After turning the hotplate on the highest setting and letting it reach steady state, the actual surface temperature of the coil was found to be 525°C, a 13% error from our analysis. This error was caused by the many assumptions and approximations made about the geometry and material properties of the heating element. Even though the actual temp was below our calculated value, it will still be high enough to fulfill the requirements.

## *Material Selection Analysis*

For the material section, we used the Granta CES EduPack computer program to search for materials that would best meet the design requirements. The search was limited to ferrous and non-ferrous metals and was narrowed down to the materials seen in Fig. 5. Then wrought austenitic stainless steel, AISI 309 was selected from the graph of comparing price and maximum service temperature show below as Fig 5. The material's corrosion resistance and tensile strength was also taken into consideration. AISI 309 has adequate corrosion resistance and a high tensile strength. This material is used in such applications as furnace parts and heat exchangers and is a good material for a gasification chamber. Another consideration looked at was the weldability of the materials. Austenitic stainless steel was found to be the better material for our application because the welded area of ferritic stainless steel is susceptible to grain growth when subjected to high temperatures for long periods of time. This can cause a loss of strength. Other materials, such as wrought ferritic stainless steel AISI 442, AISI 430FR, and High Cr white cast iron, were considered. Their material properties, along with the material properties of AISI 309 can be found in Appendix B.

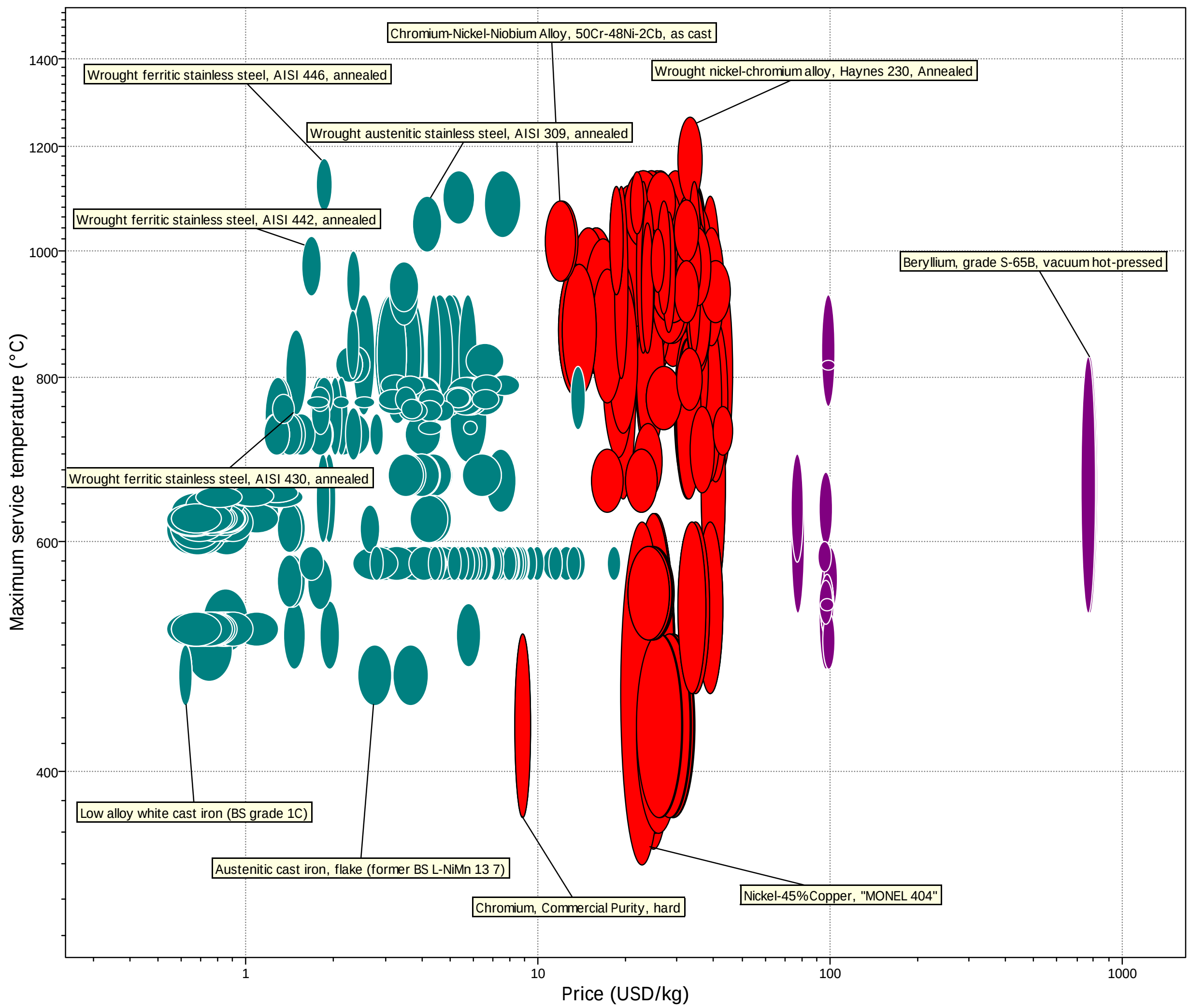



Fig. 5. Material selection chart used.

## *FE Analysis*

To complete the finite element analysis, the biomass gasification chamber was modeled in Pro/Engineer. The Pro/Engineer solid model can be seen in Appendix A. The model was based on a simple rendering of the actual gasifier, by only taking into consideration the inner and outer pipes along with the end caps. This model was then meshed and analyzed using ALGOR. The constraints of our physical design such as our selected material from above and welded joints and operating pressure were inputted into the model. Below are the screen shots taken from an analysis of an internal pressure of 50 psi. These can be seen in Fig. 6 - Fig. 9. Fig. 6 shows the stress distribution in our design. By analyzing the figure, it was determined that the stresses are well below the maximum yield stress for our design. Fig. 6 shows the strain distribution in our design. It is very similar to the stress distribution and no failure will occur do to strains. Fig. 8 and Fig. 9 show the deformation of our design under the stress. It is important to note that Fig. 9 is greatly exaggerated to emphasize where the deformations will occur. It shows that the gasifier will stretch along its axis and the end caps would bow out.

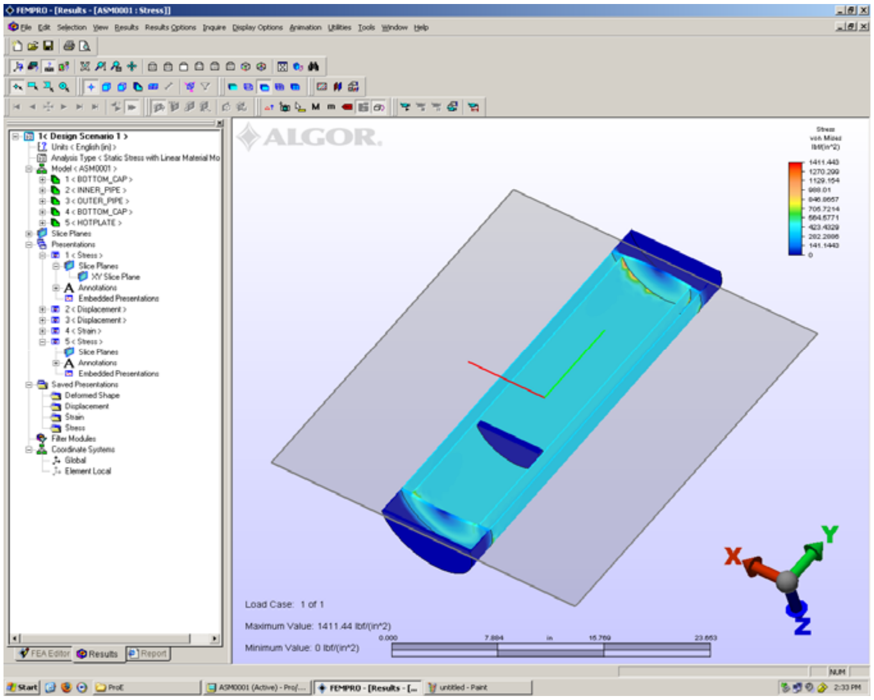



Fig. 6 – Stress analysis

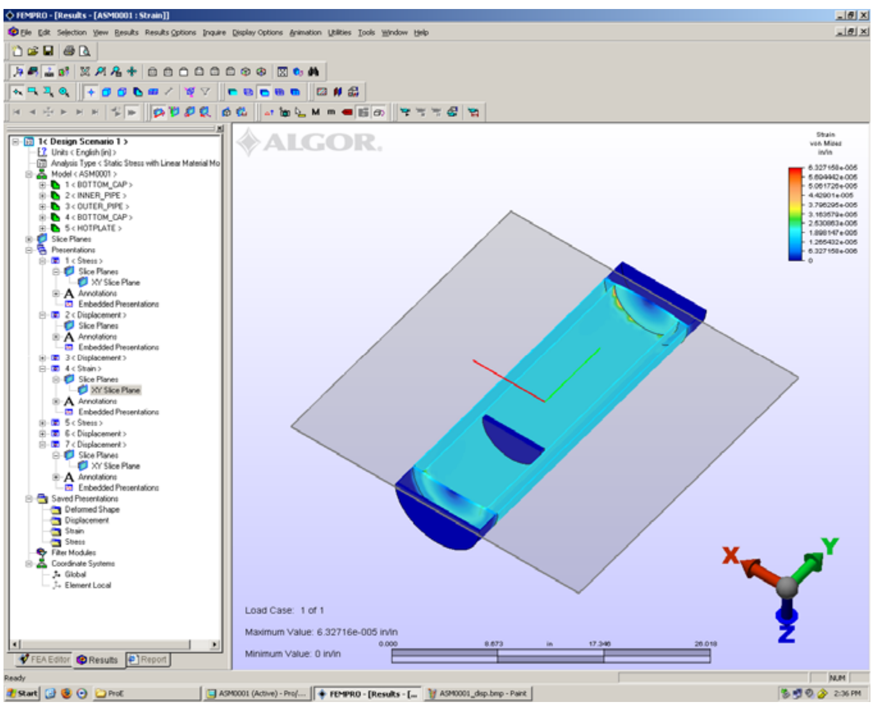



Fig. 7 – Strain analysis

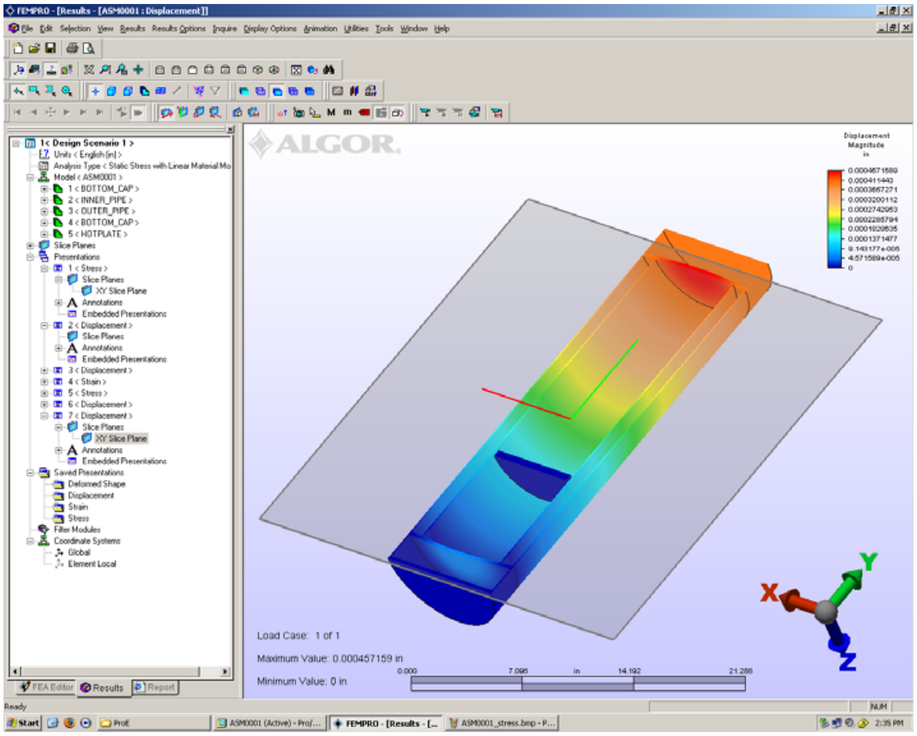



Fig. 8 – Displacement analysis

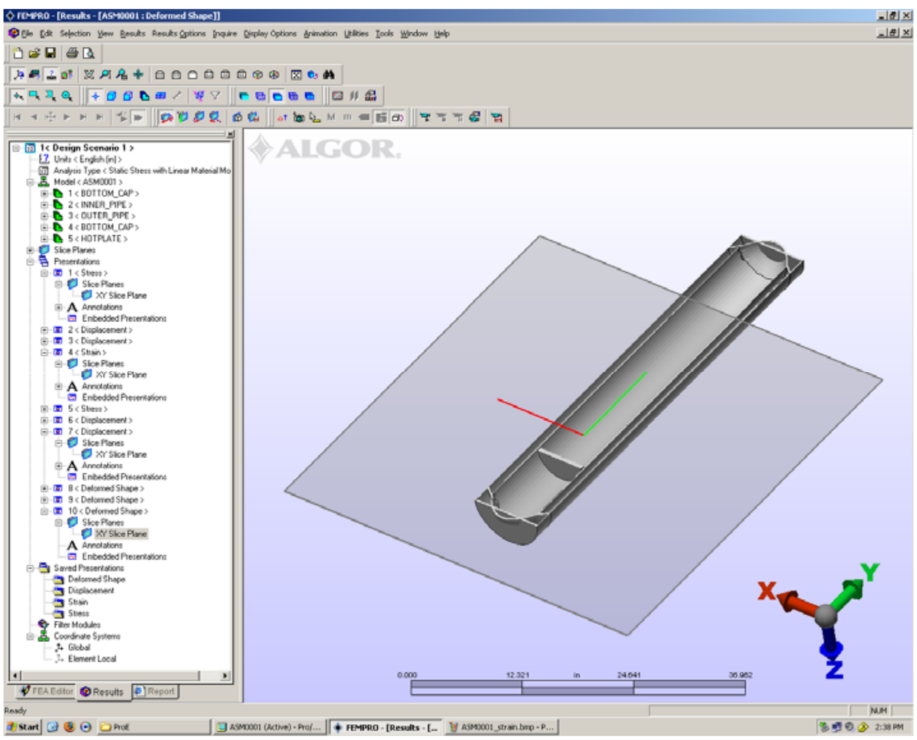



Fig. 9 – Deformation analysis

## Cost Analysis

To achieve the goal of creating a prototype of the biomass gasification chamber, it was necessary to receive funding to purchase parts and secure time in the shop for manufacturing. A formal request for funding was submitted to and approved by the Mechanical Engineering Department. We were awarded funding in the amount of 800 dollars and 13 shop hours. The monetary breakdown of the necessary parts for the chamber can be seen in Table 1. This table shows the total cost of building a prototype of a biomass gasification chamber. It is important to note that, if mass produced, the price of parts will decrease dramatically. The breakdown of the manufacturing steps and their associated shop time is shown in Table 2. Once again it is important to remember that mass production will decrease the time necessary for each step depending on the manufacturing equipment used.

| Item | size | quantity | price (USD) | total (USD) |
|---|---|---|---|---|
| hot plate | | 1 | 50 | 50 |
| inner piping | | 3 ft | 38/ft | 114 |
| insulation | | | 20 | 20 |
| outer piping | | 3 ft | 53.34/ft | 160.02 |
| pressure relief valve | | 1 | 250 | 250 |
| L-brackets | | 4 | 5 | 20 |
| clamps | | 6 | 15 | 90 |
| gasket | | 2 | 10 | 20 |
| metal sheet | 12"x18" | 3 ft | 19.62/ft | 58.86 |
| metal tubing | 1" | 1.5 ft | 10/ft | 15 |
| total | | | | 797.88 |

Table 1. Itemized cost of materials and parts for gasification chamber.

| Manufacturing Process | quantity | shop hours |
|---|---|---|
| outer pipe cut | 2 | 1 |
| inner pipe cut | 2 | 1 |
| plate cuts (caps) | 4 | 2 |
| disc cuts | 2 | 2 |
| 0.25" drill hole | 38 | 1 |
| outer pipe weld (caps) | 6 | 3 |
| inner pipe weld | 2 | 1 |
| 0.25" tubing weld | 6 | 1 |
| bracket spot welds | 3 | 1 |
| Total | | 13 |

Table 2. Steps of the manufacturing process and approximate shop time.

## Prototype

A prototype of the gasifier design was constructed and used to test the functionality. The prototype was made to the same dimensions as the final design cad drawing shows. A photograph of the gasifier can be seen in Fig. 10. The main components were constructed from medium carbon structural steel. Insulation was placed between the inner and outer pipes and in the end caps. A typical household hotplate heating element was used in the inner pipe as the heat source. A hotplate was purchased and taken apart to obtain the components necessary for our needs. The temperature control was taken off the hotplate and rewired into our gasifier so the user will have an adjustment on the heat source. This hotplate also served as the support to hold the biomass log. The gaps between the heating coil will allow the ashes and char left from the process to fall through to the bottom. This heating element can be seen in the top view of the prototype in Fig. 11. The gasket used to seal the chamber can also be seen in this figure. This gasket was made from a “make your own gasket” kit originally designed for automotive purposes. The pressure and temperature requirements for the gasifier prototype were similar to the conditions the gasket would be exposed to in an automotive application.

Fig. 10. Photograph of the entire gasifier prototype and compressed log.

Fig. 11.  Top view of gasifier prototype.


Fig. 12.  Close up of the heating element temperature control.

## Prototype Testing

After the prototype was constructed, the next step was to test. We obtained a compressed biomass log shown in Fig. 13. This log was inserted into the gasifier prototype and the heating element was turned on the highest setting. After a few seconds gas started to exit the outlet. A photograph of the test setup and production of syngas can be seen in Fig. 14. After the gasification process began, the heating element was turned off to make sure the process was self-sustainable. This was proven to be true as the gasification process continued without the input of heat to the system. Once the testing was completed we opened the top end cap and removed the biomass log. An image of this log is shown as Fig. 15. From the results of our prototype construction and testing we were able to conclude that our biomass gasification chamber design would function properly.

Fig. 13. Photograph of compressed biomass log used for testing.

Fig. 14. Image of test setup (left), and photograph of syngas leaving outlet (right).

Fig. 15. Photograph of the biomass log after partial gasification.

## Operation of System Design

This gasifier is capable of being used in an unpressurised system with the input open to the atmosphere or in a pressurized scenario. The gasification process will be more efficient in regards to capturable syngas energy output to waste material if it occurs in a pressurized environment. Fig. 16 shows how our design concept could be incorporated into a pressurized system for optimal performance.

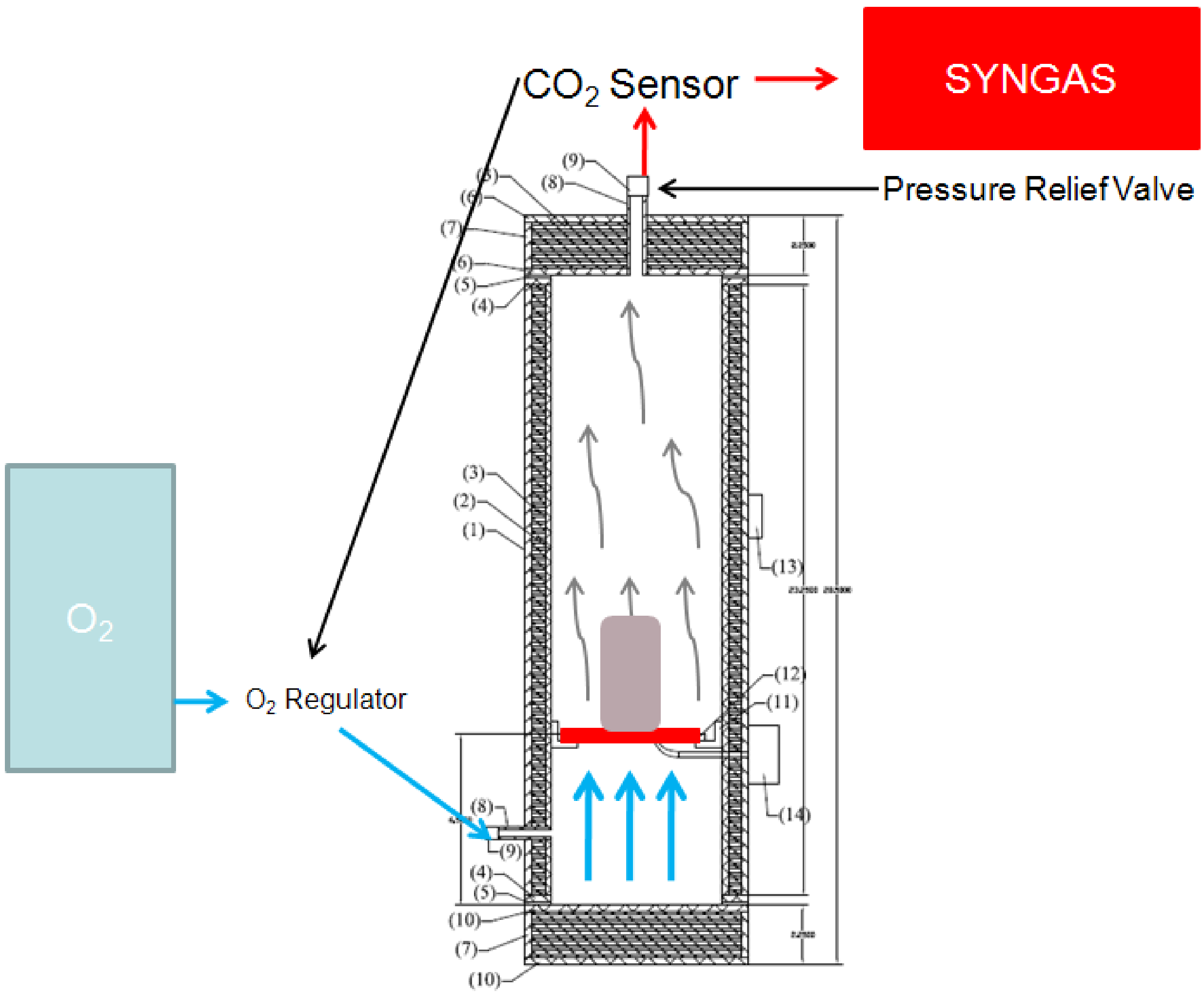



Fig. 16. Schematic of design incorporated into a pressurized system for optimal performance.

The figure shows a compressed oxygen tank connected to a regulator that is hooked up to the inlet of the gasifier. It also shows the oxygen rising up to through the heating element which the biomass log is sitting on. The gasification process then starts to occur and the syngas rises to the outlet. There is a pressure relief valve on the outlet that allows the user to adjust the working pressure of the chamber. The outlet is connected to a carbon dioxide detector which the syngas passes through and then enters a syngas tank. The black arrow represents a feedback control between the carbon dioxide sensor and the oxygen regulator. This is done because the ratio of carbon dioxide out to oxygen in is a measure of the efficiency of the gasification process.  If the amount of carbon dioxide out is too high, the oxygen input should be lowered.

## Safety

As with any engineering design, safety is essential to the success of any project. There were several safety issues apparent in our design. First and most hazardous was the production of carbon monoxide. Carbon monoxide, or CO, is extremely hazardous to humans and can cause death. Because CO production was the main goal of our gasification chamber, our team had to be very careful with how we operated the chamber. It had to be kept outside when operating to allow for the dissipation of CO gas into the atmosphere.

Another safety issue present was heat. The hotplate heated up to a temperature of about 600° C. Because of this, warning labels must be present on the chamber to warn humans of the hazard. However, due to the thickness of the wall and insulation in between the pipes, the heat on the outside wall was not an issue.

Finally, the internal pressure of the chamber was considered to be negligible due to the installation of the poppet valve. Also, as can be seen in the FE Analysis, the material used was well over specifications to withhold the necessary pressures.

## Conclusion

Finally, there were several key points that the team set out to accomplish at the beginning of the semester. First, we wanted to design a gasifier that could fill the gap in the biomass gasification market for small scale gasifiers. We successfully accomplished this with the prototype design that is found earlier in the report. Once we had the prototype designed, a thorough engineering analysis was accomplished by looking at the material selection, hotplate heat transfer and the finite element analysis of the internal pressure. After the analysis was completed and our design was theoretically sound, an actual prototype was completed. Through real world testing, it was found that our prototype lived up the original design and proved the validity of our theoretical design. Through all the above work and research, our team has found that the design meets all the goals we set out to accomplish.

Through this research, we have found that the future opportunity of biomass gasification as a reliable alternative to expensive fossil fuels is finally within reach. Because of this, we believe that biomass gasification is a technology that should be taken up heavily by researchers to further the opportunities it may provide. The long term impact has the opportunity to have significant impact on the future of global warming and the planet as a whole.

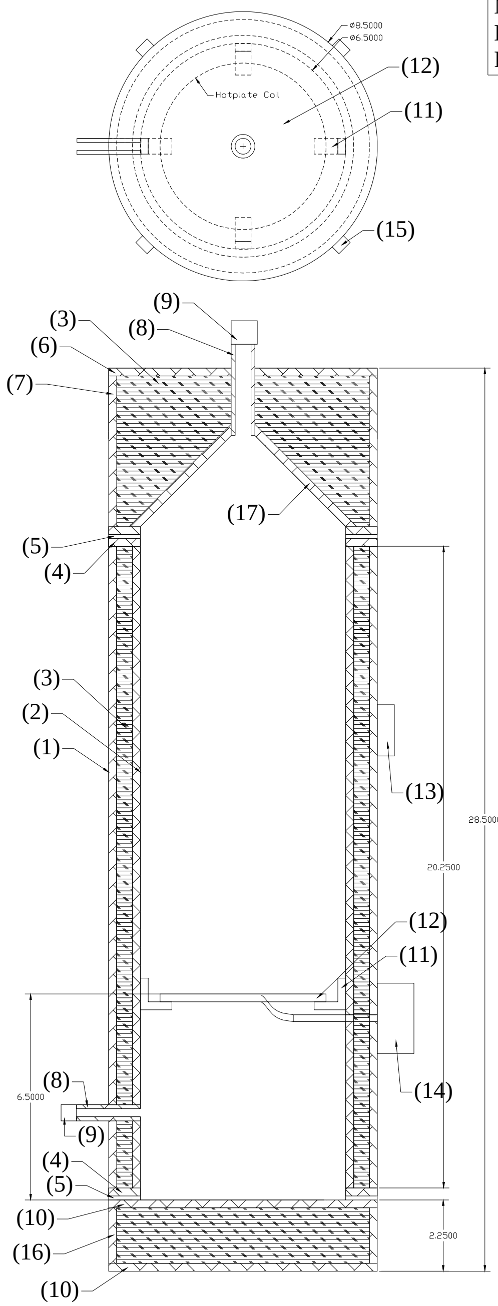
References

1. Crorey Alternative Fuels (http://www.croreyrenewable.com/)
2. Tom's Woodgas Stove (http://www.woodgas.com/bookSTOVE.htm)
3. Biomax 15 (http://www.gocpc.com/Products/BioMax%20Spec%20Sheet.PDF)
4. Dept of Energy, Small-Modular Gasification (http://www1.eere.energy.gov/biomass/small_modular_gasification.html)
5. Study on performance of biomass gasifier-engine systems (http://www.fao.org/docrep/T4470E/t4470e0i.htm)
6. USPTO Biomass Gasification (http://www.uspto.gov/web/patents/patog/week24/OG/classification/classGroup_11.htm)
7. http://members.tripod.com/~cturare/bio.htm, Biomass Gasification, Technology and Utilization
8. http://www.biomassgasification.com/, Biomass Gasification, Biomass Gasification Technologies, Inc.
9. http://www.btgworld.com/technologies/gasification.html, Biomass Gasification Technologies, BTG Bimass Technologies Group
10. http://www.nariphaltan.virtualave.net/gasbook.pdf, Biomass Gasification by Anil K. Rajvanshi Director, Nimbkar Agricultural Research Institute,
11. http://www.bgg.mek.dtu.dk/, Biomass Gasification Group, Department of Mechanical Engineering, DTU
12. http://www.iso.org/iso/search.htm?qt=pressure+vessel&published=on&active_tab=standards , International Organization of Standardization
13. http://www.gepower.com/prod_serv/products/gasification/en/overview.htm, GE Energy, Gasification
14. http://www.dakotagas.com/, Dakota Gasification Company,
15. http://www.osha.gov/pls/oshaweb/owasrch.search_form?p_doc_type=STANDARDS&p_toc_level=0&p_keyvalue=, OSHA, US Department of Labor, Occupational Safety and Health Administration.
16. http://nlquery.epa.gov/epasearch/epasearch?areaname=&areacontacts=http%3A%2F%2Fwww.epa.gov%2Fepahome%2Fcomments.htm&areasearchurl=&areasidebar=epahome_sidebar&result_template=epafiles_default.xsl&action=filtersearch&filter=&typeofsearch=epa&querytext=gasifier&submit=Go, United States Environmental Protection Agency

# Appendix A

Concept Drawings
Alternate Design 1

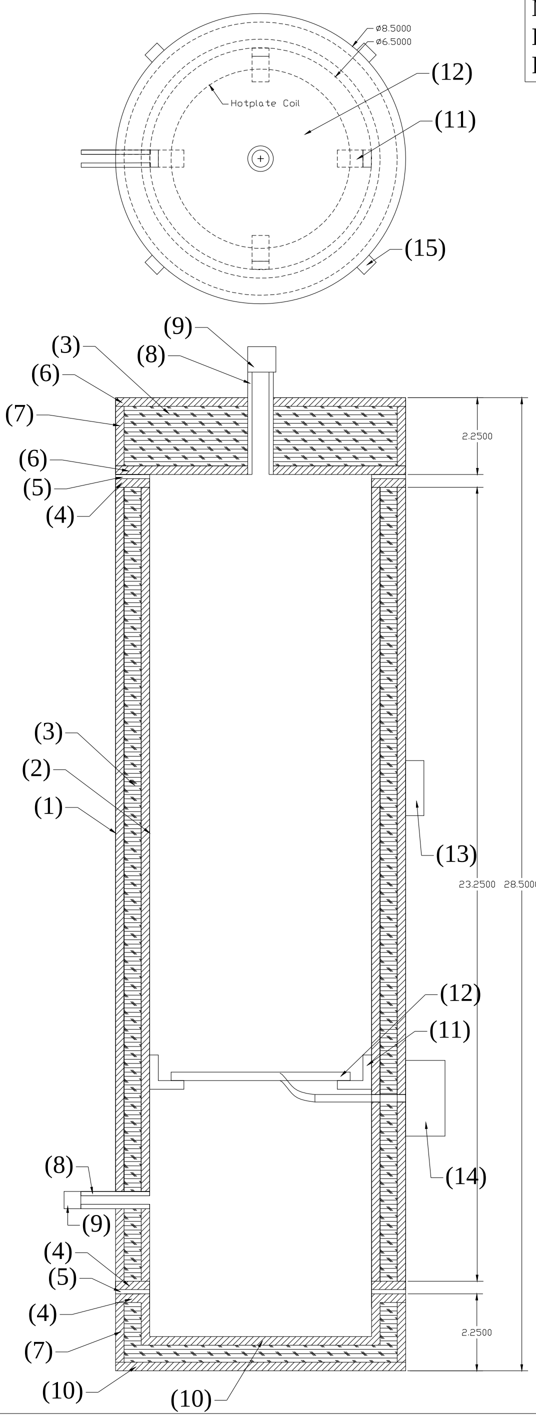
| University of Missouri Mechanical and Aerospace Engineering | | |
|---|---|---|
| Senior Capstone Design MAE 4980 | Feb. 2008 | |
| Doug Koch<br>Michael Koch<br>Dan Childress<br>Ryan Ott | Biomass Gasification Chamber | Assembly Dwg. |
| | Third Angle Projection | All Tolerances should be + or - 1/16" unless otherwise specified. |



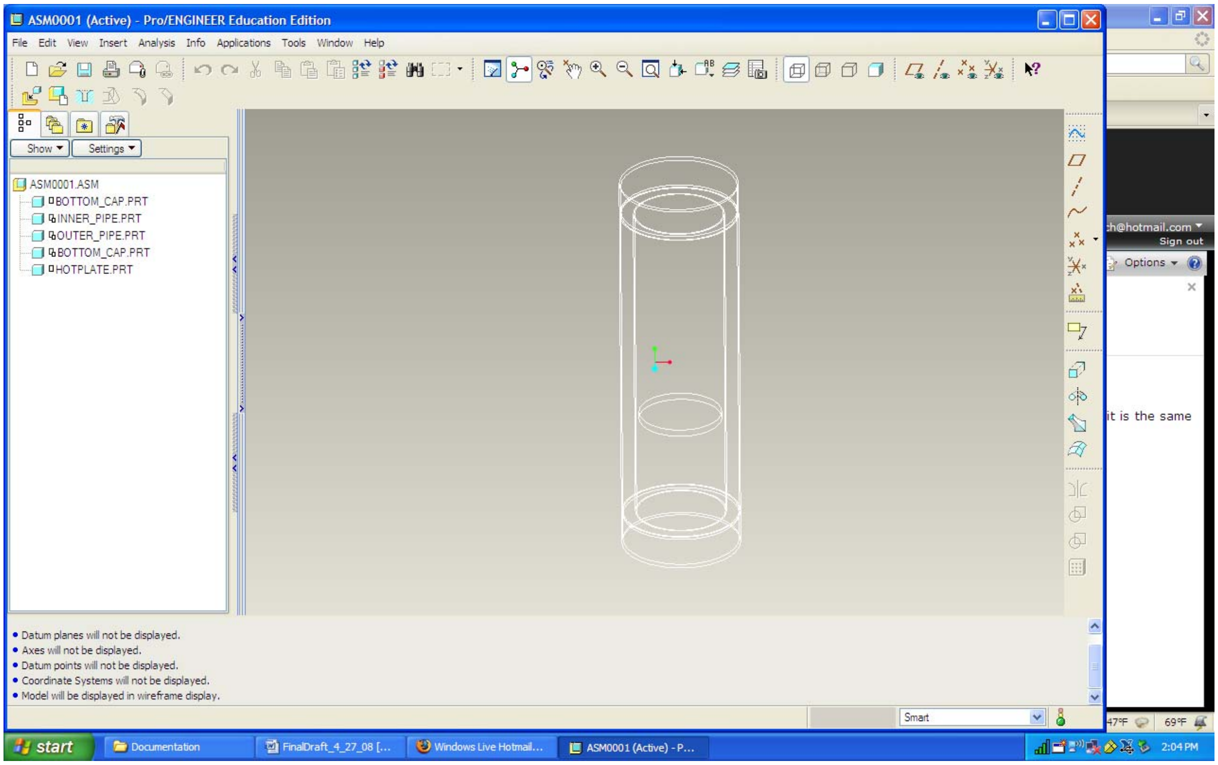

| Bill Of Materials | | |
|---|---|---|
| Item No. | Description | Qty. |
| (1) | Outer Pipe | 1 |
| (2) | Inner Pipe | 1 |
| (3) | Insulation | N/A |
| (4) | Gasket Base Ring | 2 |
| (5) | Sealing Gasket | 3 |
| (6) | Cap Ring | 1 |
| (7) | Top Cap Outer Pipe | 1 |
| (8) | Gas Line | 2 |
| (9) | Pressure Release Valve | 1 |
| (10) | Cap End | 2 |
| (11) | L-Bracket Support | 4 |
| (12) | Hot Plate Heating Element | 1 |
| (13) | Temperature Probe | 1 |
| (14) | Hot Plate Control Switch | 1 |
| (15) | Cap Latches | 8 |
| (16) | Bottom Cap Outer Pipe | 1 |
| (17) | Cap Cone | 1 |

## Alternate Design 2

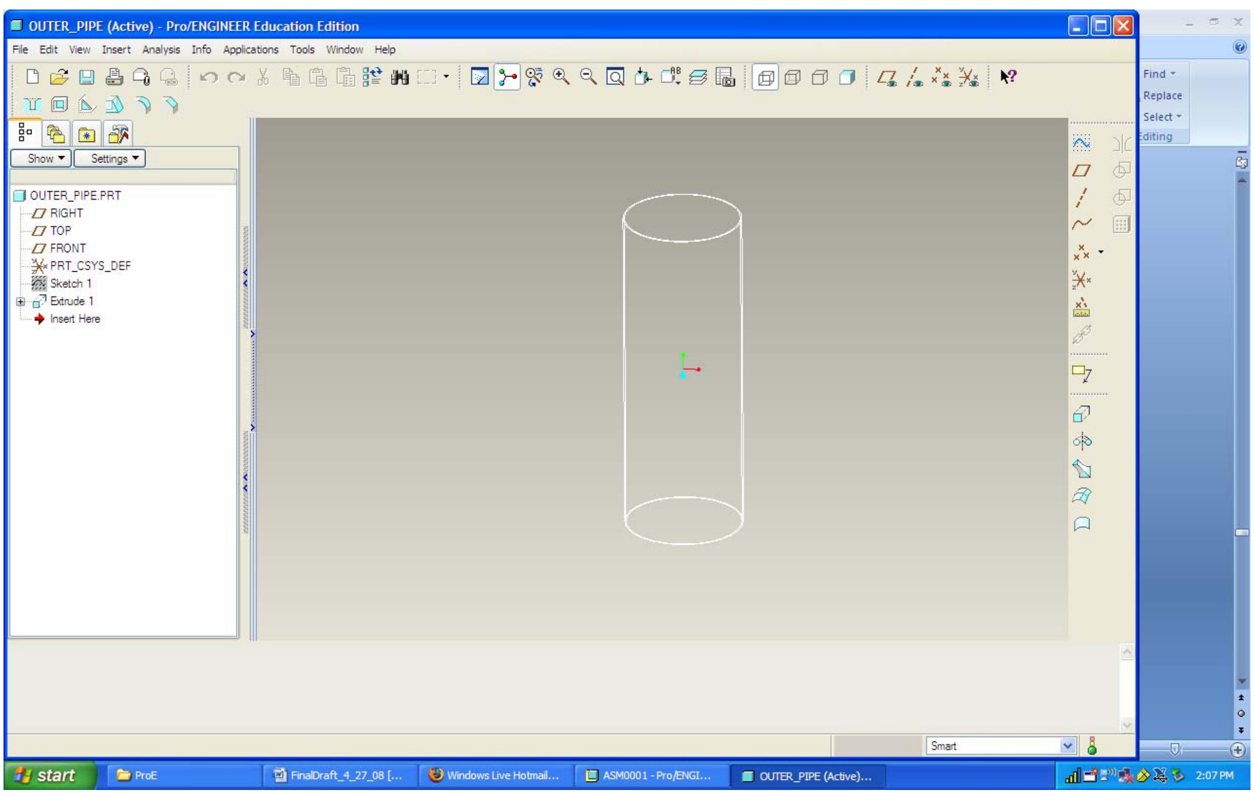
| | | |
|---|---|---|
| University of Missouri Mechanical and Aerospace Engineering | | |
| Senior Capstone Design MAE 4980 | Feb. 2008 | |
| Doug Koch<br>Michael Koch<br>Dan Childress<br>Ryan Ott | Biomass Gasification Chamber<br>Third Angle Projection | Assembly Dwg.<br>All Tolerances should be + or − 1/16" unless otherwise specified. |



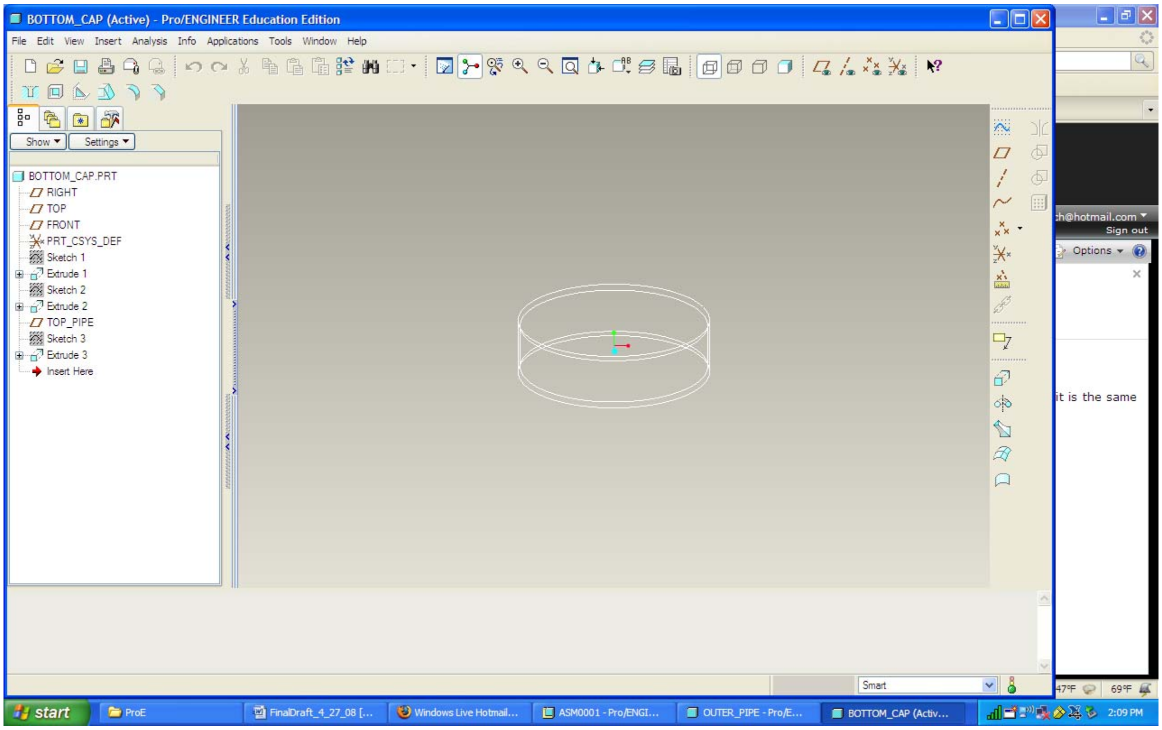

| Bill Of Materials | | |
|---|---|---|
| Item No. | Description | Qty. |
| (1) | Outer Pipe | 1 |
| (2) | Inner Pipe | 1 |
| (3) | Insulation | N/A |
| (4) | Gasket Base Ring | 2 |
| (5) | Sealing Gasket | 2 |
| (6) | Cap Ring | 2 |
| (7) | Cap Outer Pipe | 2 |
| (8) | Gas Line | 2 |
| (9) | Pressure Release Valve | 1 |
| (10) | Cap End | 2 |
| (11) | L-Bracket Support | 4 |
| (12) | Hot Plate Heating Element | 1 |
| (13) | Temperature Probe | 1 |
| (14) | Hot Plate Control Switch | 1 |
| (15) | Cap Latches | 8 |



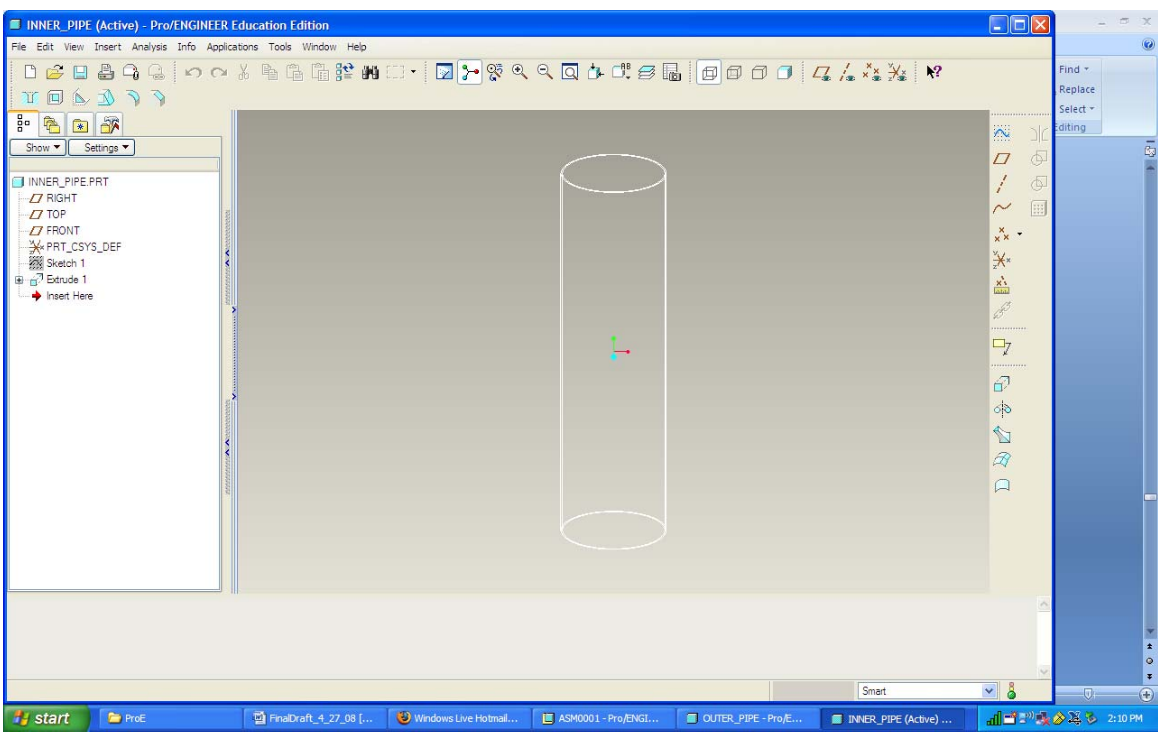

Pro/E Assembly Drawing



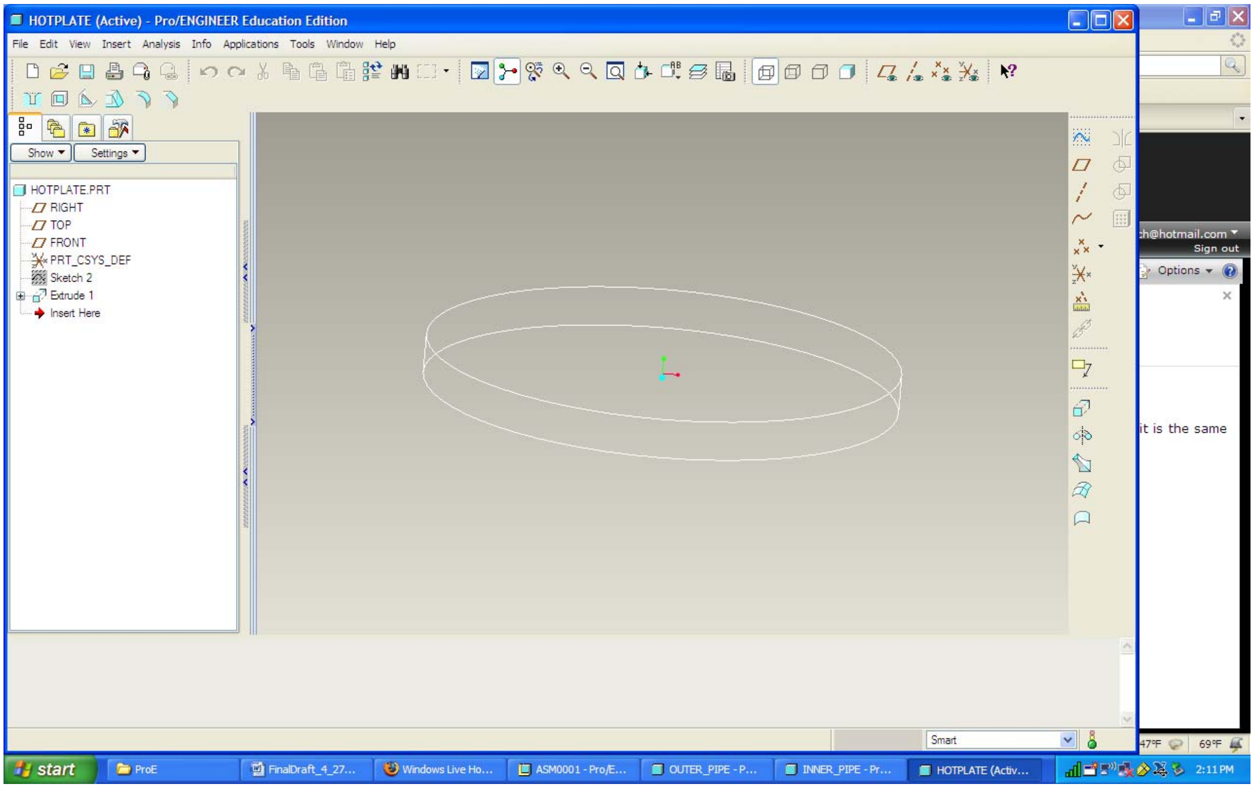

Outer Pipe




Top & Bottom End Caps




Inner Pipe


HOTPLATE (Active) - Pro/ENGINEER Education Edition
File Edit View Insert Analysis Info Applications Tools Window Help
Show
Settings
HOTPLATE.PRT
RIGHT
TOP
FRONT
PRT_CSYS_DEF
Sketch 2
Extrude 1
Insert Here
Smart
start
ProE
2:11 PM

Hotplate

# Appendix B

```
function Watts=hotplate(Ts)

e=.90;
a=.0198;
sig=5.7*10^-8;
Troom=298;
c=.54;
g=9.81;
v=27*10^-6;
alpha=40.16*10^-6;
n=.25;
l=.03712;

%takes input value of Ts and calculates the required watts
%used iteratively until desired value of Watts is
%obtained
Watts=e*a*sig*(Ts^4-Troom^4)+c*((g*(2/(Ts+Troom))*(Ts-
Troom)*l^3)/(v*alpha))^n*a*(Ts-Troom);
Tc=Ts-273
```

# Wrought austenitic stainless steel, AISI 309, annealed

## General

**Designation**

S-Steel: AISI 309, annealed

| | | | | |
|---|---|---|---|---|
| Density | 7600 | - | 8000 | kg/m^3 |
| Price | * 3.707 | - | 4.651 | USD/kg |

**Tradenames**

SPARTAN REDHEUGH 309S24, Spartan Redheugh Ltd (UK); RDN 230, Roldan S.A. (SPAIN); RDN 320, Roldan S.A. (SPAIN); EASTERN STAINLESS TYPE 309S, Eastern Stainless Corp. (USA); SANDVIK 3RE13, Sandvik Steel Co. (USA);

## Composition

**Composition (summary)**

Fe/<.20C/22-25Cr/12-16Ni/<2Mn/<1Si/<.045P/<.03S

| | | | | |
|---|---|---|---|---|
| Base | Fe (Iron) | | | |
| C (carbon) | 0 | - | 0.2 | % |
| Cr (chromium) | 22 | - | 25 | % |
| Fe (iron) | 55.73 | - | 66 | % |
| Mn (manganese) | 0 | - | 2 | % |
| Ni (nickel) | 12 | - | 16 | % |
| P (phosphorus) | 0 | - | 0.045 | % |
| S (sulfur) | 0 | - | 0.03 | % |
| Si (silicon) | 0 | - | 1 | % |

## Mechanical

| | | | | |
|---|---|---|---|---|
| Young's modulus | 196 | - | 204 | GPa |
| Shear modulus | 76 | - | 81 | GPa |
| Bulk modulus | 139 | - | 152 | GPa |
| Poisson's ratio | 0.265 | - | 0.275 | |
| Yield strength (elastic limit) | 205 | - | 310 | MPa |

| | | | | |
|---|---|---|---|---|
| Tensile strength | 515 | - | 620 | MPa |
| Compressive strength | 205 | - | 310 | MPa |
| Flexural strength (modulus of rupture) | 205 | - | 310 | MPa |
| Elongation | 30 | - | 50 | % |
| Hardness - Vickers | 205 | - | 225 | HV |
| Fatigue strength at 10^7 cycles | * 268 | - | 307 | MPa |
| Fracture toughness | * 121 | - | 228 | MPa.m^1/2 |
| Mechanical loss coefficient | * 9.5e-4 | - | 1.3e-3 | |

## Thermal

| | | | | |
|---|---|---|---|---|
| Melting point | 1400 | - | 1450 | °C |
| Maximum service temperature | 1000 | - | 1100 | °C |
| Minimum service temperature | -273 | | | °C |
| Thermal conductivity | 13 | - | 19 | W/m.K |
| Specific heat | 490 | - | 530 | J/kg.K |
| Thermal expansion coefficient | 14 | - | 16 | µstrain/°C |

## Electrical

| | | | | |
|---|---|---|---|---|
| Electrical resistivity | 73 | - | 83 | µohm.cm |

## Optical

| | |
|---|---|
| Transparency | Opaque |

## Durability

| | |
|---|---|
| Flammability | Non-flammable |
| Fresh water | Very Good |
| Salt water | Very Good |
| Weak acids | Very Good |
| Strong acids | Good |
| Weak alkalis | Very Good |
| Strong alkalis | Very Good |
| Organic solvents | Very Good |
| Sunlight (UV radiation) | Very Good |
| Oxidation at 500C | Very Good |

## Eco properties, material production

| | | | | |
|---|---|---|---|---|
| Embodied energy | * 82 | - | 90.5 | MJ/kg |
| CO2 footprint | * 5.16 | - | 5.7 | kg/kg |
| Recycle fraction | * 0.65 | - | 0.75 | |

## Eco properties, processing

| | | | | |
|---|---|---|---|---|
| Casting energy | 3.2 | - | 3.5 | MJ/kg |
| Forging, rolling energy | 5.8 | - | 6.4 | MJ/kg |
| Machining energy (per unit wt removed) | 9.1 | - | 10 | MJ/kg |
| Metal powder forming energy | 18 | - | 20 | MJ/kg |
| Vaporization energy | 20 | - | 22 | MJ/kg |

## Eco properties, recycling and disposal

| | |
|---|---|
| Recycle | True |
| Downcycle | True |
| Biodegrade | False |
| Combust for energy recovery | False |
| Landfill | True |
| A renewable resource? | False |

## Notes

### Typical uses

Carburizing boxes; electrical parts; furnace parts; heat exchangers; heat-treatment baskets; oil-burner parts; welding filler wire and electrodes.

### Reference sources

Data compiled from multiple sources.  See links to the References table.

## Links

ProcessUniverse
Producers
Reference
Shape
Structural Sections
No warranty is given for the accuracy of this data.  Values marked * are estimates.

Alternate Materials:

# Wrought ferritic stainless steel, AISI 442, annealed

## General

### Designation

S-Steel: AISI 442, annealed

| | | | | |
|---|---|---|---|---|
| Density | * 7700 | - | 7900 | kg/m^3 |
| Price | * 1.553 | - | 1.783 | USD/kg |

## Composition

### Composition (summary)

Fe/<.20C/18-23Cr/<.5Ni/<1Mn/<1Si/<.04P/<.03S

| | | | | |
|---|---|---|---|---|
| Base | Fe (Iron) | | | |
| C (carbon) | 0 | - | 0.2 | % |
| Cr (chromium) | 18 | - | 23 | % |
| Fe (iron) | 74.23 | - | 82 | % |
| Mn (manganese) | 0 | - | 1 | % |
| Ni (nickel) | 0 | - | 0.5 | % |
| P (phosphorus) | 0 | - | 0.04 | % |
| S (sulfur) | 0 | - | 0.03 | % |
| Si (silicon) | 0 | - | 1 | % |

## Mechanical

| | | | | |
|---|---|---|---|---|
| Young's modulus | * 195 | - | 205 | GPa |
| Shear modulus | * 75 | - | 81 | GPa |
| Bulk modulus | * 144 | - | 159 | GPa |
| Poisson's ratio | 0.275 | - | 0.285 | |
| Yield strength (elastic limit) | 275 | - | 345 | MPa |
| Tensile strength | 515 | - | 605 | MPa |
| Compressive strength | 275 | - | 345 | MPa |
| Flexural strength (modulus of rupture) | 275 | - | 345 | MPa |
| Elongation | 20 | - | 30 | % |
| Hardness - Vickers | 190 | - | 225 | HV |
| Fatigue strength at 10^7 cycles | * 268 | - | 302 | MPa |
| Fracture toughness | * 79 | - | 120 | MPa.m^1/2 |
| Mechanical loss coefficient | * 9.1e-4 | - | 1.12e-3 | |

## Thermal

| | | | | |
|---|---|---|---|---|
| Melting point | * 1425 | - | 1530 | °C |
| Maximum service temperature | 925 | - | 1025 | °C |
| Minimum service temperature | -73 | - | -43 | °C |
| Thermal conductivity | * 23 | - | 27 | W/m.K |

| | | | | |
|---|---|---|---|---|
| Specific heat | * 420 | - | 500 | J/kg.K |
| Thermal expansion coefficient | * 9 | - | 12 | µstrain/°C |

### Electrical

| | | | | |
|---|---|---|---|---|
| Electrical resistivity | 55 | - | 75 | µohm.cm |

### Optical

| | |
|---|---|
| Transparency | Opaque |

### Durability

| | |
|---|---|
| Flammability | Non-flammable |
| Fresh water | Very Good |
| Salt water | Very Good |
| Weak acids | Very Good |
| Strong acids | Good |
| Weak alkalis | Very Good |
| Strong alkalis | Average |
| Organic solvents | Very Good |
| Sunlight (UV radiation) | Very Good |
| Oxidation at 500C | Very Good |

### Eco properties, material production

| | | | | |
|---|---|---|---|---|
| Embodied energy | * 61.3 | - | 67.7 | MJ/kg |
| CO2 footprint | * 3.86 | - | 4.26 | kg/kg |
| Recycle fraction | * 0.65 | - | 0.75 | |

### Eco properties, processing

| | | | | |
|---|---|---|---|---|
| Casting energy | 3.1 | - | 3.4 | MJ/kg |
| Forging, rolling energy | 5.8 | - | 6.4 | MJ/kg |
| Machining energy (per unit wt removed) | 7.1 | - | 7.9 | MJ/kg |
| Metal powder forming energy | 19 | - | 21 | MJ/kg |
| Vaporization energy | 20 | - | 22 | MJ/kg |

### Eco properties, recycling and disposal

| | |
|---|---|
| Recycle | True |
| Downcycle | True |
| Biodegrade | False |
| Combust for energy recovery | False |
| Landfill | True |
| A renewable resource? | False |

### Notes

**Typical uses**

Processing of potentially corrosive liquids, e.g. chemicals, oil, beverages, sewage; Structural uses in corrosive environments, e.g. nuclear plants, ships, offshore oil installations, underwater cables and pipes;

**Reference sources**

Data compiled from multiple sources. See links to the References table.

### Links

ProcessUniverse
Producers
Reference
Shape
Structural Sections

No warranty is given for the accuracy of this data. Values marked * are estimates.

## Wrought ferritic stainless steel, AISI 430FR, annealed

### General

**Designation**

S-Steel: AISI 430, annealed

| | | | | |
|---|---|---|---|---|
| Density | 7620 | - | 7820 | kg/m^3 |
| Price | * 1.37 | - | 1.602 | USD/kg |

## Composition

**Composition (summary)**

Fe/<.12C/16-18Cr/<.5Ni/<1Mn/<1Si/<.04P/<.03S

| | | | | |
|---|---|---|---|---|
| Base | Fe (Iron) | | | |
| C (carbon) | 0 | - | 0.12 | % |
| Cr (chromium) | 16 | - | 18 | % |
| Fe (iron) | 79.31 | - | 84 | % |
| Mn (manganese) | 0 | - | 1 | % |
| Ni (nickel) | 0 | - | 0.5 | % |
| P (phosphorus) | 0 | - | 0.04 | % |
| S (sulfur) | 0 | - | 0.03 | % |
| Si (silicon) | 0 | - | 1 | % |

## Mechanical

| | | | | |
|---|---|---|---|---|
| Young's modulus | 195 | - | 205 | GPa |
| Shear modulus | 75 | - | 81 | GPa |
| Bulk modulus | 144 | - | 159 | GPa |
| Poisson's ratio | 0.275 | - | 0.285 | |
| Yield strength (elastic limit) | 205 | - | 370 | MPa |
| Tensile strength | 430 | - | 600 | MPa |
| Compressive strength | 205 | - | 370 | MPa |
| Flexural strength (modulus of rupture) | 205 | - | 370 | MPa |
| Elongation | 16 | - | 30 | % |
| Hardness - Vickers | 150 | - | 195 | HV |
| Fatigue strength at 10^7 cycles | * 237 | - | 300 | MPa |
| Fracture toughness | * 61 | - | 164 | MPa.m^1/2 |
| Mechanical loss coefficient | * 8.9e-4 | - | 1.42e-3 | |

## Thermal

| | | | | |
|---|---|---|---|---|
| Melting point | 1425 | - | 1510 | °C |
| Maximum service temperature | 750 | - | 870 | °C |
| Minimum service temperature | -73 | - | -43 | °C |
| Thermal conductivity | 23 | - | 27 | W/m.K |
| Specific heat | 450 | - | 530 | J/kg.K |
| Thermal expansion coefficient | 10 | - | 11 | µstrain/°C |

## Electrical

| | | | | |
|---|---|---|---|---|
| Electrical resistivity | 53 | - | 76 | µohm.cm |

## Optical

| | |
|---|---|
| Transparency | Opaque |

## Durability

| | |
|---|---|
| Flammability | Non-flammable |
| Fresh water | Very Good |
| Salt water | Very Good |
| Weak acids | Very Good |
| Strong acids | Good |
| Weak alkalis | Very Good |
| Strong alkalis | Average |
| Organic solvents | Very Good |
| Sunlight (UV radiation) | Very Good |
| Oxidation at 500C | Very Good |

## Eco properties, material production

| | | | | |
|---|---|---|---|---|
| Embodied energy | * 55.1 | - | 60.8 | MJ/kg |
| CO2 footprint | * 3.46 | - | 3.83 | kg/kg |
| Recycle fraction | * 0.65 | - | 0.75 | |

## Eco properties, processing

| | | | | |
|---|---|---|---|---|
| Casting energy | 3.2 | - | 3.5 | MJ/kg |
| Forging, rolling energy | 5.7 | - | 6.3 | MJ/kg |
| Machining energy (per unit wt removed) | 6.5 | - | 7.2 | MJ/kg |
| Metal powder forming energy | 19 | - | 21 | MJ/kg |
| Vaporization energy | 20 | - | 22 | MJ/kg |

## Eco properties, recycling and disposal

| | |
|---|---|
| Recycle | True |
| Downcycle | True |
| Biodegrade | False |
| Combust for energy recovery | False |
| Landfill | True |
| A renewable resource? | False |

## Notes

### Typical uses

Auto trim; decorative and household trim; fasteners; flatware (dishes etc.); interior architectural sections; piping and heat exchanger tubings;

### Warning

When used with nitric acid, failures due to crevice corrosion have been experienced.

### Reference sources

Data compiled from multiple sources. See links to the References table.

## Links

ProcessUniverse
Producers
Reference
Shape
Structural Sections
No warranty is given for the accuracy of this data. Values marked * are estimates.

# High Cr white cast iron (BS grade 3D)

## General

### Designation

White CI: high Cr, BS grade 3D

| | | | | |
|---|---|---|---|---|
| Density | 7600 | - | 8000 | kg/m^3 |
| Price | * 2.222 | - | 2.444 | USD/kg |

## Composition

### Composition (summary)

Fe/2.0-2.8C/22-28Cr/<1.5Mo/<1Si/.15-1.5Mn/<2Ni/<2Cu/<.1P/<.1S

| | | | | |
|---|---|---|---|---|
| Base | Fe (Iron) | | | |
| C (carbon) | 2 | - | 2.8 | % |
| Cr (chromium) | 22 | - | 28 | % |
| Cu (copper) | 0 | - | 2 | % |
| Fe (iron) | 61 | - | 75.85 | % |
| Mn (manganese) | 0.15 | - | 1.5 | % |
| Mo (molybdenum) | 0 | - | 1.5 | % |

| | | | | |
|---|---|---|---|---|
| Ni (nickel) | 0 | - | 2 | % |
| P (phosphorus) | 0 | - | 0.1 | % |
| S (sulfur) | 0 | - | 0.1 | % |
| Si (silicon) | 0 | - | 1 | % |

### Mechanical

| | | | | |
|---|---|---|---|---|
| Young's modulus | 165 | - | 220 | GPa |
| Shear modulus | 64 | - | 87 | GPa |
| Bulk modulus | 119 | - | 167 | GPa |
| Poisson's ratio | 0.27 | - | 0.28 | |
| Yield strength (elastic limit) | * 300 | - | 450 | MPa |
| Tensile strength | 300 | - | 450 | MPa |
| Compressive strength | * 500 | - | 900 | MPa |
| Flexural strength (modulus of rupture) | 720 | - | 920 | MPa |
| Elongation | 0 | | | % |
| Hardness - Vickers | 450 | - | 700 | HV |
| Fatigue strength at 10^7 cycles | * 120 | - | 180 | MPa |
| Fracture toughness | * 11 | - | 22 | MPa.m^1/2 |
| Mechanical loss coefficient | * 1.5e-3 | - | 2.5e-3 | |

### Thermal

| | | | | |
|---|---|---|---|---|
| Melting point | 1130 | - | 1357 | °C |
| Maximum service temperature | 900 | - | 1000 | °C |
| Minimum service temperature | * -15 | - | 15 | °C |
| Thermal conductivity | * 19 | - | 29 | W/m.K |
| Specific heat | * 520 | - | 560 | J/kg.K |
| Thermal expansion coefficient | * 8 | - | 12.5 | µstrain/°C |

### Electrical

| | | | | |
|---|---|---|---|---|
| Electrical resistivity | * 60 | - | 100 | µohm.cm |

### Optical

| | |
|---|---|
| Transparency | Opaque |

### Durability

| | |
|---|---|
| Flammability | Non-flammable |
| Fresh water | Very Good |
| Salt water | Very Good |
| Weak acids | Very Good |
| Strong acids | Good |
| Weak alkalis | Very Good |
| Strong alkalis | Poor |
| Organic solvents | Very Good |
| Sunlight (UV radiation) | Very Good |
| Oxidation at 500C | Good |

### Eco properties, material production

| | | | | |
|---|---|---|---|---|
| Embodied energy | * 74.7 | - | 82.4 | MJ/kg |
| CO2 footprint | * 4.7 | - | 5.19 | kg/kg |
| Recycle fraction | * 0.75 | - | 0.85 | |

### Eco properties, processing

| | | | | |
|---|---|---|---|---|
| Casting energy | 3.1 | - | 3.4 | MJ/kg |
| Forging, rolling energy | 5.7 | - | 6.3 | MJ/kg |
| Metal powder forming energy | 17 | - | 19 | MJ/kg |
| Vaporization energy | 20 | - | 22 | MJ/kg |

### Eco properties, recycling and disposal

| | |
|---|---|
| Recycle | True |
| Downcycle | True |

| | |
|---|---|
| Biodegrade | False |
| Combust for energy recovery | False |
| Landfill | True |
| A renewable resource? | False |

## Notes

### Typical uses

Abrasion resistant components, typically in mineral-pulverizing mills, e.g. grinding balls, drum liner plates, spiral classifier-shoes, pulverizing-bars.

### Warning

Very brittle.  Very low resistance to thermal or mechanical shock.  So hard as to be unmachinable - finish by grinding, if needed

### Other notes

Gets its name from the white crystalline appearance of its fracture surface, which is caused by the fact that all the carbon is present as iron carbide (FeC), in a martensite/austenite matrix.  The FeC makes the hardness:yield stress ratios very high.

### Reference sources

Data compiled from multiple sources.  See links to the References table.

## Links

ProcessUniverse
Producers
Reference
Shape
Structural Sections

No warranty is given for the accuracy of this data.  Values marked * are estimates.

# Appendix C

Fig. 17. Crorey Biomass Gasifier

Fig. 18. Biomass CHP Plant

Fig. 19. Biomax 15 Gasifier


Fig. 20. Tom's WoodGas Stove

**Appendix D**

# Personal Biomass Gasification Chamber for Syngas Production

Ryan Ott
Dan Childress
Doug Koch
Michael Koch

UNIVERSITY OF MISSOURI-COLUMBIA
Mechanical and Aerospace Engineering

*Personal Biomass Gasification Chamber for Syngas Production*

## Outline

- Introduction
- QFD
- Concept Generation
- Cost Analysis
- Engineering Analysis
- Prototype
- Safety
- Conclusion

UNIVERSITY OF MISSOURI-COLUMBIA
Mechanical and Aerospace Engineering

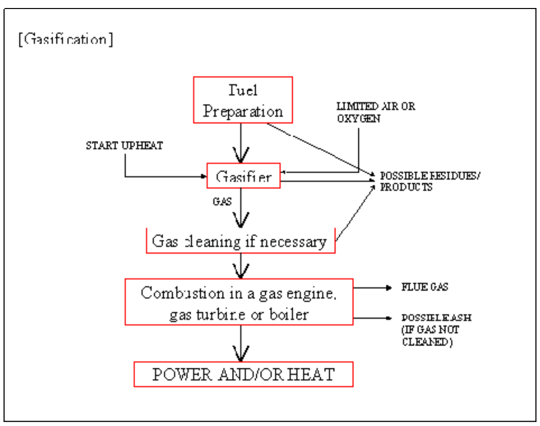
*Personal Biomass Gasification Chamber for Syngas Production*

# Introduction

- Motivation
  - Rising energy prices
  - Increased possibility for recycling waste
  - Reducing effects of global warming
  - Market for small gasifiers



# Basic Technology




$$C + \frac{1}{2}O_2 \rightarrow CO$$

UNIVERSITY OF MISSOURI-COLUMBIA
Mechanical and Aerospace Engineering

*Personal Biomass Gasification Chamber for Syngas Production*

# Existing Gasifiers

Crorey Biomass Gasifier

Biomax 15

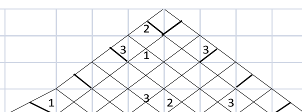
Tom's WoodGas Stove

Biomass CHP Plant

UNIVERSITY OF MISSOURI-COLUMBIA
**Mechanical and Aerospace Engineering**

***Personal Biomass Gasification Chamber for Syngas Production***

# QFD

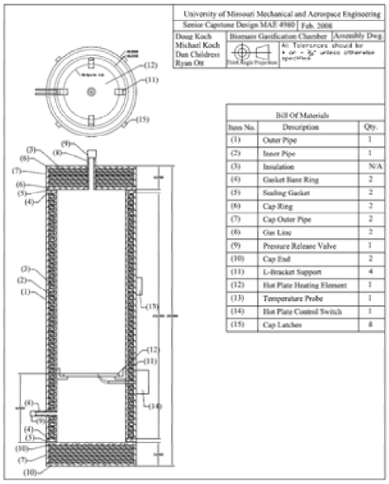


| Functional Performance | User | Manufacturer | Marketing | Maintenance | Cost ($) | Size (m^3) | Capturable Gas Output (KJ/s) | Heat Loss (%) | Efficiency (%) | # Of System Components | Degree of Manufacturing Difficulty (1-10) | Working Pressure (KPa) | Tom's Woodgas Stove | Biomax 15 | Crorey Biomass Gasifier |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sales Price | 6 | 1 | 8 | 1 | 5 | 1 | | | | 2 | 2 | | 7 | 4 | 2 |
| Capturable Syngas Output | 8 | 4 | 7 | 2 | | 3 | 5 | | 4 | | | 1 | 1 | 8 | 8 |
| Physical size | 4 | 5 | 5 | 5 | 1 | 5 | | | | | | | 8 | 2 | 7 |
| Insulation | 2 | 2 | 1 | 6 | | | | 5 | 1 | | | | 2 | 5 | 1 |
| Simplicity | 3 | 6 | 4 | 7 | 1 | 1 | | | | 4 | | | 5 | 1 | 6 |
| Safety | 7 | 7 | 6 | 8 | | | | 3 | | | | 5 | 6 | 6 | 5 |
| Gasification Efficiency | 5 | 3 | 3 | 4 | | | 4 | 1 | 5 | | | 1 | 3 | 7 | 3 |
| Manufacturability | 1 | 8 | 2 | 3 | 1 | 1 | | | | 4 | 5 | | 4 | 3 | 4 |
| Tom's Woodgas Stove | | | | | 55 | 0.004 | 0 | 100 | 40 | 1 | 1 | 0 | | | |
| Biomax 15 | | | | | 27,000 | (50) | 50 | 10 | 55-75 | 10 | 10 | 137 | | | |
| Crorey Biomass Gasifier | | | | | (50,000) | 15 | 150 | 20 | 65 | 7 | 8 | 0 | | | |
| Target | | | | | 800 | 1 | 2 | 15 | 60-70 | 2 | 3 | 70 | | | |

UNIVERSITY OF MISSOURI-COLUMBIA
**Mechanical and Aerospace Engineering**

***Personal Biomass Gasification Chamber for Syngas Production***

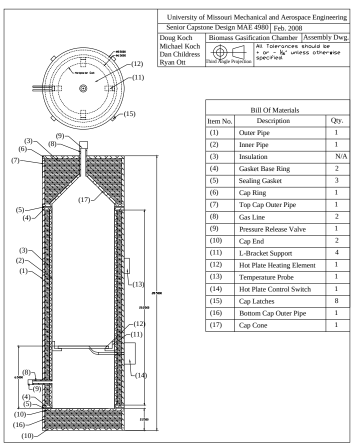
# Concept Generation

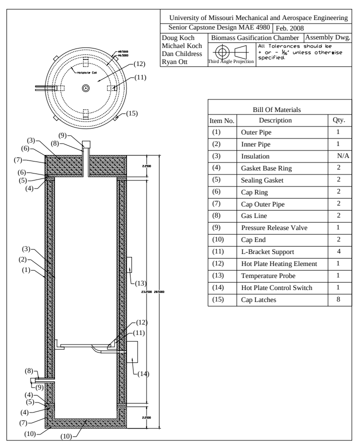



UNIVERSITY OF MISSOURI-COLUMBIA
**Mechanical and Aerospace Engineering**

***Personal Biomass Gasification Chamber for Syngas Production***

# Concept Generation




UNIVERSITY OF MISSOURI-COLUMBIA
**Mechanical and Aerospace Engineering**

***Personal Biomass Gasification Chamber for Syngas Production***

# Concept Generation

Decision Matrix

| Criteria | Importance | Cone Design 1 | Alternatives CAD version Design 2 | Resevior Design 3 |
|---|---|---|---|---|
| Price | 5 | - | | + |
| Capturable Syngas | 6 | + | | = |
| Physical size | 2 | = | | + |
| Insulation | 1 | = | | = |
| Simplicity | 3 | - | | - |
| Safety | 7 | = | | - |
| Manufacturability | 4 | - | | - |
| | Total Plus | 1 | | 2 |
| | Total Minus | 3 | | 3 |
| | Overall Total | -2 | | -1 |
| | **Weighted Total** | **-6** | **0** | **-7** |

UNIVERSITY OF MISSOURI-COLUMBIA
Mechanical and Aerospace Engineering

*Personal Biomass Gasification*
*Chamber for Syngas Production*

# Cost Analysis

| Item | size | quantity | price | total |
|---|---|---|---|---|
| Hot plate | | 1 | 50 | $50.00 |
| Inner piping | | 3 | 38/ft | $114.00 |
| Insulation | | | 20 | $20.00 |
| Outer piping | | 3 | 53.34/ft | $160.02 |
| Pressure relief valve | | 1 | 250 | $250.00 |
| L-brackets | | 4 | 5 | $20.00 |
| Clamps | | 6 | 15 | $90.00 |
| Gasket | | 2 | 10 | $20.00 |
| Metal sheet | 12"x18" | 3 | 19.62/ft | $58.86 |
| Metal pipe | 1" | 1.5' | 10/ft | $15.00 |
| Total | | | | $797.88 |

UNIVERSITY OF MISSOURI-COLUMBIA
Mechanical and Aerospace Engineering

*Personal Biomass Gasification*
*Chamber for Syngas Production*

# Engineering Analysis

- Constraints
  - Price
  - Capturable Syngas Output
  - Physical Size
  - Simplicity
  - Safety
  - Manufacturability
  - Temperature (Hot Plate)

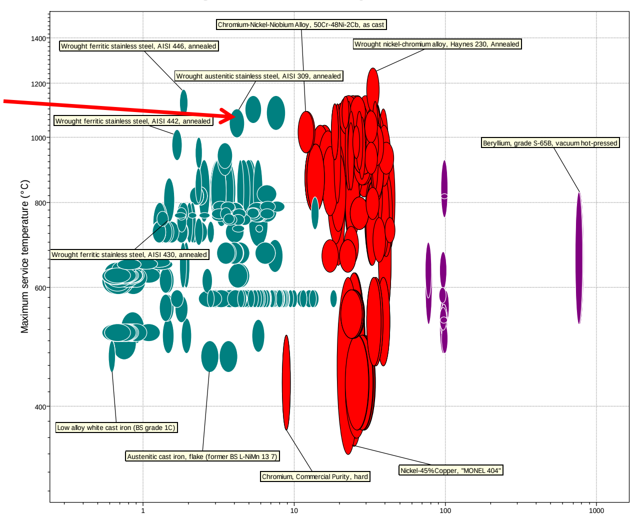
UNIVERSITY OF MISSOURI-COLUMBIA
Mechanical and Aerospace Engineering

***Personal Biomass Gasification Chamber for Syngas Production***

# Engineering Analysis

Material Selection

Wrought austenitic stainless steel, AISI 309, annealed

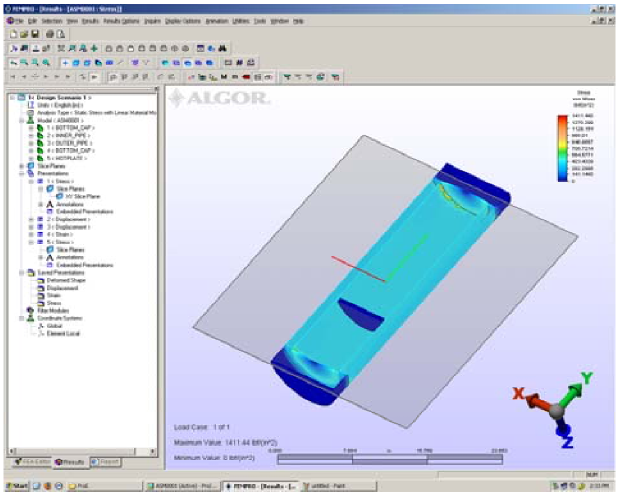



UNIVERSITY OF MISSOURI-COLUMBIA
Mechanical and Aerospace Engineering

***Personal Biomass Gasification Chamber for Syngas Production***

# Engineering Analysis

Stress Analysis

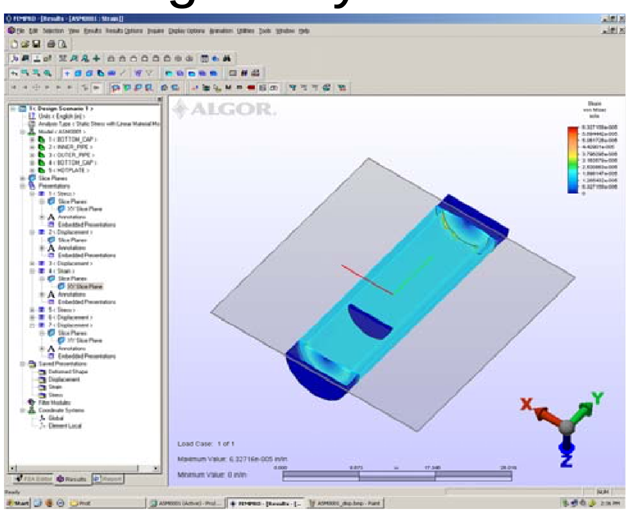



UNIVERSITY OF MISSOURI-COLUMBIA
Mechanical and Aerospace Engineering

***Personal Biomass Gasification Chamber for Syngas Production***

# Engineering Analysis

Strain Analysis

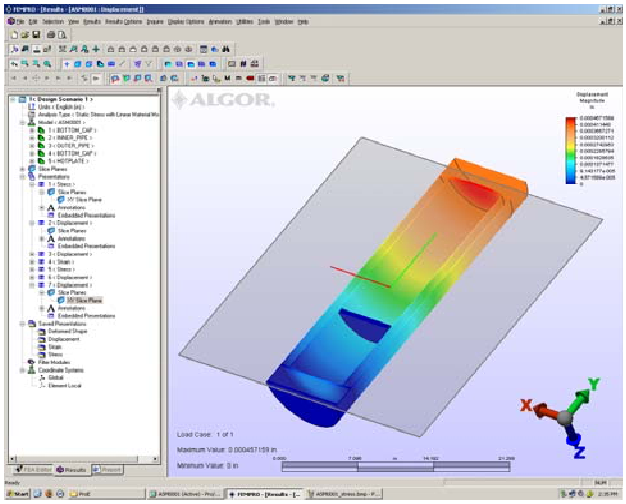



UNIVERSITY OF MISSOURI-COLUMBIA
Mechanical and Aerospace Engineering

***Personal Biomass Gasification Chamber for Syngas Production***

# Engineering Analysis

Displacement Analysis

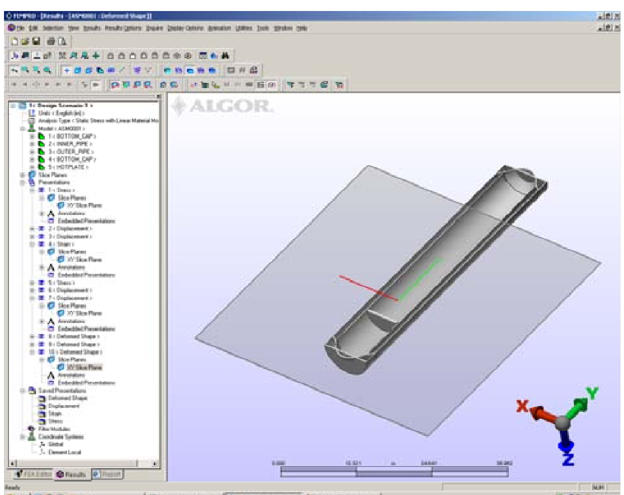



UNIVERSITY OF MISSOURI-COLUMBIA
**Mechanical and Aerospace Engineering**

***Personal Biomass Gasification Chamber for Syngas Production***

# Engineering Analysis

Deformation Analysis




UNIVERSITY OF MISSOURI-COLUMBIA
**Mechanical and Aerospace Engineering**

***Personal Biomass Gasification Chamber for Syngas Production***

# Prototype

UNIVERSITY OF MISSOURI-COLUMBIA
**Mechanical and Aerospace Engineering**

***Personal Biomass Gasification Chamber for Syngas Production***

# Prototype

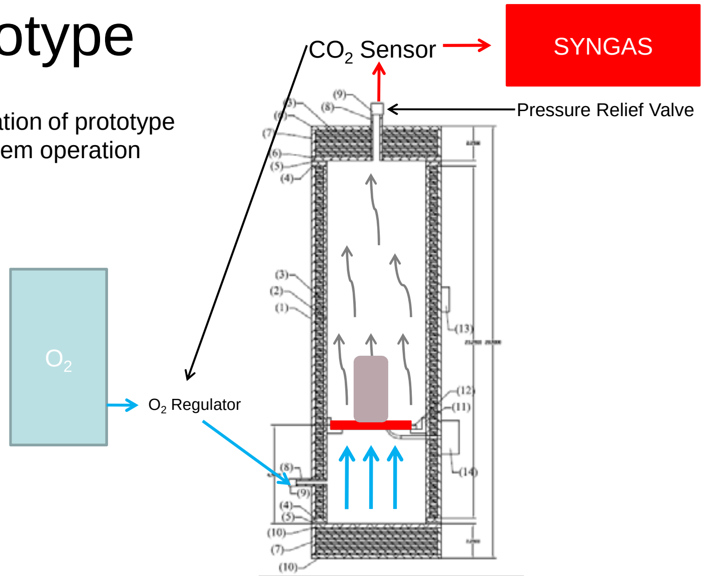
- Medium Carbon Steel
- Hotplate
- Green Fiber Insulation
- Head Gasket

UNIVERSITY OF MISSOURI-COLUMBIA
**Mechanical and Aerospace Engineering**

***Personal Biomass Gasification Chamber for Syngas Production***

# Prototype

Illustration of prototype
in system operation






# Safety

- Carbon Monoxide
- Heat
- Pressure
- Oxygen Control

# Conclusion

- Goals:
  - Design Small Scale Gasifier
  - Analyze Design
  - Create Working Prototype
  - Test

UNIVERSITY OF MISSOURI-COLUMBIA
Mechanical and Aerospace Engineering

*Personal Biomass Gasification Chamber for Syngas Production*

# Questions

UNIVERSITY OF MISSOURI-COLUMBIA
Mechanical and Aerospace Engineering

*Personal Biomass Gasification Chamber for Syngas Production*