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Development and Performance Evaluation of Dual Powered Baking Oven

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Authors' contributions

This work was carried out in collaboration between all authors. Author AA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors OO, AT, LM and OH managed the analyses of the study. Authors LM and OH managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Due to the problem of irregularity of power supply eminent in underdeveloped and developing countries and the growing cost of hydrocarbon, there arises the need to develop alternative energy source to power heating oven. The dual powered baking oven is the joining or mixing together of components that make use of alternative heat sources. The primary purpose of this research work is to develop a dual powered (gas and electricity) baking oven which is efficient, cheap and cost effective both in production and operation. The upper chamber is supply energy through electricity while the lower chamber works by the supply of gas which is located outside the chamber as heat source. In the upper chamber, there exist a heating element which produces and weakened heat

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within the enclosure. Cooking gas is provided to the burner which is situated in the lower chamber of the oven through a pipe connection to the gas cylinder. Perforation gives room for heat dissipation inside the range of the lower chamber. From the tests carried out, as the temperature rises, the time required to prepare the food reduces. When the performance evaluation of the oven was carried out, it was discovered that it is efficient and quicker. The baking oven is quicker and thus baked more faster when compared with existing one. The oven is suitable for domestic and industrial purposes and have been discovered very useful in bakery industries.

Keywords: Dual powered baking oven; gas; electricity; heat; temperature; time.

1. INTRODUCTION

An oven is a thermally protected enclosure used for dry heating of a substance. Baking oven is widely used appliance in food service industry. In a baking oven, the hot air flows over the baking material either by natural convention or forced by a fan, the convention heat transfer from the air, the radiation heat transfer from the oven heating surfaces, and the conduction heat transfer across contact area between product and metal surface [1]. These are the simultaneous momentum, heat and moisture transfer mechanisms within a baking product [2,3] and between the product and its environment [4], which theoretically are well known.

The earliest ovens were discovered in Central Europe and dated to 29,000 BC, it was used for roasting and boiling pits situated around yurt structures. They were used to bake mammoth in Ukraine from 20,000 BC they used pit with hot covered in ashes [5]. The food was covered with leaves and placed on top then covered with earth [6]. Settlements within the Indus Valley had an oven across each mud-brick house by 3200 BC [7]. Hence, before the invention of modern baking oven, people had several means of cooking and baking but the alternatives they chose led to the destruction of lives and properties. The various types of baking oven are Earth oven, Ceramic oven, Charcoal oven, Solar oven, Gas oven, Masonry oven and Electric oven.

Charcoal is a dark substance that looks like coal and is used as a source of fuel despite being used in the production of various objects ranging from crayons to filters [8]. Charcoal produces heat that is higher in temperature. It produces flames and heat cleaner than wood, making it more ideal for cooking than wood. The charcoal oxidises provided there is adequate oxygen at the fire-bed and just above the coals [8]. Charcoal ovens have been found to be more efficient and effective; baking with charcoal gives you a lot of merits, especially in this part of the world where electricity supply is the main challenge. The baking oven is useful in the rural and urban settlements for small-scale and domestic use. The efficiency of a charcoal baking oven solely depends on the optimal use of three different parts of the device: the walls, the tray and the ventilation system [9].

Solar ovens are used in situations base on the necessity. Here, energy from the sun (or solar energy) is harnessed and converted for use in heating and cooking. Solar ovens are however best suitable for domestic use and may not be appropriate for commercial purposes. Oven design is determined through the constraints related to providing efficient heat transfer, allowing fast and accurate temperature control under varying load conditions and transferring heat in predominately one or more of the three modes required. Many types of solar cookers exist, including curved concentrator solar cookers, solar ovens, and panel cookers, among others. Zeleke and Sameer [10] describes the performance evaluation of a double-glazed box-type solar oven with three reflectors and with a vapour wiper mechanism fabricated using locally available materials.

The electric oven is a heating chamber which is meant for baking foods by means of conversion of electrical energy to heat or thermal energy. Due to vast improvement in technology, the new and interesting idea of an electric baking oven was brought about by an American Engineer called Dr. Percy Spencer. By late 1946, the Ray Theon Company had filed a patent suggesting that baking ovens can be used to cook food, baked bread and pre heat food. It can also be used for heat treatment of engineering materials such as steel and its alloys. Adegbola et al. [11] design and fabricated a domestic electric oven. Hence after the oven has been tested, it was discovered that It is effective and faster, It does not darken the baking pan and It is free from pollution.

Energy Gas cookers were found in most households by the 1920s with top burner and were used as interior ovens. A British inventor, James shape patented a gas cooker in 1826 which was the first successful gas stove ever to appear in the market. Gas works through the liquefied petroleum gas for the baking of the bread, cake and biscuit. The most important operational principle of the gas oven is the process of heat transfer. Heat transfer tends to occur whenever there is a temperature difference. Heat can be transferred in the gas oven through convection. Genitha et al. [1] carried out a study on development and performance evaluation of domestic gas cooker. It was discovered that the designed gas oven can be better used for the baking of the cakes, cookies and all the bakery products with good quality parameters like color, texture and the taste and good volume in the fermented products.

Modern ovens are fuelled by gas, electricity or both and are commonly used for drying, baking and roasting. Almost all of today's great inventions have each step being a development, an improvement, or a byproduct of previous technology and so has been the development of ovens. It has been a change from large and bulky size of each invention to more portable and lighter versions, and a change of fuel or source of energy used. Conventional ovens consist of a simple thermostat which puts the oven on and off and thereby controlling its operating temperature. A timer may allow the oven to be turned on and off automatically following pre-set times.

Oven can be used to preserve the perishable commodities, especially food stuff. The other functions are in heating, drying and baking of consumable materials. Hence there is an increasing need to design a compact, easy to transfer heating and drying system of acceptable standard that will meet certain essential requirements such as efficiency and cost effectiveness. Study of baking oven is important as it could lead to a more efficient process of baking favorable to energy efficiency and better product quality [12]. This oven will work on dual and alternate power sources by incorporating electric heating element and a gas burner to the interior of the oven. The major reason we embark on this project is to explore the potentials in us towards the fabrication of the high performance dual baking oven (gas/electric-baking oven) with temperature regulator. This will soon compete to any length with the original models of gas and electric baking ovens in the market, and with the current rise in the cost of gas baking oven and electric baking oven.

The main aim of this project is to design and fabricate a dual powered (gas and electricity) baking oven which is efficient, cheap and cost effective both in production and operation.

The objectives of this work are:

1. To design a dual powered baking oven (electricity and gas) that will be economical, and to explore the usefulness of a dual powered oven in the economy and technological growth of the nation.

2. To design and fabricate a drying system with a high performance, high efficiency, and which can be easily maintain.

2. MATERIALS AND METHODS

This construction requires the use of locally available materials.

2.1 Material Selection

This section deals with the issue of the materials required for the design, fabrication, and testing of the dual powered baking oven. The base material selected for this research work was mild steel, due to the following conditions:

i. It is a cheap and locally available material.
ii. It has a high resistance to rust.
iii. It is durable (that is, it has a long life span).
iv. It has the required mechanical properties for the project, which are the following:

- **Durability:** It works under a really long life span
- **Ductility:** During the construction, the sheet was drawn and stretched, without breaking.
- **Toughness:** This material can resist bending, breaking or scratching.
- It has a high specific gravity.
- **Malleability:** This is the ability of a metal (including mild steel) to be rolled, hammered or bent without breaking.

Part names, selection of materials and quantity were shown in Table 1.

The procedures for assembling of the parts were shown in Table 2.

Table 1. Part names, selection of materials and quantity

S/N	Part names	Materials	Ouantity
1	Top Cover	Mild Steel	1
2	Oven Door	Mid Steel	2
3	Insulator	Fiber	1
4	Door Handle	Aluminium	2
5	Gas Burner	Mild Steel	1
6	Oven Lock	Mild Steel	1
7	Plug	Plastic	1
8	Gas Inlet	Aluminium	1
9	Oven Stand	Mild Steel	1
10	Electric Housing	Mild Steel	1
11	Electric Switch	Plastic	1
12	Oven Wall	Mild Steel & Fiber	4
13	Indicator Light	Plastic	1
14	Layer Net	Iron Rod	1

2.2 Operational Principle of Electric and Gas Baking Oven

The major operational principles of the dual powered baking oven are the processes of heat transfer. Heat is transferred by

i. Conduction
ii. Convection
iii. Radiation

These three (3) phenomena may occur in a given system one at a time or simultaneously.

2.3 Electrical Energy Requirement

Average baking temperature = T

Let, M_b = Mass of fish or meat

C_b = Specific heat capacity of fish or meat [13] (1)

TRM = Oven room temperature

Heat required

$Q_H = M_b \times C_b \times TRM$

This indicates quantity of heat required to bake piece of fish or meat.

2.3.1 Energy requirement for cooking gas (Methane)

The combustion reaction of methane is given by;

$CH_4 (g) + 2O_2 (g)$ ----- $CO_2 (g) + 2H_2O (g)$ + Heat (kJ) (2)

But heat of formation of water vapor;

$2H (g) + O (g) \longrightarrow H_2O (g)$ [13] (3)

Heat of formation of Carbon IV Oxide;

$C (s) + O_2 (g) \longrightarrow CO_2 (g)$ (4)

Total Heat required in the combustion reaction of methane is:

(Heat of formation of CO_2 + 2 x Heat of formation of H_2O) – (Heat of combustion of CH_4 + 2 x Heat of combustion of O_2) (5)

2.3.2 Capacity of electric heating element

Power of Electric Heating Element is given as

P = Rate of expenditure of energy = Energy / Time (6)

$P = I^2/R = V^2/R$ (7)

Also Power = I X V (8)

Where,

R = electric resistance in ohms
t = time in seconds
I = Current in ampere
V = Voltage in volt
P = 13A x 240V=3120 W or 3.12 Kw

Thus power of the electric heating element is 3.12 Kw

2.4 Capacity of the Oven

i. Mass of fish/meat (Before baking) = M kg
Size of tray = length x width

Size of fish/meat (after baked) considered

Capacity of Oven using dough mass M kg:
= Size of tray / Size of fish or meat

Table 2. Procedures for assembling of the parts

Procedures	Operation	Descriptions	Tools
1.		Collection of the materials for the installation of the parts	Through Free hand
2.	Measurement	Marking out the measured points on the mild steel and the galvanized plate	Scriber Meter rule
3.	Cutting	Cutting of the measured point from the mild steel and the galvanised plate	Shear cutting machine Hack saw
4.	Bending	Curve some of the parts to 30mm as shown in the AUTOCAD	Plate bending machine
5.	Welding	Welding of the outer section of the component	Electrical welding machine
6.	Insulation	Placing fibers into the oven walls as shown in the AUTOCAD design preceding final welding	Free hand
7.	Welding	Welding of the galvanise steel bent to the mild steel to cover the fibers forming the inner section	Electrical welding machine
8.	Welding	Welding of the mechanical unit to the food chamber and connecting the electrical unit to the mechanical unit through riveting the pins	Electrical welding machine
9.	Welding, Electrical connection	Fixing of the electrical component to the inner part of the as shown in the AUTOCAD design.	Free hand in the connection and welding machine
10.	Welding Gas connection	Fixing of the gas element to the lower part of the interior of the oven	Electrical welding machine Free hand for the connection
11.	Grinding	Grinding of the welded parts on the oven.	Plate grinding machine
12.	Electrical connectivity	Connection of the electrical wire from the electrical component to the interior and to the back of the oven.	Free hand
13.	Painting	Paint the outside of the baking oven.	Painting brush
14.	Electrical connectivity Gas connectivity	Insert the plug into the socket Insert the hose to the gas cylinder	Free hand

3. RESULTS AND DISCUSSION

The dual powered baking oven (Appendixes 5-6) was tested in order to determine its efficiency and effectiveness through some food items like, fish and meat. The experiment was carried out for each of them. The measurement was taken with respect to corresponding temperature and time-taken at a particular turning level of the timer and the temperature control switch that is graduated between low, medium and high. The machine was set on while the timer was put to the expected marked point gradually.

The electric and the gas chambers were tested and evaluated respectively and simultaneously, so as to ensure accurate results without any thermal interference. At every interval of 10 minutes, the food item was checked and tested. The following results (Tables 2-5) were obtained during conducted experiment.

The following graphical plots (Figs. 1-4) for both fish and meat were obtained for analysis:

(i) Graph of Time versus Calibrated Mark (For Electric chamber).
(ii) Graph of Time versus Temperature (For the Gas chamber).

Table 3. Time taken by the electric oven for fish

Calibrated mark	1	2	3	4	5
TIME (Min)	35	30	25	15	10

Table 4. Time taken by the electric oven for meat

Calibrated mark	1	2	3	4	5
TIME (Min)	50	37	25	20	11

Table 5. Time taken and temperature obtained by the gas oven for fish

Temperature	Low (120-150°C)	Medium (180°C)	High (200-230°C)
TIME (Min)	25	15	5

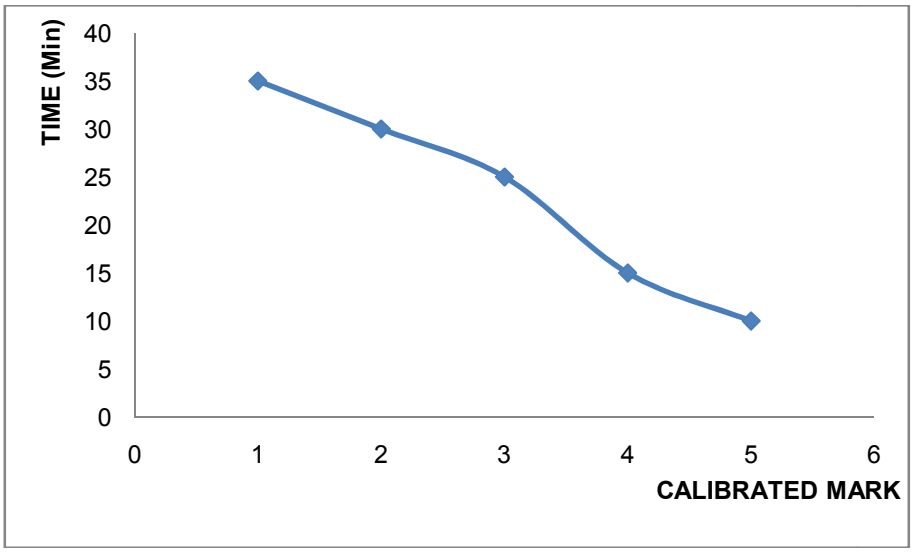

Fig. 1. Graph of time against Calibrated Mark (For Electric chamber) for fish

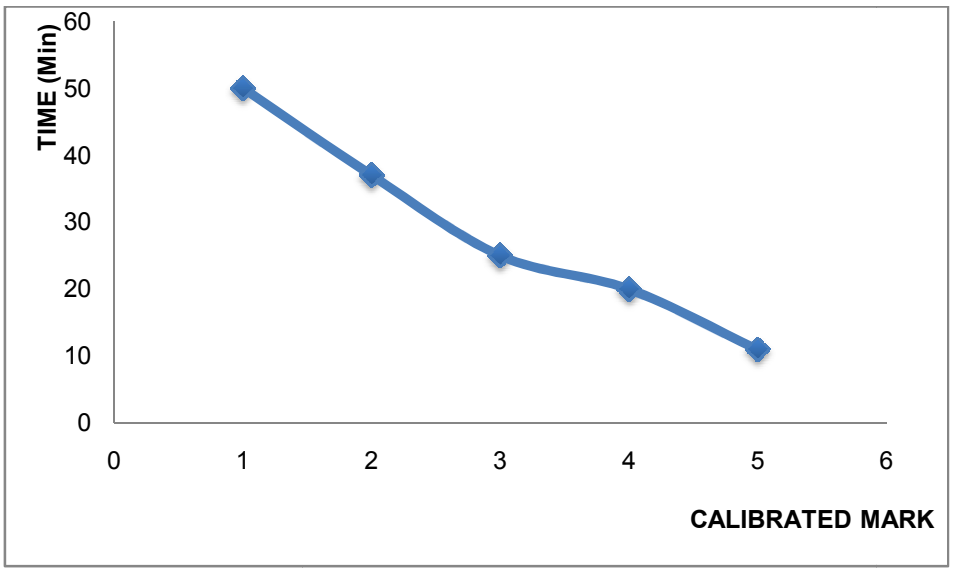

Fig. 2. Graph of time against Calibrated Mark (For Electric chamber) for meat

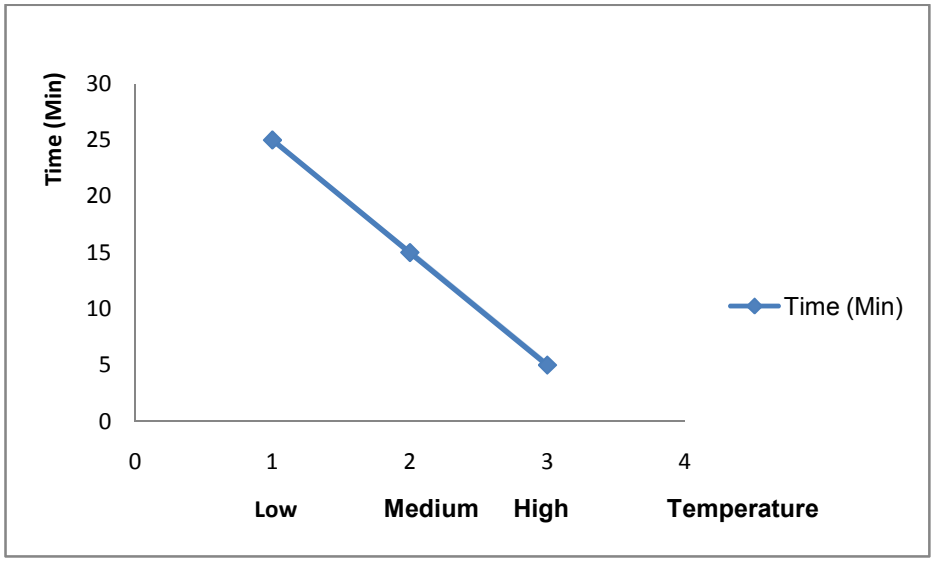

Fig. 3. Graph of time against power (For Gas chamber) for fish

Table 6. Time taken and temperature obtained by the gas oven for meat

Temperature	Low (120-150°C)	Medium (180°C)	High (200-230°C)
TIME (Min)	30	20	10

Table 7. Time taken to dry fish

Size of the fish (g)	Designed project	Existing oven
Small size (60-71)	15 minutes	20 minutes
Average size (100-115)	25 minutes	30 minutes
Large size (150-150)	35 minutes	40 minutes

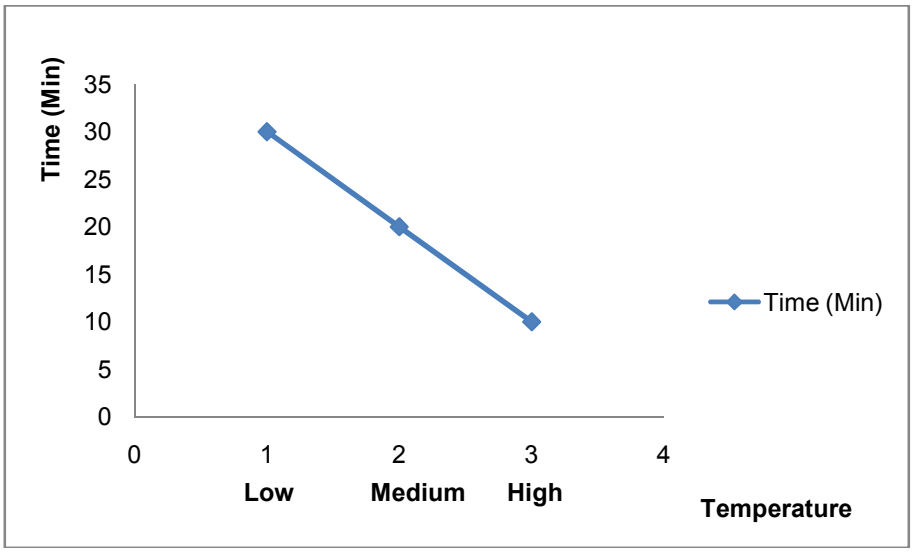

Fig. 4. Graph of time against Power (For Gas chamber) for meat

The graph of time against the calibrated marks reveals that temperature rises with an increase in degrees of turning of the plate or dish, for all food. The graph of time versus power

Table 8. Time taken to dry meat

Size of the meat (g)	Designed project	Existing oven
Small size (175-372)	20 minutes	35 minutes
Average size (379-596)	30 minutes	45 minutes
Large size (604-704)	40 minutes	1 hour

reveals that foods are baked within smaller time with increase in temperature. From the Tables, it can be deduced that as the temperature rises, the time required to cook the food reduces. In comparing with the already existing electric oven (Appendix 7) using fish and meat, the following results were obtained (Tables 7-8).

The results showed that the designed project baked faster and more effectively when compared with existing one. It does not darken the tray and it is pollution free.

4. CONCLUSION

The dual energy source that uses both electrical and gas for baking oven (dual baking oven) has been successfully developed.

From the results obtained, it can be concluded that;

(1) As the cooking temperature rises, the time required to cook the food decreases.
(2) In comparison with the already existing oven using fish and meat, the designed project was found to be faster and thus baked more effectively.
(3) The design project is cheap in production.
(4) The designed project

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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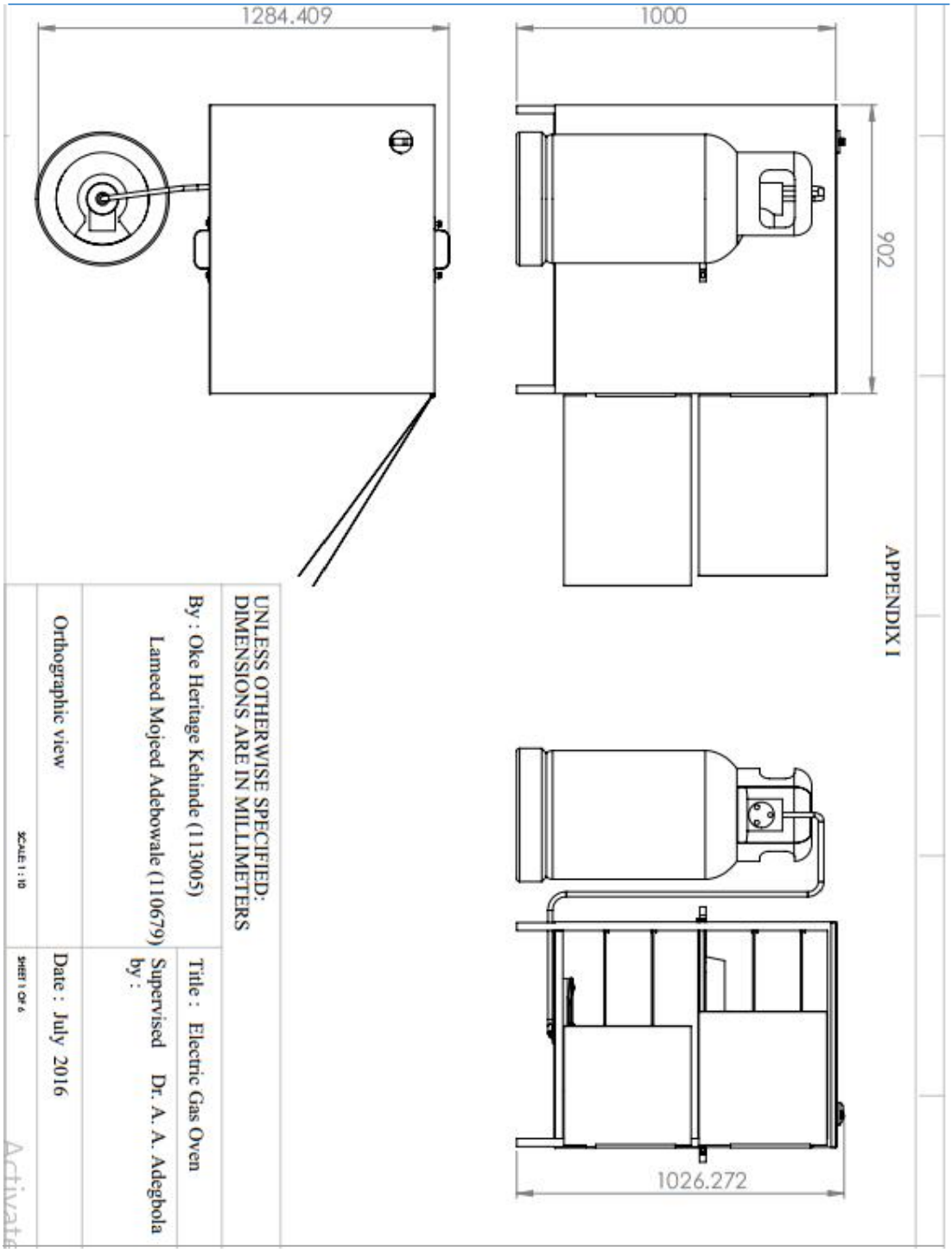
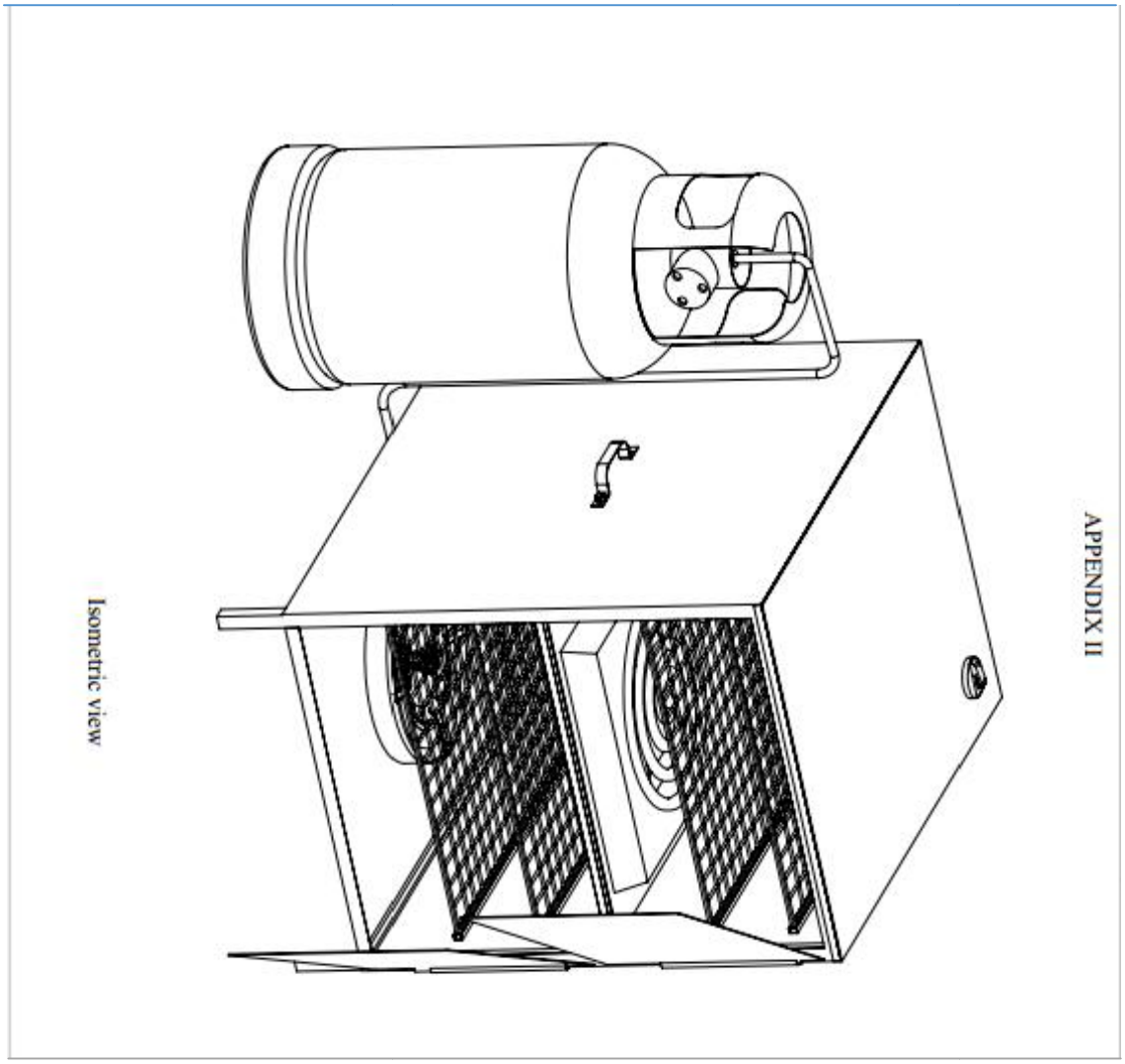
APPENDIX 1


1284.409
1000
902
1026.272
APPENDIX I
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
By : Oke Heritage Kehinde (113005)
Lameed Mojeed Adebowale (110679)
Title : Electric Gas Oven
Supervised by : Dr. A. A. Adegbola
Orthographic view
Date : July 2016
SCALE 1 : 10
SHEET 1 OF 6

APPENDIX 2



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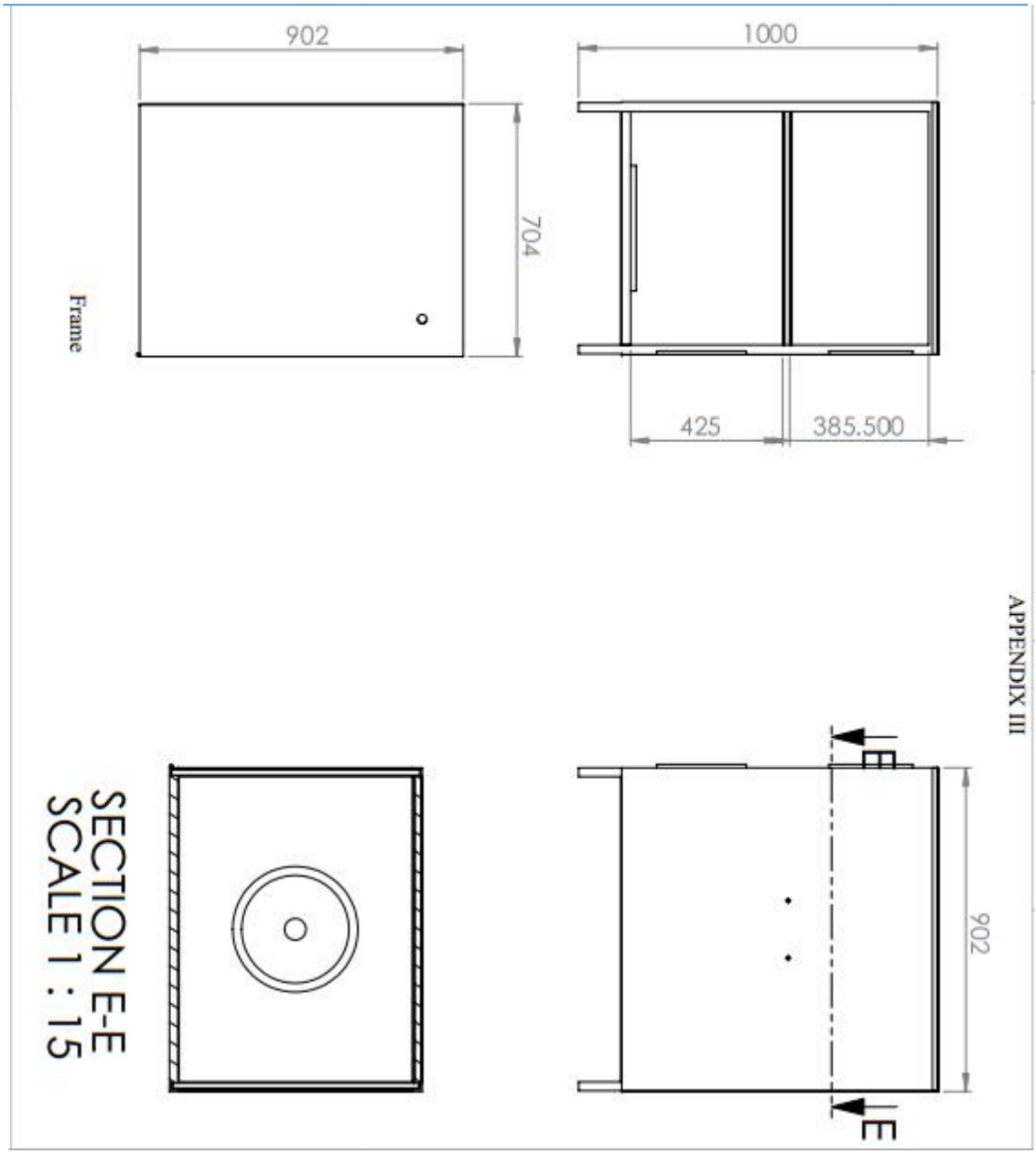
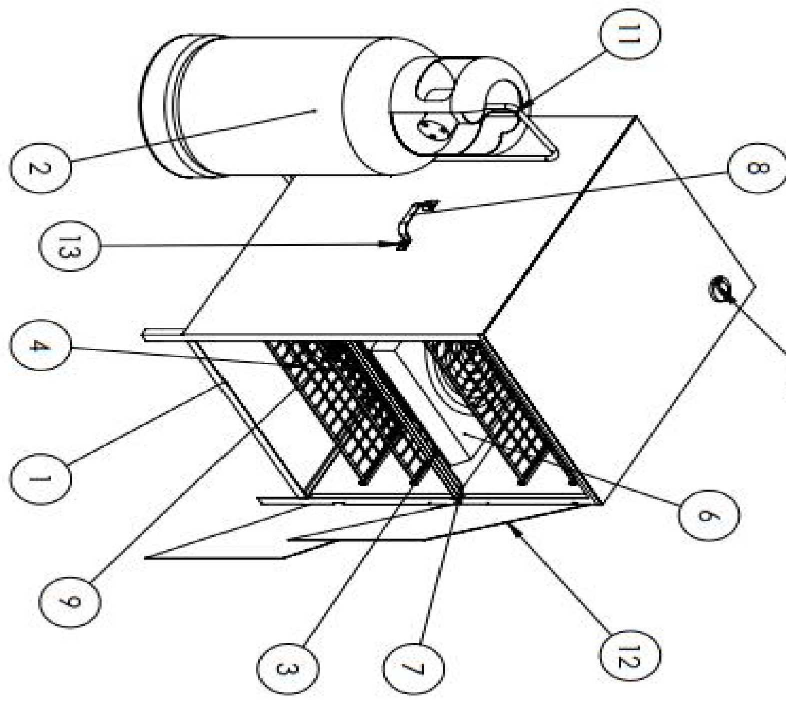

902
704
Frame
1000
425
385.500
APPENDIX III
E
E
902
SECTION E-E
SCALE 1 : 15

APPENDIX 4

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Frame		1
2	Gas cylinder	Purchased	1
3	Hangers		8
4	Tray		4
5	Knob		1
6	Element	Purchased	1
7	Flat plate		1
8	Handle		2
9	Burner head		1
10	Burner		1
11	Pipe	Purchased	1
12	Door		2
13	HFBOLT 0.4375-14x0.75x0.75-N		20



APPENDIX 5

APPENDIX 6

APPENDIX 7

APPENDIX 8

Bill of Engineering Measurement and Evaluation (BEME)

S/N	Construction	Amount (N)
1	AutoCAD	6,000
2	Typing	5,000
3	Mild Steel	8,000
4	Galvanized Steel	8,500
5	Iron rod	1,500
6	Element	1,500
7	Electrical switch	200
8	Light indicator	150
9	Insulation materials	10,000
10	Hinges	400
11	Handle	300
12	Gas inlet	800
13	Pipe	600
14	Paint	500
15	Fuel	500
16	Workmanship	5,000
17	Oven Transport	150
Total		**N49,100**

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