Fabrication, Automation and Testing of Multi-Fuel Geyser Backup for Solar Water Heating System

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Declaration

We certify that this research work titled "*Fabrication, Automation and Testing of Multi-Fuel Geyser Backup for Solar Water Heating System"* is our own work. The work has not been presented elsewhere for assessment. The material that has been used from other sources it has been properly acknowledged / referred.

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Language Correctness Certificate

This thesis has been read by an English expert and is free of typing, syntax, semantic, grammatical and spelling mistakes. Thesis is also according to the format given by the university.

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Copyright Statement

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Table of Contents

List of Figures

List of Tables

Abstract

Since solar energy is an intermittent source and hot water requirements are round the clock for a house-hold in a cold climate. The need for a back-up system arises that can solve this problem and another problem that arises i.e. what fuel to be used for the back-up heating system? How to ensure that that fuel will be available always in that particular location? To answer this question a furnace had been developed that can be run on multi-fuels by the students from the 2009 Batch. We improved the efficiency of the furnace by reducing the losses through its walls. A residential solar hot water system along with alternate back-up furnace has been developed for developing countries. This system will be installed into existing water plumbing and provide approximately 100 liters of 40°C water for early morning bathing. We have automated the combustion control system for Natural Gas, Coal and Biomass (wood chips).The system is constructed using local materials and labor to minimize cost and maximize the impact.

To begin with the previous design was tested using coal and wood and then losses were calculated. Pro-engineer was used to modify the existing design of the furnace and suggest improved design. Bill of materials provided an estimate for the product. After the manufacturing of the furnace the combustion control for coal and biomass was implemented using Microcontroller interface. Energy consumed using various fuels for Temperature rise up to 60°C was Calculated and measured. Cost analysis was performed to calculate cost of each fuel was found out. It was concluded from the results that the most economical fuel would be dry wood. However, results differ by the atmospheric conditions in which testing is performed and also on the moisture and other issues related to the wood. Efficiency of furnace was calculated considering each fuel.

1. Introduction

1.1 Problem Statement

Obtaining hot water is energy intensive. In developing nations, heating water for bathing and cooking is often the quite expensive and time-consuming process in the household energy budget. Solar hot water systems could present a sustainable solution for poor households if the upfront prices of these systems were competitive with current methods.

Since solar energy is an intermittent source, there is no solar energy available on foggy days and nights and hot water requirements are round the clock for a house-hold in a cold climate the need for a back-up system arises that can solve this problem and another problem that arises i.e. what fuel to be used for the back-up heating system? How to ensure that that fuel will be available always in that particular location? For Example Natural gas is not always available in northern areas of Pakistan nor is sunlight. How a house of five to eight residents meets its hot water needs?

Heating water dominates the energy needs of households worldwide. For households in developing nations, heating water is often the most energy intensive process, and therefore the most expensive or time-intensive. In communities throughout the developing world, poor households struggle to meet their hot water needs. Some households rely on biomass to heat water. In many countries demand for fuel wood is one of the principal contributors to deforestation. Others rely on electricity or liquid fuels such as propane to heat their water.

Many communities face limited or intermittent access to fuel and/or electricity, limiting their ability to access hot water for hygiene and domestic uses.

There has been no research or any work on such a water heater that is versatile and as cheap as current methods. Clearly attention is needed on this issue and a team of dedicated researchers and engineers can come up with a feasible solution to this problem.

1.2 Objectives

Our objective is to create an improved and efficient (as compared to the previous design) back-up heating system that can solve the problem of intermittency and of the unavailability of natural gas i.e. a hybrid back-up for a solar water heater system. We are also supposed to design a combustion control system for the combustion of Coal and Biomass. Then based on the Economic analysis of various fuels conclude the cheapest fuel.

1.3 Proposed Solution

A previously fabricated design of furnace and attached water tank was available to us we were supposed to improve the efficiency of the furnace. So for this purpose first of all testing was performed on the previous design and then it was concluded that majority of losses through the furnace are due to very large area of walls. As the area of walls was significantly large so the conduction heat losses were very large. To counter this problem we suggested to reduce the area of walls and hence reduce the conduction heat losses.

Furnace will have a sliding grate to burn wood that can be pulled out to replace wood or a sliding tray to remove ash from the bottom of the furnace. Natural gas burners placed in the combustion chamber to heat up the water tank. These burners will be supplied gas by the gas mains or a cylinder attached to them. That is joined to the solar water tank and supposedly fitted into the mains water supply of the house hold. The combustion unit will be located at the bottom whilst surrounded by the body and above the burners will be a stainless steel water tank approximately 100 liters. This water tank will be covered by insulation that is polyurethane.

The furnace will also have a combustion control system for coal and wood burning. We will use this combustion control system to regulate the temperature of water inside the water tank i.e. maintain water temperature between two constant values.

Size of the water tank in the furnace will be according to the tank of the solar water heater joined to the heater. There will be thermal sensors installed in the solar water heater after the water reaches a certain temperature the air vent will be shut in order to kill the combustion. The nozzle arrangement will be as to maximize the heat transfer to the tank. A big door is in the furnace and that helps in easy maintenance of the tank i.e. inspection of insulation and the burners and also for cleaning purposes. Other sensors include the water level and pressure measurement. An air vent will be designed in the body to control the flow of air through the furnace. Materials for the grate and the furnace will be as to maximize the life and feasibility of the furnace. Local market will be consulted to purchase these products or buy the materials required. Machining of any kind will take place in the SMME workshop and if it is not possible here then some external vendor will be contacted. If possible exhaust emission control system will also be implemented to control the SOx and CO emissions.

2. Literature Review

2.1 Furnace Types and Fuels

We can distinguish several types of furnaces: central and ductless; gas, electric and oil furnaces; multi-stage and single-stage furnaces; low-, mid- and high-efficient furnaces. This page will briefly overview and highlight a few helpful hints on each type of furnace.1

2.1.1 Central Gas Furnaces

That's the most common type of furnaces in the market. Top new gas furnaces are multi-stage and speed variable units, with air-sealed combustion. They are safer, and provide more comfort and energy savings than low and mid-efficiency models.

There are however improved versions of older gas furnaces – what we can call mid-energy-efficient furnaces.

New top furnaces are of condensing type (they recapture and reuse the water vapor and the combustion gases) and have an energy efficiency – AFUE - above 90%: they convert more than 90% of the fuel they burn into heat, contrary to mid-efficiency furnaces and low-efficiency furnaces (with an AFUE below 80%).

When buying, prefer a top 90%+ furnace. In homes with high heating loads, it's not difficult to recover the higher initial investment in energy savings.

2.1.2 Oil Furnaces

New oil furnaces can also be fairly efficient and relatively clean and safe. There are now oil furnaces mimicking close-sealed combustion high efficient gas furnaces, able to provide high levels of efficiency.

2.1.3 Electric Furnaces

Electric heating is typically expensive, and traditional electrical furnaces are big energy hogs. Manufacturers are now offering new electric heat pump

[1] (http://www.houseenergy.com/Furnaces/EfficiencyFurnaces.html, 2013)

"furnaces": these furnaces have electric resistance elements, but in their core they are air-source heat pumps (they use the air conditioners technology in reverse). This type of new "furnaces" can be a good choice for climates without long periods of freezing temperatures.

2.1.4 Pellet Furnaces

Pellet furnaces have little in common with traditional Midwest wood furnaces. The best units are sophisticated equipment, mimicking many of the features of the best gas furnaces. They are relatively easy to maintain and to use, and have a low carbon footprint, if we consider that their fuel is largely made from recycled wood wastes.

But the best models are a lot more expensive than gas furnaces, and they aren't as sophisticated and flexible and cost competitive as top gas furnaces.

2.1.5 Ductless Furnaces

Ductless direct-vent furnaces are a great option for homes in moderate climates, or homes with high levels of air sealing and insulation, or for heating hard-to-heat areas like basements, bonus rooms, carriage houses or in-law suites.

The installation of this type of furnace is easy, since the venting only requires a 3" wall hole.

2.2 Combustion Chemistry

2.2.1 Coal Combustion

2.2.1.1 Coal Classification

[2]Coal is classified into three major types namely anthracite, bituminous, and lignite. However there is no clear demarcation between them and coal is also further classified as semi- anthracite, semi-bituminous, and sub-bituminous. Anthracite is the oldest coal from geological perspective. It is a hard coal composed mainly of carbon with little volatile content and practically no moisture. Lignite is the youngest coal from geological perspective. It is a soft coal composed mainly of volatile matter and moisture content with low fixed carbon. Fixed carbon refers to carbon in its free state, not combined with other

[2] (www.enercon.gov.pk/images/pdf/2ch1.pdf, 2010)

elements. Volatile matter refers to those combustible constituents of coal that vaporize when coal is heated.

The common coals used in Pakistan and India are bituminous and sub-bituminous coal. The gradation of Indian coal based on its calorific value is as follows:

Grade	Calorific Value Range (in kCal/kg)
A	Exceeding 6200
B	5600 – 6200
C	4940 – 5600
D	4200 – 4940
E	3360 – 4200
F	2400 – 3360
G	1300 – 2400

Table 1 Range of Calorific Values for Different type of Indian Coal

Normally D,E and F coal grades are available to Indian Industry. The chemical composition of coal has a strong influence on its combustibility. The properties of coal are broadly classified as

1. Physical properties

2. Chemical properties

2.2.1.2 Physical Properties

Heating Value:

The heating value of coal varies from coal field to coal field. The typical GCVs for various coals are given in the table below:

Parameter	Lignite	Indian Coal	Indonesian Coal	South African Coal
GCV (kcal/kg)	4,500	4,000	5,500	6,000

Analysis of Coal:

There are two methods: ultimate analysis and proximate analysis. The ultimate analysis determines all coal component elements, solid or gaseous and the proximate analysis determines only the fixed carbon, volatile matter, moisture and ash percentages. The ultimate analysis is determined in a properly equipped laboratory by a skilled chemist, while proximate analysis can be determined with a simple apparatus. It may be noted that proximate has no connection with the word "approximate".

Measurement of Moisture
Determination of moisture is carried out by placing a sample of powdered raw coal of size 200-micron size in an uncovered crucible and it is placed in the oven kept at 108 °C along with the lid. Then the sample is cooled to room temperature and weighed again. The loss in weight represents moisture.

Measurement of Volatile Matter
Fresh sample of crushed coal is weighed, placed in a covered crucible, and heated in a furnace at 900 + 1500 °C. For the methodologies including that for carbon and ash, refer to IS 1350 part I: 1984, part III, IV. The sample is cooled and weighed. Loss of weight represents moisture and volatile matter. The remainder is coke (fixed carbon and ash).

Measurement of Carbon and Ash
The cover from the crucible used in the last test is removed and the crucible is heated over the Bunsen burner until all the carbon is burned. The residue is weighed, which is the incombustible ash. The difference in weight from the previous weighing is the fixed carbon. In actual practice Fixed Carbon or FC derived by subtracting from 100 the value of moisture, volatile matter and ash.

Proximate Analysis
Proximate analysis indicates the percentage by weight of the Fixed Carbon, Volatiles, Ash, and Moisture Content in coal. The amounts of fixed carbon and volatile combustible matter directly contribute to the heating value of coal. Fixed carbon acts as a main heat generator during burning. High volatile matter content indicates easy ignition of fuel. The ash content is important in the design of the furnace grate, combustion volume, pollution control equipment and ash handling systems of a furnace.

TYPICAL PROXIMATE ANALYSIS OF VARIOUS COALS (IN PERCENTAGE)			
Parameter	**Indian Coal**	**Indonesian Coal**	**South African Coal**
Moisture	5.98	9.43	8.5
Ash	38.63	13.99	17
Volatile matter	20.70	29.79	23.28
Fixed Carbon	34.69	46.79	51.22

Table 2 Proximate Analysis of Various Coals

a) Fixed carbon:

Fixed carbon is the solid fuel left in the furnace after volatile matter is distilled off. It consists mostly of carbon but also contains some hydrogen, oxygen, sulphur and nitrogen not driven off with the gases. Fixed carbon gives a rough estimate of heating value of coal

b) Volatile Matter:

Volatile matters are the methane, hydrocarbons, hydrogen and carbon monoxide, and incombustible gases like carbon dioxide and nitrogen found in coal. Thus the volatile matter is an index of the gaseous fuels present. Typical range of volatile matter is 20 to 35%.

Volatile Matter

- Proportionately increases flame length, and helps in easier ignition of coal.
- Sets minimum limit on the furnace height and volume.
- Influences secondary air requirement and distribution aspects.
- Influences secondary oil support

c) Ash Content:

Ash is an impurity that will not burn. Typical range is 5 to 40%.

Ash

- Reduces handling and burning capacity.
- Increases handling costs.
- Affects combustion efficiency and boiler efficiency

• Causes clinkering and slagging.

d) Moisture Content:

Moisture in coal must be transported, handled and stored. Since it replaces combustible matter, it decreases the heat content per kg of coal. Typical range is 0.5 to 10%

Moisture

• Increases heat loss, due to evaporation and superheating of vapour

• Helps, to a limit, in binding fines.

• Aids radiation heat transfer.

e) Sulphur Content:

Typical range is 0.5 to 0.8% normally.

Sulphur

• Affects clinkering and slagging tendencies

• Corrodes chimney and other equipment such as air heaters and economizers

• Limits exit flue gas temperature.

2.2.1.3 Chemical Properties

Ultimate Analysis:

The ultimate analysis indicates the various elemental chemical constituents such as Carbon, Hydrogen, Oxygen, Sulphur, etc. It is useful in determining the quantity of air required for combustion and the volume and composition of the combustion gases. This information is required for the calculation of flame temperature and the flue duct design etc. Typical ultimate analyses of various coals are given in the Table.

Typical Ultimate Analyses of Coals		
Parameter	**Indian Coal, %**	**Indonesian Coal, %**
Moisture	5.98	9.43
Mineral Matter (1.1 x Ash)	38.63	13.99
Carbon	41.11	58.96
Hydrogen	2.76	4.16
Nitrogen	1.22	1.02
Sulphur	0.41	0.56
Oxygen	9.89	11.88

Table 3 Ultimate Analysis of Different Coals

Combustion Equations:

Combustion Equations Combustion equation for coal:

$$C + O_2 \rightarrow CO_2$$

$$(12\ kg\ C) + (32\ kg\ O) \rightarrow (44\ kg\ CO_2)$$

Combustion equation for hydrogen:

$$2H_2 + O_2 \rightarrow 2H_2O$$

$$(2\ kg\ H) + (32\ kg\ O) \rightarrow (36\ kg\ H_2O)$$

Combustion equation for sulphur:

$$S + O_2 \rightarrow SO_2$$

$$(32\ kg\ C) + (32\ kg\ O) \rightarrow (64\ kg\ SO_2)$$

2.2.2 Wood Combustion

2.2.2.1 Types of Wood

Wood or Biomass is classified into following types:

Feedstock Type	Definitions	Resources
Sugars/Starches	Traditional agricultural crops suitable for fermentation using 1st generation technologies Some food processing residues are sugar and starch materials	•Agricultural crops (sugars/starches) •Food processing residues (w/residual sugars)
Lignocellulosic Biomass	Clean woody and herbaceous materials from a variety of sources Includes clean urban biomass that is generally collected separately from the municipal waste stream (wood from the urban forest, yard waste, used pallets)	•Agricultural residues •Cellulosic energy crops •Food processing residues •Forest residues, mill residues •Urban wood wastes •Yard wastes
Bio-oils	Traditional edible oil crops and waste oils suitable for conversion to biodiesel	•Agricultural crops (beans/oils) •Waste oils/fats/grease
Solid Wastes	Primarily lignocellulosic biomass, but that may be contaminated (e.g., C&D wood) or co-mingled with other biomass types	•Municipal solid waste (biomass component) •Construction & Demolition (C&D) wood •Food wastes •Non-recycled paper •Recycled materials
Other Wastes	Other biomass wastes that are generally separate from the solid waste stream Includes biogas and landfill gas	•Animal waste (farm) •Wastewater treatment biogas •Landfill gas

Figure 1 Biomass Classification

2.2.2.2 Sources of Woody Biomass

[3]Woody biomass is the solid portion of stems and branches from trees or residue products made from trees. Woody biomass can come from a variety of sources, including:

Non-timber tree removal – removing dead and dying trees, unwanted urban trees, or trees impeding land development.

Forest management harvesting – the removal of small diameter trees from overpopulated stands for wildfire hazard fuel reduction, pre-commercial thinning of timber stands, or forest health improvement.

[3] (ucanr.org/sites/woodybiomass)

Timber harvesting and logging residues – non-merchantable wood including branches, undersized trees, and non-commercial species removed during typical timber harvesting operations.

Sawmill and other wood manufacturing residues – includes bark, undersized and defective wood pieces (e.g. lumber edging and end trimming), sawdust, and other wood waste.

Landfill diversion – wood debris from tree removal and pruning, construction, demolition, discarded shipping materials (boxes, crates, pallets), and other trashed wood products.

Chaparral management – removal of excess woody shrubs and plants for wildfire fuel hazard reduction or other vegetation management goals.

Dedicated forests (plantations)—fast growing trees grown specifically for biomass markets.

2.2.2.3 Composition of woody Biomass

[4]Wood is composed primarily of cellulose, hemicellulose, lignin, and mineral elements.

Cellulose: Cellulose is the structural component of a green plant's cell walls. It is comprised of carbon, hydrogen, and oxygen in the form of starches, proteins, and sugars and is the most abundant organic material on earth. Cellulose makes up approximately 50% of woody biomass' dry weight. Cellulose from wood is isolated during the pulping process and processed to yield ethanol, cellophane, cardboard, paper, and cellulose ethers such as acetate, rayon, and nitrates.

Hemicellulose: Hemicellulose is another component of a green plant's cell walls. Unlike cellulose, which contains only one sugar (glucose), hemicellulose can include a number of sugar monomers (xylose, hexose, mannose, and galactose, for example). Hemicellulose makes up 25 to 35% of the dry weight of woody biomass.

Lignin: Lignin is a polymer (or glue-like substance) that holds cellulose and hemicellulose together. It makes up approximately 15 to 25 percent of the dry

[4] (Ohta K, 1993)

weight of woody biomass and is what can make the biochemical conversion of woody biomass difficult. Lignin has not yet been used as a raw material for industrial purposes in large quantities.

Mineral Elements: Woody biomass is composed of many elements. Principal elements include carbon, oxygen, and hydrogen. Woody biomass is also composed of mineral elements such as nitrogen, sulfur, chlorine and heavy metals and while these elements do not produce energy during combustion, they do affect the energy content of different types of woody biomass. On average, hardwoods have a higher concentration of mineral elements than softwoods. However, the presence of mineral elements in woody biomass is more dependent on the site where the particular species of tree is grown rather than the particular species itself.

- **Nitrogen** is a component of all fuel systems. During the combustion process, it is oxidized into nitrogen oxide (NOx). When emitted from combustion facilities at relatively low levels, NOx may have a useful fertilizing effect on forests. However, as emission levels increase, NOx produces adverse health effects and increases the acidification of water and soils.
- **Sulfur** emissions from combustion of fuels cause extensive damage to ecosystems and buildings, so fossil fuels are often graded by the amount of sulfur present. As with nitrogen, sulfur is oxidized during combustion to form sulfur oxide (SOx). This compound can have serious environmental effects and causes the acidification of soils and water.
- Most **chlorine** in trees is found in the foliage as an essential component in chlorophyll. Although only present in trace amounts, its ability to form alkali compounds with potassium and sodium, resulting in oxidation and corrosion, can create serious problems for boiler equipment during combustion2. Eliminating foliage from woody biomass feedstocks can reduce corrosion problems, as can co-firing biomass resources with higher sulfur content fuels such as peat or coal.
- **Heavy metals** tend to vaporize during combustion. The remainder contributes to ash formation. Should levels of heavy metals be high, recycling of ash as fertilizer is restricted by environmental legislation, since the metals may leach into groundwater or be absorbed by crops.

Element	Share, % of dry matter weight
Carbon	45-50% (solid 11-15%, volatile 35%)
Hydrogen	6.0-6.5%
Oxygen	38-42%
Nitrogen	0.1-0.5%
Sulphur	max 0.05

Table 4 Average Chemical Contents of Woody Fuels

Moisture Content

[5]The moisture content of biomass material varies greatly and plays a large role in determining the most suitable energy conversion process. Wet conversion processes such as fermentation are often more suited to biomass with a higher moisture content (e.g. corn, sugarcane, barley straw). Dry conversion processes such as pyrolysis, gasification, and combustion are more suited to biomass with a lower moisture content (e.g. wheat straw, pine, switchgrass etc.). Generally, wet conversion processes are used when the moisture content of the biomass requires excessive energy for drying, compared to the energy content of the end product.

Energy yields are often expressed as net caloric values. These values increase as wood moisture content is reduced.

The moisture content in wood depends on a combination of climatic conditions, time of year when harvesting takes place, and the duration and method of storage. These simple formulas can calculate the moisture content of woody biomass:

$$A = total\ weight\ of\ wet\ wood$$

$$\mathrm{B} = oven\ dry\ weight\ of\ wood$$

$$Moisture\ Content(wet\ basis) = ((A - \mathrm{B})/\mathrm{A})\ \times 100$$

$$Moisture\ Content(dry\ basis) = ((A - \mathrm{B})/\mathrm{B})\ \times 100$$

[5] (Wright LL, 1996)

2.2.2.4 Reactions controlling Wood Combustion

Wood combustion is a two stage reaction and first step is highly endothermic while energy is released in the second step. The amount of energy which is released depends upon type of wood, moisture content etc. However the typical reaction which governs the combustion of wood is as under:

[6] $$6C_{10}H_{15}O_7 + Heat \rightarrow C_{50}H_{10}O + 10CH_2O$$

$$CH_2O + O_2 \rightarrow H_2O + CO_2 + CO + C + N_2$$

2.2.2.5 Heating Values

[7]

Fuel	Net Calorific Value (CV) by mass GJ/tonne	Net Calorific Value (CV) by mass kWh/kg
Wood chips (30% MC)	12.5	3.5
Log wood (stacked - air dry: 20% MC)	14.7	4.1
Wood (solid - oven dry)	19	5.3
Wood pellets	17	4.8

Table 5 Heating Value Comparison for different types of Wood

[8]2.3 SOLAR WATER HEATING DESIGNS

New solar hot water systems, for cold climates, have relatively complex designs to avoid freezing and to provide a higher efficiency.

2.3.1 Five Main Designs

Solar hot water heaters range from the very simple (for hot and moderate climates) to the fairly complex (for colder climates):

- batch systems (an ultra-simple system for moderate climates);

- thermo siphon systems (moderate and hot climates);

[6] (http://science.howstuffworks.com/environmental/earth/geophysics/fire1.htm, n.d.)
[7] (http://www.biomassenergycentre.org.uk/portal/page?_pageid=75,20041&_dad=portal&_schema=PORTAL, n.d.)
[8] (Talha, Usman, & Taimoor, 2013)

- drain-back systems and glycol and other closed loop systems for cold climates

2.3.2 Batch Solar System Design

The batch system (or ICS) is the simplest and the most direct heirs of the first solar water heaters.

It hasn't pumps, separated storage tanks or anti-freezing.[9]

It combines a solar panel and a storage tank into one single unit, and in its most simple version is a mere water tank within a glazed box.

2.3.3 The Thermo-siphon System

Thermo-siphon solar systems are simple, very efficient and very popular in moderate and hot climates.

They are cheap and do not include pumps or special controls; they can be installed in colder climates when equipped with small circulating pumps (to move water and to prevent it from freezing). That's a simple design.

2.3.4 DRAINBACK SOLAR WATER HEATERS

There are different types of solar water heaters for cold climates. This page covers the drain-back system, a design recommended for its relatively simplicity and long lifespan.

Typical drain-back water heater systems comprise of:

1) Solar panels
2) Controller
3) Pump
4) A large storage tank (say, 80 gallon);
5) A small drain-back reservoir tank (say, 10 gallon/38 liters);
6) A heat exchanger (usually internal to one of the tanks) and sensors and other minor accessories.

Modern drain-back systems use tube panels and distilled water or a glycol anti-freezing mixture as the heating fluid.

2.3.5 How Drain back Systems Works

The differential controller starts the pump (or pumps) and routes the distilled water into the system.

The process begins whenever the sensors attached to the collector detect useful sunlight available (which happens when the temperature in the solar panels is higher than the temperature of the water at the bottom of the storage tank).

[9] (http://www.house-energy.com/The%20best-of/The-Best-of-WaterHeaters.html, n.d.)

The system routes the distilled water from the reservoir tank to the solar panel on the roof and back, in a continuous loop. As the distilled water passes through the solar collector, it heats up, and once in the drainback reservoir tank (or in the storage tank, depending on the designs) it passes its heat to the potable water – usually through a heat-exchanger linked to the tank.
Pumps will continue circulating the water through the system as long the controller detects useful solar heat.
The on-off cycle of the pumps continues throughout the day, with the controller stopping the pumps at night and periods without useful solar heat.
When the system is not pumping, the distilled water/anti-freezing mixture drops into the drain-back tank, usually located just above the solar storage tank.

2.3.6 Design and Storage Tank Location

The drain-back design rests largely on the gravity-fed principle (that's why the system is technically called unpressurized). The draining of the fluid into the drain-back reservoir is based on that principle, which requires the collector to be located higher than the storage tank. The figure shows a typical Solar Hot Water System.

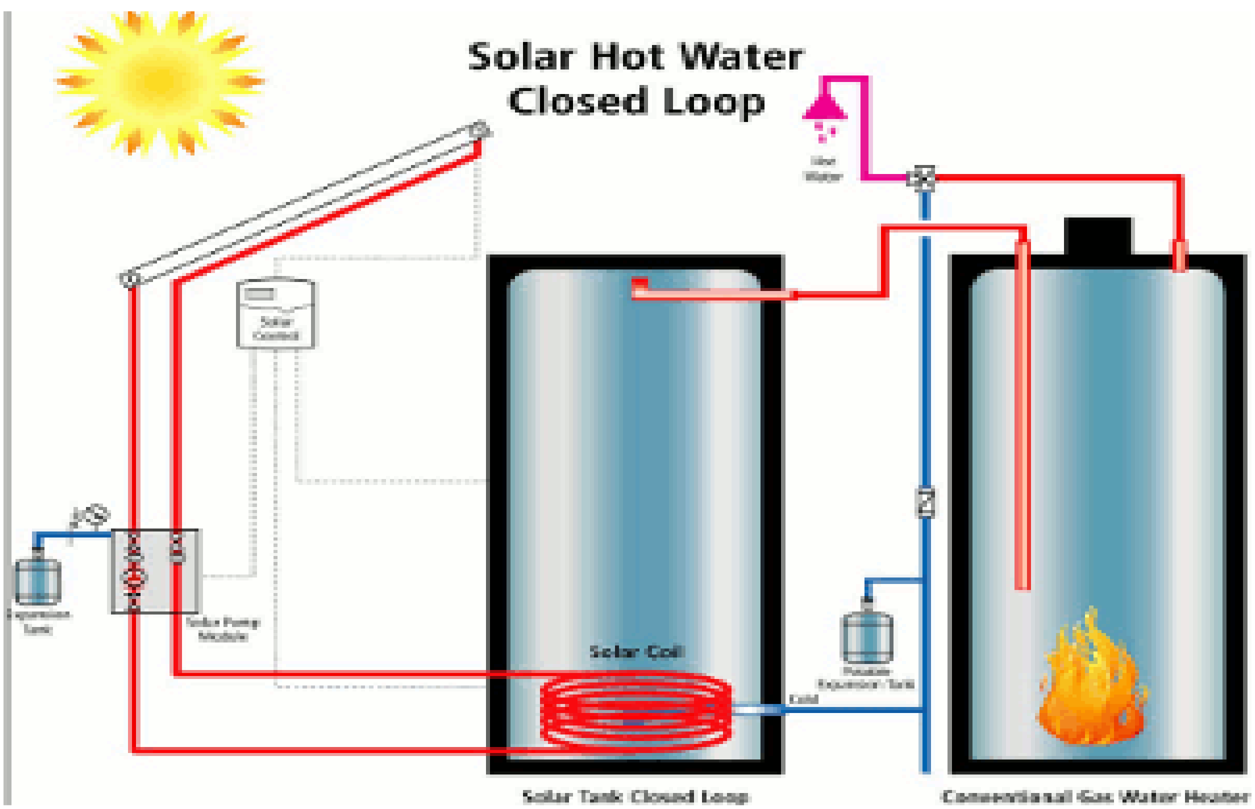


Figure 2 Solar Hot water Closed Loop

Unless the system involves a second pump to route the distilled water between the two tanks, the drain-back reservoir should also be located well above the storage tank, eventually in the attic (a solution that requires the use of glycol, in attics prone to seasonal extreme temperatures).

2.3.7 Advantages: Reliability and Energy Efficient

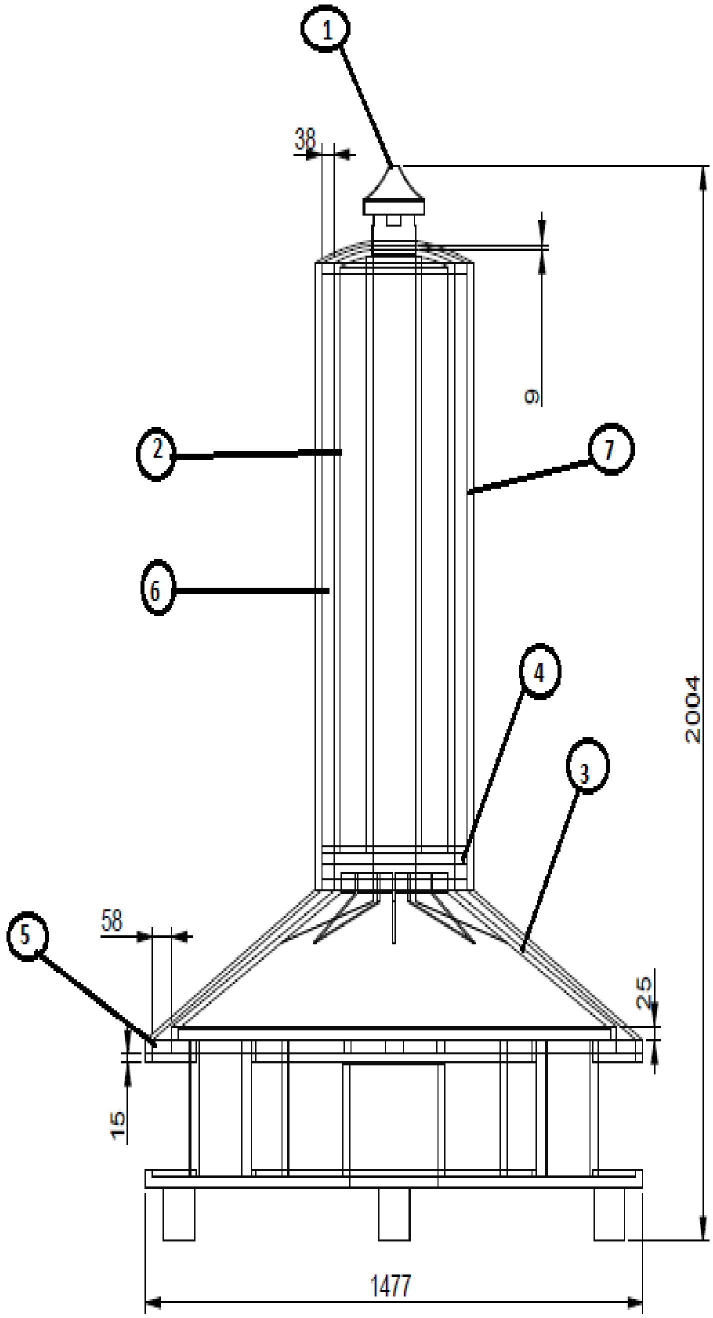
Drain-back systems are energy-efficient and reliable; and they require very little maintenance. The heating fluid (distilled water) rarely has to be changed.
The SRCC (Solar Rating and Certification Corporation: a certification entity that sets solar equipment standards for the solar industry), recommends these systems for cold climates due to their simplicity and long life.
Their lifespan and reliability are largely explained by the use of gravity and water instead of pressure mechanisms and glycol. The system has less moving components (valves, air vents etc) than pressurized anti-freezing systems, and is immune to pump fails and damages.
A possible downside of drainback solar water heaters is that they require large or relatively large pumps, especially in designs in homes with two or more stories.

2.3.8 Glycol and Other Closed Loop Systems

Old climates require more complex solar water heaters. Batch systems are clearly inadequate in freezing conditions, and the thermo siphon design can be too simple.
One of the most popular systems for freezing climates - the closed loop systems - comprises an anti-freezing fluid (glycol, usually), a differential controller, a storage tank, a heat exchanger, sensors and valves. That's a much more complex design than those mentioned earlier.

3. A brief review of Previous Design

3.1 Drawings and CAD Model



Sr	NAME	Drawing no.	Material
1	Chimney	01	
2	Water Tank	02	
3	Water Tank Fro	03	
4	Support Ring	04	
5	Frock Support	05	
6	Insulation	06	
7	Outer Body	07	

1	Name	FURNACE Top
2	Drawing no.	F_1-1
3	Materials	Various

Figure 3 Drawing of Previous Model

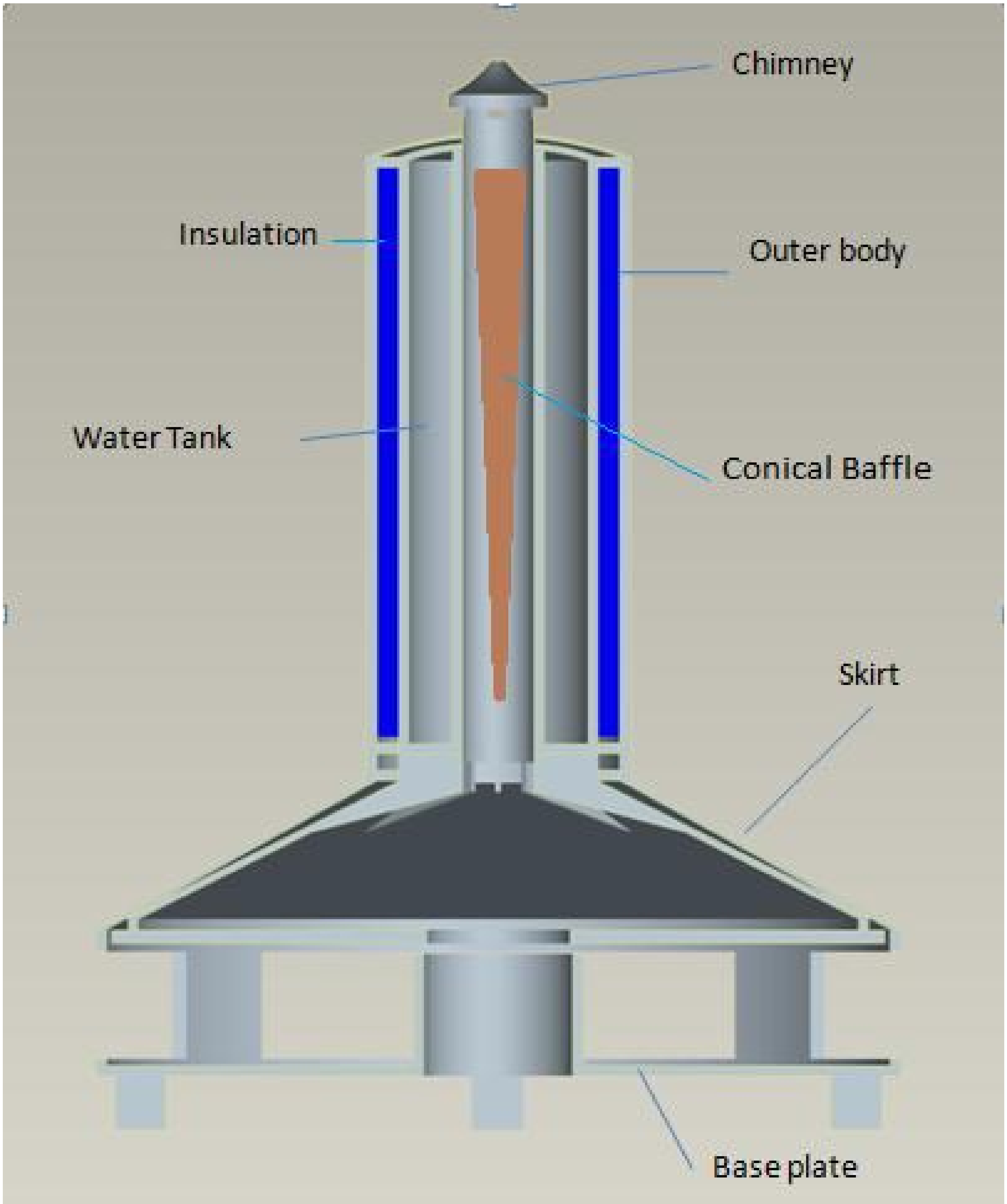


Figure 4 CAD Model of Previous Design

Figure 5 Previously Fabricated Model

3.2 Issues with Previous Model

3.2.1 Heat Losses

The surface area of previously fabricated Furnace was kept very large to account for combustion of any fuel but this increased area was contributing significantly towards the heat losses from the furnace. It also increased the idle time of the furnace.

3.2.1.1 Thermal Losses calculation

We used the method of Thermal Resistance network to find the heat Losses through previous design. We used K type thermocouple to determine the mean average Temperature on the inside of the furnace. Using this information total amount of heat lost through the furnace per unit time was determined. Following is the resistance Network

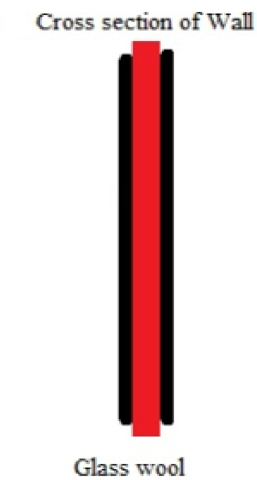


Figure 6 Cross Section of the wall of furnace

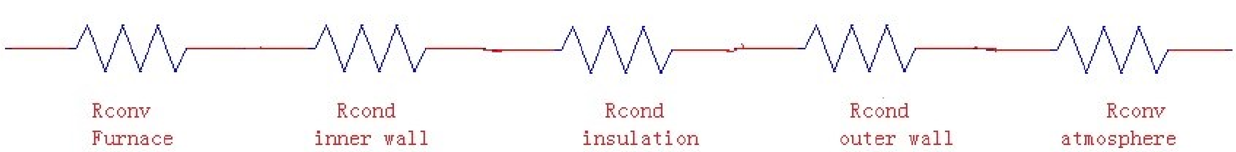


Figure 7 Complete Resistance Network for heat transfer through the Furnace walls

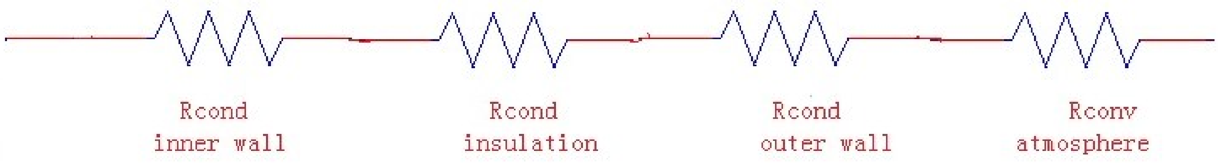


Figure 8 Simplified Resistance Network for heat transfer through the Furnace Walls

The average Temperature inside wall of the furnace was determined to be 200°C and heat loss was calculated due to variation of the ambient Temperature.

Following is the detailed Procedure followed to calculate the losses.

$$Q = (T_{inside} - T_{ambient})UA$$

$$U = Overall\ Heat\ Transfer\ Cofficient$$

$$UA = \frac{1}{R_t}$$

$$R_t = R_1 + R_2 + R_3 + R_4$$

$$R_1 = Conduction\ Resistance\ of\ inner\ wall = \frac{L}{k_{steel} \times A} = \frac{0.001214}{53.6 \times 0.9128} = 0.0000248\ (K/W)$$

$$R_2 = Conduction\ Resistance\ of\ insulation = \frac{L}{k_{insulation} \times A} = \frac{0.0186}{0.037 \times 0.9128} = 0.55037 (K/W)$$

$$R_3 = Conduction\ Resistance\ of\ outer\ wall = \frac{L}{k_{steel} \times A} = \frac{0.0005}{53.6 \times 0.9128} = 0.00038\ (K/W)$$

$$R_4 = Convection\ Resistance\ of\ outer\ wall = \frac{1}{h_{outer} \times A} = \frac{1}{h_{out} \times 0.9128} = \frac{1.0955}{h_{out}}\ (K/W)$$

[10]

$$h_{out} = 10.45 - v + 10\sqrt{v}$$

$$v = 2\ (m/s)$$

$$h_{out} = 22.59\ (W/m^2K)$$

$$R_4 = \frac{1.0955}{h_{out}} = \frac{1.0955}{22.59} = 0.04849\ (K/W)$$

$$R_t = R_1 + R_2 + R_3 + R_4$$

[10] (http://www.engineeringtoolbox.com/convective-heat-transfer-d_430.html, n.d.)

$$R_t = 0.5996\ (K/W)$$

At $T_{amb} = 24$℃

$$Q = \frac{4 \times (T_{inside} - T_{ambient})}{R_t}$$

$$Q = \frac{4 \times (200 - 24)}{0.5996}$$

$$Q = 1174\ (J/s)$$

3.2.2 Idle Time

Another issue with the previous furnace was that the fuel placing chamber was significantly low i.e. the distance between water tank and the fuel grate was very large.

3.2.3 Low Utilization

The fuel grate had a very large surface area and it could handle very large amount of solid fuel but due to the improper design of fuel grill only small part of this fuel got proper Oxygen supply for combustion. The remaining fuel remained unburnt due to lack of supply of Oxygen. Since the unburnt fuel was not directly below the Conical baffle so even when burning this fuel only contributed towards the heat losses through the walls.

3.2.4 Improper Insulation Thickness

In the previous design the insulation thickness was not constant throughout the body of furnace. The insulation thickness reduced as we moved downwards.

3.2.5 Structural Defects

The weight of the entire structure was supported by the inner metallic sheet which was in continuous state of creep.

There were numerous leakages in the furnace from where flue gases leaked and hence reduced the efficiency of the furnace.

3.2.6 Geometric Defects

In the previous design the burner of Natural gas was very high and almost inaccessible to a person igniting it.

3.3 Analysis of Previous Design

3.3.1 Efficiency Calculation

We performed testing on the previous design and found out its efficiency using coal and wood as fuel. The temperature of water was raised up to 60°C. Following were the results:

$$m_{coal} = mass\ of\ coal\ consumed \approx 5\ kg$$

$$Q_{fuel} = Amount\ of\ Fuel\ Energy\ used = m \times HV = 5 \times 16077 = 80385\ kJ$$

$$HV = Heating\ Value$$

$$Q_{water} = mC_p\Delta T = 100 \times 4.18 \times (60 - 24)$$

$$Q_{water} = 15048\ kJ$$

$$\eta = \frac{Q_{water}}{Q_{fuel}} = 18.71\ \%$$

3.3.2 Heat Loss Variation

We Calculated heat losses through the furnace and studied its variation against the ambient temperature. Following were the results:

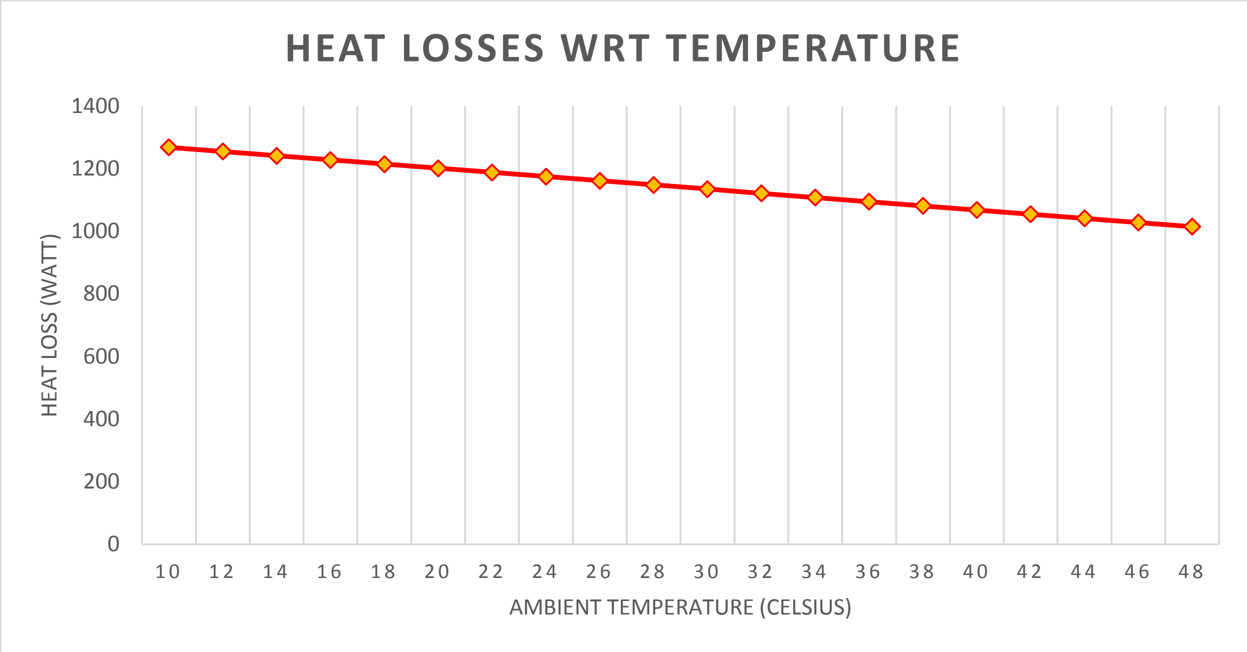


Figure 9 Heat Losses as a function of Ambient Temperature

4. Modified Design

4.1 Drawing and CAD Model

The main point kept in mind while modifying the previous design was to reduce the area through which heat losses are occurring. We optimized the dimensions of the furnace in order to achieve this objective.

Following is the drawing of the furnace

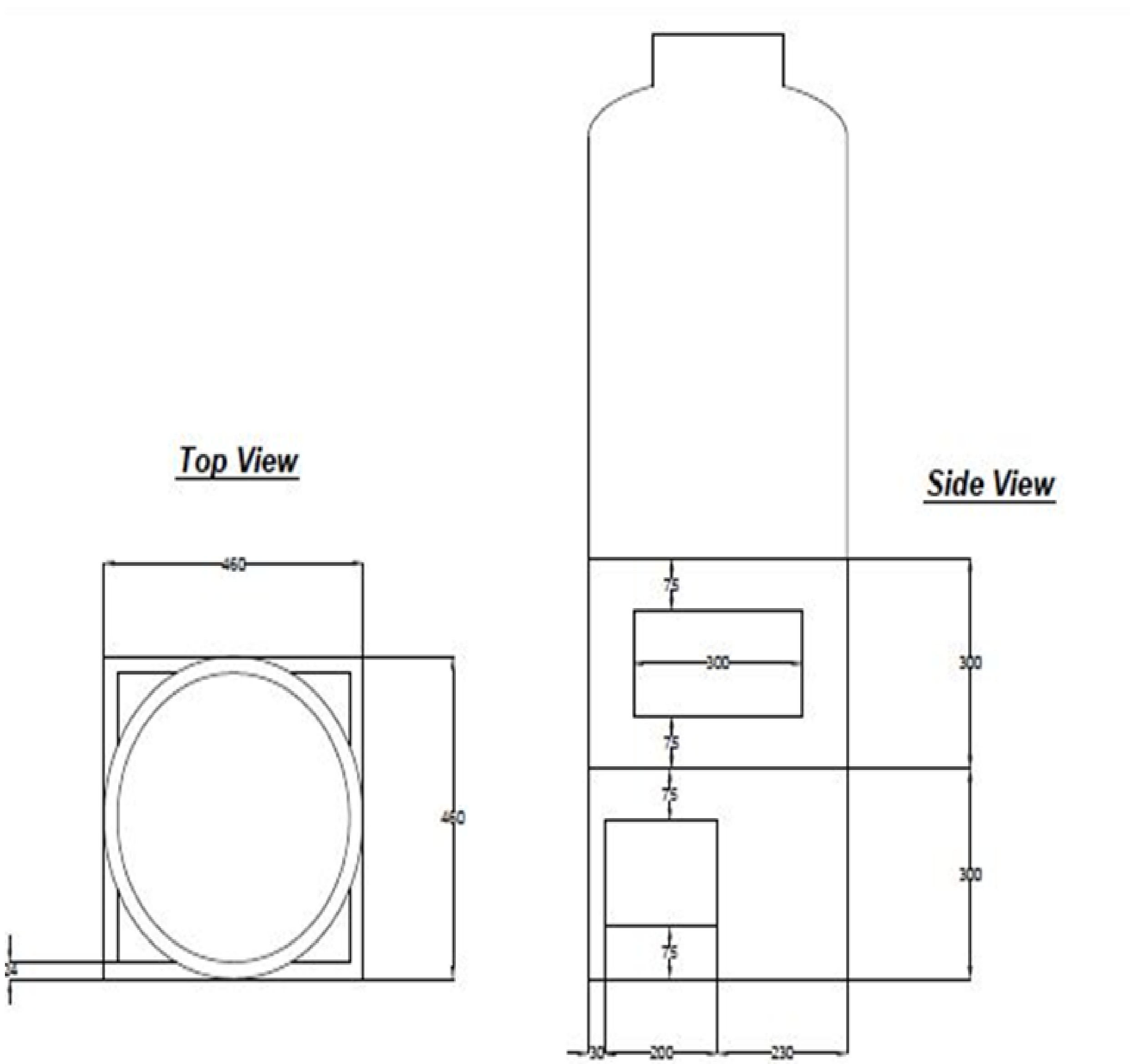


Figure 10 Drawing of the Furnace

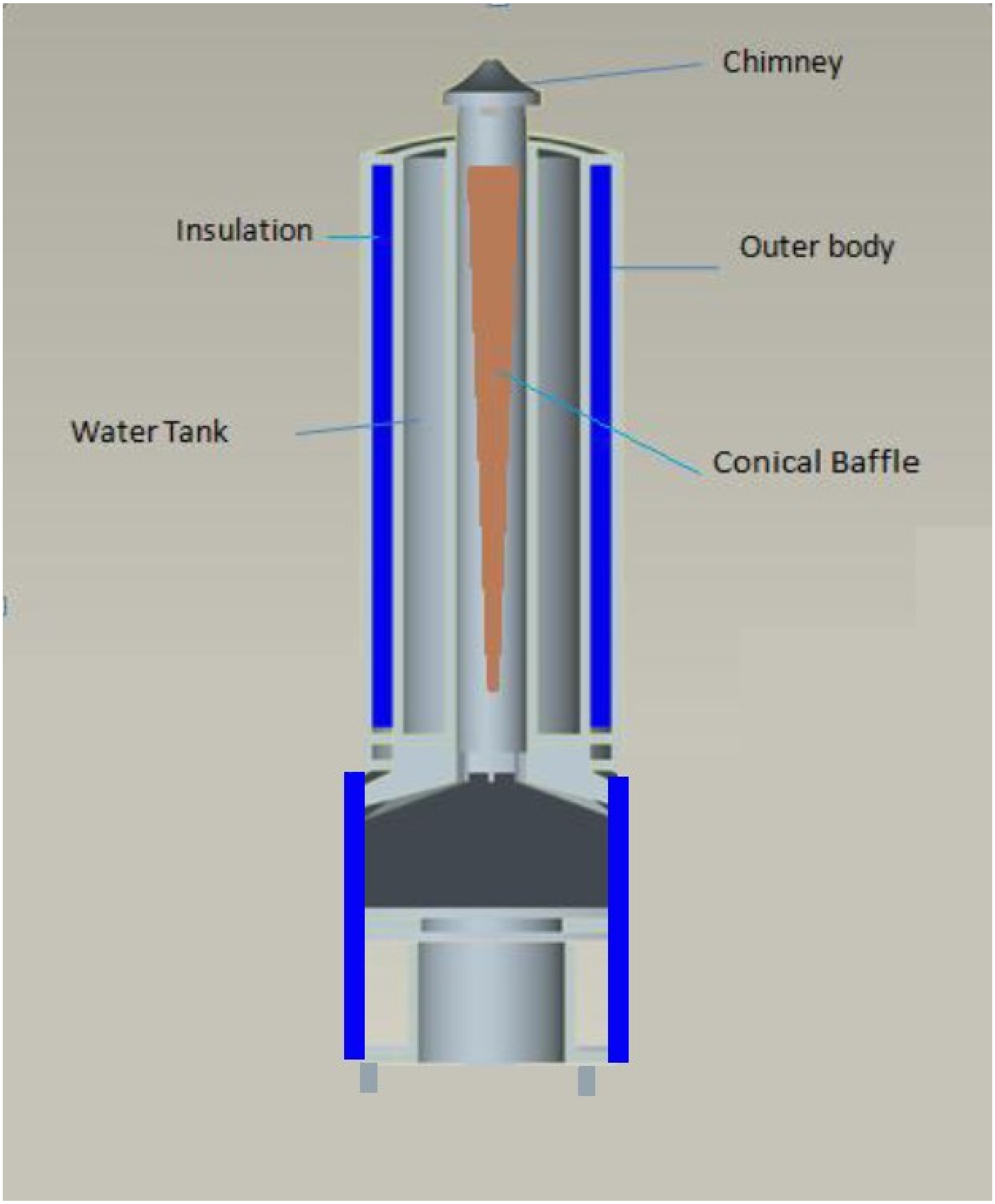


Figure 11 CAD Model

4.2 Fabrication of New Design

4.2.1 Materials

As soon as the design was finalized a bill of materials was prepared and cost for the project was estimated.

Following are the main materials that were used:

4.2.1.1 CGI Sheet

Commonly known as corrugated galvanized iron and commonly abbreviated CGI is a building material composed of sheets of hot-dip galvanized mild steel, cold-rolled to produce a linear corrugated pattern in them.

Galvanization is the process of producing a galvanized steel sheet usually involves nothing more than dipping that sheet into very hot zinc. After the steel is galvanized, the zinc coating will react with oxygen in order to create zinc oxide, which further reacts with water, producing zinc hydroxide. In time, zinc hydroxide will react with carbon dioxide and form zinc carbonate, a gray layer that helps slow the reaction rate of the zinc and helps to protect the steel.

Sheets of varying thickness were used measured according to the **Birmingham Wire Gauge**. The outer body of the furnace was of higher gauges because a smaller thickness was desired. The lowest BWG was 18, and it was used for inner wall of furnace. Other than that BWG 20 sheets were used for outer walls.

4.2.1.2 Stainless Steel Square Pipes

Stainless steel is a generic term for a family of corrosion resistant alloy steels containing 10.5% or more chromium. All stainless steels have a high resistance to corrosion. This resistance to attack is due to the naturally occurring chromium-rich oxide film formed on the surface of the steel. Although extremely thin, this invisible, inert film is tightly adherent to the metal and extremely protective in a wide range of corrosive media. The film is rapidly self-repairing in the presence of oxygen, and damage by abrasion, cutting or machining is quickly repaired. Stainless Steel Pipes with square cross section of *18 gauge and 18.75 x 18.75* cross-section were used to make the basic structure of the furnace.

4.2.1.3 MS Plate

Mild Steel is an Engineering Material and is commonly called MS. This Plate has been used to make the feet supports of the structure and also to make supports for the water tank to rest on the furnace. The water tank supports have been welded to the inner walls of furnace and take all the load of the water tank.

4.2.1.4 MS Angle Iron

Angle Iron has been used to make supports for the Vent Sliding System.

4.2.1.5 Glass Wool Insulation

[11]Polyurethane Glass wool is a the perfect source of insulation to be used in the furnace because it is light and thin, which allows more space as useful area by being easily wrapped around our product and it is very simple to use. Another superiority it has over other insulation types is that it is also moisture proof along with being a reliable thermal insulator. The thermal insulation consists of intertwined and flexible glass fibers, which causes it to "package" air, resulting in a low density that can be varied through compression and binder content. It can be a loose fill material, blown into attics, or, together with an active binder sprayed on the underside of structures, sheets and panels that can be used to insulate flat surfaces such as cavity wall insulation, ceiling tiles, curtain walls as well as ducting.

Glass wool Insulation has been used between inner and outer walls of the furnace.

4.2.2 Bill of Materials

As soon as the design of the furnace the materials to be used were finalized we were able to come up with the bill of materials that is a document that consists of the material needed to construct the furnace along with the dimension and the quantities.

4.2.3 Manufacturing Operations

4.2.3.1 Sheet Metal Work

[12]Sheet metal fabrication is a classification of manufacturing processes that shape a piece of sheet metal into the desired part through material removal and/or material deformation. Sheet metal, which acts as the work-piece in these processes, is one of the most common forms of raw material stock. The material thickness that classifies a work-piece as sheet metal is not clearly defined.

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[11] (Talha, Usman, & Taimoor, 2013)

[12] (http://www.custompartnet.com/wu/sheet-metal, n.d.)

However, sheet metal is generally considered to be a piece of stock between 0.006 and 0.25 inches thick. A piece of metal much thinner is considered to be "foil" and any thicker is referred to as a "plate". The thickness of a piece of sheet metal is often referred to as its gauge, a number typically ranging from 3 to 38. A higher gauge indicates a thinner piece of sheet metal, with exact dimensions that depend on the material.

Basic Sheet metal operations such as cutting, filing etc. were used to cut the sheets to the required size according to the proposed dimensions. Filing was done to smoothen the edges. The holes at the desired places were drilled using high Power Drilling Machine.

Riveting was used to attach the Aluminum sliding mechanism on to the angle iron welded on the outer walls of furnace. The water Tank; in addition to welding; was attached firmly to the furnace frame by riveting it with outer sheet.

4.2.3.2 Welding

The simplest definition of welding is the joining together (metal pieces or parts) by heating the surfaces to the point of melting with a blowpipe, electric arc, or other means, and uniting them.

We used Electric arc welding to weld the steel pipes to make the basic structure. The sheets were welded on to the structure, Water Tank was welded onto the supports and feet supports were welded to the structure using electric arc welding. Electric arc welding was also used to weld the angle iron support on to the outer sheet.

[13]**Shielded metal arc welding** (SMAW), also known as manual metal arc welding (MMA or MMAW), flux shielded arc welding or informally as stick welding, is a manual arc welding process that uses a consumable electrode coated in flux to lay the weld. An electric current, in the form of either alternating current or direct current from a welding power supply, is used to form an electric arc between the electrode and the metals to be joined. As the weld is laid, the flux coating of the electrode disintegrates, giving off vapors that serve as a shielding gas and providing a layer of slag, both of which protect the weld area from atmospheric contamination.

[13] (Cary, Howard B. and Scott C. Helzer (2005). Modern Welding Technology. Upper Saddle River, New Jersey: Pearson Education)

[14]Because of the versatility of the process and the simplicity of its equipment and operation, shielded metal arc welding is one of the world's most popular welding processes. It dominates other welding processes in the maintenance and repair industry, and though flux-cored arc welding is growing in popularity, SMAW continues to be used extensively in the construction of steel structures and in industrial fabrication. The process is used primarily to weld iron and steels (including stainless steel) but aluminium, nickel and copper alloys can also be welded with this method.

[15]**Gas tungsten arc welding (GTAW)**, also known as tungsten inert gas (TIG) welding, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal is normally used, though some welds, known as autogenous welds, do not require it. A constant-current welding power supply produces energy which is conducted across the arc through a column of highly ionized gas and metal vapors known as a plasma. GTAW is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as aluminum, magnesium, and copper alloys. The process grants the operator greater control over the weld than competing processes such as shielded metal arc welding and gas metal arc welding, allowing for stronger, higher quality welds. However, GTAW is comparatively more complex and difficult to master, and furthermore, it is significantly slower than most other welding techniques. A related process, plasma arc welding, uses a slightly different welding torch to create a more focused welding arc and as a result is often automated.
Oxyacetylene gas welding is commonly used to permanently join mild steel. A mixture of oxygen and acetylene, burns as an intense / focused flame, at approximately 3,500 degrees centigrade. When the flame comes in contact with steel, it melts the surface forming a molten pool, allowing welding to take place. Oxyacetylene can also be used for brazing, bronze welding, forging / shaping metal and cutting.

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[14] (Jeffus, Larry (1999). Welding: Principles and Applications. Albany: Thomson Delmar.)
[15] (American Welding Society (2004). Welding handbook, welding processes Part 1. Miami Florida: American Welding Society.)

4.2.3.3 Surface Finishing Operations

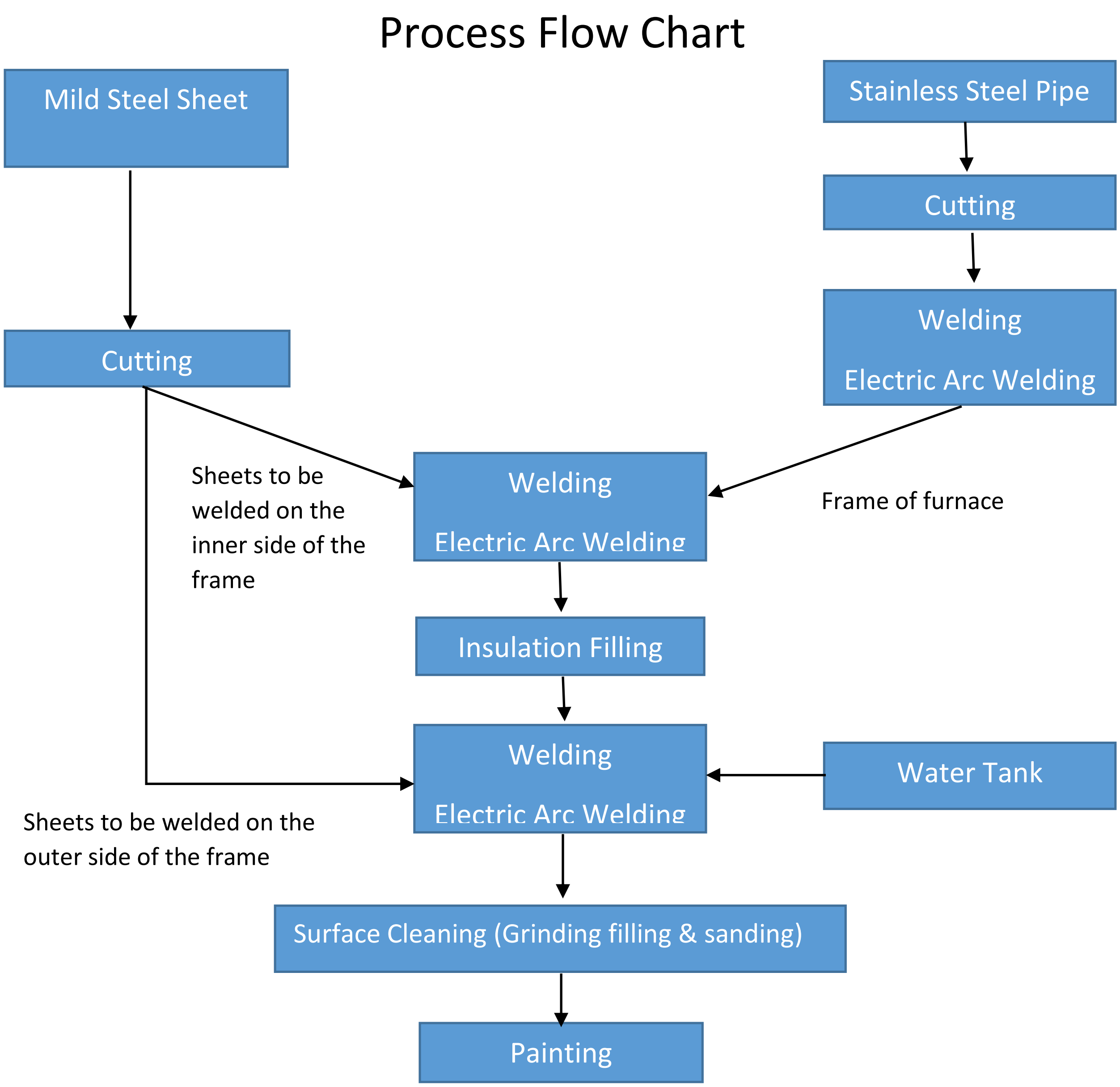
We used Surface cleaning operations like sanding to clean the sheets and remove any dirt and dust.

Hand grinder was used to even out the surface that had welds.

Steel Filler (commonly referred to as steel Puteen in native language) was used to fill the small holes left on the sheets after welding.

In the end the model was painted using Dark Gray spray paint.

4.2.3.4 Process Flow Chart



4.3 Final Design

The Specification of the final design are given below in tabular form:

Parameter	Specification
Water Tank Capacity	100 liter (0.0001 m^3)
Height	7.5 ft (2250 mm)
Width	1.5 ft (460 mm)
Charging Door Size	1 ft x 0.5 ft (300 mm x 150 mm)
Air Vent Size	0.67 ft x 0.5 ft (200 mm x 150 mm)
Furnace Capacity	5 kg (approx.)
Ash Removal Tray	1 ft x 1ft (300 mm x 300 mm)

Table 6 Specification of Fabricated Design

Following are some of the pictures of the final design:

Figure 13 Fuel Charging door and Furnace Cleaning Door

Figure 12 Air Vent and Sliding Mechanism

Figure 14 Design after Fabrication

5. Automation

5.1 Introduction

The main issue associated with the combustion of coal and wood is that once the burning starts, if it is required to stop the combustion, one has to do so manually. We have implemented a system in which the water temperature from the outlet of geyser is sensed using K Type Thermocouple. And this Temperature is controlled/regulated within two specific levels (upper temperature and lower Temperature).

5.2 Procedure

We will be checking the temperature of water at the outlet of the geyser if the temperature is above $60°C$ we will shut down the combustion by closing the air vents which will in turn cut-off air supply to the furnace and if the temperature reaches $40°C$ the air vents will be opened and the combustion will be started again. The design of igniter is not covered in the scope of our project.

We have used microcontroller (Arduino UNO) for controlling the opening and closing of air vents. Thermocouple (K type) is used to detect the value of temperature at the outlet of geyser, the microcontroller interprets the value from thermocouple and converts the reading to temperature. Once the value from thermocouple is converted to temperature the microcontroller checks the validity of different conditions and performs accordingly. The code is attached in the references section.

The conditions are:

- If the temperature is less than $40°C$ and the air vents are closed, the microcontroller actuates the motor in clockwise direction to open the vents.
- If the temperature is than $60°C$ and the air vents are open, the microcontroller actuates the motor in anti-clockwise direction to close the vents.

H Bridge is used to reverse the direction of the motor.

5.3 Simulation

The simulation of Electronic circuit was made using Proteus.

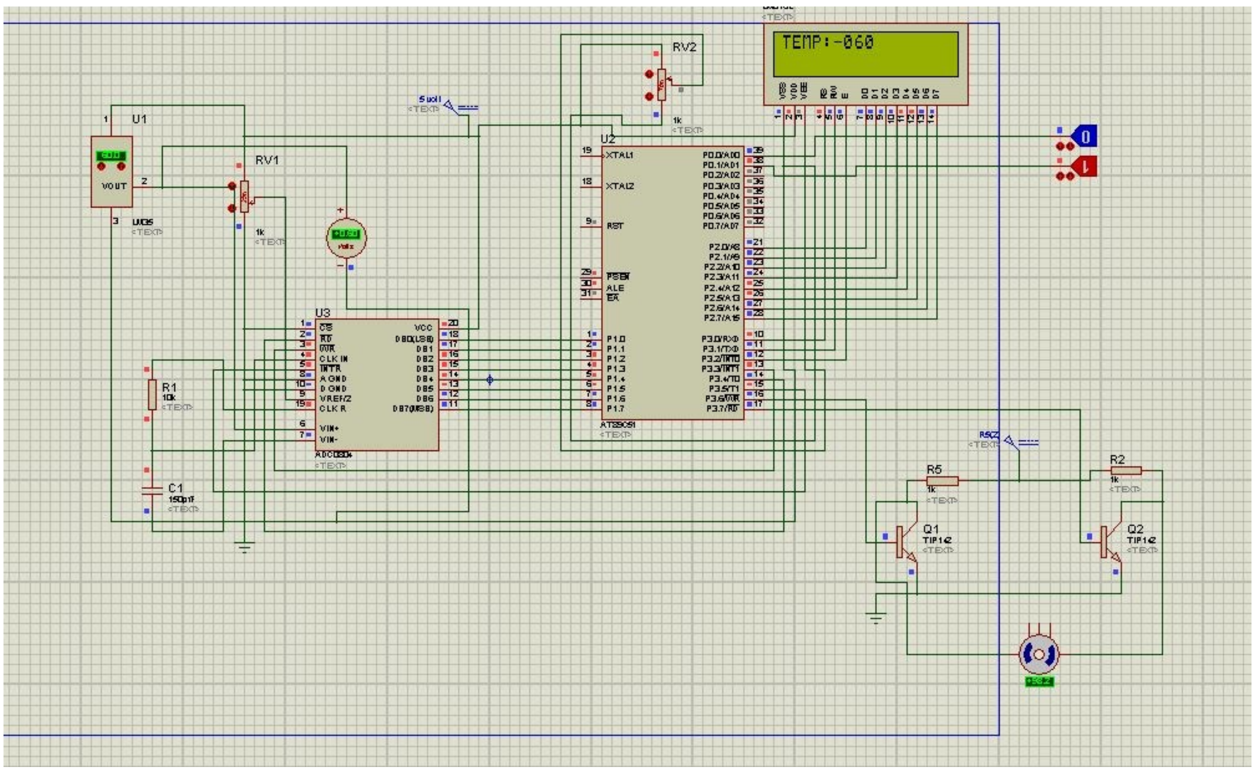


Figure 15 Simulation of Electronic Circuit used for automation

5.4 Mechanism

The main issue in the assembly of mechanism was to determine an adequate place on the outer body of furnace where the motor can be mounted. After careful considerations we decided to mount motor by welding it on the angle iron supporting the sliding mechanism. Pulleys were also used to convert the rotary motion of the motor into the translational motion of the air vent. We used fishing rod wire as a belt for the pulley mechanism. This wire was used to connect the air vent to the motor. We used Fishing rod wire because of its high strength, small diameter, low flexibility and temperature resistance. The air vent slides on aluminum sliding mechanism similar to the one used in sliding glass windows. We specifically used this mechanism due to its reduced thickness and very low friction.

Figure 16 Air Vent Sliding Mechanism

6. Testing

After the successful Fabrication, Testing was performed on the new model and results were recorded and compared with the previous Model.

6.1 Heat Losses

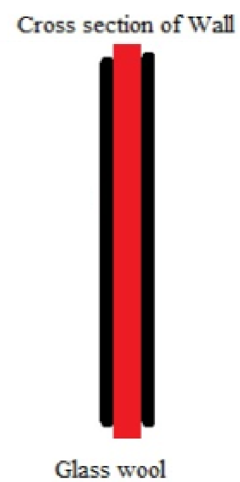


Figure 17 Cross Section of furnace walls

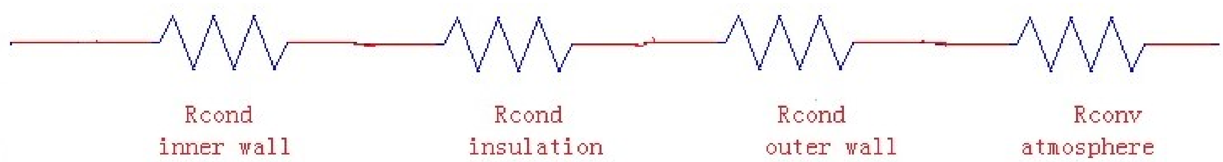


Figure 18 Simplified Resistance Network

The average Temperature on the inside wall of the furnace was determined to be 200°C and heat loss was calculated due to variation of the ambient Temperature.

Following is the detailed Procedure followed to calculate the losses.

$$Q = (T_{inside} - T_{ambient})UA$$

$$U = Overall\ Heat\ Transfer\ Cofficient$$

$$UA = \frac{1}{R_t}$$

$$R_t = R_1 + R_2 + R_3 + R_4$$

$$R_1 = Conduction\ Resistance\ of\ inner\ wall = \frac{L}{k_{steel} \times A} = \frac{0.001214}{53.6 \times 0.135} = 0.000168\ (K/W)$$

$$R_2 = Conduction\ Resistance\ of\ insulation = \frac{L}{k_{insulation} \times A} = \frac{0.0186}{0.037 \times 0.135} = 3.7237 (K/W)$$

$$R_3 = Conduction\ Resistance\ of\ outer\ wall = \frac{L}{k_{steel} \times A} = \frac{0.0005}{53.6 \times 0.135} = 0.00257\ (K/W)$$

$$R_4 = Convection\ Resistance\ of\ outer\ wall = \frac{1}{h_{outer} \times A} = \frac{1}{h_{out} \times 0.135} = \frac{7.4074}{h_{out}}\ (K/W)$$

[16]

$$h_{out} = 10.45 - v + 10\sqrt{v}$$

$$v = 2\ (m/s)$$

$$h_{out} = 22.59\ (W/m^2K)$$

$$R_4 = \frac{7.4074}{h_{out}} = \frac{7.4074}{22.59} = 0.3279\ \ (K/W)$$

$$R_t = R_1 + R_2 + R_3 + R_4$$

$$R_t = 4.054\ (K/W)$$

At $\boldsymbol{T_{amb} = 24}$℃

$$Q = \frac{4 \times (T_{inside} - T_{ambient})}{R_t}$$

$$Q = \frac{4 \times (200 - 24)}{4.054}$$

$$Q = 173.6\ (J/s)$$

6.1.1 Comparison with Previous Model

From Section 3.2.1.1 for previous Model

$$Q = 1174\ (J/s)$$

So Percentage reduction in Losses

$$\%\ losses\ reduction = \left(\frac{1174 - 173.6}{1174}\right) \times 100 = 85.21\ \%$$

So we can see how heat Losses are reduced in our new model to account for improvement in efficiency.

[16] (http://www.engineeringtoolbox.com/convective-heat-transfer-d_430.html, n.d.)

6.2 Efficiency

We performed testing on the new design and found out its efficiency using coal and wood as fuel. The temperature of water was raised up to 60°C. Following were the results:

$$m_{coal} = mass\ of\ coal\ consumed \approx 2.5\ kg$$

$$Q_{fuel} = Amount\ of\ Fuel\ Energy\ used = m \times HV = 2.5 \times 16077 = 39694\ kJ$$

$$HV = Heating\ Value$$

$$Q_{water} = mC_p\Delta T = 100 \times 4.18 \times (60 - 24)$$

$$Q_{water} = 15048\ kJ$$

$$\eta = \frac{Q_{water}}{Q_{fuel}} = 38\ \%$$

For the Previous design Efficiency using Coal was merely 18% so we have improved the efficiency by 111.11%.

$$m_{wood} = mass\ of\ wood\ consumed \approx 4.5kg$$

$$Q_{fuel} = Amount\ of\ Fuel\ Energy\ used = m \times HV = 4.5 \times 12600 = 56700\ kJ$$

$$HV = Heating\ Value$$

$$Q_{water} = mC_p\Delta T = 100 \times 4.18 \times (60 - 24)$$

$$Q_{water} = 15048\ kJ$$

$$\eta = \frac{Q_{water}}{Q_{fuel}} = 26.54\ \%$$

6.3 Rise of Water Temperature

We measured the temperature of the water at outlet of the geyser after regular intervals and found out that for temperature rise up to 60°C it took

- For Coal 2hrs 30 min
- For Wood 3hrs 40 min
- For Natural Gas 50 min

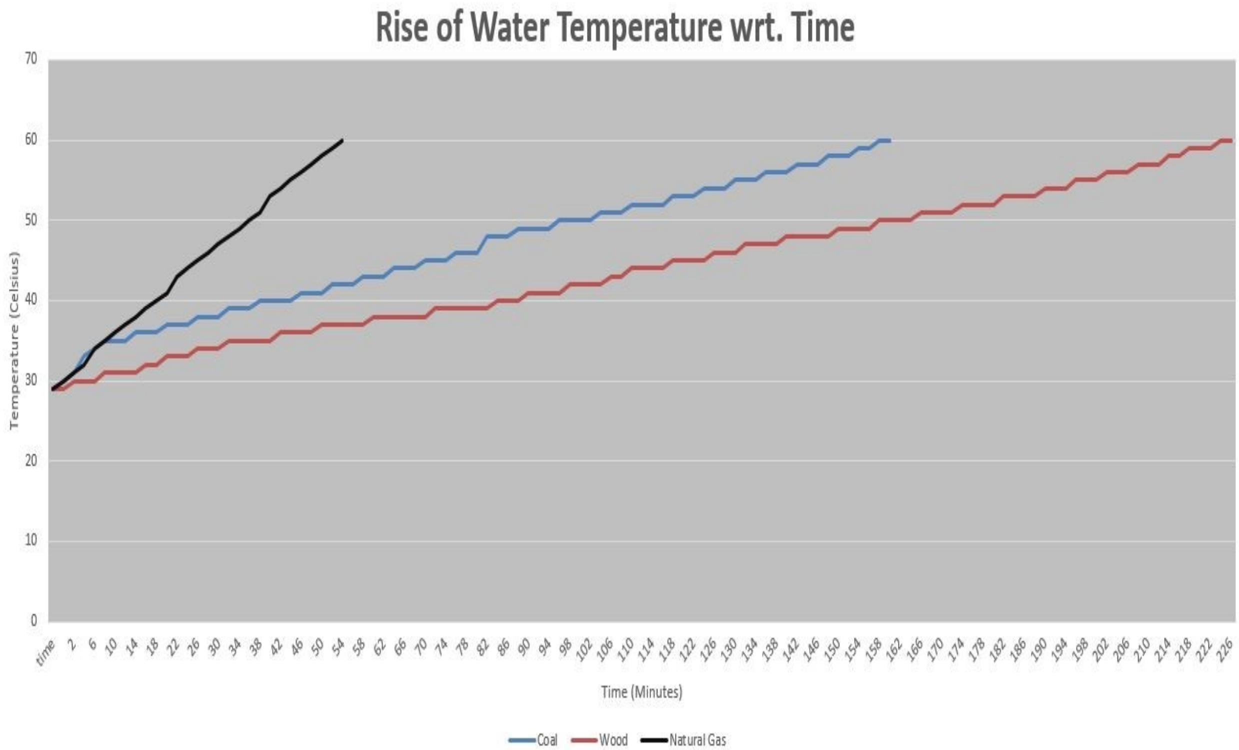


Figure 19 Time variation of water Temperature wrt. Time

6.4 Heat Losses Variation wrt. ambient Temperature

Following is a variation of Heat Losses when ambient temperature varies:

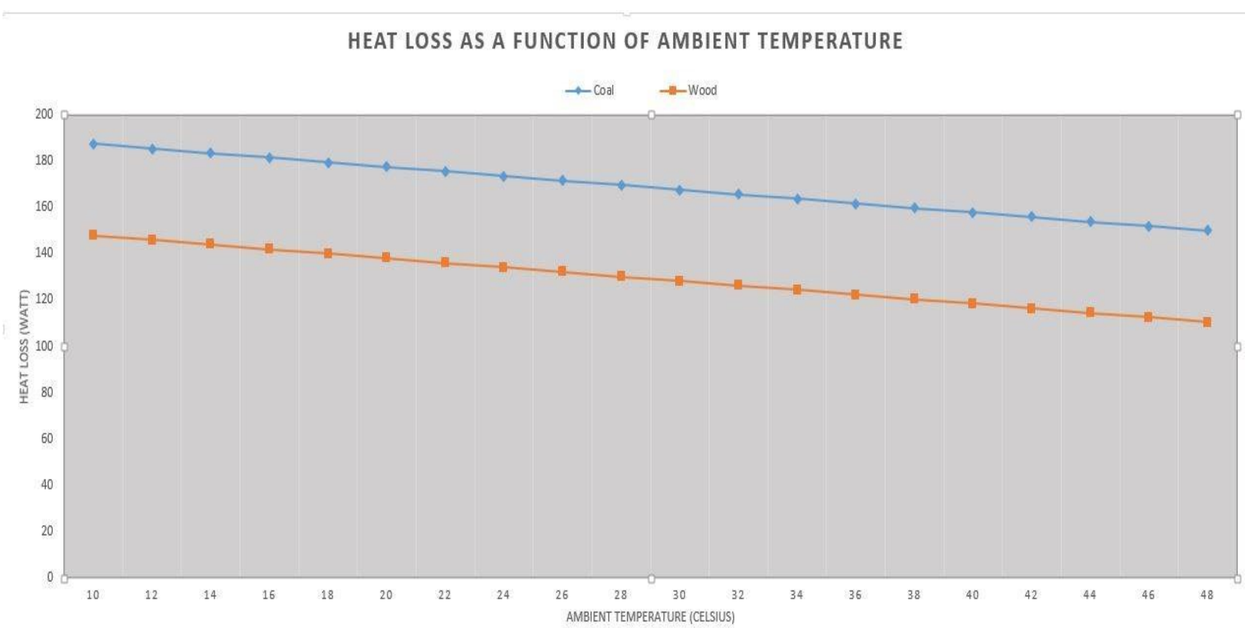


Figure 20 Heat losses as a function of Ambient Temperature for new Design

Comparison with Previous Model

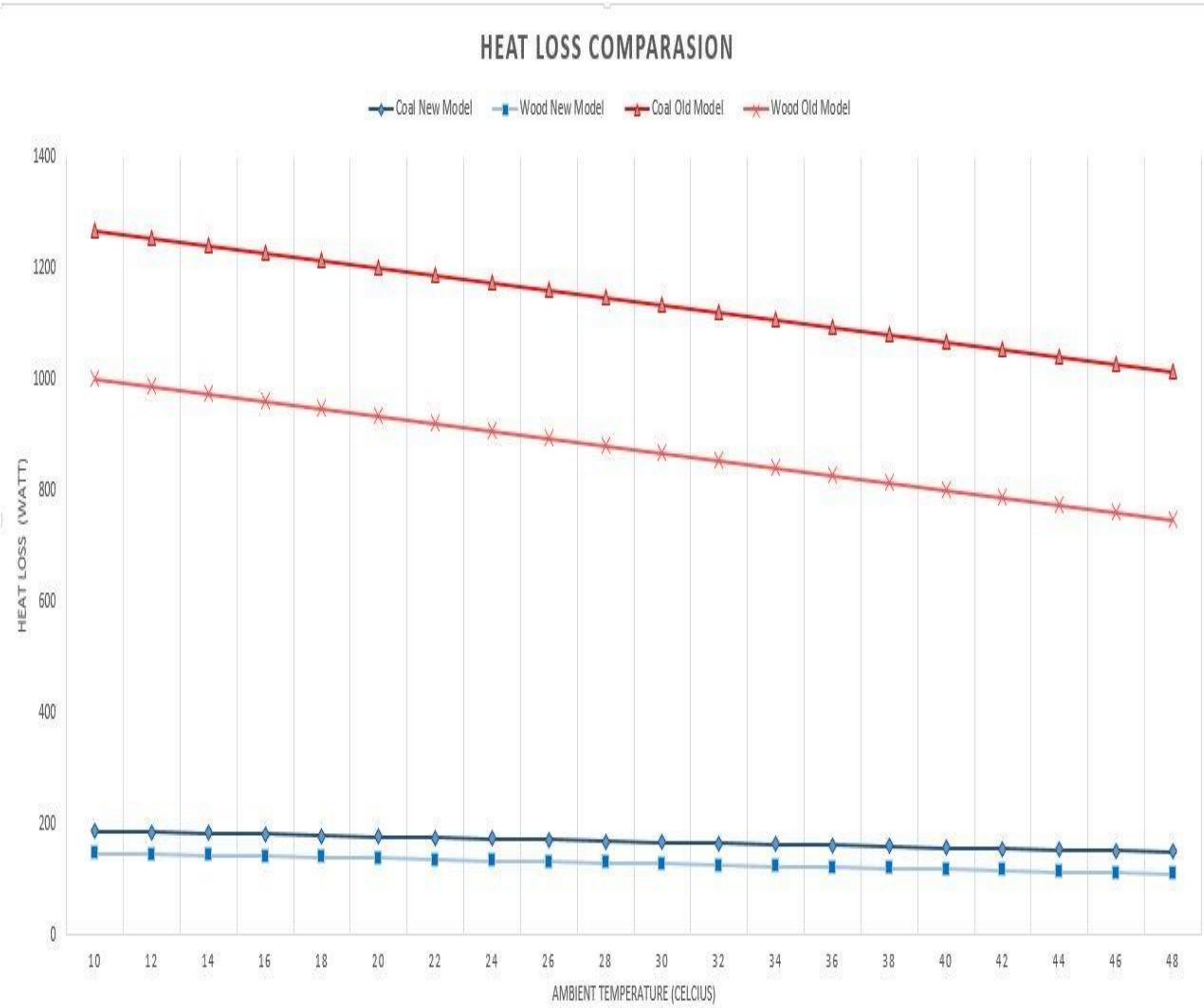


Figure 21 Heat Loss Comparison between old and New Model

6.5 Economic Analysis

Cost of Coal:

Referring to 6.2

Mass of Coal = 2.5 kg

Price of 1 kg Coal = Rs. 50

Total Cost = Rs. 125

Cost of wood:

Referring to 6.2

Mass of wood = 4.5 kg

Price of 1 kg wood = Rs. 20

Total Cost = Rs. 90

So Wood is the more Economical Fuel.

7. Future Work and Recommendations

Currently the automation mechanism has been implemented but due to limited funds we could not implement the auto ignition mechanism, which means that once the combustion of coal and wood extinguishes it has to be reignited manually.

During the combustion of Coal and Wood SOx emission takes place and can severely affect the environment. We could not implement Emission Control Chamber due to shortage of funds and lack of availability of proper emission testing equipment.

It is highly recommended that some group should work on the emission control chamber of the geyser and should implement auto ignition mechanism inside the furnace. Efforts should be made to couple the backup system geyser with Solar Water heating system.

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Appendix

Code for Automation Using Arduino UNO Microcontroller.

```
double sensorpin = A0;
int motorPin1 =  12;
int motorPin2 =  8;
int opened = 7;
int closed = 4;
double sensorValue = 0;  // variable
to store the value coming from the
sensor
int temperature = 0;
double t = 0;
double a0 = 0.226584602;
double a1 = 24152.109;
double a2 = 672233.4248;
double a3 = 2210340.682;
double a4 = -860963914.9;
void setup()   {
  pinMode(motorPin1, OUTPUT);
  pinMode(motorPin2, OUTPUT);
  pinMode(opened, INPUT);
  pinMode(closed, INPUT);
}
void loop()
{
  digitalWrite(motorPin1, LOW);
  digitalWrite(motorPin2, LOW);

  sensorValue =
analogRead(sensorpin);
  t = sensorValue+0.00088;
  temperature =
(a0+(a1*t)+(a2*t*t)+(a3*t*t*t)+(a4*
t*t*t*t));
 int op = digitalRead(opened);
 int cl = digitalRead(closed);
if(temperature <= 40)
 {
  if(cl == HIGH && op == LOW)
  {
    digitalWrite(motorPin1, HIGH);
    while(op == LOW)
  {op = digitalRead(opened);}
    digitalWrite(motorPin1, LOW);
}
}
if(temperature >= 60)
 {
  if(op == HIGH && cl == LOW)
  {
     digitalWrite(motorPin2, HIGH);
     while(cl == LOW)
     {cl = digitalRead(closed);}
     digitalWrite(motorPin2, LOW);
  }
 }
  else
  {
    digitalWrite(motorPin1, LOW);
    digitalWrite(motorPin2, LOW);
  }
}
```

Automation Code using 8051 Microcontroller

```
#include<reg51.h>
#define ldata P2
#define temp P1
sbit r= P3^3;  // Write pin. It is
used to start the conversion.
sbit d= P3^4;  // Read pin. It is
used to extract the data from
internal register to the output
pins of ADC.
sbit rs = P3^0;  //register select
pin
sbit rw = P3^1;  // read write
pin
sbit en = P3^2;  //enable pin
sbit m=P3^6;
sbit n=P3^7;
sbit limit1=P0^0;
sbit limit2=P0^1;
void lcdcmd (unsigned char
value);
void lcddata (unsigned char
value);
void lcddata1 (unsigned char
value);
void delay(unsigned int msec )
// The delay function provides
delay in msec.
{
int i,j ;
for(i=0;i<msec;i++)
  for(j=0; j<1275; j++);
}
void main()
{
signed int a,b,c;
while(1)
{
d=1;
r=0;
delay(1);
r=1;
delay(1);
d=0;
delay(1);
lcdcmd (0x38);
delay (1);
lcdcmd (0x0C);
delay (1);
lcdcmd (0x80);
delay (1);
delay (1);
lcddata ('E');
delay (1);
lcddata ('M');
delay (1);
lcddata ('P');
delay (1);
lcddata (':');
delay (1);
lcddata ('-');
delay (1);
c=temp/100;
lcddata1(c);
delay (1);
a=(temp/10)-(c*10);
lcddata1(a);
delay (1);
b=temp%10;
lcddata1(b);
delay (1);
if(temp>40&&temp<60)
{
m=0;
n=0;
}
if(limit1==1)
{
if(temp<=40)
{
n=0;
delay (1);
m=1;
while(limit2==0);
m=0;
}
}
if(limit2==1)
{
if(temp>=60)
{
m=0;
delay (1);
n=1;
while(limit1==0);
n=0;
}
}
}
}
void lcdcmd (unsigned char
value)
{
ldata =value;
rs=0;
rw=0;
en=1;
delay (1);
en=0;
return;
}
void lcddata1 (unsigned
char value)
{
value=value+0x30;
ldata =value;
rs=1;
rw=0;
en=1;
delay (1);
en=0;
return;
}
void lcddata (unsigned char
value)
{
ldata =value;
rs=1;
rw=0;
en=1;
delay (1);
en=0;
return;
}
```

Bill of Materials:

Sr. No.	Material	Specification(mm)	Description	Quantity
1.	Mild Steel/GI sheet	456*600	Sheet Thickness = 18 gauge Internal wall of Furnace	4
2.	Mild Steel/GI sheet	460*600	Sheet Thickness = 20 gauge External wall of Furnace	4
3.	Mild Steel/GI sheet	300*150	Sheet Thickness = 20 gauge Fuel charging door	1
4.	Mild Steel/GI sheet	200*150	Sheet Thickness = 20 gauge Air vent	2
5.	Mild Steel/GI sheet	1260*150	Sheet Thickness = 18 gauge Water tank support	1
6.	Mild Steel/GI sheet	460*150	Sheet Thickness = 20 gauge Joining water tank and funace	4
7.	Stainless Steel Pipe	460	Pipe Thickness = 18 gauge Supporting structure of Furnace	12
8.	Stainless Steel Pipe	650	Pipe Thickness = 18 gauge Supporting structure of Furnace	4
9.	Stainless Steel Pipe	2300	Pipe Thickness = 18 gauge Securing and sealing door and vents	1
10.	Mild Steel Plate	456*51	Plate Thickness = 4mm Water Tank support on furnace	4
11.	Mild Steel Plate	51*51	Plate Thickness = 4mm Feet Support	4
12.	Mild Steel Angle Iron	460*18.75	Fixture for aluminum sliding fixture	2
13.	Glass Wool	460*600	Insulation	4
14.	Aluminum Sliding system	460	Opening and closing of automated Air vent	1

15.	Pulley	D=50	For enabling vent control using motor	3
16.	Fishing rod wire	950	Used as a belt	1
17.	Arduino UNO	-	Micro-Controller For Signal detection, processing and emitting	1
18.	H-Bridge	-	To change the direction on motor in the response of microcontroller	1
19.	K-Type Thermocouple	-	For detection of water temperature in the tank	1
20.	Motor	9V, 6RPM	For opening and closing of the automated air vent	1