



The present work was submitted to the Faculty of Engineering

# **AUTOMATION OF COAL BRIQUETTE-FUEL FIRED STOVE FOR GERS**

**Bachelor Thesis**

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Ulaanbaatar/Nalaikh, 05/16/2022

## Statutory Declaration

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I hereby affirm in lieu of an oath that I provided the submitted bachelor thesis.

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## **Abstract**

Over the past few decades, there has been a consistent growth in the use of stoves for heating in a traditional Mongolian house, so called Ger.

The main objective of this research is to implement automation of the existing stove in technical and environmental perspectives and to minimize human manual activities when they use the coal briquette fuel stove.

The new design of automation was made to the “Ulzii” stove produced by Turkey. Applying new design method on the existing stove the construction and operating costs were found lower than the original design.

All the drawings and three-dimensional virtual models of the components have been implemented using computer-aided design program so that the prototype of the new design can be manufactured.

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## **Abbreviation**

**UB** Ulaanbaatar

**WHO** World Health Organization

**MAQS** Mongolian Air Quality Standard

**MCC** Millennium Challenge Corporation

**MMCA** Mongolian Millennium Challenge Account

**CAP** Clean Air Project

**°C** The degree Celsius

**Rathole** cylinder-shaped hole that develops in a mass of bulk solids

**CEMA** Conveyor Equipment Manufacturers Association

**EC** Equivalent Capacity

**RC** Required Capacity

**CS** Conveyor Speed

**HP<sub>f</sub>** Horsepower to overcome the friction

**HP<sub>m</sub>** Horsepower to transport the material

**F<sub>o</sub>** Overload factor

**TSHP** Total Shaft Horsepower

**CGL** Central Geological Laboratory

**LLC** Limited Liability Company

# 1 Introduction

The majority of Mongolian families live in gers and houses and use stoves to cook and heat. The project, which was named “Clean-Air”, was supported by the government and new stoves were distributed to most households. Imported stoves from the project posed many challenges for consumers. Based on these issues, the aim is to create a favorable environment for citizens by automating stoves.

## 1.1 Traditional and Ulzii Stove in Ger

The Mongolian ger is circular, with the stove located in the center of the ger to distribute heat evenly throughout the ger. The national stove was initially designed to burn wood by hand. The stove consists of two general structures and is divided into a body and a smoke extractor, as shown in [Figure 1](#). The internal structure of the furnace is straightforward: combustion takes place in the body part, and the smoke extractor part absorbs the smoke from the combustion. The primary material of the national stove is thin iron, and thin iron is easy to mold by hand. In order to reduce the corrosion of the thin sheet metal used to construct these artisanal stoves, people took to lining them with clay bricks. This extended the stove's life but isolated the fire and sent more hot flue gas into the chimney, reducing heat efficiency and increased fuel consumption.



*Figure 1: Traditional Mongolian Stove located in the center of a ger*

Ulzii stove is one of the imported stoves in Mongolia and was firstly sold in Mongolia as part of the "Clean Air" project implemented by the Mongolian Millennium Challenge Corporation. The stove is shown in [Figure 2](#) and consists of three main parts: the body, the base, and the smoke extractor part. Combustion takes place in the stove's body,

where the ash falls into the ash pan at the base, and the smoke from the combustion exits through the smoke intake. The smoke extractor of the Ulzii stove is much shorter than a traditional stove. The stove distributes heat evenly on all five sides and uses 71 percent of the heat released from solid fuels. It also retains heat for 8-12 hours, so it is enough to fire only twice a day. These 70-burner stoves are made of cast iron and have good heat storage and transfer capacity. The stoves are sold more nationally than other imported stoves and are easier to use than others. It is also the most suitable combustion stove in the Mongolian ger compared. to other stoves. Like the traditional stove, it is located in the center of the ger.



*Figure 2: Ulzii stove*

This slows down coal combustion, reduces heat loss to the air, and retains heat longer, reducing coal consumption. The stoves included in the Clean Air Project CAP program emitted 65% less PM<sub>2.5</sub> and 16% less CO than conventional stoves. In addition, the massive majority of Mongolia Millennium Challenge Account MMCA stove users believe that improved stoves have significantly better appearance, pollution reduction, fuel consumption, ash management, and longer heat retention than traditional stoves. Aggrieved parties included difficulty in cooking, a high risk of burns, and high levels of ignition. Household daily coal consumption decreased by 17% compared to traditional stoves when using MMCA stoves as instructed. This was close to the laboratory standard.

## **1.2 Problem Statement**

The capital city of Mongolia, Ulaanbaatar (UB), has a population of over 1.4 million. About 51.3 percent of the population, or 200,000 households, live in suburban ger areas (1). About half of all households living in the suburbs of UB live in traditional ger home,

which consists of a one-room tent structure. Gers can have four, five, and in some cases, six walls and usually have an interior area ranging from 20 m<sup>2</sup> to 30 m<sup>2</sup>. In the center of the ger is a stove used for both heating and cooking. Because the average annual temperature makes UB the coldest capital globally, traditional ger stoves are usually operated in the winter from October to March. The temperature often drops to -40 degrees at night. According to a study, households in ger areas with traditional stoves use an average of 4.18 tons of coal and 3.18 tons of wood per year to meet their heating and cooking needs (2). This data was very high in densely populated UB, so the air quality is so polluted.

Mongolian traditional stoves have significant disadvantages, such as low thermal conductivity and support for incomplete combustion. Traditional stoves are fired with hot ash or charcoal over a fire, while Millennium Challenge Corporation MMC stoves are filled with coal and then fired with wood from above. However, the fire must be completely extinguished before additional firing. This method reduces the combustion of coal and reduces PM<sub>2.5</sub> emissions by allowing heating and incomplete combustion gases and particles to pass through the combustion. In a traditional stove, all of this pollution passes through the coal. Also, compared to traditional stoves, the combustion zone is located above the coal, which does not heat the coal below and limits the burning of all the coal simultaneously, as shown in [Figure 3](#).



*Figure 3: Differences in Combustion between Traditional Stove and Millennium Challenge Account Stove*

Households with project stoves are considered sufficient to fire twice a day, but in practice, this is unlikely. The average temperature in our country during the cold season is shallow, and at this time, the home temperature drops rapidly. When the home temperature drops rapidly, the combustion inside the stove slows down, and the stove's heat output decreases. At this point, the consumer has to choose between two primary options: to cause incomplete combustion or to wait until the fire in the stove cools down

at home. Most families with young children or elderly start fire by dumping ashes and re-igniting them. This has a significant negative impact on consumers' fuel costs and air quality. However, young families do not re-burn until the fire is extinguished and, in some cases, use heaters with different heating systems. So there are negative comments among users. Therefore, the main purpose of the thesis is to stop the continuous firing of the stove and to make it no longer necessary to fire the stove once.

As shown in [Figure 3](#), the smoke intake section of the project stove chimney is much shorter than the traditional stove. This indicates a lack of space when cooking in a large pan on the stove. The average Mongolian family has four to five members and requires at least an 8-liter pan for cooking. At this point, the pan becomes more significant than the stove, making it impossible to cook. Therefore, most families need to buy an additional electric cooker. This is one of the following significant issues for this stove to solve.

### **1.3 The Possible Way to Improve the Ulzii Stove**

The best way to improve a stove is to automate it, which means keeping the stove running continuously. Continuous operation of the stove maintains the home's heat at a constant temperature, maintains the comfort and safety of the user, and most importantly, reduces emissions and increases efficiency. Automation is directly related to many factors and can reduce or increase the heat inside the ger compared to the heat outside, the speed of the screw conveyor, and the mass of air blown out of the air blower. For example, when the outside temperature is minus 20 degrees and the indoor temperature is plus 10 degrees, the stove needs to bring the home heat to the average temperature for a short time. Therefore, the stove will switch to a fast combustion mode, during which a large amount of heat will be released, and the home temperature will quickly return to normal. In order to achieve rapid combustion, the speed of the screw conveyor must be increased, and the briquettes must be transported to the combustion chamber quickly. It is also necessary to support combustion by blowing the required air faster during combustion with an air blower. However, when the temperature inside the house is higher than average, the combustion inside the stove should slow down, and the stove's heat output should be reduced. In this case, the screw conveyor, which is the coal conveyor, must rotate at a speed slower than the average rotational speed and

provide fewer briquettes in the combustion chamber of the furnace. It will also slow down the combustion process by reducing the air required during combustion.

Ulzii stove's air systems will be upgraded to support and control combustion rates and heat emissions. The old-fashioned air system was located at the bottom of the Ulzii stove and was a simple hand-operated valve, Figure 4. The user opened the air valve when the fire started in the furnace, which was a form of intake of air required for combustion. At that time, it was challenging to control air combustion. Therefore, in the new model furnace, this air duct was improved, and an innovative idea was introduced to eliminate and close the valve. The new model stove air blower has been changed to an automatic blower. This change allows the air blower to regulate the combustion rate of the furnace and the heat emitted from the furnace.



Figure 4: a) Isometric view of the Ulzii stove b) The back view of the Ulzii stove.

When the ash is completely burned in the auspicious furnace, it is trapped on the burner, preventing it from falling through the burner hole or turning the burner 90 degrees. In most cases, it is compacted on the burner. When briquettes are lit, briquettes are placed vertically on top of each other in large quantities. Briquettes also contain specific amounts of binders. As a result, the briquettes, which are layered on top of each other, become sticky and stick when burned. At this time, the burner must be rotated 90 degrees to remove the ash. This is another part of the stove that needs to be improved.

## **1.4 Limitations**

Ulzii stoves are not currently being re-manufactured in Mongolia, and individual households will need to be collected to upgrade their stoves. Alternatively, the stoves need to be upgraded by assembling them in each khoroo which is an administrative subdivision of UB, in a unified manner. There are several difficulties in assembling the stoves, and some stoves may not provide the technical specifications.

During the renovation of the stove, there were small parts and elements in the stove that were difficult to study and could not be calculated accurately. In order to calculate this small fraction, it was necessary to conduct an actual experiment, and based on an oral survey of households that use auspicious stoves, in consultation with my supervisor, these tiny fractions were approximated. For example, accurate calculations of combustion heat increased the amount of heat required from briquettes and wood when lighting a fire. Every household lit briquettes and wood of different weights to light a fire. It was also challenging to make accurate calculations during the system for adjusting the speed of the screw conductors and the air blower depending on the temperature. The additional resistances could only be accurately calculated during the experiment.

Most of the briquettes sold in the market are produced by Tavan Tolgoi Tulsh LLC, and it is not possible to say what the briquette ingredients are when asked by the company and the composition engineer. The reason for the company's secrecy was that it was challenging to study briquettes in detail. There was also a lack of detailed information on stoves used in Mongolia on the internet and reliable sources. Most stove-related news was simple ad sites. It is challenging to trust them fully, and additional research and analysis were required to verify their accuracy.

## **1.5 Methodology**

The design of the new stove was based on a meeting with many sources and individuals. At the beginning of the study, it was necessary to get acquainted with the general structure of the stove. Because the structure of the stove was more complicated and dangerous than it looked, this information was also used as a basis for meetings with individuals and families who work with or sell stoves. Decisions made in consultation with the supervisor during the study sometimes differed in the calculations. During the calculation, some items were changed from the original decision following international standards.

The new design required the construction of a test furnace. However, it was costly financially, and to save this cost, all the small parts and elements of the newly designed stove were created in AutoCAD using real-time drawings. This image incorporates all the information obtained during the study and provides a detailed picture. In this program, it is possible to identify and simulate all designs except combustion. This drawing was a great help in developing an advanced design solution.

The additional parts to be placed in the stove have been analyzed and calculated in detail, and details can be found in Chapter 3.

Estimates of the briquettes used in the stoves were followed by studies in other countries. The results of the calculations and details are detailed in Chapter 2.

## 2 Literature Review

The stove, a device used for heating or cooking, originated many centuries ago and is still evolving rapidly. The first historical record was built in 1490 in Alsace, entirely of brick and tile, including the flue. The later Scandinavian stove had a tall, hollow iron flue containing iron baffles arranged to lengthen the travel of the escaping gases in order to extract maximum heat. The Russian stove had as many as six thick-walled masonry flues. It is still widely used in northern countries. The stove is often installed at the intersection of interior partition walls in such a manner that a portion of the stove and the flue is inside each of the four rooms. A fire is maintained until the stove and flues are hot, and then the fire is extinguished, and the flues closed, storing the heat.

The first manufactured cast-iron stove was produced at Lynn, Mass, in 1642. This stove had no grates and was little more than a cast-iron box. About 1740, Benjamin Franklin invented the Pennsylvania fireplace, which incorporated the basic principles of the heating stove. The Franklin stove burned wood on a grate and had sliding doors that could be used to control the flow of air through it. Because the stove was relatively small, it could be installed in a large fireplace or used free-standing in the middle of a room by connecting it to the flue. Its design influenced the potbellied stove, which was a familiar feature in some homes well into the 20<sup>th</sup> century. The first-round cast-iron stoves with grates for cooking food on them were manufactured by Isaac Orr in Philadelphia (3).

Cooking became the predominant function of stoves in the 20<sup>th</sup> century as central heating became the norm in the developed world. Iron cooking stoves using wood, charcoal, or coal tended to radiate large amounts of heat that made the kitchen unpleasantly hot during the summertime. However, in the 20<sup>th</sup> century, they were replaced by steel ranges or ovens that are heated by natural gas or electricity. The latest development is to use of electricity and the creation of automatic stoves. That way, we do not have to burn the stove all the time.

The “Ulaanbaatar-Clean Air Project” has been implemented in Mongolia, and in order to reduce air pollution in Ulaanbaatar, “New Project Stoves” have been imported and given to the people at a discounted price. This project is a joint project of the United States Millennium Challenge Corporation and the Government of Mongolia. The aim was to reduce the PM emitted from stoves by reducing the cost of energy-efficient products and encouraging public procurement, thereby reducing the cost of air pollution-related

illnesses. In addition, increasing the efficiency of stoves aims to save fuel and reduce fuel costs. The project offers eight different types of stoves: Dul, Nomin, Och, Vekas 107, Golomt, Jijig Dul, Chin, and Ulzii. These stoves operate on a different principle than conventional stoves, and they have many advantages, such as low coal consumption, good heat retention, no ash emissions, and adjustable heating. Of these, the Ulzii stove distributes heat evenly on all five sides and uses 71 percent of the heat released from solid fuels. It also retains heat for 8 to 12 hours, so it is enough to fire only twice a day. These 70-burner stoves are made of cast iron and have good heat storage and transfer capacity. The introductory price of the Ulzii stove is 457,000 thousand MNT, and citizens could buy it through the khoroo for 221,000 thousand MNT. These results have ultimately boosted economic growth and reduced poverty.

In the world, stove manufacturers and stove designers are well supported by a relatively large number of organizations and industries. The development of next-generation and clean wood stoves has been supported by ERA-NET Bioenergy, and the project name is WoodStoves2020. The next generation of improved stoves includes the following characteristics shown in Figure 5.

- It is a free-standing room heater, not walled, and usually with a front window.
- Only a relatively small amount of heat storage is possible due to the low mass of the stove.
- Fuel is charged in a single layer onto the ember.
- Frequent recharging is required.
- Heat is released by radiation from the window or from other surfaces and by convection via air ducts and outlets.



*Figure 5: Examples of next-generation and clean wood stoves*

The project WoodStoves2020 aimed at the development of innovative measures and technologies in order to further reduce emissions from wood stoves, increase their thermal efficiency and expand their field of application from solely single room heating to central heating. The objective of this project is divided into three main groups, objectives related to emission reduction, objectives related to increasing efficiency and new fields of application, and objectives related to the implementation and evaluation of the different measures. With the new technologies developed within the project, an emission reduction between 50 and 80 percent and an increase of the efficiencies in a range above 90 percent shall be possible. If in the future, all newly installed wood stoves in Europe were equipped with these new technologies, a PM emission reduction of 60 to 90 percent could be achieved. In order to reach these objectives, a consortium of 4 research organizations and four industrial partners from 4 European countries collaborated within WoodStoves2020 (4). A prominent representative of these ancillary organizations is the ERA-NET Bioenergy association. ERA-NET Bioenergy is a network of national research and development programs focusing on bioenergy which includes 14 funding organizations from 10 European countries: Austria, Denmark, Finland, France, German, Ireland, The Netherlands, Poland, Sweden, and the United Kingdom. Its mission is to enhance the quality and cost-effectiveness of European bioenergy research programs through coordination and cooperation between EU Member states.

## **2.1 Mongolian Current Situation**

Mongolia is a landlocked country in Central Asia and a continental climate associated with large landmasses and characterized by an extreme annual range of temperature and cold winters lasting 7 to 8 months. It is this unrelenting cold that labels UB the coldest capital city in the world. Temperatures during these months often range between -16 to -40 ° C, and although sunny days are possible, they will be cold; the heating of a traditional 'ger,' or a similar-sized small one or two-room house, requires burning about 25 kg of lignite per day.

In 2010, a study found that smoke in Ulaanbaatar's ger districts significantly exceeded the World Health Organization's permissible levels and reached levels that could be very harmful to human health. A 2009 World Bank study in Mongolia established that unrefined coal-fired home stoves are a significant source of air pollution, emitting up to 70 percent of PM2.5 in ger areas, and poor households spend up to 40 percent of their

income on fuel, which has a negative impact on poverty reduction. In addition, the only way to supply heat to ger area households is to import low-combustion but toxic, low-emission, fuel-efficient stoves based on Mongolia's current gasoline and fuel reserves without creating dependence on other sources of fuel such as liquefied gas. **Error! Reference source not found.** shows that air pollution in ger areas is more severe than in urban areas (5).

Location	PM <sub>10</sub> µg/m <sup>3</sup>	PM <sub>2.5</sub> µg/m <sup>3</sup>	Exceeding air quality standards	
			MACS	WHO
City center	150-250	75-150	3-6	7-15
Ger districts	350-700	200-350	7-14	17-35

Table 1: The annual average of fine particles in Ulaanbaatar

The Millennium Challenge Corporation's (MCC) Clean Air Project was aimed at supporting, implemented in 2011-2012, is part of a compact agreement funded by the United States Millennium Challenge Corporation to provide consumers with a 90 percent subsidy to use more fuel-efficient, low-emission products in their gers and other activities. In 2011, a technical assistance project implemented by the Ministry of Mineral Resources and Energy, funded by the Asian Development Bank, established a laboratory to test stove emissions and efficiency. The laboratory evaluated several fuel-efficient stoves based on criteria such as emissions, fuel consumption, efficiency assessment, and market opportunities. More than 80 tests were carried out on these furnaces. Selenge Construction LLC's Turkish-made Ulzii (Mini Silver), Khas (Silver Turbo), and Royal Uushn's Chinese-made Golomt and Dul the stoves reduced PM2.5 emissions by 70-89% and coal consumption by 11-26% (6).

In order to reduce air pollution in UB and protect the health of its residents, the Government of Mongolia has issued a license for electricity and heat generation companies operating in Bayangol, Bayanzurkh, Songinokhairkhan, Sukhbaatar, Khan-Uul, and Chingeltei districts of Ulaanbaatar. Citizens, business entities, and organizations are prohibited from using raw coal from May 15, 2019. The decision was made on the assumption that instead, the use of improved combustion and energy-intensive briquettes is expected to reduce air pollution by 60-80 percent, the target of "23,000 tons" and "improved fuel production will reach 90,000 tons per year". In 2020, 38.2 percent of all households lived in a ger, and 31.5 percent of all households lived in

houses with a stove (7). They consume 320000 tons of briquette coal in 2019-2020, 430000 tons in 2020-2021, and 620000 tons in 2021-2022.

## 2.2 Choice of Fuel

For the improved design of the Ulzii stove, solid fuel was evaluated. The selection to evaluate coal briquettes and brown coal was taken on local availability within Ulaanbaatar.

The following is an example of how many kilograms of briquettes are needed to boil 5 liters of water with this briquette from the average room temperature to 100 degrees (8).

Based on specific heat capacity, we need 1,630,980J of energy to pan to boil 5-liter of water (=5000g) from room temperature to 100 degrees, given its specific heat capacity of 4182 J/kg °C.

$$\text{Equation 1: } Q = m * c * \Delta T$$

Where Q is the heat energy, m is the mass of substance, and  $\Delta T$  is the temperature difference.

$$5kg \times 4182 \frac{J}{kg \text{ } ^\circ C} \times (100 \text{ } ^\circ C - 22 \text{ } ^\circ C) = 1,630,980 \text{ J of energy to water}$$

At 71% of the heat released from solid fuels efficiency, whereby all the briquette coal is transferred to the water, and the caloric content is 9683.6 kcal/kg (29219.38 J/g) (9), we would require

$$\frac{1630980}{29219.38 \times 0.71} = 78.62 \text{ g of briquette coal}$$

Assuming a thermal efficiency of 35% and energy loss of 65%, 224.63g of briquette fuel would be required to boil 5 liters of water, as shown below.

$$\frac{78.62}{35} * 100 = 224.63 \text{ g of briquette coal}$$

Therefore, the fuel chamber needs to be designed to hold at least 225g of briquette coal.

Similarly, 86.63g of brown coal with an average calorific value is 4500 kcal/kg (18828 J/g) (10) would generate 1,630,980J of energy required to boil 5 liters of water if fuel conversion efficiency was 71%.

$$\frac{1630980}{18828} = 86.63 \text{ g of brown coal}$$

For a thermal efficiency of 35%, 247.5g of brown coal is therefore required, as shown below:

$$\frac{86.63}{35} * 100 = 247.5g \text{ of brown coal}$$

Therefore, the fuel chamber needs to be designed to hold 247.5g of brown coal.

The decision to use coal as a fuel in the stove model is based on the goal of 35% efficiency, as it will be 71% efficient for the improved stove. It has been observed that more briquettes are required to accomplish the same cooking task as coal. Therefore, the most suitable fuel choice for the stove was briquette coal in Mongolia.

### 2.3 Coal Briquettes in Mongolia

Improved briquettes are fuels with specific shapes, sizes, compositions, and properties that have been physically and mechanically processed. From 2019, Mongolia will produce briquettes according to the new standard. It was an improved solid fuel standard of 5679:2019 (11). The ingredients of the improved solid fuels are intended to reduce the impact on human health and the environment and are prohibited from being sold if they

No	Types of fuel	Moisture (W <sup>a</sup> )%, not-much	Total sulfur (S <sup>d</sup> )%, not-much	Volatile substances (v <sup>d</sup> )%, not-much	Ash A <sup>d</sup> %, not-much	Calories(Q) (kcal/kg) not-much	Durable % not-much (free fall)
1	Coal briquettes	≤ 10,00	≤ 1,00	≤ 22,00	≤ 29,00	≥ 4200	≥ 80
2	Semi-coked briquettes	≤ 10,00	≤ 1,00	≤ 22,00	≤ 30,00	≥ 4500	≥ 85
3	Sawdust briquettes	≤ 10,00	-	-	≤ 5,00	≥ 4000	≥ 80

*Table 2: Ingredients of improved solid fuels and raw materials*

do not meet this standard. The product shall meet the technical requirements specified in Table 2.

The "free fall" method is also used to determine the strength of improved briquettes. Select 5 to 6 samples from the product and drop them vertically below 1.80 m and onto

a hard surface. The amount of strength can be calculated by collecting the crumbly parts of the dropped sample, sifting them through a sieve, weighing them on a sieve, and comparing them to the weight of the original fuel.

Coal briquettes sold in Mongolia were tested at the Central Geological Laboratory CGL, and the improved fuels met the standard requirements. The laboratory analyzed technical parameters of briquettes, free flow index, and chemical composition. The results of the technical analysis are shown in Table 3. In addition, when the degree of coking of coal was measured, the degree of free flow was 1, which indicates that it is low-energy coal such as coking. Coal with such characteristics can be used for domestic purposes.

Laboratory	Moisture (W <sup>a</sup> )%, not-much	Ash A <sup>d</sup> %, not-much	Volatile (v <sup>d</sup> )%, not-much	Total sulfur (S <sup>d</sup> )%, not-much	Calories (Q <sup>adb</sup> ) (kcal/kg) not-much
Central Geological Laboratory (CGL)	1.9	22.7	19.8	0.87	6983.6

Table 3: Technical analysis of improved coal briquette

Briquette coal used for stove combustion is sold in 381 locations in Ulaanbaatar (12), indicating that they are widely sold. It will take 9,137 kilograms of air to burn 1 kilogram



Figure 6: a) Briquette coal b) Sacks of briquette coal

of this briquette shown in Figure 6, and this air will only come from the air conditioner. Depending on the air coming from the ventilator, you can adjust how fast the briquettes burn in the firebox. The more air there is, the faster the combustion takes place, and the more heat is released.

## 2.4 Combustion of Coal Briquettes

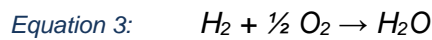
The results of the analysis of the chemical elements in briquettes in the laboratory of the Mineral Testing Authority are shown in Table 4. From this result, we can see the content of chemical elements in briquettes, which account for the majority of carbon, or 65.1%. When briquettes are burned, carbon reacts with Oxygen, as shown below.



1,736 kg of Oxygen or air is required to complete this reaction. Oxygen consists of two atoms, the molecular mass of Oxygen is 32, and the atomic mass of carbon is 12.

$$0.651 * \frac{32}{12} = 1.736 \text{ kg of Oxygen}$$

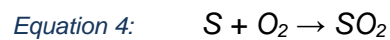
The hydrogen content is 5.4%. The chemical reaction is shown below.



0.432 kg of Oxygen is required to complete this reaction. Hydrogen is made up of two atoms, and the molecular mass of hydrogen is 2, and carbon is made up of 2 atoms, but in this reaction, the number of moles is  $\frac{1}{2}$ , so the molecular mass is 16.

$$0.054 * \frac{16}{2} = 0.432 \text{ kg of Oxygen}$$

The sulfur content of briquettes is 0.87%, and the chemical reaction is shown below.



0.0087 kg of Oxygen is required to complete this reaction. Sulfur has one atom and a molecular mass of 32, Oxygen has two atoms, and Oxygen has a molecular mass of 32.

$$0.0087 * \frac{32}{32} = 0.0087 \text{ kg of Oxygen}$$

Laboratory	Carbon, % C	Hydrogen, % H	Nitrogen, % N	Oxygen, % O
Mineral testing laboratory	65.1	5.4	1.32	7.57

Table 4: Element analysis of improved coal briquette

The total amount of Oxygen required to burn one kilogram of briquettes is 2.1767 kg.

$$1.736 + 0.432 + 0.0087 = 2.1767 \text{ kg of Oxygen}$$

Subtract the amount of Oxygen contained in the briquettes from this total amount of Oxygen. This will give us the absolute mass of air needed to burn one kilogram of briquettes. This amount is 2,101 kg.

$$2.1767 - 0.0757 = 2.101 \text{ kg of Oxygen}$$

Oxygen contains 23.2% of the total weight of air. Therefore, the total amount of air we need will be 9,056 kg of air.

$$2.101 * \frac{100}{23.2} = 9.056 \text{ kg of air}$$

The amount of air required for the complete combustion of briquettes in our country is about 2 kg more than the number of briquettes in the world average.

## **2.5 Fundamentals of Automated Control Systems for Stove**

Advanced automated control systems contribute to the reduction of customer operating errors as they provide the basis for low-emission and high-efficiency stoves. Therefore, the optimization and implementation of such a system, which is not currently widely used, will have a massive impact on reducing stove emissions. These are the basis for low emissions not only in test parking conditions but also in real life during operation. In addition, the existing stove control units open up a more comprehensive range of emissions reduction options. The automatic boiler control system can control and optimize the operation of the stove but does not affect the fuel used. Therefore, it is essential that the consumer ensures the sound quality of the fuel required to operate the stove efficiently and cleanly.

Some modern stoves automatically control the combustion of air. It can be electronic (via motor-driven flaps) or thermomechanical (flaps are operated via a temperature-sensitive expandable liquid). These features often have the advantage that they offer optimal combustion and prevent false positives such as shutting off the grate airflow after the first heating phase is complete (13).

The general concept of wood stoves is usually controlled manually (by a control switch). Therefore, process control efforts are usually limited to a change in the combustion air distribution at the end of the ignition phase. Recent technical solutions toward stove

automation can be divided into automatically controlled stoves and stove add-ons, which feature an automatic control (14).

- Stove add-ons and retrofit systems, which feature an automatic control
  - Chimney draught stabilizer and flue gas fans
  - Air and flue gas flaps
  - Electronic air distribution systems
- Automatically controlled stoves
  - Thermo-mechanically operated air flaps
  - Electronic sensors drove automatic control concepts.

## **2.6 Sensors for Automated Control Systems**

In order to implement a reliable automatic control system based on electronic sensors, it is essential to choose a sensor. Selection should take into account specific criteria such as price, availability, service life, temperature resistance, signal selectivity, stability, and processing. The most important criterion is to ensure that the price of sensors and devices is acceptable. This is because the cost of installing the sensor will be relatively higher than the market price of a conventional stove. Criteria for resistance to temperature and other environmental conditions affect the ability of the sensor to be located. The monitoring system must be able to place the sensors in representative locations to provide a fast and convenient signal for operation. For example, the placement of a temperature sensor in a flue gas outlet provides a less sensitive, dynamic control signal than a sensor in a suitable location in the combustion chamber, which weakens the capacity of the control system (15).

Depending on the kind of automatic control system, different sensors can be used, for example:

- Temperature sensors
- Gas sensors
- Pressure sensors
- Other sensors, for example, detectors for recognizing flame or door opening.

## **2.7 Retrofit Components and Accessories**

The furnace can be equipped with the following additional components to improve combustion performance.

- ❖ A flue gas thermometer allows you to determine the correct charging time. Moreover, it is used to measure the temperature of the smoke in the flue pipe right above the stove. Such thermometers are available from specialized suppliers. They require a small hole in the flue to accommodate them, but there are also models of magnetic thermometers.
- ❖ A bleed air flap is fitted at the chimney bottom (in the basement) to avoid excessive chimney draught, shown in Figure 7. For stoves with a central air inlet socket, a unique bleed air flap can also be mounted at the stove's flue gas outlet and, via at-fitting, be connected to the central air canal to allow combustion air to bypass the stove.
- ❖ Electronic combustion air supply control can be applied if the stove is equipped with a central air inlet socket.
- ❖ Manostat is a sensor that is located in the room where the stove is operated. It is connected to any stationary electric ventilators, which can evacuate the room (16).
- ❖ Fan on the chimney top, exhaust fans are mounted at the top of the chimney and literally suck smoke or gas up the flue. The chimney fan is designed to disperse the



smoke sideways like a regular chimney cap. Chimney fans also help to reduce the amount of creosote in the flue while preventing back puffing.

*Figure 7: a) Bleed air flap for chimney b) Electronic air supply control c) Flue gas thermometer.*

## 2.8 Temperature Controller

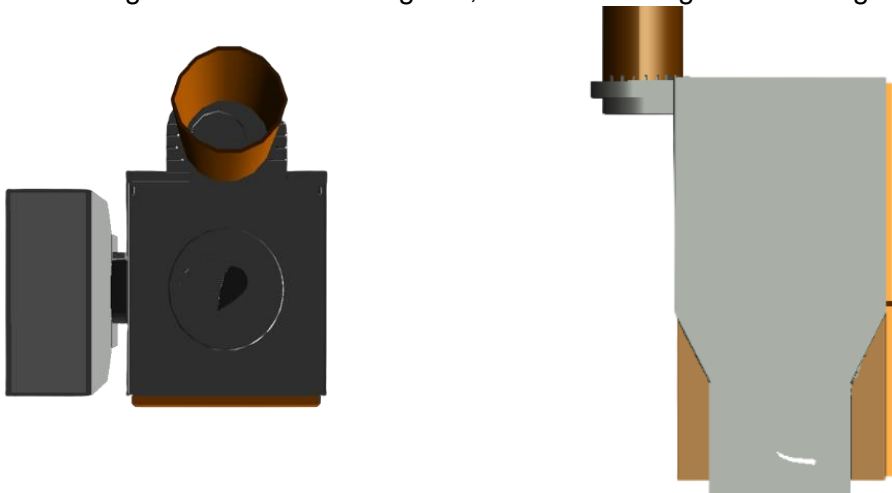
The furnace receives information from three types of sensors, which are processed in a data control system to adjust the air blower speed and the screw conveyor speed. There are three types of sensors: indoor heat sensors, outdoor heat sensors, and stove combustion sensors. This provides information to the management system. If the control system is informed that the house is cold, the control system will need to distribute a large amount of heat quickly. At this point, the speed of the air blower increases, and a large amount of air is distributed to the furnace, which speeds up combustion. It is also

necessary that the faster the fire, the faster the speed of the screw conveyor. The furnace control system did not need to be studied in detail in the thesis.

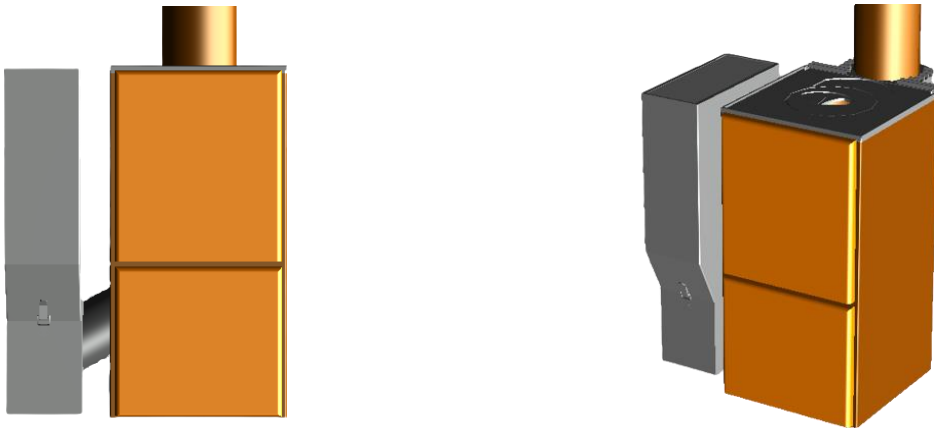
### 3 Design of Attachments to Ulzii Stove

This research is not just about automation, but it also covers the design of additional parts to be placed in the furnace, how to place them optimally, how to connect the attachments, as well as how to change the original design of the furnace. Engineering design is the process of designing a system, component, or process to meet the desired need. It is a decision-making process and is often used in the basic sciences, mathematics, and engineering to efficiently convert resources to achieve defined goals. Key elements of the design process include goal criteria, synthesis, analysis, construction, testing, and evaluation.

A number of additional parts and items are being added to automate the Ulzii stove, such as bunker, motor, screw conveyor, and electronic devices are shown in Figure 8. The automation process transports the coal from the hopper through a screw conveyor, the speed of which is modified based on the length and diameter of the screw conveyor. This speed will be adjusted according to the combustion rate and heat in the ger or house. So, it can be easy to control how much feed enters the firebox from the hopper. Moreover, to replace the grate of the stove. For the reason that the old-fashioned stove grate is designed for manual firing. So, I have to change the stove grate for the new



model. The new model has two majority parts, the furnace and hopper, and they are



connected by a turbo, which covers the screw conveyor and acts as a support. It directly depends upon the screw conveyor's length and width.

The original width and length of the stove will be unchanged, and the combustion section will generally remain the same. The distance between the hopper and the stove is 60 millimeters. This value is calculated based on the amount of heat loss from the furnace and the heat absorption of the hopper material. Proximity to this distance will allow the hopper to absorb more heat, which will reduce the efficiency of heating the coal inside the hopper. The reason for the decrease in inefficiency is that the heat emission of coal is calculated by Equation 1, and the higher the initial temperature, the lower the gain for us.

*Figure 8: a) Top view of the design of new stove b) Left side view of the design of new stove c) Front view of the design of new stove d) Isometric view of the design of the new stove.*

$$\text{Equation 5: } Q = m * c * \Delta T$$

Absorbed heat  $Q$ , the mass of substance being heated  $m$ , the specific heat of substance  $c$ , and change in temperature  $\Delta T$ . There is also a risk of burns to human hands when refilling the hopper or handling it.

The screw conveyor is located at the bottom of the hopper and is directly connected to the motor. There is also a box that includes it, which includes not only the screw transmission but also the air conditioner. This saves space and is the perfect design solution. The Oxygen used during combustion passes through a gas pipe. The air from the ventilator passes through a pipe in the ventilation system to the combustion chamber, which is connected in parallel with the screw conveyor to the combustion chamber. Combustion efficiency is high due to the heat of the combustion air. If the heat from the furnace can be used to generate high temperatures using less material, then helpful work

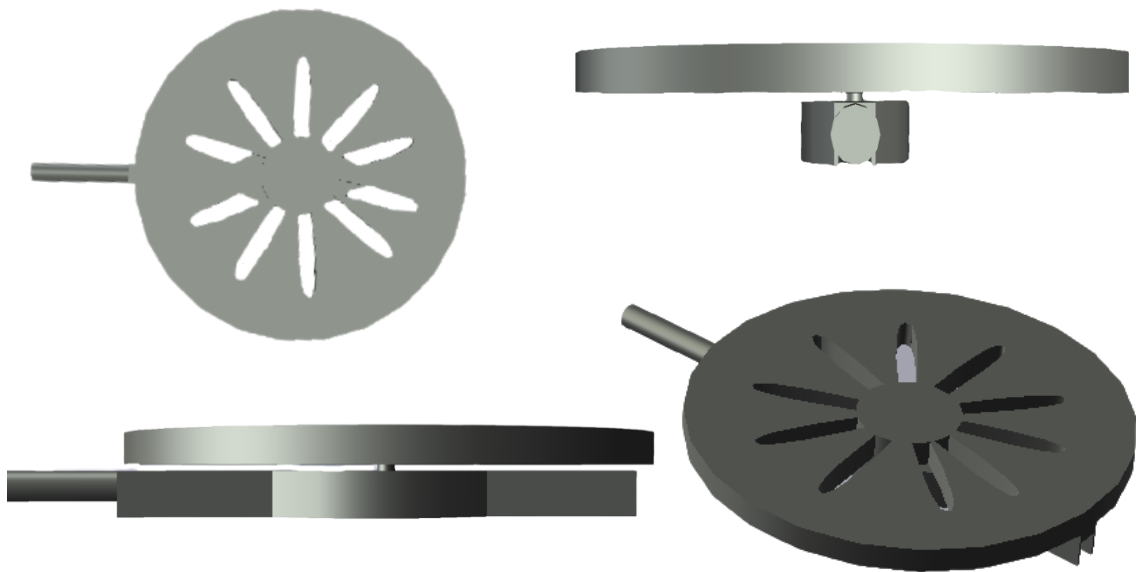
is being done. Therefore, this model is used as a solution to increase the heat of the air flowing through the air ducts.

Combustion should be considered the most important. Depending on how fast and slow the combustion is, the heat released from it will be determined. Combustion is a chemical process in which a substance reacts rapidly with oxygen and gives off heat. This means that through the furnace air system, we can control how much air enters the furnace's firebox—the more air that enters, the more combustion inside the stove and the faster the combustion. As a result, a large amount of heat is released, and the home temperature rises rapidly. It is suitable when the fire is extinguished for a long time or when the house temperature is low, and the outside temperature is below minus  $-25^{\circ}\text{C}$ . However, excessive air supply will result in incomplete combustion and the disadvantages of using large amounts of briquettes.

The air intake of the old stove was simple mechanical and was located at the back of the stove ashtray. In the new model, this air inlet must be permanently closed and air-tight. The airstream escapes from the air conditioner, passes through a pipe to the combustion grate, burns the briquettes, and is sucked out by the smoke and exhaust. If additional airflow is added to this airflow, this operation may be performed incorrectly, and a dangerous situation may arise. Care should also be taken to ensure that the hopper lid and isolating section are very careful. If this airflow is directed to the hopper, the coal inside the hopper will burn and evaporate, resulting in incomplete combustion.

The lower part of the stove is higher in height than the old size and has been renovated. The reasons for this were influenced by a number of factors, the largest of which was the height of the hopper and its suitability for combustion. It also updated the waste collection container and created a new design. Excessive elevation of the combustion grate during combustion can adversely affect the combustion process and reduce heat emissions. The location of the combustion grate too low promotes incomplete combustion and creates a risk of fumes. Therefore, the original height was changed and increased. Waste bins or ashtrays are being refurbished, and current upgrades are becoming more sophisticated. When the ashes of the old ashtray were dumped, the ashes were agitated, and particles were released into the air, and when they fell from the combustion grille, they did not fall entirely into the ashtray and caused pollution. The new ashtray can solve these problems.

The old stove burner was 100 millimeters in diameter and had a round body shown in Figure 9. It will have a hole around its axis, through which the briquettes that have burned will fall. In some cases, the ash from the briquettes is entirely dependent on the binder and cannot be dropped through the burner hole. The briquettes stove in an old burner would fall through the burner or turn the burner upside down by 90 degrees after the fire was extinguished. The current model of the stove has run out of briquettes and is pressed into the coal coming from below, falling over the walls of the cone-shaped burner into the tray. This eliminates the extra parts and functions used in older stoves. In some cases,



*Figure 9: a) Top view of old stove burner b) Left side view of old stove burner c) Front view of old stove burner d) Isometric view of old stove burner*

briquettes do not burn or have incomplete combustion, and when they fall, they can clog the pipes. At this time, open the top lid of the stove and drop it with a long stick.

The screw conveyor is connected to the motor from the bottom of the hopper and continues to the furnace. The length of the screw conveyor will be 280 millimeters and will be located from the hopper to the entrance to the furnace. Because the temperature inside the furnace is high and there is a risk of expansion and melting due to the high temperature of the screw for a long time. If the screw conveyor is made of heat-resistant and durable material, the cost will be too high. This could reduce consumer demand and put pressure on prices. Therefore, the screw conveyor will extend to the stove, and the remaining space to the burner will be made of fire-resistant, low-cost clay material. The

briquettes entering the pipe section made of clay material are compressed into the briquettes of the screw conveyor and reach the burner.

The air blower is responsible for blowing air at high speeds and supplying air to the firebox. An air blower is located under the hopper and connected to the air duct to support the firebox with air. The length of the air duct shall be equal to the length of the screw pipe from the hopper to the furnace, after which the pipe shall be made of fire-resistant material. Because only air flows through this pipe, only fire-resistant material is sufficient.

The overall size of the stove is raised by 114 millimeters. It was the most suitable height for screw conveyors and coal pipelines. This is because the screw conveyor is positioned 29 degrees along the horizontal axis. It is placed depending on the combustion firebox and the burner.

### **3.1 Design of Hopper**

Bulk material has a given ability to slide and fall when it is stored in a hopper. A key variable that will have an impact on the flow of product outside of a bin is its cohesive strength. In a bunker, the coal is submitted to pressure due to the fact that there is a height of powder in the bunker, the coal on top pushing on the coal below the hopper. Due to the pressure, some solids tend to be more cohesive; when coal becomes cohesive, it can form arches or rathole, two phenomena very detrimental to the flow of coal and the discharge of the hopper. The coal is consolidated in the top part due to pressure. However, in the cone, the stress applied to the coal decreases, which means that the forces pushing the product to flow are minimal; arching can thus happen at this level in the hopper. The design of the hopper has an objective to find the couple cone

angle + perimeter of outlet that will manage to keep a constraint on the powder high enough to break arches and make the product flow naturally (17).

The outlet of the hopper can be calculated in order to avoid both arching and ratholing, thus maximizing the chances to ensure a proper flow of product, as can be seen in Figure 10. In the design process, to determine the fundamental properties needed to predict the flow behavior of bulk solids, such as cohesive strength, internal friction, compressibility, wall friction, and permeability. When designing a hopper, the following parameters must be calculated, discharge diameter, which can avoid arching and ratholing, discharge angle, the volume of the hopper, and the discharging rate from the bunker. The results are used to calculate the size of the hopper section outlet and the recommended hopper angle.

Knowing the characteristics of the product to discharge is the first and mandatory step to properly designing a hopper. The briquette coal characteristics can be determined. From these characteristics, a critical discharge diameter can be calculated. The critical discharge diameter is the Diameter under which the product will risk arching. It must be noted that different diameters can be calculated depending on the type of bin to be implemented.

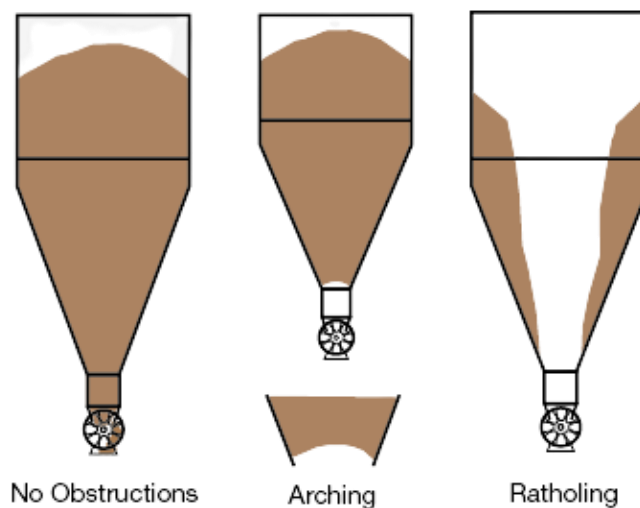


Figure 10: Cohesive arches and ratholes prevent flow through a hopper

One of the following essential things to consider is that one sack of briquette coal weighs 25 kg, and our hopper should contain all of this 25 kg of briquette coal in one charge. Thus, it can prevent particles and dirt from cluttering around. It will also be easier to lift and recharge the hopper. The hopper consists of two main parts, a prismoid and a

rectangular bin. We can see that the design of the bunker in Figure 11, the top side of the prismoid bin is 340 mm in length, 150 mm in width, and the bottom side of the prismoid is 225 mm in length, 150 mm in width, and height of prismoid bin is 120 mm.

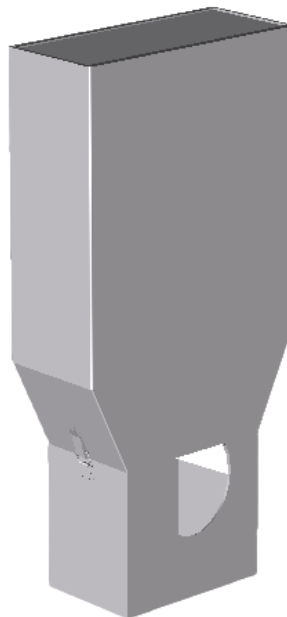
**The volume of Prismoid  $V_1$** , calculating the volume of a prismoid, can be used to find the capacity of a prismoid.

$$\text{Equation 6: } V_1 = 1/6 * H_1 * (2 * L_1 * B_1 + L_1 * B_2 + L_2 * B_1 + 2 * L_2 * B_2)$$

$$V_1 = 1/6 * 120 * (2 * 340 * 150 + 340 * 150 + 225 * 150 + 2 * 225 * 150) = 5,085,000 \text{ mm}^3$$

As can be seen in Figure 11, the rectangular container is 150 mm wide, 340 mm long, and 400 mm high. These results are calculated in terms of the volume and capacity of each bin. **The volume of Rectangular Bin  $V_2$**  is equal to the length, width, and height of the bin, and calculating the volume of a rectangular bin can be used to find the capacity of a bin.

$$\text{Equation 7: } V_2 = B * L * H_2$$



*Figure 11: a) Top view of the bunker b) Front view of the bunker c) Left side view of the bunker d) Isometric view of the bunker.*

$$V_2 = 150 * 340 * 400 = 20,400,000 \text{ mm}^3$$

**Total height H**, the total height of the hopper is less than the height of the stove. The total height of the furnace is 714 millimeters, and the total height of the hopper is

520 millimeters, according to Equation 5. An additional box is being placed at the base of the hopper to increase this size and bring the height of the stove and hopper to the same level. The box contains a screw conveyor and an air blower. In addition, the box will not affect the capacity at all.

$$\text{Equation 8: } H = H_1 + H_2$$

$$H = 120 + 400 = 520 \text{ mm}$$

**The capacity of Prismoid  $C_1$**  is equal to the volume times density of the material. Dividing by 1 million is only a unit transfer.

$$\text{Equation 9: } C = \frac{V}{1,000,000,000} * \rho$$

$$C_1 = (5,085,000/1,000,000,000) * 1200 = 6.102 \text{ kg}$$

#### **Capacity of Rectangular Bin, $C_2$**

$$C_2 = (20,400,000/1,000,000,000) * 1200 = 24.48 \text{ kg}$$

**The total capacity of Hopper  $C$** , the total capacity shall be the sum of the capacities of the prismoid and rectangular bin, and it shall be such as to hold one sack of coal as a whole. This means that our hopper can hold 25 kilograms of briquettes per refill.

$$\text{Equation 10: } C = C_1 + C_2$$

$$C = 6.102 + 24.48 = 30.582 \text{ kg}$$

Moreover, the hopper has two lids at the top and bottom, and each lid must be tightly sealed. Figure 12 shows the top cover of the hopper, which will be a lid. The roller shutters are very good at preventing airflow and air ingress. When the amount of coal inside the hopper is reduced, and the hopper needs to recharge, the screw conveyor and the lower hopper covers will be closed, and the upper roller shutter will be opened. When the cover is opened, it folds into the box shown in yellow in Figure 12. This makes it possible to fill the hopper with briquettes without any obstacles. The hopper can be fully charged with one sack or 25 kg of coal at a time. When repositioning the hopper and closing the roller shutter, make sure that the cover plate is in its path and that the cover is completely closed. If the lid is not entirely closed, normal continuous combustion will start to burn backward. As a result, there is no risk of fire coming into the bunker in a short period of time, causing combustion, fumigation, and poisoning due to incomplete

combustion. Therefore, each time you fill the hopper, make sure that the The roller shutter is completely closed.

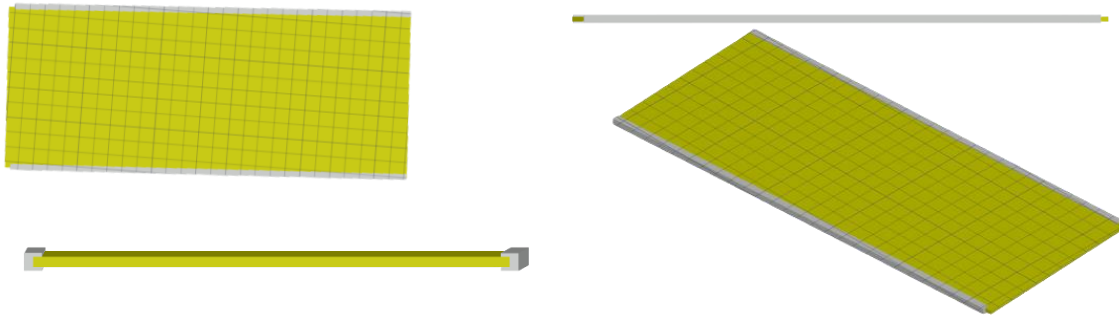


Figure 12: a) Top view of hopper lid b) Left side view of hopper lid c) Front view of hopper lid d) Isometric view of the hopper lid.

### 3.2 Design of Screw Conveyor

Screws are one of the oldest methods of transporting materials and are still used in their original design more than two thousand years ago. The first conveyor was designed by Archimedes to remove water from the ship and to raise water from the river to farmland. Since the screw conveyor came into general use a little over a century ago for moving grains, refined coal, and other bulk material of the times, it has come to occupy a unique place in a growing area of material handling processing. Today, modern technology has made the screw conveyor one of the most efficient and economical methods of moving bulk material. For screw conveyor design purposes, conveyed materials are classified in accordance with the code system. This system conforms to that of the Conveyor Equipment Manufacturers Association (CEMA), which ranks each material into five categories. Many years of experience in the design and practical application of screw conveyors have resulted in the refinement of conveyor design.

There are many advantages of screw conveyors, such as conveyors are compact, which means they are easily adapted to congested locations. It can be used to control the flow of material in processing operations which depend upon accurate batching. Another is used as a mixer or agitator to blend dry or fluid ingredients, provide crystallization or coagulant action, or maintain solutions in suspension. Also, the main head of the screw conveyor is versatile, which means it can be employed in vertical, horizontal, and inclined

installations. Figure 13 shows the design of the screw conveyor with a tube for the new model of the Ulzii stove.

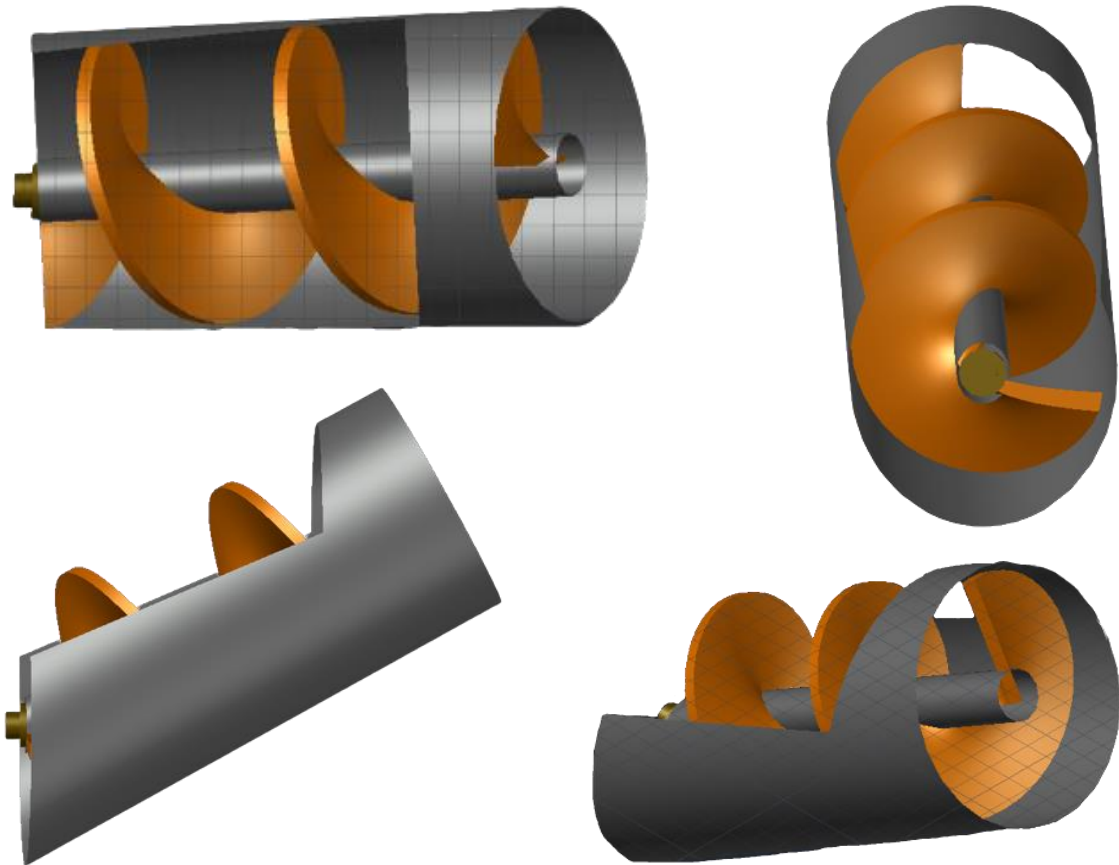


Figure 13: a) Top view of screw conveyor with tube b) Left side view of screw conveyor with tube c) Front view of screw conveyor with tube d) Isometric view of screw conveyor with the tube.

It is essential to know several parameters surrounding the application when properly designing a conveyor. The first step is to establish the characteristics of bulk material and write down the following information such as maximum particle size, bulk density, trough loading, HP factor, abrasiveness, corrosiveness, and flowability. The second step is to determine conveyor size and speed based on capacity. The characteristics of the bulk material to be conveyed have been determined, and the next step is to calculate the capacity in cubic feet per hour. Always use the lowest bulk density when calculating capacity in order to get the highest potential volumetric capacity. For the calculation of conveyor speeds where particular types of screws are used, such as short pitch, cut flights, cut and folded flights, or ribbon flights, an equivalent required capacity must be used, based on factors in Table 5. The equivalent capacity (EC) is then found by multiplying the required capacity (RC) by three of the capacity factors that are involved.

$$\text{Equation 11: } EC \text{ (ft}^3\text{/h)} = RC \times CF_1 \times CF_2 \times CF_3$$

$$EC = 0.03679 \text{ ft}^3\text{/h} * 1 * 1 * 1.24 = 0.045615 \text{ ft}^3\text{/h}$$

<b>Special screw pitch capacity factor CF<sub>1</sub></b>				
<b>Pitch</b>	<b>Description</b>			<b>CF<sub>1</sub></b>
Standard (full)	Pitch = Diameter of screw			1.00
Short	Pitch = 2/3 Diameter of the screw			1.50
Half	Pitch = 1/2 Diameter of screw			2.00
Long	Pitch = 1 1/2 Diameter of screw			0.67
<b>Particular screw flight modification capacity factor CF<sub>2</sub></b>				
<b>Type of flight</b>	<b>Conveyor loading</b>			
	<b>15%</b>	<b>30%</b>	<b>45%</b>	
<b>Standard</b>	<b>1.00</b>	<b>1.00</b>	<b>1.00</b>	
<b>Cut</b>	<b>1.95</b>	<b>1.57</b>	<b>1.43</b>	
<b>Cut &amp; Folded</b>	<b>Not rec.</b>	<b>3.75</b>	<b>2.54</b>	
<b>Ribbon</b>	<b>1.04</b>	<b>1.37</b>	<b>1.62</b>	
<b>Special screw mixing paddle capacity factor CF<sub>3</sub></b>				
STD paddle per pitch set at 45° reverse pitch				
<b>None</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
<b>1.00</b>	<b>1.08</b>	<b>1.16</b>	<b>1.24</b>	<b>1.32</b>

Table 5: Capacity factor

In this case, the EC will be used to select the proper screw conveyor diameter and speed from Table 6. Using the recommended trough loading and calculated EC, select the

proper conveyor diameter. The EC must be less than the maximum capacity given in the Capacity table. The Conveyor Speed (CS) N is calculated by dividing the EC by the capacity at 1 RPM (17).

$$\text{Equation 12: } N = \frac{\text{Equivalent Capacity (EC)} \frac{ft^3}{hr}}{1 \text{ rpm capacity from Conveyor Capacities}}$$

$$N = (31 \text{ ft}^3/hr) / (3 \text{ ft}^3/hr) = 0.015 \text{ rpm}$$

Percent trough load	Screw diameter	Maximum Recommended RPM	Capacity at MAX RPM	Capacity per RPM
95%	4 inch	354 degree	654 RPM	2.3 RPM
95%	5 inch	333 degree	980 RPM	3 RPM
95%	6 inch	300 degree	1,415 RPM	4.7 RPM
95%	9 inch	275 degree	4,832 RPM	17.6 RPM
95%	12 inch	255 degree	10,760 RPM	42 RPM
95%	14 inch	240 degree	16,342 RPM	68 RPM

Table 6: Conveyor capacity

The third step is to calculate horsepower, and a 5-inch diameter screw conveyor was selected in step 2. The horsepower required to operate a horizontal screw conveyor is based on proper installation, uniform and regular feed rate to the conveyor, and other design criteria. The horsepower requirement is the total of the horsepower to overcome the friction ( $HP_f$ ) of the conveyor components and the horsepower to transport the material ( $HP_m$ ) multiplied by the overload factor ( $F_o$ ) and divided by the total drive efficiency ( $e$ ) (18).

### Friction Loss

$$\text{Equation 13: } HP_f = (L * N * F_b * F_d) / (1,000,000)$$

$$HP_f = 2 * 10^{-7} \text{ HP}$$

### Required power for transporting material

$$\text{Equation 14: } HP_m = (C * L * D * F_m * F_f * F_p) / (1,000,000)$$

$$HP_m = 6 * 10^{-6} \text{ HP}$$

The Total shaft horsepower (TSHP) by summing the friction horsepower and the corrected material horsepower. Drive efficiency (e) for a typical screw conveyor drive with shaft-mounted reducer and V-belt drive is 44 percent.

### Total Horsepower

$$\text{Equation 15: } HP_{total} = \frac{(HP_f + HP_m) * F_o}{e}$$

$$HP_{total} = 1 * 10^{-5} \text{ HP}$$

TSHP is typically rounded up to the following commonly available motor size.

### 3.3 Design of Burner

The combustion chamber is designed to receive briquette coal and enhance the complete combustion of combustible gas released during the coal-burning briquette process. The combustion chamber is embedded in a frustum (the portion of a solid that lies between one or two parallel planes cutting) of cone constructed using granite rock and clay. As can be seen in Figure 14, the upper Diameter of the burner is designed by 200 mm, and the diameter of the bottom side is designed by 150 mm. The combustion chamber and outer retort are designed in a way that a 20 mm gap is left in to provide a free movement of air and enhance resistance to heat transfer to the inner wall of the outer retort. This concentrates a large amount of heat from the burning briquette coal at the bottom of the cooking pan, thereby increasing thermal efficiency.

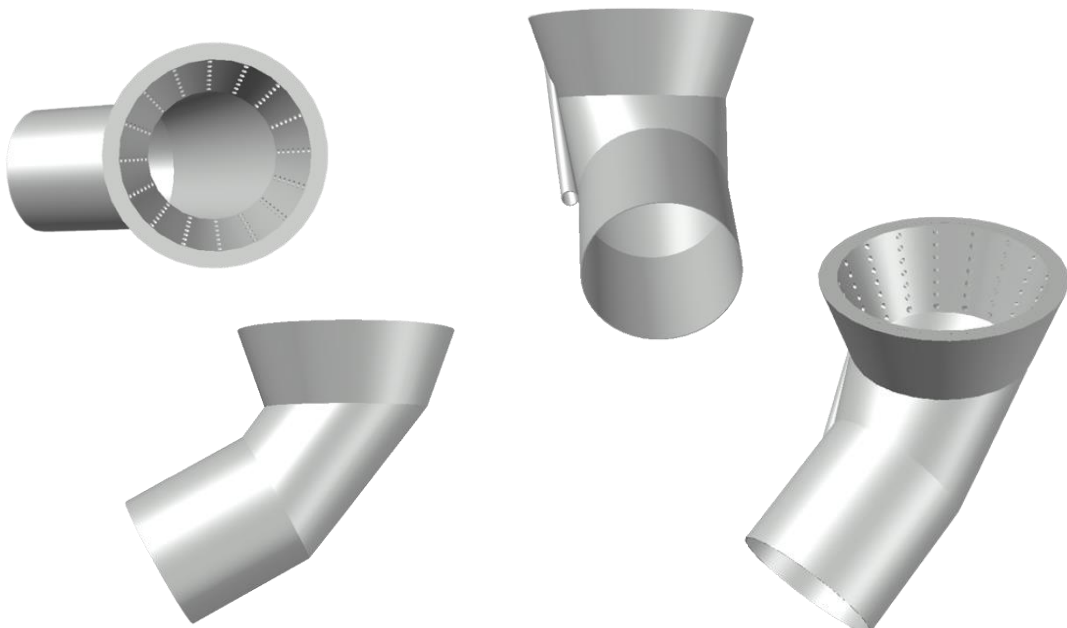


Figure 14: a) Top view of burner b) Left side view of burner c) Front view of burner d) Isometric view of the burner

### **3.4 Design of Ash Trash**

Coal ash is the residue left after burning the coal. It includes bottom ash, flies ash, and boiler slag. Fly ash is an excellent powder composed of silica made by the burning finely coal on a stove as well as bottom ash is too large to be carried into the chimney, and angular ash particles are formed at the bottom of the coal stove. Boiler slag is usually formed in the case of cooling with water and burning large amounts of coal, so it is almost not formed in our furnaces.

The ashtray of the old stove was a simple square container and had several problems. It was 310 millimeters long, 230 millimeters wide, and 90 millimeters high. This amount is 3 to 4 times less than the amount of ash emitted per day from burning coal, and the user must pour the ash before lighting the stove. It was very difficult for the users, and every time they dumped the ashes, tiny particles of ash swarmed and polluted the environment.

The ash content of briquettes used in Ulaanbaatar ranges from 15 percent to 24 percent, with the most commonly used being 22.7 percent. If the amount of briquettes burned per day is estimated at 25 kilograms, 5.675 kilograms of ash will be released. Thus, 5.675 kilograms of ash will fit in a volume of 5,358,830 cubic millimeters. Due to the low density of ash, large-capacity containers are required. In the new model, the height of the stove was increased by 131 millimeters, which made it possible to increase the height of the ashtray. The new ashtray is 310 millimeters long and 300 millimeters wide, and 125 millimeters high. The volume of this container is 11,625,000 cubic millimeters, which means that it is not necessary to remove the ashes in 2 or 3 days. It also solves all of the above problems, and the tank will have a semi-automatic lid. The ashtray will have a sliding lid that will have a look at the beginning. There will be a loop at the mouth of the stove to hold the ashtray. When the ashtray is inserted, the hook is inserted into the loop in the stove so that the lid of the ashtray is opened and placed in the oven. Conversely, when removing the ashtray from the stove, the hook in the loop will cover the container to prevent particles from swirling and contaminating the area.

Finally, when discarding the ashes from the stove, take the ashes to the waste disposal site, open the lid and discard them. I think that this new model will be user-friendly.

### 3.5 Design of Blower

A blower is a device that increases the speed of air and gas through an equipped impeller. They are mainly used for air/gas flow required for exhaust, suction, cooling, ventilation, and transmission. The blower is also called a centrifugal fan in the factory.

The Ulzii stove did not have an air blower, and the airflow could only be controlled manually. Open the air valve for a period of time to allow air to enter and ignite the fire, leaving the valve open for a period of time. When the fire started, the air valve was closed or lowered. An air blower has been added to the new stove so that the air entering the stove can only be controlled automatically by the air blower, as shown in Figure 15. This has a significant impact on automation. This is because the combustion is directly dependent on the air, and the more air is blown, the faster the combustion inside the furnace and the greater the amount of heat released. However, when the air is shut off or blown in a small amount, the combustion inside the furnace slows down and switches to heat storage mode.

Calculations were made to select the most suitable and efficient air blower for the furnace, and the calculation was based on the maximum air blower. The air blower selected for the new furnace measures 65 \* 35 millimeters and is capable of blowing at a maximum power of 13.5 CFM. This size is selected according to the fan capacity required for the new furnace. The advantage of this blower is that it can rotate at high speeds and which is small in size. It is also affordable, selling for \$ 13 a piece (19).

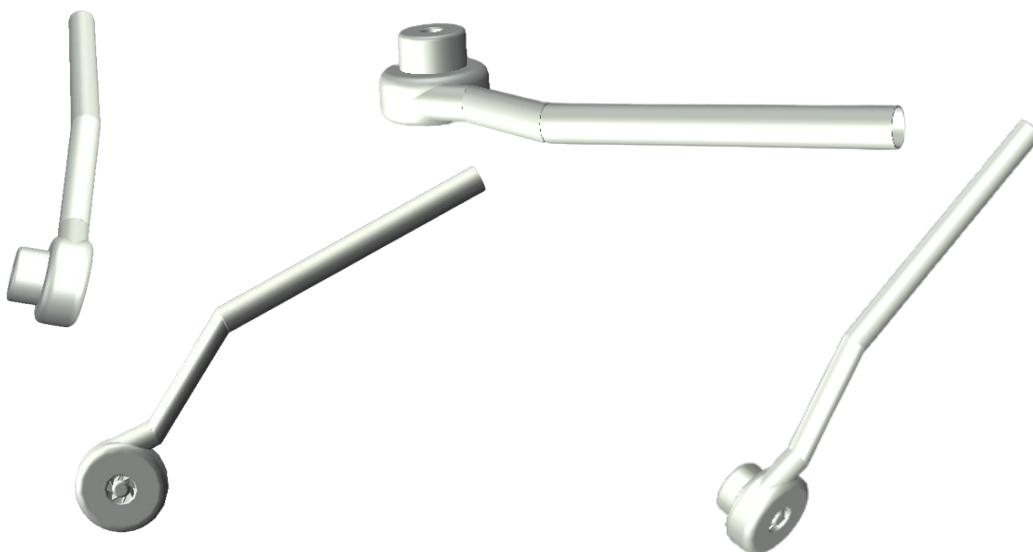
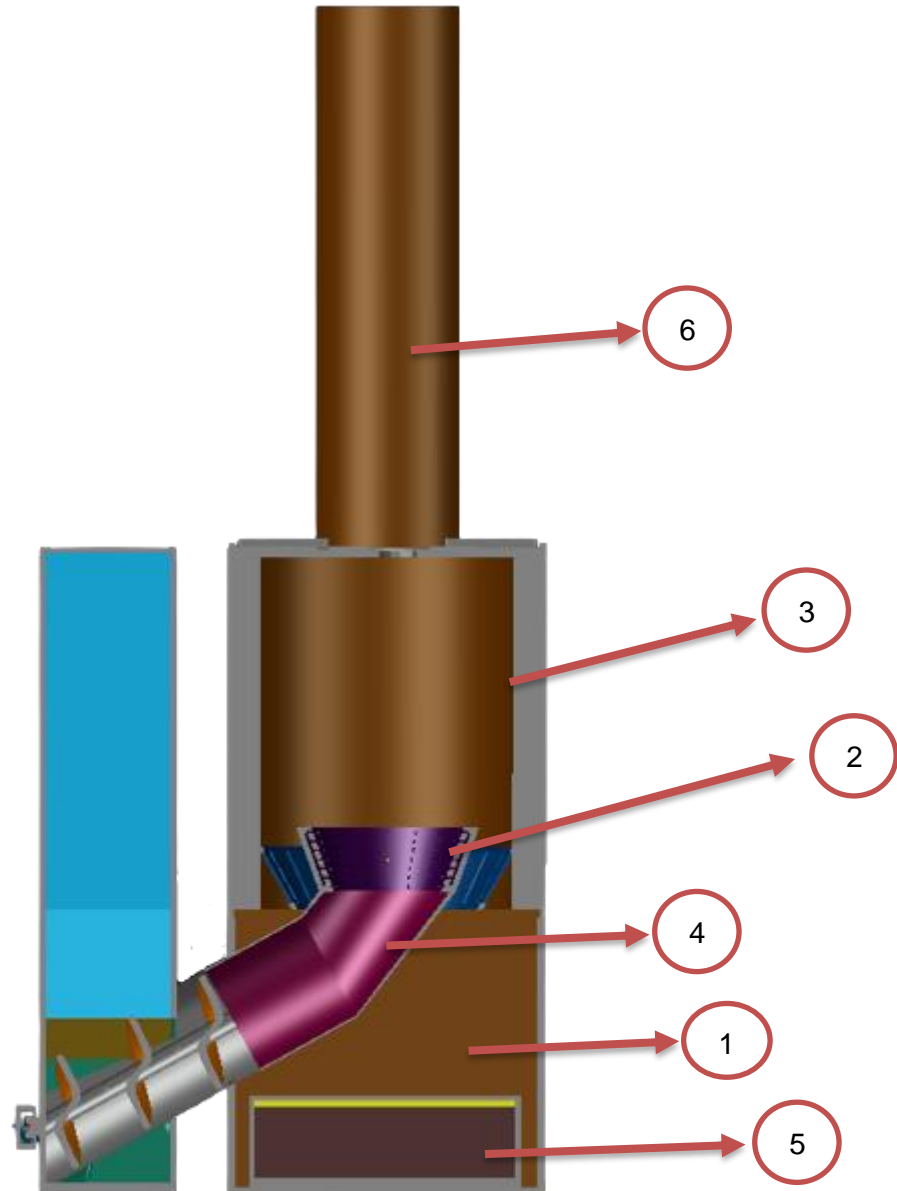


Figure 15: a) Top view of air blower b) Left side view of air blower c) Front view of air blower d) Isometric view of air blower

## 4 The Computer-Aided Design (CAD) of the New Ulzii Stove



*Figure 16: Front cross-sectional view of the stove*

The computer-aided designs of the new design of Ulzii stove are created on the AutoCAD program. Each of the designs is explained below.

Figure 16 is a cross-sectional view of the front of the stove, with a cross-sectional view of the inside of the stove. This section highlights the stove in a variety of colors, with the aim of showing each part of the stove clearly and clearly showing the connections.

- 1 - Stove body. The body of the stove is highlighted in brown, and the stove contains many parts.
- 2 - Burner. Combustion will take place in this burner, and the burner will be made of cast iron and highlighted in purple.
- 3 - Firebricks or liners. Generally, line the inside of the stove and protect the body of the appliance. They also reflect the heat back into the stove, improving efficiency.
- 4 - Conductive pipe. It is responsible for transporting the coal transported by the screw conveyor to the burner. The pipeline is made of fire-resistant material, which is cast iron and is shown in pink.
- 5 - Ashpan. It is responsible for collecting the ash from the combustion and, most importantly, preventing contamination from spilling into the furnace. The ashtray is shown in Figure 16 in dark brown.
- 6 - Stovepipe. Otherwise known as a chimney, it is used for conveying exhaust gases from a fireplace and joins the appliance to the flue system. It would be brown in color, similar to the body of the stove.

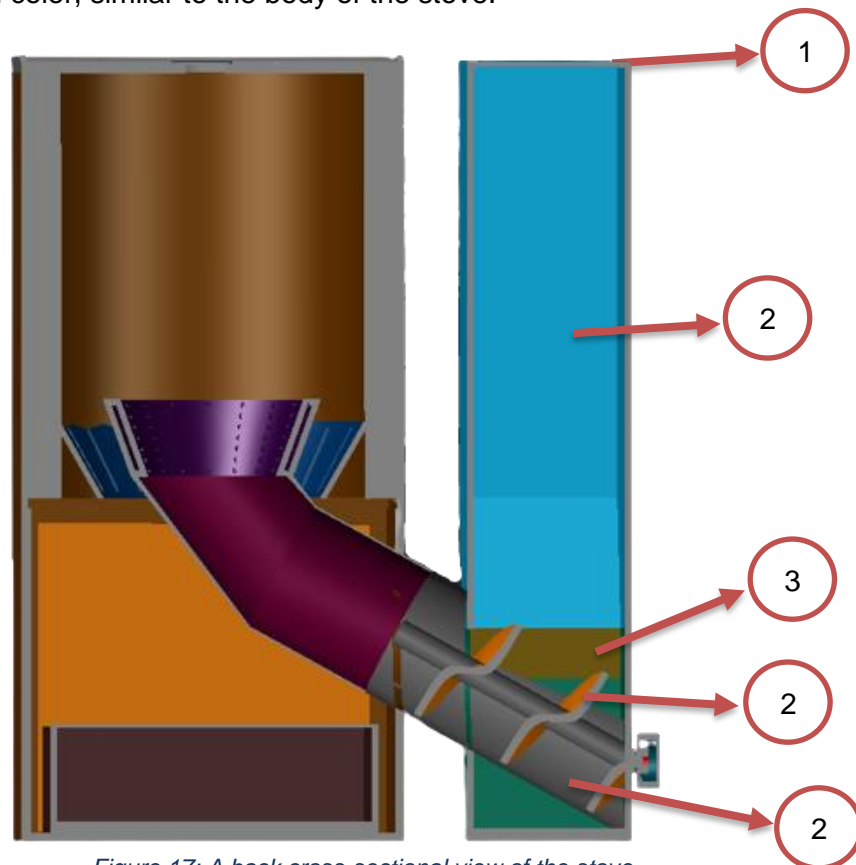


Figure 17: A back cross-sectional view of the stove

The cross-section of the stove from the back and the parts inside the stove can be seen from the back, as shown in Figure 17. Figure 16 describes the location and appearance of the furnace sections, while Figure 17 describes the bunker sections below.

- 1 – Bunker lid. This will cover the hopper and lid the hopper very well to prevent airflow. It folds up and appears grey in the picture above.
- 2 - Bunker body. The body of the hopper consists of two parts, and it is shown in blue.
- 3 - Feed chute. This section is located at the top of the screw conveyor and is responsible for feeding the screw conveyor from the hopper. It will also prevent coal from entering the base of the bunker. The feed chute is shown in greenish-brown.
- 4 - Screw the conveyor. The screw conveyor is the primary conductor that carries the feed from the hopper to the combustion section. This transmitter is shown in orange in Figure 17.
- 5 - Pipeline. The pipe will contain a screw conductor and will be a kind of housing. It is one of the most valuable things for transporting fuel. In the picture above, it is shown in gray.

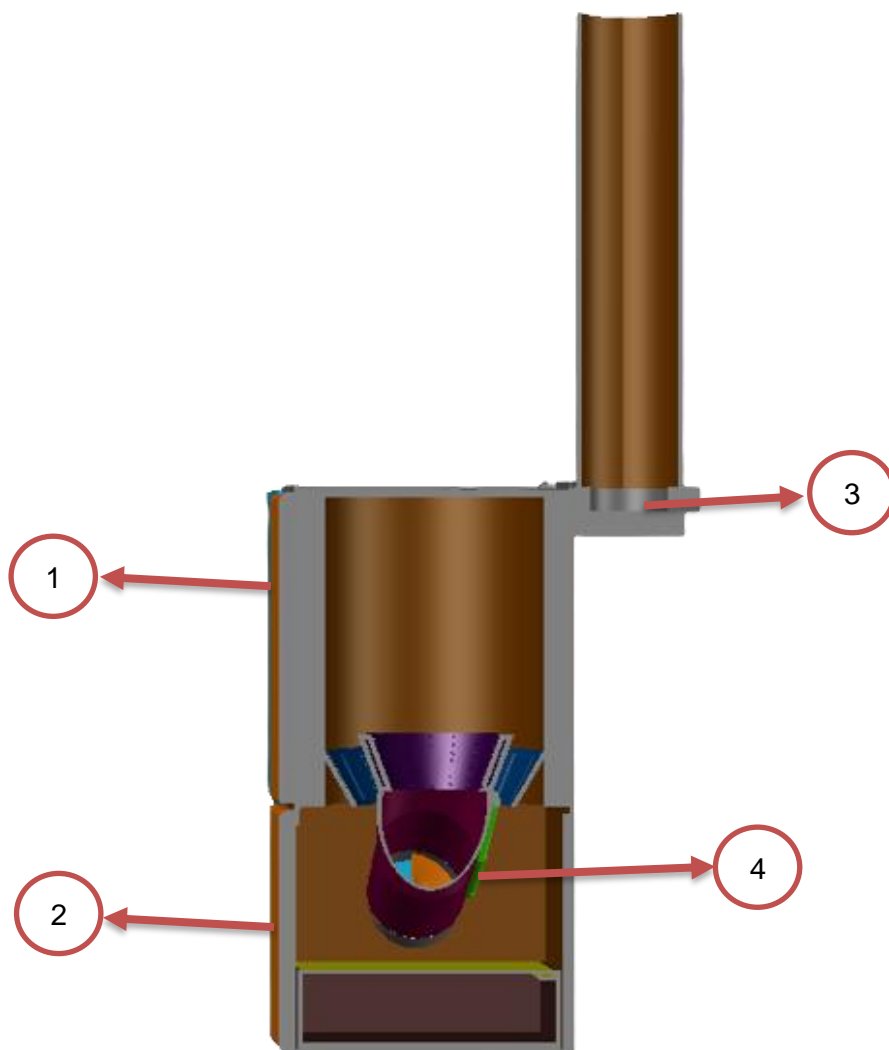


Figure 18: Right side cross-sectional view of the stove

The right cross-section of the stove looks like in Figure 18, which is similar to the one on the right side of the stove body. The body and parts of the furnace are drawn according to real-life dimensions, and the proportions of the parts can be seen in Figure 18.

- 1 - Main fire door. On the reverse will be a cast iron with a gasket seal and fixings. The door has a rope seal to ensure the door is air-tight. Furthermore, it would be brown in color, similar to the body of the stove.
- 2 - Ashtray door. It will be similar to the main fire door but small-scale in size, and on the opposite side will be a cast iron with gasket seals and fasteners. Also, the door has a rope seal to ensure the door is air-tight.
- 3 - Flue collar. Joins the appliance to the flue system.
- 4 - Air pipe. It is a pipe designed to carry air from the air blower to the combustion chamber. The air duct consists of two main parts, and the inner part of the stove is made of fire-resistant material. In Figure 18, this tube is shown in green.

## 5 Conclusion

Stoves have been used for heating in our country and have developed over time. However, the stove had a number of disadvantages and shortcomings during operation. In addition, stoves are being designed and manufactured at a much higher level than stoves used in our country around the world. This is confirmed by customer satisfaction ratings, stove structure, appearance and design. Therefore, this research was aimed to create a favorable environment for consumers by creating new models of auspicious stoves based on the models and designs of stoves used in foreign countries.

Ulzii stove automation is the simplest solution, saving additional costs and making it the easiest for users to use and very close to the previous technique. As a result, households using the Ulzii stove will be more willing to upgrade or improve their stoves. The general structure of this stove is to transport the briquettes from the hopper to the stove burner to feed the fire. Continuous supply of fuel to the burner will ensure constant combustion in the furnace. The stove is kept at a constant temperature above the normal temperature in the house or keeps this heat. The air required for combustion is supplied to the new furnace by a blower. The briquettes are passed through a screw conveyor. By adjusting the screw speed and the air speed blowing from the air blower, it is possible to fully automatic the combustion of the stove.

A lot of basic research and analysis has been done to make this design. For example, to research the briquette sales, costs, ingredients, prices, and so on. This helped to create a new design, taking into account many factors, such as the combustion process of the furnace, the power required from the screw conveyor, and the capacity of the hopper.

Based on the selected design idea, the automated stove was drawn in AutoCAD, computer-aided designing software. During operation, these stoves will operate at high temperatures and high loads, and some risks are likely to arise. Therefore, in order to prevent any risks and damage, the design of the stoves has been developed so that parts can be placed separately and replaced. This allows the stove's parts to be replaced in the event of a minor breakdown.

## **5.1 The Future Improvements**

In order to make the Ulzii stove more perfect in the future and bring this model to the next generation of the stove in the world, we need to study or calculate more on the following issues.

- The appearance of the stove can be made to great aesthetics.
- To change the leading fire door and ashtray door to a glass door.
- Clean burning, reducing soot and air pollution within your home
- Real-time safety alerts for you and your family
- Innovative efficiency, which translates into savings for you

The new design of the stove control system is straightforward and old-fashioned. In the 21st century, system control has evolved rapidly, and new technologies have become very intelligent. The stove can also be controlled remotely, and the stove can be connected to a telephone or other intelligent operating system to adjust the heat output of the stove. This means that the user can remotely adjust the home heating even when they are not at home. This can create more peace and comfort for users.

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## **7 Appendix 1.**

### **List of Drawings**

1. Engineering Drawing of Hopper
2. Engineering Drawing of Screw Conveyor
3. Engineering Drawing of Burner
4. Engineering Drawing of Ashtray