THE DEVELOPHENT OF CERAMICS PROTO-TYPE GAS STOVE OSING LOCALLY AVAILABLE RESOURCES.

BY

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A PROJECT SUBMITTED TO THE DEPARTMENT OF INDUSTRIAL DESIGN, FACULTY OF ENVIRONMENTAL DESIGN AHMADU BELLO UNIVERSITY, ZARIA, IN PARTIAL FULFILMENT FOR THE AWARD OF MASTERS OF ARTS, DEGREE (M.A. INDUSTRIAL DESIGN).

DECEMBER 1995

CERTIFICATION.

This Thesis Entitled the Development of a Ceramic Prototype Gas Stove using locally available resources, by Alkali Vershima, meets the regulations governing the award of the degree of Master of Arts (Industrial Design) of Ahmadu Bello University, Zaria. It has this day, been approved for its contribution to knowledge and literary presentation.

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ACKNOWLEDGEMENT

I want to express my sincere gratitude to my major supervisor and mentor, Dr. A. M. Ahuwan for the unquantifiable assistance, guidance and prompt supervision rendered to me in the course of this research. I acknowledge his thoughtfulness,and ideal academic leadership. My sincere appreciation goes to my minor supervisor Mr. James Ewule whose devotion and commitment to the success of this project is worth commendation.

I specially acknowledge the enormous assistance and fatherly care of my Uncle Professor D I Saror to whom I dedicate this thesis. His encouragement, motivation and financial commitment has led to the success of this project.

I also avow the assistance of the present Head of Industrial Design Department A.B.U.,Zaria, Dr. B. Kparevzua whose beneficent fellowship, counsel and academic leadership braced me up and thus led to the successful completion of this course.

I would like to express my deep sense of gratitude to my friend Mr. Patrick Adeh who single handedly took up the responsibility of computing and typing this thesis through the computer. I am indebted to his mickle support.

I want to appreciate the support of my Inlaw,Barrister E. K. Ashiekaa, whose initial support and co - sponsorship was a great source of encouragement and incentive towards the completion of this project as well as my present academic attainment.

I thank the entire staff of the ceramics section whose support and cooperation I enjoyed during the pursuit of this programme.

ABSTRACT.

Alkali Vershima "The development of ceramics prototype gas stove using locally available resources. The entire thesis is made up of 57 pages, six tables, eight figures, five pictures, seventeen references.

The problem of this study is to develop a prototype ceramics gas stove using locally available materials. Ceramic objects are made of brittle materials and since a slight pressure can fracture them, this is generally considered a serious drawback when one considers using them to solve a structural problem. Various studies aimed at improving this property are continuing. This study is aimed at utilizing these materials, improving their strength and using them to solve the problem of this study.

The study also aims at producing a prototype ceramics gas stove that will ease the difficulty encountered by cooks through the use of fire wood and kerosine. It will also encourage small scale production of gas stove devoid of the use of massive machineries as is the case with steel.

There is a mass migration of people from rural to urban areas due to widespread unemployment , unequal social benefits and opportunities. The most outstanding need is to develop technologies and projects that will promote autonomous economy and social development and rely on local skills and resources rather than foreign imports. This will help compliment large

scale industrial projects to create employment opportunities. Based on this, there is an increasing call by the government for an indigenous technology that is at least 50% self dependent. "Therefore do it yourself " and sustain the dynamic needs of the society has largely become the canon of the day. Now, with emphasis being placed on made in Nigeria goods, due to soaring cost of foreign exchange, this research aims at providing a significant solution to these problems and serving as an answer or response to calls that help solve economic and technological problem of the nation.

It is assumed that the need for this project is indispensable and that there are enough resources and technologies that can sustain its production.

In attempting to solve the problem of the study, the researcher employed methods which included seeking alternative materials to steel, testing them to ascertain their strength, functional capacity and economic viability. All studio test and experiments were successful, Based on these experiments, the following findings were made:

That effective and accurate combination of Silica, Kaolin, Alumina, Fire clay in correct percentages yielded the desired body for the construction of gas frames. And that Silica, Alumina Bone ash, Fire clay and fine grog in correct proportions proved positive in the construction of burner tip for gas burning.

Findings also showed that the gas stove frame is free from corrosion and rust commonly associated with steel. And that it is rigid, compact and strong enough to withstand impact weight and heat from gas burning. The choice of aerated burner design and the materials for its construction showed that blue and luminous flame cannot only be achieved with steel materials.

Considering the significance and indispensability of ceramics in our day to day use as well as in national development and academics. One hopes that the study will not only contribute to the body of knowledge in industrial sector of ceramics but will serve as useful tool on the house hold chores and also ease the problem encountered by cooks in the use of fire wood and kerosine.

DEFINITION OF SPECIAL TERMS.

1. Aerated Burner. Is a gas burner provided with primary air suction where the oxygen and gas mix together creating turbulence before the gas gets to the flame zones where it is ignited.
2. Bio - gas stove. A metal device that transfers gas from gas plants for cooking.
3. Bio - gas plant. A gas plant that uses cow dung as its fuel, which when heated produce combustible gas which was used as cooking fuel.
4. Burner. is the principal heat release equipment that has the ability to transfer any fuel through the process of gasification which results from corporate reaction of all the component.
5. Body. A mixture of two or more clay or minerals to form a structure or ceramic wares.
6. Bisquite firing. A name given to a once fired ceramic body on which there is no glaze. usually to a temperature not more than 950^0.
7. Calcination. To disintegrate by heat. The strong heating of a material result to its weakening through physical or mechanical change.
8. Ceramics. (Greek keramos). A general word for all pottery and used today in connection with industries such as glass and cement.

9. Combustion. Is the act by which oxygen of the air combines with fuel elements to generate heat that results to naked flames. These elements are carbon, sulphur and hydrogen.

10. Corrosion. Act of weathering or wearing away of metals caused by chemical reaction moist or disease.

11. Casting(or slip casting). A reproductive process of forming clay objects by pouring a clay slip into a hollow plaster mold and allowing it to remain long enough for a layer of clay to thicken on the mould wall . after hardening the clay object is removed. Nelson(1960).

12. Coefficient of expansion. The ratio change between the length of a material mass and the temperature.

13. Crawling. Separation of the glaze coating during firing, which exposes areas of unglazed clay caused by too heavy application. The glaze cracks upon drying or from uneven contraction rates between glaze and body.

14. Crazing. An undesirable and excessive crack in the glaze, which penetrates through the glaze to the clay body.

15. Fire clay. a clay having a slightly higher percentage of fluxes than pure clay used in the manufacture of refractory materials.

16. Flux. Lowest melting compound. It combines easily with silicate and thereby help higher - melting Alumina, silicate compounds.

17. Glaze. A liquid suspension of finely ground minerals that is applied by brushing, pouring dipping or spraying on a fired ceramic ware. When fired it turns glassy.

18. Grease. is a material that is used to rub on the block model before pouring plaster of pairs. It helps to separate the mould from the block model.

19. Kiln. A furnace made of refractory clay materials for firing ceramics products.

20. Levigation A method of refining clay by water floatation, the heavier particles settling out.

21. Plasticity. The quality of clay that allows it to be manipulated and still maintain its shape without cracking or sagging.

22. Pressing (or press molding). forming of clay objects by pressing softclay between two plaster models, such as in the production of cup handles and other productions.

23. Refractory. Quality of resisting the effects of high temperatures. Also materials, high in alumina and silica that are used for making kiln insulation, kiln furniture and other products.

24. Shrinkage. Contraction of the clay in either drying or firing stages.

25. Warpage. Distortion of clay products in drying or firing stages.

TABLE OF CONTENT.

CHAPTER ONE

1.1 INTRODUCTION AND BACKGROUND OF THE STUDY.

Ceramic is undoubtedly a profession that has tremendously served the human race in diverse capacities. Although its exact origin is still a mystery, the profession is believed to be one of the oldest next to farming.

Whereas people thought that ceramics products were ordinary and casually used items and as such had limitations. Ceramic especially among local practitioners have fallen into a very narrow groove which reflects pure aesthetics and functional table wares for domestic use. in practice, even modern ceramics studios confine their work within an almost incredible limited range of house hold products. What readily comes to mind at the mention of ceramics is table wares, sanitary fixtures and items for ritual. Today's review however, shows that ceramics covers every aspect of human existence. From the bathroom to the kitchen, its usage is indispensable. Builders cannot do without it, Electrical Engineers borrow them to help solve their problems. Aero - Space Engineers depend largely on ceramics products, ceramics products among others include, tiled roof, clay pipes for water supply and drainage, electrical insulators and ceramics stoves. The refrigation and Engineering constructions all require ceramics. With this in mind, it becomes obvious that ceramics is essential to any civilized society, and nation. It provides both essential utility and beauty to the home.

Throughout history, ceramics has played an infinitely large role in the development of local and global civilization. Today with such dramatic changes as the introduction of new materials and technologies coupled with the increasing borderless nature of the industry ,ceramics has engendered greater potentials covering even broader domains than before. Modern writers who deal with the process of ceramics production see it as naturally easier now than it was in the pre - industrial ages . Nowadays, we have electric wheels with smooth speeds, electric and gas furnaces for quick firing. The local craftsmen of the past generation worked mostly with single materials like iron, bronze, clay etc. Materials at the disposal of the modern ceramics designers are numerous and every material requires a dozen processes or more. These industrial facilities and techniques which prevail in ceramics production takes us out of contact with circumstances under which ceramics items have been produced in the past. It makes ceramics an art with tones of meaning that have far less in common with ceramics of the past. With this new challenge as a back - drop, it is natural and imperative that more research be conducted to increase its importance as a gate way to technology break through.

The word technology is fast acquiring a current popularity in our world. The concept is not new . man has always combined skill and science to device methods of solving his problems. When one adopts the resources available to him to create techniques and tools which are consonant with a particular situation, then he is applying the most appropriate technology. Thus in seeking a better future and improved conditions of living and probing into yet unknown potentials of ceramics, one looks forward to explore more into the field. This one hopes will add a new leaf in furthering the cause of the current transition from simple ceramics to more diversified ceramics application and from simple domestic function to interdisciplinary ceramics technology.

In the past,the pre - historic man depended solely upon his strength and that of the animal in obtaining the energy he needed for domestic cooking. As the world advanced in age, a point in time came, probably some thousands of years ago when the prehistoric man discovered how to make fire. now he can burn his wood and other primitive fuels such as dried peat and animal dung to keep himself warm and to cook his food.

Much value is now placed on gas for both domestic and industrial applications. Nigeria in particular is on the developing track undergoing a gradual but steady industrial revolution. The use of gas is undoubtedly a new trend of development replacing kerosine and fire wood in solving most of our domestic and industrial problems. The next profound problem that preceeds the discovery of gas as a cooking fuel is the development of gas transfer equipment for domestic cooking.

Even before modern civilization came, stoves have been used for cooking food in many parts of the world.The devices in use today range from very rudimentary to the sophisticated gas and electric appliances found in households.Most of these stoves have design specifications that make more effective use of a heating fuel, whether it be wood , charcoal, gas or kerosine. However,a large percentage of the people still depend solely on fire wood and kerosine stove to cook their food. Most of these cooking methods are associated with high incidence of eye defect due to excessive exposure to smoke and rising gases. the need for an effective, smokeless and portable gas stove is imperative.

However, there are three major obstacles to the successful introduction of gas cooking stove on our modern kitchen. These are the cost, lack of technical know - how and materials. Many researchers especially from ceramics design do not know that one does not have to depend on Technicians and Engineers to make gas stoves. Many ceramics designers believe that the scope of their activities is limited to the production of domestic wares like table wares and sanitary fixtures.

This unsatisfactory approach to this stems from lack of engineering background and knowledge on the treatment of this subject. Ceramics Researchers again do not see the need for developing a ceramics gas stove because they feel there is no real and potential advantage that ceramic has over steel real and potential advantage that ceramic has over steel

material.Clay and other related materials like silica and alumina are commonly known to be the kind of materials that one would not think of using for a function of this nature because they fall easily and shatter under impact. However, people should not be unaware of the improvements that can be made on these weak materials for practical application in solving various manufacturing problems.

It is a conclusive fact that vast quantities of goods and services are required to meet basic human needs. One of these is the need to cook our food. It is therefore necessary to use various technological processes that are appropriate to achieve this. For cooking purpose, a proto - type gas stove could be much more efficient and easy to handle than open fire, electric ovens and utilization of wood or charcoal supplies.

1.2 STATEMENT OF THE PROBLEM.

The problem of this study is to develop a proto - type ceramics gas stove using locally available resources.

1.3 OBJECTIVES.

The aims of this study are:

(1) To find alternative material to steel and metals in the production of gas stove frames and burner tips for

domestic cooking.

(2) To produce a proto - type from local materials, a ceramics gas stove that will ease the difficulty encountered by cooks through the use of fire wood and kerosine.

(3) To discourage the urban dwellers from the use of wood which is neither cost effective but rather hazardous to health.

(4) To encourage small scale production of gas stove devoid of the use of massive machineries as is the case with steel.

(5) The government has in recent years embarked on a campaign aimed at discouraging de - afforestation of our large forest reserves. This research aims at making available to the common man, a semi - modern cooking facility thus shifting their emphasis from the use of fire wood.

1.4 SIGNIFICANCE OF THE STUDY.

Conventional development programmes have generated some degree of success in encouraging ceramics artist to delve into and establish links with various professions to help speed the current transition from simple ceramics to diversified ceramics productions.

However, ceramics designers and manufacturers have not evidently attempted to adopt the local ceramics materials to develop an effective functional project like the gas stove in question. This is a dangerous lapse because our over-dependence on other industrial sectors for the production of this equipment may lead to long term disappointment. Most of the companies producing them may cease to exist due to shortage of materials and other unforseen factors resulting to untold economic and social squalid.

There is a mass migration of people from rural to urban areas due to wide spread unemployment, unequal social benefits and opportunities. The most outstanding need is to develop technologies and projects that promote autonomous economy and social development and rely on local skills and resources rather than foreign imports. This will help to compliment large scale industrial projects to create employment opportunities. This research aims at providing a significant solution to these problems.

Furthermore, it is estimated that more than half of the urban population and almost 99% of the rural settlers in Nigeria use wood as their primary source of fuel .Recent studies have shown that low income earners in urban areas use as much as 15% of their income on fire wood, Bradford and Hugh (1986).

Although the late 1980 and early 1990's appears to be a time of rapid increase in world oil production, the cost of energy from oil products cannot be compared with the high cost of fire wood especially in the northern part of this country.

Added to this is that, wood which is a common cooking fuel is running out as a result of excessive usage and cutting due to various development projects currently going on. Moreso, there are threats of catastrophe and desert encroachment due to ecological disasters. The need for a shift towards other sources of energy is increasing. The cost of oil placed alongside with wood is still fairer needless to mention the efficiency of such fuels in cooking. The production of gas stove will facilitate this drive from fire wood to gas as cooking fuels.

Today in almost every developing country like ours, there are serious unemployment problems. There are uncontrolled migration from the rural areas to the urban centres. There are increased debt repayment due to increasing hike in economic and technological dependence on the developed countries. Based on this, there is an increasing need for an indigenous technology that is at least 50% self dependent. According to Fafunwa (1990) "A nation that refuses to inject technology into every aspect of its development be it social, economic or political is doomed to fail ". According to him, the rule of the thumb in the practice of human development was only good for the ancients.

Therefore "do it yourself" and sustain the dynamic needs of the society has largely become the canon of the day. With emphasis being placed on made in Nigerian goods due to the soaring cost of foreign exchange, the research objectives are channelled at curbing this disturbing problem.

1.5 BASIC ASSUMPTION.

The study is based on the following assumptions.

(a) That there is need for such a project because of its indispensability in the day to day running of the home.

(b) The second assumption is that there is adequate technology to make the idea work.

(c) That the country is blessed with abundance of clay resources and materials for the production of ceramic gas stove.

(d) That the proposed proto type gas stove will perform and compete favourably with the steel stove.

(e) That gas which is its primary source of energy is in abundance when fully harnessed.

1.6 LIMITATION.

The study is partly aimed at achieving maximum body strength and compatibility that is equal to metals. To achieve this, the clay body has to be subjected to firing temperature of not less than 1,700^{0}C. However, this is limited by the absence of furnace or kilns that can attain that firing temperature. Thus firing could only get to 1,300^{0}C.

1.7 DELIMITATION.

The study is delimited to Kaduna and Katsina states.

Kaolin and Silica from Katsina State have been tested by previous Researchers and found reliable for other projects previously done. According to Umar (1991) and Gukas (1985) the materials abound in commercial quantities in Kankara (Katsina State). Although these materials abound in other localities like Barkin Ladi Plateau State. Auchi (Edo State), Samples are taken from Katsina and the project executed in Zaria (Kaduna State).

Although the success of this research depends largely on the availability of suitable local ceramics materials, the research is not wholly aimed at improving the strength of the material, but to choose a suitable alternative material to steel as a medium chiefly used in the production of gas stove. In the absence of steel manufacture, one can depend on ceramics materials

It is important to note that gas stove construction through the use of ceramics materials is a recent development in the country. As at now, no records have indicated that this research has been conducted elsewhere,hence it is one of the first steps towards an appropriate indigenous technology.

Advanced countries have made tremendous impact in the manufacturing sector by the conversion of ceramics materials into useful manufacturing materials that have largely served various purposes. Nigeria is yet to develop refractory insulation materials to produce marketable products. This research appears to be a major step among many steps to actualise this dream. One hopes that giving it a wider acceptability, an extensive capital investment can be made by the government to enhance its mass manufacture at a price permitting widespread distribution at affordable prices.

CHAPTER TWO

RELATED LITERATURE REVIEW.

2.1 INTRODUCTION.

The review synthesised records from various books, journals and seminar papers that deal with various developmental stages of the progress made in ceramics technology. It deals with the progress made in the development and inventive methods of suitable cooking devices particularly gas stove. It also deals with the appropriate burner system for the effective combustion of gas fuel.

The last aspect of the review deals with the various ceramics materials used both in the past and present for the development of this and other similar equipments. Under this consideration are, Refractory materials like Silica, Kaolin,fine grog. Others include born ash & Bentonite. Some of these materials have been used in the production of furnace linings for steel production, molten metal mould, grinding wheels and ceramics cooks stove.

Others include materials used for glaze composition for the coating of the stove frame. These include clay, Feldspar, flint, talc, wood ash. The last material is plaster of paris for mould making.

In this century, science and technology have brought about a revolution to the home. The house hold of today have been developed through many devices which though many regard as curiosities and luxuries,are meant to improve the living standard of the people. The house wife or the cook in general needs to have leisure and spend less time, cost and energy on house hold chores. Progress in ceramics technology has improved our local clays through various refinery processes.The physical properties of alumina and Silica have been purified and converted to solve various manufacturing problems including the problem of this study.

According to Pebbles (1980) several companies and individuals in the past attempted and eventually came out with practical results and a lot of innovations made in this area of study. However, most of these inventions have become obsolete with time especially in Europe and other developed countries. In Nigeria this is undoubtedly a new trend of development.

Acharya (1961) reveals that there were widespread usage of cattle waste or animal dung in several countries as cooking fuels. This resulted into serious problems since they hardly had enough cattle waste to use as fertilizers for their agricultural produce. In order to make cow dung available for more useful purpose of soil fertilization, an alternative cooking fuel had to be sought.

In developing countries, it is estimated that one third of their urban population and only two third of the rural populace use modern cooking devices. The rest use wood as a primary source of fuel. Ottawa (1976). The result is a disastrous desert encroachment and other ecological catastrophes. To save these nations from impending doom as a result of excessive use of wood,other cooking fuels had to be sourced and used.

In India for instance, several research were done to solve this problem. The result was the development of Bio - gas plants which produce combustible gas to be used as cooking fuels. Gas was generated from these plants and collected to the top of the cap which feeds the gas to the point of consumption where cooking was done. This crude method of extracting gas for cooking continued until a biogas stove was manufactured. Ottawa (1976).

The material used for the production of Bio - gas stoves was iron,they were made of cast iron,metal injectors and had thermal efficiency in the order of 60%. The pressure was controlled by loading bags of sand on the gas cap. The more the pressure, the more the flame, the less the weight, the less the flame.

Pebbles (1980) takes us back to the first use of gas by the chinese probably three thousand years ago for heating of pans of brims water to obtain salt. The word "gas" was coined by the flemish scientist, Jan Bapista (1644). In his work the origin of medicine , he presented the findings of his experiments in which he had discovered that a wild spirit escaped from heated coal and wood. He concluded, that which escaped in form of vapour hitherto unknown is called "gas".

The derivation of the name is generally thought to be the Greek word "Chaos". According to Baptista (1644) in the absence of the name contrary to normal practice, he gave this vapour which differs very little from chaos of the ancients the name gas.

It is not possible to pinpoint the discovery of manufactured gas with precision.

Pebbles (1980) records many reported experiments in Britain, France, Belgium, Germany, elsewhere in the seventeenth century which resulted in the discovery of combustible forms of gas made from coal wood and peat. It is recorded that around 1681, Professor Becker of Germany discovered combustible gas resulting from the heating of coal in the absence of air. Becker and Clayton are but two prominent persons among others who have been credited with the invention of combustible gas in the seventeenth century. Pebbles (1980). Both the Romans and the Greeks among others were said to have known about the use of gas for both cooking and burning of sacred lamps. Although the historical records relevant to the use of gas are available, they have no direct information as to the beginning of the development of gas stoves.

History reveals that the first known individuals to have probably attempted the making of gas stove were professor Becka and clay of Germany in 1681. More probable was that several individuals were working quite independently and unknown to each other, made the same sort of discovery at about the same time. Some years later in 1820, the worlds first gas stove was produced and called the "Black beauty " in England by James Sharp and was put into use in 1851. Although the stove was first demonstrated in the United State in 1851,it was not until the early part of twentieth century that cooking stove began to gain widespread acceptance. Since then it has been on the kitchen scene for many years until recent innovations rendered it obsolete especially to the developed world.

The pattern and space of development varies increasingly from one country to another and thus, does not lend itself readily to a generalised account. The use of gas stoves in many countries have been displaced by electric cooking devices and infra - red radiation induced by vibrations of electrons,atoms and molecules. While the use of gas stoves have ceased to be competitive and regarded as old fashion cooking device in many places, right here in Nigeria. It is rather gaining ground.

No date is yet given as to when it first came on the Nigerian technological scene,but it is obviously an event of the 1980's,when people began to respond to various calls by the government for indigenous technology spearheaded by the Structural Adjustment Programme (S.A.P). Presently,the fundry division of Delta Steel Company, Warri is known for the production of the best steel type gas stove Steel business Digest (1990).

A few decades ago, attempts were made by various researchers in some parts of the world to find a suitable material that will out-place steel in the manufacturing industry. The use of ceramics in developing functional products was an attractive approach to solve some of the problems regarding steel processing. According to Wheild (1960) Alumina and Silica and several other ceramics materials in their high hardness, chemical inertness and resistance to degradation would compete favourably and possibly out-place steel in various functional capacities. A research on this was conducted later in Kenya. Initially, the Indians in Kenya dominated the manufacture of cooking stove using metals as its chief medium. After independence however,African artisans entered this sector as the Indians left to pursue investment opportunities elsewhere. Today, virtually all traditional metal cookstove popularly called "Charcoal jiko" are manufactured by Kenyan artisans. However, as in most developing countries, the major impediment to the successful introduction of cooking stove was the production cost, as steel is not just a material that one would handle without the use of machineries. Based on this, it was desirable that the traditional Jiko stove made with steel be discarded. A new ceramics Jiko cooking stove which was affordable and socially acceptable especially for low income house holds was developed by Maxwell Kinyanjui. Ottawa (1986).

This development started in 1982 when Maxwell and a group of artisans visited Thailand to study Thai method s of cooks stove production and marketing. on their return,the first proto - type was made. It consisted of a bucket shaped metal body and a ceramic grate . This combination had already been found to give the best performance in terms of fuel economy and stove durability. Later,a ceramics stove without metal cladding was produced. Local ceramics materials and existing facilities were used to minimise production cost. It was made simple and at the same time efficient in the use of energy.

The efforts made by artisans to convert ceramics materials into production of useful and functional products are commendable. These attempts have not been exhausted one expects improvement. The researcher has gone a step further by using ceramics materials to develop, this time not a charcoal ceramic stove but ceramics gas stove.

2.2 BURNERS.

The production of ceramics gas stove is an art that involves several complex technologies and sciences. Already, it is held that successful ceramics artist must have the basic knowledge of Chemistry and Physics to achieve excellence in the handling of clay and heat. The art of heat treatment and fuel combustion is such a delicate one that requires adequate care and research to achieve a high level management in ceramics production.

After successful attempts were made at ascertaining and developing through chemical analysis the ceramics materials that were needed to produce a ceramics gas stove, the major threat to the success of the project was the aspect of its burner system. For the project to be highly successful, burners of different grades had to locally developed to sustain the widespread use of gas as a fuel. With the drift from the use of fire wood for cooking purposes to gas, the process of heat release through the employment of burner system had to be developed. Consequent to this, several attempts were made to tackle this technological problem by selecting and developing the burners they had developed.

Local materials mainly iron in combination with hard clays were sourced and developed to achieve this goal. The technology was simple enough to be used by people who had limited education and skills.

Initially, a simple iron pipe made from old iron and scrap steel was designed and linked to the source of the gas. A gas stopper or pressure control device was created in the middle part of the iron pipe and was controlled by the placement of heavy rocks or sacks of sand on the stopper. When lifted, the gas flowed to the top of the pipe and mixes with the air and burns blue - red as it gets ignited. Some sort of arrangement of stones to support the cooking pots under the gas pipe was made round the burner. However, lack of control over air intake reduced the efficiency of the burner giving a flame temperature of 400 - 500^0C. Excess carbon was built around the pot giving it black stains. Prolonged use in a poorly ventilated kitchen usually caused offensive odour and injurious to the health of the household. (see appendix one figure one).

There was great scope for both new research and blending of past and present techniques to initiate changes and develop new innovations. As in almost every research, the definition of the problem and statement of need comes from the local community, but the solution to the problem comes mostly from Engineering and research areas. According to Bonlter (1974) India in 1900 was faced with the problem of acute shortage of cattle waste for soil fertilization as most of the animal dung was diverted as fuel for cooking. In order to seek an alternative fuel to animal dung so that the dung could serve its major purpose of soil fertilization, the Indian agricultural research institute was able to respond by providing the scientific and engineering techniques which led to the development of appropriate and portable burners for combustion of gas supplied from the fuel gas plants for cooking.

The local system of fuel burning was subsequently modified. In this new approach, a short length of copper tubing complete with gas top and flame check was soldered into a whole cut in the side of a tin can. The lid of the tin can was perforated with a series of small holes spaced about 2cm apart. The can was filled with pebbles which stabilizes the burner and also caused the gas to spread evenly before it escapes and burns. This type of burner system likewise had the problem of uncontrolled air mixture resulting to unstable flame and red light. Ottawa (1980) see Appendix one figure two.

Most important of all these invention was the Bunsen Burner, named after a German Scientist, Robert Wilhelm Bunsen (1811 - 1899) Pebbles (1980). It was the atmospheric burner in which a jet of gas aspirated part of the air for combustion into a mixture before reaching the burner ports and flame zones. In this type of burner, suction induced by the jet of gas draws in primary air which can be controlled by the shape and dimension of the burner throat or a slide controlling of the area of primary air port. This significant invention opened the way for gas to be used as a fuel for both the home and a whole variety of industrial applications. The original Bunsen burner has of course been modified and improved by subsequent cook stove manufacturers. Under this modification are three separate types and design. The non -aerated burner aerated and surface combustion burners.

The non - aerated burners are of the Bray jey bats wing type for small applications such as domestic gas fires for cooking and oven baking. With this burner system, no primary air is supplied with the gas which burns with a luminous flame. Secondary air is obtained by entrailment from the atmosphere or with lazy flames by admission at various points along the flame path. The flame is slightly luminous and no carbon is deposited at the burner tip. See appendix one figure three.

The Bray jet is a small cylinder with two small ports set at an angle of 45^0C in a porcelain tip. The shape of the pots causes the sides of the gas streams to impinge so as to flatter the flame see Appendix one figure four.

The aerated burners are by far the greatest proportion of gas burners with a variety of design for industrial and domestic use. They are all based on the principle of the Bunsen burner. The jet of the gas draws in primary air which can be controlled by the shape and dimension of the burner throat or by a slide manipulation of the area of the primary air port.

If by bad design, the rate of the supply of primary air is much greater than the flame speed, the flame can blow off and the tube and the burner extinguished. With insufficient primary air, the flame is long, lazy and slightly luminous. With increase in primary air supply, the flame shortens and becomes non luminous. See Appendix one figure five.

The surface combustion burner is the type which hot surfaces have the property of increasing the rate of combustion of air. Combustion by definition is the act in which oxygen of the air combines with combustible elements of a fuel to generate heat. These elements are carbon, sulphur and hydrogen.

The surface combustion burner system initially had a bone court system in which gas and air were fed in correct proportions under pressure into a chamber closed by a porous refractory diaphragm. After a short time, the flame disappeared from the front of the diaphragm and the gas burned there at high rates and temperature. Because of the high temperature, radiation of heat is high which enables efficient cooking and other domestic application.

It is important to know that before aerated gas burners can burn and work effectively, three basic reactions must take place. Time, Turbulence and temperature. Time is usually required to supply oxygen to the surface of the burner tip.This creates turbulence, that is the intermixing of the fuel with air through primary air suction. Once these two reactions begins to take place, combustion starts through the ignition of the fuel due to the oxygen supplied. At this stage, the presence of moisture is lost completely from the fuel. This occurs at 105 - 110^{0}C At about 150 - 180^{0}C, the fuel gets to its required temperature that permits ignition. At this point the reaction becomes complete and can be self sustaining with constant supply of air through air sockets.

2.4 MATERIALS.

According to estimates quoted by Chester, 1973, Silica and Kaolin constitutes not less than 59% of the outer most layer of the crust. Though much of these are present in combination with other oxide giving materials that are refractory. Recent geological findings by Ajayi 1988 have shown that these materials are available in large quantities at Kankara, Katsina State. His estimate shows that Silica constitutes about 99.4% of the Baure sand in Katsina State.

Kaolin is a very pure form of clay. Though never used alone as a body. It serves as a standard with which to compare other clays. It is white in colour and can be fired to an extremely high temperature. Kaolin provides a source of alumina and silica for both glazes and other industrial applications and is thus useful in the execution of this project.

Fire clay is a refectory clay commonly used for insulating bricks, hard fired bricks and other applications. Its physical characteristics vary. Some fire clays have a fine plastic quality,while others are coarse and granular and unsuitable for casting or throwing. Fire clays generally contain some iron as an impurity but seldom have calcium or feldspar. They are usually high in flint and or alumina and therefore have special industrial uses. Nelson (1960) Bone ash.

Bone ash is the only major ceramics material that is not derived directly from the earth. Although bone ash was added in small quantities to glazes or body compositions for many centuries among the Chines and Britain, its real use was established by Josiah Spode at the end of the eighteenth century. Allen Dinsdale (1986). Its function is to give a white,translucent appearance. It lowers the co efficient of thermal expansion thereby increasing the tensile strength.

The source or supply is mainly bone and when this has been collected from abattoirs most of the organic constituents are separately removed. The bone has to be calcined to 1000^0C and crushed into powder for onward use.

Clay according to Nelson (1960) derives from the disintegration of granite and other feldspar rocks which as they decompose deposit alumina and silica particles. Nelson 1960, refers to clay as the basic ingredient in ceramics productions, it is added to glaze to increase the viscosity of the fusion. Secondary clay is available along Kano road and Bomo village in Samaru and other places in the country.

Feldspar, Nelson (1980) states that it is a crystalline rock composed of the alumina silicates, potassium, sodium and calcium. These silicates are not found in pure states but in a mixture. With one or the other predominating. For convenience in ceramics glaze calculations their formulas are usually given as follows:

K_2O -	AL_2O_3	$6SIO_2$	Potash feldspar
Na_2O	AL_2O_3	$6SIO_2$	Soda feldspar
CaO	AL_2O_3	$6SIO_2$	Lime feldspar

An addition of feldspar to a glaze increases resistance to breakage due to stress or impact. Improving thermal endurance of the glaze. Increase chemical durability and decreases tendency of the glaze to devitrify. Nelson (1960).

Flint, Flint is a form of Silcondioxide produced from quartzite sand can be used as a filler to clay body that is used to raise the maturing temperature and increase the resistance to abrasion of ceramics products. Large quantities of it are found in Sokoto river Bida (Niger State) and Hadeija river near Kano.

Whiting is a calcium carbonate produced domestically by processing marble or limestone,sometimes obtained from chalk desposites. Whiting is a major high fire flux, although it has a limited use in bodies where a small amount will lower vitrification temperatures and reduce porosity. As a flux, it produces much harder and tougher silicates than will either the lead or alkaline compounds. Nelson (1960).

Talc is the chief mineral derived from steatite rock. Nelson 1960 affirms that it is used for the formulation of clay bodies particularly in white ware bodies firing at moderate temperatures. It is used in lowering the firing temperatures of kaolin, ball clays and feldspar.

In summary, it is important to know that while this chapter partly deals with the progress made in ceramics technology particularly in the inventive methods and development of suitable cooking stoves, little or no records are found on the processes involved in its production. Pebbles (1980) believes that techniques of production largely lies with the manufacturers and is not open to any organisation or individual manufacturer. The researcher will thus hinge on his initiative to effect its success.

CHAPTER THREE

PROCEDURE AND METHODOLOGY.

This chapter deals with data collection techniques and the procedure for data analysis. It also covers design, preparation of materials and testing, modelling and production.

3.1 DATA COLLECTION.

The quest for historical accounts in form of literature relating to this subject appeared to have yielded very little result as far the design and construction of this project is concerned. There are few previous written accounts in the area of gas stove production. A handful of books are written on the origin of gas stove, its evolution and development. However, since this project is an original design experiment based on ceramics materials, its production method and technique solely lies in the inventive initiative of the researcher and the useful help of the mentor as well as the fabrication unit of the Industrial Development Centre (I D C).

Another aspect of data collection procedure involved several field trips to the foundry unit of the Delta Steel company, Warri. Where the researcher undertook an observatory and participatory method of research on the subject. The trip enabled the researcher to ascertain the local materials that are useful for the common steel type gas stove, its burner system was also accessed which eventually inspired an initiative that led to the development of a ceramics proto-type gas stove using ceramics materials.

Visits were also conducted at various plumbing and scrap shops to evaluate the cost and materials that could serve as a useful source of experiment, Materials such as steel pipes and gas jet of various sizes, copper linings, bolts, flat metal sheets which form the down part cladding, robber horses and clips were sampled.

Thirdly, visits to clay sites like the Kano - Zaria road and Bomo village Zaria were conducted to collect secondary clay that have less impurities and iron content so that proper extraction of the desired workable body could be derived.

it is commonly observed that surface clays especially that of Kano- Zaria road is full of sand.For that reason,the surface layers are usually scrapped off before the real pure clay is obtained. Kaolin was got through local supplies by contractors, it is obtained at Kankara village in Katsina State.

The location and procurement of these materials was directed by previous written accounts and practicing ceramics artist. The suitability of these materials were based on random sampling within the local population. These were practically tested by the researcher before ascertaining their reliability. Other materials used include Feldspar, Fired clay, whiting, cobalt oxide, Bentonite, These were obtained by practical beneficiation within the local studio.

3.2 DESIGN.

This project is invariably an industrial product designed for mass production and manufacture which can permit subsequent capital investment for onward production for local consumers.With this as a backdrop, it was important that an acceptable design form be achieved to appeal both to function and the user.

Design as commonly held, create in the consumer the desire to possess. It also creates enthusiasm as well as ensure maximum sales. Since this is a comparatively new product open to competition and scrutiny, it was worthy that a profitable time and skill be employed to beget a competitive product that could serve as a presentable and valuable tool for the modern ceramics industry.

Design ease production. Apart from the order or dictates of function, the unique qualities as well as the delicate nature of plaster permits the realisation of a conceivably good design. Apart from that, where a firing process is involved in the production of any functional work, a good design must be ensured to obtain a near perfect form where heavy and solid forms are avoided. Design apart from making the process of production easy, it serves as a working guide. This is very essential because one who does not spend much time and money on the onset for intelligent and well articulated design will waste such monies at the end. Based on this , the Researcher took a considerable time to design on paper by first of all introducing various experimental sketches and eventual selection of the most appropriate design. On ascertaining the most appropriate design considering all the factors stated earlier, technical materials like letterer sets and tracing paper were procured to introduce a technical approach to the design. Initially, a blue print of the product in graphic form was thought to be the most effective and economical method to convey the conceived idea. however, after much consideration, a technical approach was most desirable and thus employed so that subsequent researchers could look at it and produce the same or develop further on it. See page 31 figure 1 & 2

Apart from the paper work, prototype was produced with clay so that one can get a feel of the design in three dimensions, thus achieving a full size clay model similar to the final sketch. Considering the casting process involved, it was necessary to modify certain aspects of the design to meet certain specifications after which the final drawing was made. Since this aspect is primarily a visual work, one needed only to show in one of the drawings those lines and dimensions which express the exact exterior dimensions of the finished model.

However, this product is open to proper examination and evaluation and accessement and eventual modification, it was thus necessary that inner sections of the finished work be shown in the clearest and readable detail. This is necessary because the exterior design of the product and its mechanical operation are closely interrelated. See figure 1 & 2 next page

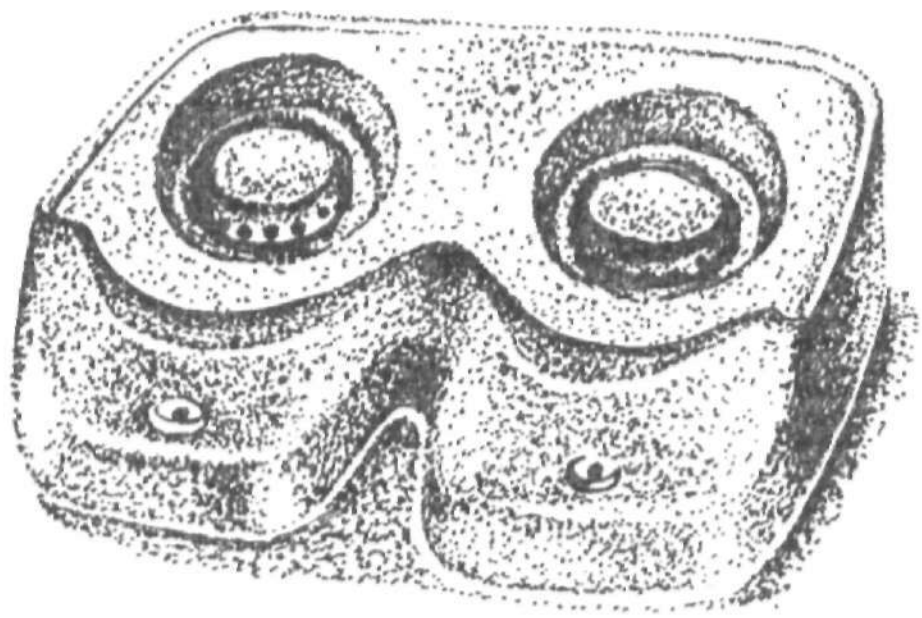
3.3 BURNER DESIGN

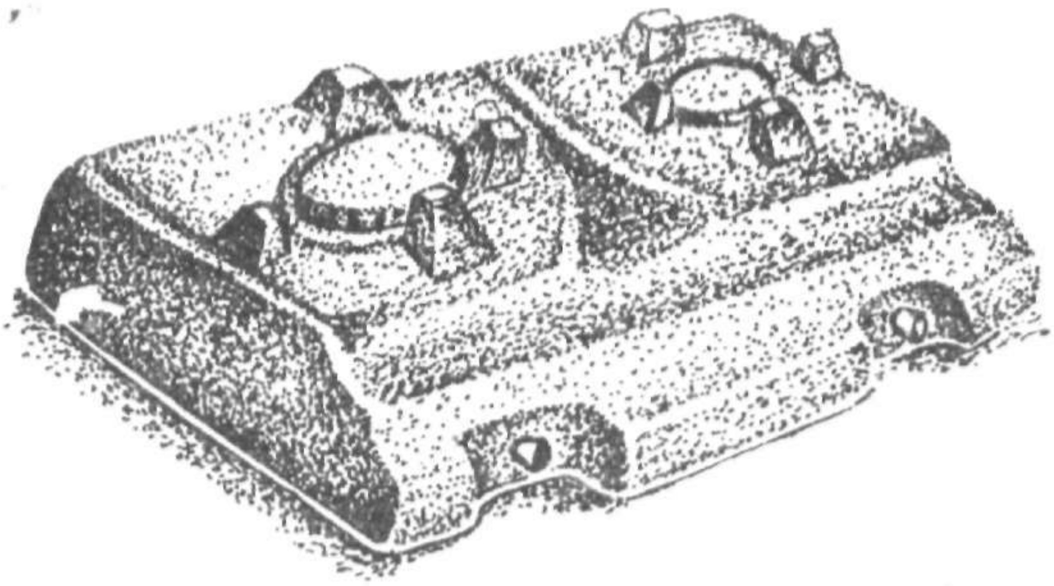
Another important aspect of the project design that required careful planning was the burner. Designing the burner is like designing the whole gas stove. This is because the burner is what makes the stove.

Although earlier book review shows that there are different types of burners with different functional capacities for different purposes as well as different modes of operation, the researcher chose to work on the aerated burner for domestic cooking.

Moreso, the researcher undertook a detail study on the burners commonly obtained in our market and redesigned a new burner incorporating the use of refectory ceramics for the burner tip and other aspects of the burner. Also one did not only present the graphic or mechanical illustration of the burner but also employed the use of clay material to construct a model of the new design. The low cost of maintenance as well as easy replacement constitutes the basis for the selection of the aerated burner system and the choice of materials. See burner design next page.

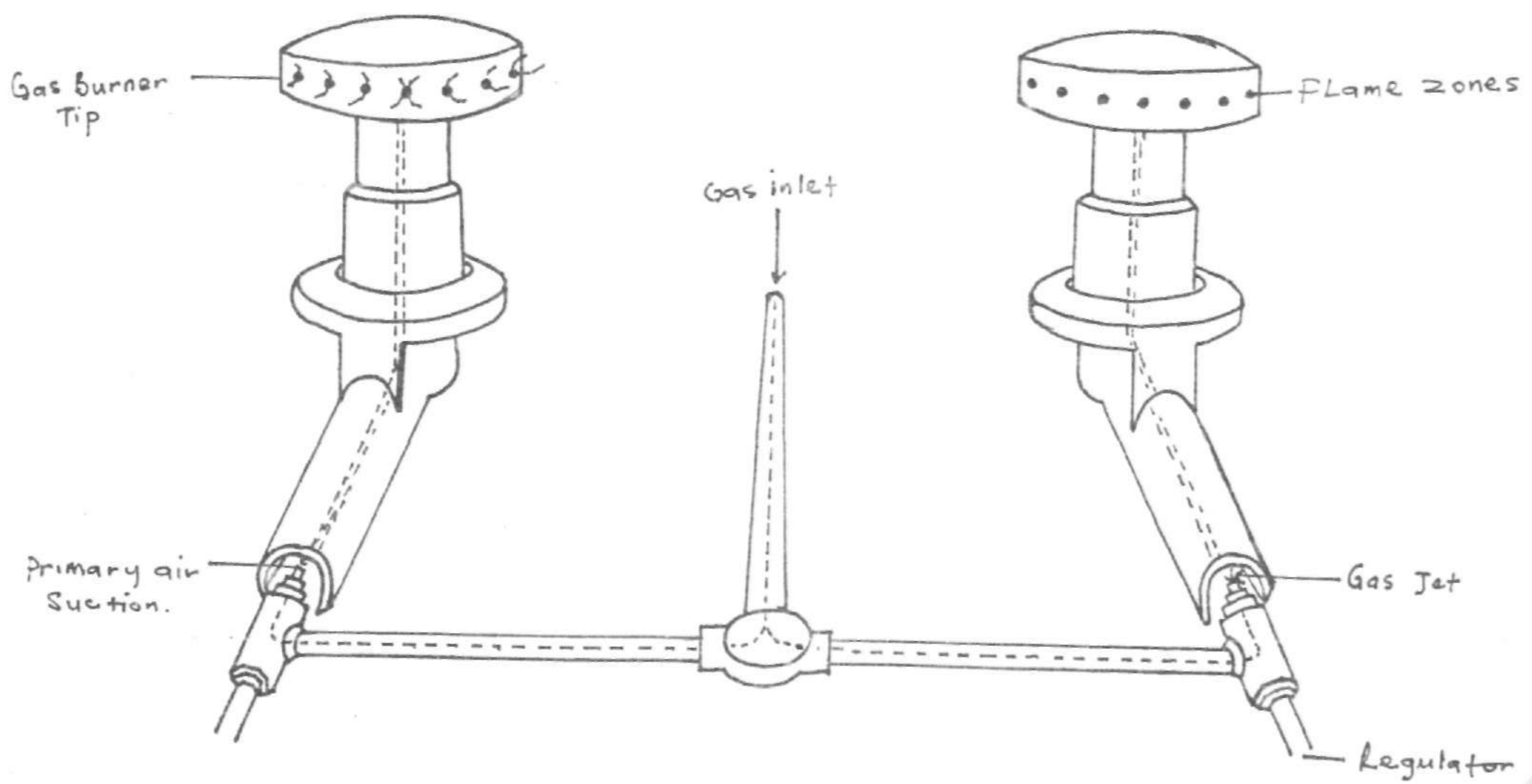
GAS STOVE DESIGN





The Selected Final sketches, Ready for Block modelling.

GAS BURNER DESIGN



3.4 **RAW MATERIALS PROCESSING & BODY COMPOSITION.**

This stage involved the processing of various raw materials collected from mining sites and craft shops for body and glaze composition. They include clay, Quartze, Grog, Alumina, bone ash, fire clay, Feldspar, whiting,cobalt oxide Iron oxide, wood ash. Apart from Quartze, wood ash, Bone ash, Felspar, Kaolin, the rest of the other materials were bought at the craft shops. Below are the processes involved in the beneficiation of these materials:

(1). Quartze.

This was calcined to about 1000^0C,crushed in the jaw crusher, milled for 12 hours and dried.

(2). Wood ash.

This was soaked for 48 hours, washed and sieved through mesh 80 and dried.

(3). Feldspar.

This was washed and calcined to 1000^0C, crushed in the jaw crusher, milled for 12 hours and dried.

(4). Bone ash.

Obtained from abbatoirs and calcined to about 1000^0C and crushed in the jaw crusher, milled for 24 hours and dried.

(5). Clay.

Clays brought from mining sites usually contain few impurities and reasonable quantities of silica. Because of its coarse powder form it is usually broken down further and soaked in a container. This is followed with a thorough mixture to obtain a consistent clay slip which is further sieved through mesh 30 to separate the clay from coarse impurities. Due to levitation process involved ,it was necessary to have additional containers and larger amount of water. The sieved clay is then transfered into other containers and allowed to settle. Usually, silica which is slightly heavier condenses at the bottom after a few minutes stirring. The excess water and clay is turned out and the free silica allowed to settle again after which the clay is separated from the silica and allowed to dry into powder.

3.5 BODY COMPOSITION.

To obtain a workable body that has the desired property was slightly a problem. Ceramics products usually can be made from a wide range of inorganic materials, but because of the technical requirement demanded of this product, it was necessary that the choice of materials be limited to just a few. It is important to know that pottery body materials are divided into three to fulfil functional requirement.

The first class are the materials that assist in the forming process. By forming process one means, materials that can deform, be imposed and have enough strength in unfired state to withstand handling and other subsequent processes. These features are usually found in clay.

The second functional requirement for a workable body is the flux. Although it is true that many clays are vitrifiable in themselves. However primary clays usually needs to be fired to a very high temperature in order for them to be of practical use. This requires huge cost and energy. Fluxes are thus introduced to lower the melting point of these clays which plays an important role in cementing the crystalline components together.

The third functional requirement is the filler. The role of the filler is to occupy the space left by clay and the flux. It provides a rigid skeleton giving ability, reducing contraction and distortion. The researcher in the quest for suitable materials had to abide strictly by this formula to obtain a durable and workable result. Under this consideration, clay both kaolin and bentonite, silica and alumina, and Feldspar were combined and tested to obtain the exact property that is suitable for the desired function. In doing this, several factors were taken into consideration.

(a). The desired tensile strength.

(b). The ability to resist warpage.

(c). Plasticity and cohesion of the body.

(d). Fusion of the glaze to the body.

(e). Desired firing temperature.

below is the table indicating the formula used for body composition.

TABLE 1: BODY/SLIP COMPOSITION.

MATERIAL	PERCENTAGE
QUARTZE	60
KAOLIN	25
POTASH FELDSPAR	10
BALL CLAY	3
SODIUM SILICATE	2
TOTAL	100

Source, studio experiment.

TABLE 2: BODY/SLIP COMPOSITION.

MATERIAL PERCENTAGE	
QUARTZE	52.3
KAOLIN	24.0
CALCINED ALUMINA	15.0
FIRE CLAY	4.7
SODIUM SILICATE	4.0
TOTAL	100

Source, studio experiment.

These materials were proportionately mixed together in a single metal bin for slip casting of the gas stove frame.

The composition of the burner tip is slightly different from that of the gas stove frames as indicated. Here the few materials were mixed together in liquid form and a sample piece was casted and also tested. What was desirable was to obtain a slightly coarse refractory body that would be free from expansion, thermal shock and stress, it is important to know that all materials expand upon heating, but this depends largely on the temperature they are subjected to. Refractory materials usually expand by just one percent when fired to

1250^{0}C. Henrick 1989. Below is the table showing the obtained body for burner tip

TABLE 3:

MATERIAL	PERCENTAGE
SILICA	50
ALUMINA	20
FIRE CLAY	8
BONE ASH	12
FINE GROG	10
TOTAL	100

Source studio experiment.

Before the casting would commence, it was needful to dry these materials and get them fired to ascertain their strength, shrinkage percentage and its cohesive ability as well as the adhesion of the glaze. A small amount of this material was dried into a pliable state and rolled into a ball. This was later flattened by means of a roller and cut into a rectangular bar. The bar size was 4 inches long and 1½ inches wide and half an inch thick. To measure the shrinkage uniformly during drying and firing, a shrinkage scale was made on each moist piece. Two marks were made three inches apart from the drying stage. The first shrinkage test was measured after the first and second firings. After the first firing, the piece of the body was introduced into a glaze batch to test the adhesion and fusion ability of the body and glaze and fired to 1300^{0}C.

Below is the composition of the glaze batch.

TABLE 3.1 GLAZE BATCH 1

MATERIAL	KILOGRAM	PERCENTAGE
POTASH FELDSPAR	12.41	62.2
WHITING	1.52	7.5
KAOLIN	5.0	5.0
FLINT	25.2	25.3
COBALT	0.5	
TOTAL	44.63	100

SOURCE: NELSON: 1960.

TABLE 3:2 GLAZE:

MATERIAL	KILOGRAM	PERCENTAGE
POTASH FELDSPAR	6	27.27
WHITING	6	27.27
WOOD ASH	4	18.18
BENTONITE	4	18.18
RED IRON OXIDE	2	9.09
TOTAL	22	100

SOURCE: STUDIO EXPERIMENT.

3.6 PREPARATION OF PLASTER BLOCK AND CASE MOULD.

Several stages were involved in the making of plaster mould. First, the original model was made out of clay. It is usually adviceable that the original block clay model be made and finished with great care so as to eliminate those areas that could be non functional or too difficult to produce in the plaster. In doing this also, one took into consideration the possible shrinkage rate that would likely occur. Shrinkage actually occurs in the drying and firing stages of the production. Thus the model needed to be slightly oversized so that acceptable potable size could be achieved.

Secondly, from the original model, a positive cast was made in plaster known as the case mould. Traditionally, the most commonly used material for mould making is plaster of paris. The researcher had to follow suit to avoid complications that arise from the use of unfamiliar materials, like wood and cement. After the proto type model made of clay was completed, the next stage was the preparation of plaster mould. There are various plaster of different hardness and setting rates used in the production of moulds. One had to choose the fine or dental grade that sets almost immediately it is poured. Sixty pounds of water was poured into a plastic bin of a fairly large size almost simultaneously with 100 pounds weight of plaster. This was immediately followed with a thorough mixture through constant stirring to achieve proper flow and thickness and poured into the wooden box hedging the model. This process required proper timing because once the plaster begins to set in the mixing container, it becomes useless,so one needed to be more faster probably because of the quick setting ability of the plaster.

Theoretically, 18.6 pounds of water will set 100 pounds of plaster, but studio practice proved otherwise probably because of the type of plaster used in the research. The plaster used was the dental grade.The function of the mould is to reproduce the required profile, and extract water from the body or slip. Thus in mixing the plaster, it was necessary to take note of strength and porosity of the mould. This was a bit hard task because plaster mould that have high porosity tends to be less stronger.And for a gigantic size mould like this, one needed to get a fairly strong mould that would withstand stress . A balance therefore needed to be achieved between strength and porosity of the mould. Usually when a larger amount of water in proportion to the plaster is used, the porosity is always high while the strength is reduced. Larger amount of plaster in proportion to water was mixed to get a good consistency that could balance the porosity and strength requirements.

After 24 hours of adequate drying, the mould was disengaged from the model and omo was used to wash away the grease deposited on the mould as a result of the vaseline used. It is usually adviceable that the mould be subjected to a firing temperature of about 100 - 200^{0}C to get the grease burnt off. The researcher felt this was a suitable alternative that would provide safety for the mould.

3.7 SLIP CASTING.

The previous processes stated earlier in this chapter indicated the various stages the researcher employed to produce the gas frames for onward construction of this project. Slip Casting is one of the major steps that brings out the form and the frame of the stove. Here the processes involved are simple.

The local materials brought from various sources were reduced to liquid or viscous state and thoroughly mixed to dissolute air bubbles and unslip - like clays. The slip was then poured into the hollow absorbent mould and allowed to stay for about 30 minutes. The amount of time the slip stays in the mould depends largely on the absorbent capacity of the mould. Moulds that have high rate of porosity absorb clays faster and this also depends on the ratio of water to plaster as earlier mentioned. Thirty minutes after the slip was poured,a film of firm clay appeared on the inner surface of the mould. As more water is absorbed, the clay becames thicker and thicker until a reasonable thickness that can withstand pressure, handling and weight was achieved.

After the desired thickness was achieved, the excess slip was poured out into a container. Following this, the clay coating on the mould was allowed to harden and shrink away from the mould to create an allowance that would make its removal easy. However, to avoid continuous slip addition during casting, a collar made of ordinary clay was added to the top of mould hedging the original piece which helped to reserve slip. The collar used as a guide was then cut off with a sharp table knife. After this the cast piece was then turned upside down on a flat wooden sheet and the casting seams on the body removed with the aid of a sponge to enhance a smooth surface.

3.8 FIRING.

The final step involved in the production of the ceramics frames for the construction of gas stove is firing. This process is very crucial because it introduces strength and compatibility to the frames for easy handling and other application. Two stages were involved in this firing the first stage of firing is called the bisque firing. This is done after the work is dry and little moisture is left. The firing temperature was about a thousand, 1000^0C, cone 06. This was so because of the composition of the body, usually the bisque temperature ranges generally between cone 010 and cone 09. At this stage, the wares were hard enough to endure normal handling especially in the glazing operation, yet sufficiently absorbent to permit glaze adhesion.

After this process, the fired wares were then submerged into a large bin containing the prepared glaze batch. This process is called glazing. A glaze is nothing more than a thin, glass like coating that is fused to the body of the ware by process of heat. Thus after glaze was applied, it went through another period of firing to about 1280 to 1300^0C. This apart from helping the glaze to melt and fuse to the body, almost climaxed the strength of the frames. Although this clay body could stand further heating to a temperature not more than 1600^0C, lack of kilns with such heating capacity compared the researcher to depend solely on what is available, thus achieving only a maximum of 1300^0C.

It is important to state here that the process of glazing could easily be avoided in the production of this work because it has very little bearing with the subject matter. However, since facilities are not available to ensure maximum smooth surfaces of the body, it was necessary to introduce glazes to achieve better appearances as well as ease the cleaning process and hygienic orientation.

By the process of bisque and glaze firings, the procedures for making gas stove . ames through ceramic medium are completed. However,as earlier mentioned, this research is not independent in its approach to produce a ceramics gas stove. In fact, there is no such thing as independent technology. Thus one had to combine skills, tools, materials and technologies from the Engineering sector to complete the process of this production.

3.9 COST OF PRODUCTION.

As earlier on mentioned, the accompanied aim of this project is to develop a product that will attract capital investment from either government or private individuals which can be produced at a price permitting widespread distribution at affordable prices. The researcher borne in mind that there are several other non - indigenous and home made steel gas stoves that stand to challenge both the cost and the entire ceramics make of this stove. The prices would therefore have to be comparatively less than the ones found in our market.

Below is the cost of production of the first proto-type ceramic gas stove.

QUANTITY	DESCRIPTION	COST
Two bags of	Plaster of paris	₦2200.00
One bag of	Quartz	₦800.00
One bag of	Potash Feldspar	₦1200.00
One bag of	Whiting	₦1000.00
Four	Gas Jets	₦600.00
Four	Aluminum burner holders	₦600.00
Two hundred	Litres of kerosine for firing	₦2000.00
	TOTAL	₦8400.00

Other materials were procured locally and processed at virtually not cost at all.

This estimate however excludes the cost of equipment like, Kilns and ball mills etc used in the process of preparing raw materials for production of this stove. In a studio situation where these machines are absent, then the cost of procuring and installing them will come under the estimate as well.

It is important to note that the above cost is the cost involved in the production of the proto-type and therefore should not be used as a determinant of the market price. From this proto-type however, subsequent editions will be produced at a much lower cost and that would partly determine what the market price should be.

CHAPTER FOUR.

4.1 ANALYSIS OF EXPERIMENTS DATA AND FINDINGS.

In attempting to solve the problem of this study which involved the use of local ceramics materials to replace or substitute steel in the production of gas stoves, the researcher employed methods which included seeking alternative materials to steel, testing them to ascertain their strength, functional capacities and economic viability. This chapter is a documentation of the analysis and results from various test and experiments conducted in the studio to support the quest for a solution that solves the problem of this study.

4.2 RESULT OF CLAY TEST.

Two different clay bodies were sampled and tested. As earlier stated, in trying to solve the problem of this study, one needed a material that could help in the forming process. That means it must be a plastic material that can deform, be imposed and strong enough in unfired state to withstand handling. Secondary clay obtained from Kano - Zaria road was found to be a feasible medium towards achieving this goal. It was also found to have less iron content,thus helping to improve the whiteness or purity of the body.

Another type of clay sampled and tested was the primary clay known as "Kankara clay". Since secondary clay vitrify at much lower temperatures, causing rapid shrinkage and warpage, Kaolin clay was an added advantage in curbing this problem since it is refractory and melts at much higher temperature.

4.3 RESULT OF PLASTICITY AND COHESION OF THE BODY.

Both the forming and production of this product involved the composition of various materials which are unique in their characteristics. Despite this, there is one fundamental requirement that is needed to achieve their workability and this is plasticity or cohesion. Both Quarts, Alumina Kaolin, Potash Feldspar boneash and ball clay combined effectively to achieve the desired plasticity and cohesion which reduced the problem of handling and compatibility and survival under heat.

4.4 RESULT OF WARPAGE RESISTANCE.

Due to the delicate nature of the construction which involved inner lining of pipes with straight and coiled shapes with precision, it was desirable to have a stove frame that is free from unwanted curves or warpage noticeable in most ceramics productions. Taking this factor into consideration, the composed clay body needed to have the ability to resist excessive warpage due to the expansion and contraction experienced during firings at high temperature. The materials combined were found capable of reducing the problem of excessive expansion and warpage.

4.5 RESULT OF STRENGTH AND ABILITY TO WITHSTAND IMPACT.

Obviously, this is a research work aimed at obtaining a body that is close to metals in strength. The essence of this is to achieve a structure that cannot easily shatter under impact and also able to withstand the weight from cooking utensils as well as pressure from heat. Several body compositions from previous researchers were found stronger than metals when subjected to temperatures not more than 1700^0C.

The selected materials when tested proved strong enough to give the required strength at least to withstand impact and heat.There are several methods by which the production of this stove frame could be approached. It could be by hand moulding, press moulding, slip casting etc. Both the press moulding and casting methods were employed in the production of this project. Because of the size of the frame and thus the plaster mould,it was a bit difficult turning the gigantic mould to remove excess slip after the desired thickness or film is achieved. Thus it was recommended that a hole be drilled at the bottom of the plaster mould with a wooden or metal holder to hold back the slip or allow easy drainage. This, though not tested by the researcher,is practically possible as it was previously tested and suggested by Umar 1993.

4.6 RESULT OF FREE EXPANSION AT LOW TEMPERATURE.

Studio experiments and experience showed that almost all bodies designed to hold either electric element or gas burners for cooking crack after just one hour of continuous cooking as a result of heat that emanates from the hot blue flames. Moreso, as gas stove users seek replacement of their broken or lost metal gas burners spots with ceramics devices, this forced several students into seeking alternative materials to these metal burners. The result had always been unsatisfactory as clients come back complaining of the same problem of cracks, due to expansion. Based on this one realised this will constitute the same problem with the on going research. It became imperative, therefore, that a careful search be conducted to derive a refractory ceramic body that can withstand the hot blue flames that ensue from gas combustion. Silica, Alumina, Fire clay, Bone ash and fine grog at correct percentages yielded the desired result.

4.7 RESULT OF GLAZE ADHESION TO THE BODY.

Not all glazes melt and adhere to all ceramics bodies. There could be disharmony in their behavioural characteristics resulting to the following unhealthy results. Crowling, crazing,weathering, pinholing, peeling and dunting. The studio result however showed that the composed glaze melted and adhered very well to the body leaving it with very smooth surfaces.

4.8 RESULT OF THE DESIRED FIRING TEMPERATURE.

All ceramics materials have their independent melting points which when subjected to temperatures exceeding their capacities begin to verify and collapse or distort uncontrollably. This body is however designed to withstand temperatures measuring at least 1600^0C. At 1300^0C of firing,the result still showed that it could be further fired to an additional 300^0C without any visible impact.

4.9 RESULT OF AERATED BURNER.

The researcher was free to choose from several types of burner designs. The non - aerated burners, surface combustion burner and the aerated burner. The researcher chose to adopt the aerated burner to solve the problem of this study. The result proved positive and satisfactory.

4.9.1 RESULT OF THE DESIRED FLAME TEST AND COMBUSTION RATE.

One of the objectives of this research is to achieve a burner that burns blue hot and luminous. Previous practice showed that most burners burn with a red luminous flame resulting to unhealthy deposit of carbon at the burner tip and pots which constitutes a health hazard and darkens the kitchen room. The aerated burner however proved contrary as it gave a hot blue flame that cooks within the shortest time.

4.9.2 RESULT OF DURABILITY, FREE CORROSION.

It is common knowledge that gas stoves made of metal corrode and rust with time due to constant contact with water and atmospheric moisture. This reduces the life span of the stove and its capacity to perform and eventually become useless. The newly formed body made to replace steel in the production of this stove was tested and proved much durable and free from corrosion.

4.9.3 FINDINGS.

Based on the results of the experiments carried out in the cause of this study, the following findings were drawn:

(1). That the clay bodies used in the formation of original models of the frames are the ideal medium for the production of ceramics gas stove.

(2). That effective and accurate combination of quarts, Kaolin, Potash Feldspar, Alumina Bone ash at correct percentages yielded the desired plasticity and cohesion required in the process of production, giving adequate compatibility and rigidity of forms.

(3). That the materials stated above in correct combinations would reduce to a bare minimum the problem of excessive warpage prevalent in most ceramics production.

(4). The selected materials for the formation of the stove frame when subjected to the temperature of about 1300^{0}C would give the required tensile strength capable of withstanding impact and accommodate weights up to 20 kg without loosing its strength.

(5). Also that when these materials are fired to 1300^{0}C they become indestructible, eliminating the problem of corrosion and rust caused by water and atmospheric moisture commonly associated with all steel gas stoves.

(6). Studio research on the frame's burner tips, showed that the clay bodies when well composed and fired to the required temperature not less than 1300^{0}C cannot expand when heated to a temperature less than 200^{0}C.

(7). Although not all glazes melt and adhere very well to all bodies, without much problems, yet this research proved that the glazed composition designed for this body stuck and maintained its permanence,on the ware reducing the problem of cleanliness and hygienic orientation.

(8). Research findings also showed that the clay formed for the purpose of this project can withstand temperatures above 1300^{0}C without any distortion to its original shape.

(9). The choice of aerated burners which provides primary air suction permitting free supply of oxygen for effective combustion was better improvisation than the other types. The findings are thus satisfactory.

(10) The choice of the aerated burner design as well as the choice of materials for its production showed that blue and luminous flames cannot only be achieved with steel materials. The flame burned hot and cooks within a short time.

(11) The method employed in the production of this stove is found to be the most practical and easy method in the production of this stove frame and burner tips as very little problems and loses were incurred.

(12) Findings also showed that the ceramic gas stove is free from corrosion and rust commonly experienced with the steel type. It has the characteristics found in all durable clay products.

(13) In the cause of production, it was found out that incorrect and inappropriate mixture of materials resulted to the problem of warpage, shocks and cracks and

unattainable temperature. It is therefore advised that the formula adopted in the formation of this body be strictly adhered to except when otherwise improved upon.

(14) The study also found out that not all ceramics materials survive the hot blue flame that comes from the gas burning. Experiments showed that most materials shatter within the first five minutes of heating. A workable and enduring composition was thus imperative in order to achieve a minimum efficiency.

CHAPTER FIVE.

SUMMARY, CONCLUSION AND RECOMMENDATION.

5.1 INTRODUCTION.

The researcher has worked within the confines and scope of the selected topic,which is strictly aimed at developing a ceramics prototype gas stove using local resources. In the cause of this study, series of experiments and observations were made which proved either positive or negative. These have been recorded in the previous chapters. This chapter carries the sum of the entire procedures, observations and suggestions that are likely going to advance the cause of the current transition from local ceramics to diversified ceramics application.

5.2 SUMMARY.

The review of related literature identified one significant problem that drove ceramics production into a narrow groove covering just a limited number of activities mainly within the confines of functional table wares, the bathroom and the kitchen scene. The limited use of materials within our local studios kept us out of contact with the present reality which makes ceramics an art with tones of meaning.

Furthermore, with the dynamic nature of the present world, one gradually envisage a time when other primitive fuels like fire wood would be knocked out, if civilization does not knock it out, then the ensuing problem of decertification will do. While other industrial sectors based on the current trend are trying to eliminate the problem through the production of modern cooking devices, ceramics artist and Engineers appear to be unflapple. It was with this as a back drop that this project was initiated.

In doing this, a wide range of literature was read and several field trips both to mining sites and industries were conducted. Studio experiment which involved the use of raw materials for body formation, production techniques and firing were done. Test were made, based on this, suitable results were arrived at which from all indication seemingly solved the problem of this study.

Today, it is glaring that local materials can be improved upon and made to replace steel in the production of functional structures like gas cooking stoves. And that ceramics artist with very little help from other industrial sectors can produce unquantifiable products including the problem of this study. Moreso,that without much of foreign import, the nation can still survive. The current transition from simple ceramics to more diversified application is further advanced.

.3 CONCLUSION.

Based on the above analysis, the following conclusions are articulated and annotated.

(1). All materials used in the formation of clay bodies are affordable at very low cost or sometimes at no cost at all. And that when beneficiated, can be utilized to produce many functional products that can substitute steel currently identified as a major medium for the production of gas stove.

(2). That devoid of industrial machineries, ceramics manufacturers can still employ the use of local materials to produce structural equipment that can serve the local man on the household chores.

(3). That observing the behavioural characteristics of clay and its outstanding quality in terms of plasticity, strength, rigidity, durability etc, one foresees that the problem of raw materials and over dependence on foreign imports can be eliminated or minimized in the production and utilization of domestic and industrial wares.

(4). Consistent and durable burners can be made with the use of ceramics materials. Also, that new design and production methods can be incorporated into the production of this stove and gas burners.

5.4 GENERAL RECOMMENDATION.

Considering the significance and indispensability of ceramics in our day to day use as well as in national development including academics, one would like to proffer the following recommendations.

(1). Over the years, government has neglected the educational sector which is the bed rock of all civilization and technologies. Such neglect has yielded undesirable impact resulting to loss of standard and motivation as well as lack of incentive for meaningful work. Based on this, one would recommend that the government should gear more of its efforts towards resuscitating the cold brains that are lying dead in our universities through adequate funding and provision of research facilities. this will salvage the power house of all creativity and technologies from this present debacle.

(2). Raw materials that can move the nation forward and boost production in this sector are available and yet unharnessed. the researcher recommends that graduate should be trained abroad in more qualified research centres so as to provide the needed manpower that would sustain the already existing research centres in the country. Close to this is the establishment of more ceramics raw materials and research centres across the nation. Hence the importance of equipping such must be re emphasised.

(3). Ceramics artist should diversify their skill and interest from studio ceramics to the industrial sector of the profession so as to lean modern techniques and skillful handling and utilization of the existing raw materials for the purpose of producing different equipment and services.

(4). The tertiary institutions and private library owners should make more provision of current literature in the area of industrial design especially in the area of gas stove production.

(5). An interdependent disciplinary approach should be encouraged between ceramics artist, practicing Engineers of theoretical scientist, so that production of more qualitative outputs in ceramics can be achieved.

5.5 RECOMMENDATION FOR FURTHER STUDIES.

Based upon the general problems encountered in this study and the prospects in the field of learning and production, the researcher recommends the following propositions to enhance technology and learning.

(1) That medium size studio kilns that can attain temperatures not less than 1700^0C be constructed, so that more ceramics productions that require metallic strength can be produced locally. And that such kilns should have maximum efficiency in the use of cheap fuels.

(2). Investigation aimed at achieving body formations that can make frames for electric stoves or burner plates for electric stoves should be carried out.

(3). Thirdly, it is recommended that researchers adopt our local ceramics materials to produce more domestic wares like kitchen ovens, glazed cooking pots and mixers which are produced from steel, aluminum and other metals.

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APENDIX I

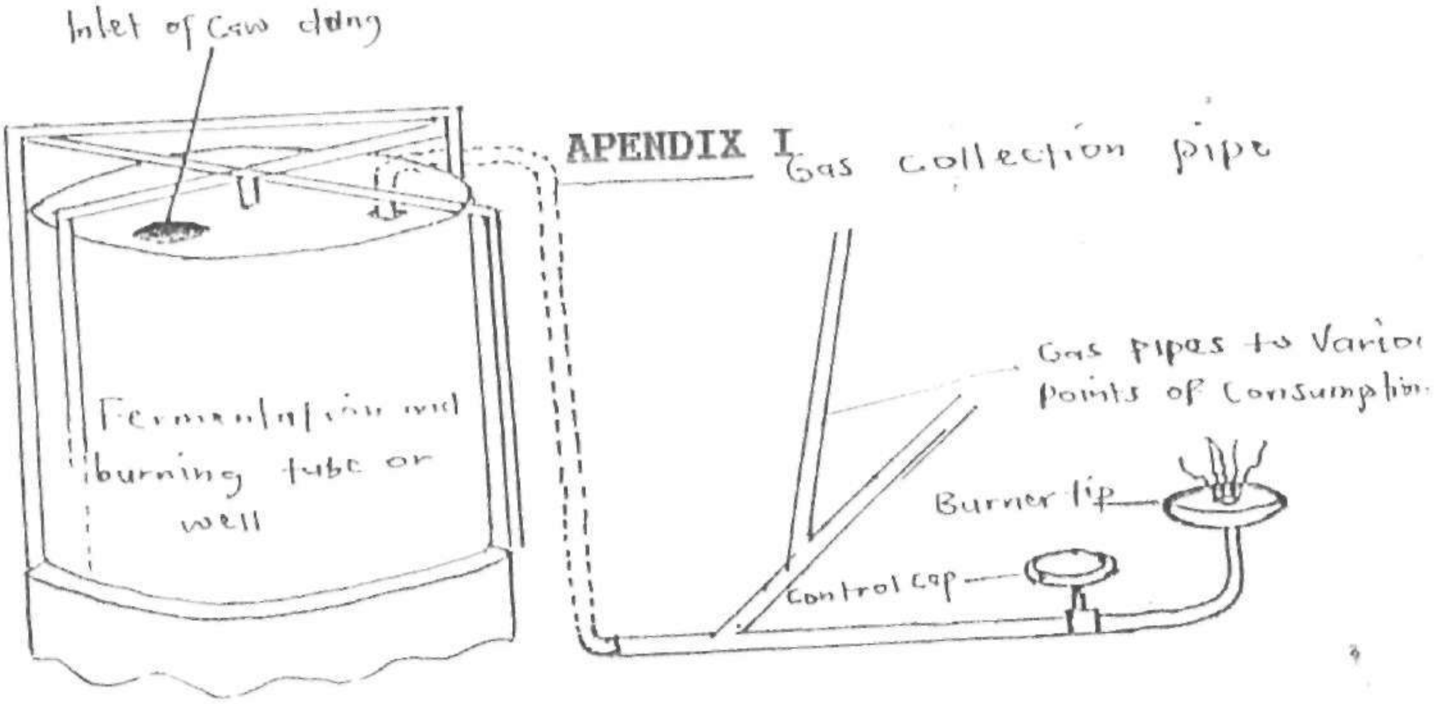

Figure 1

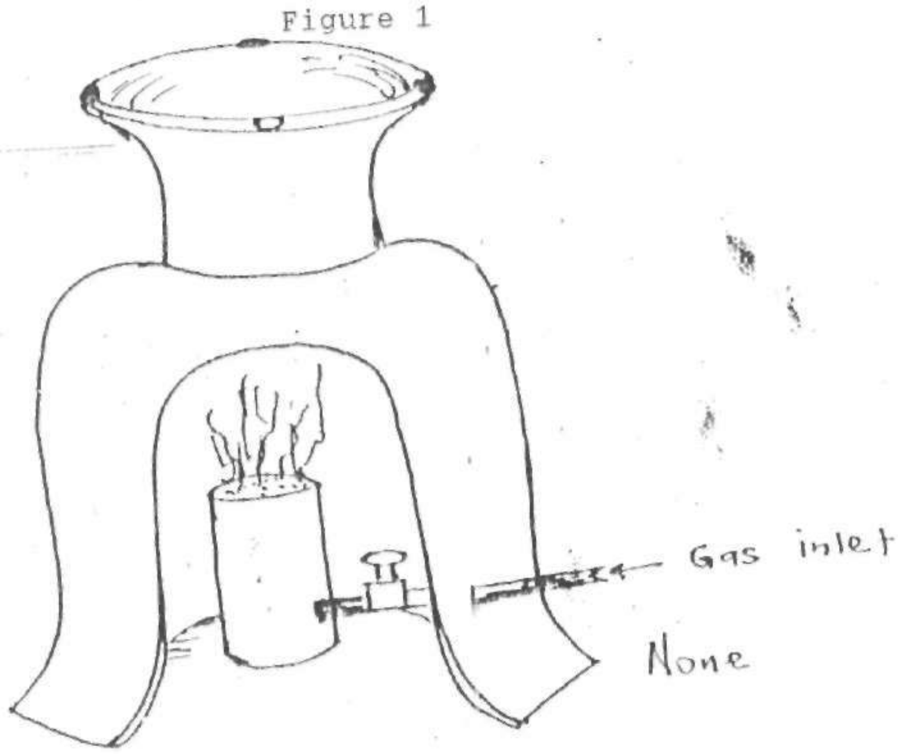

Figure 2

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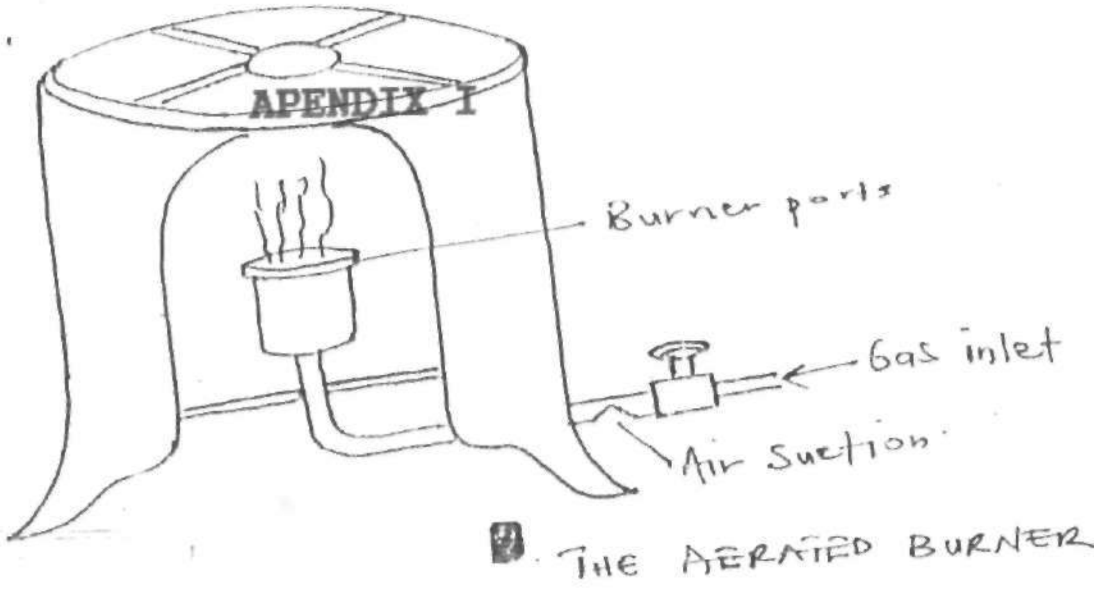

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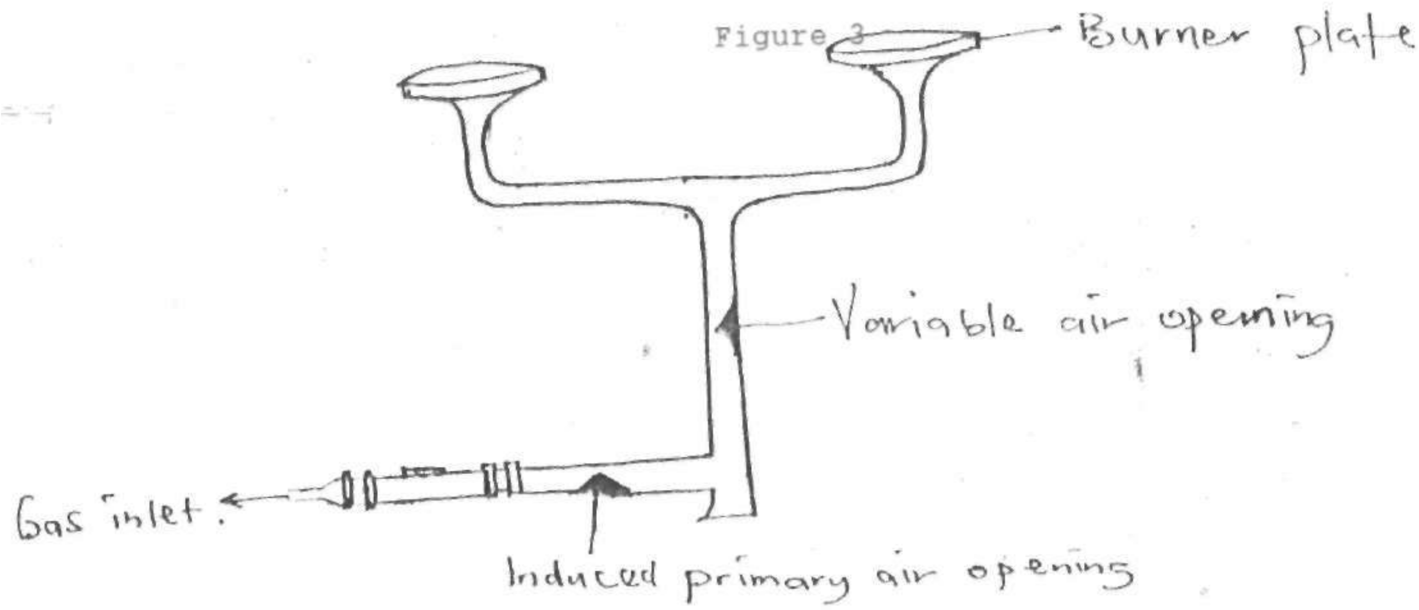

Figure 4

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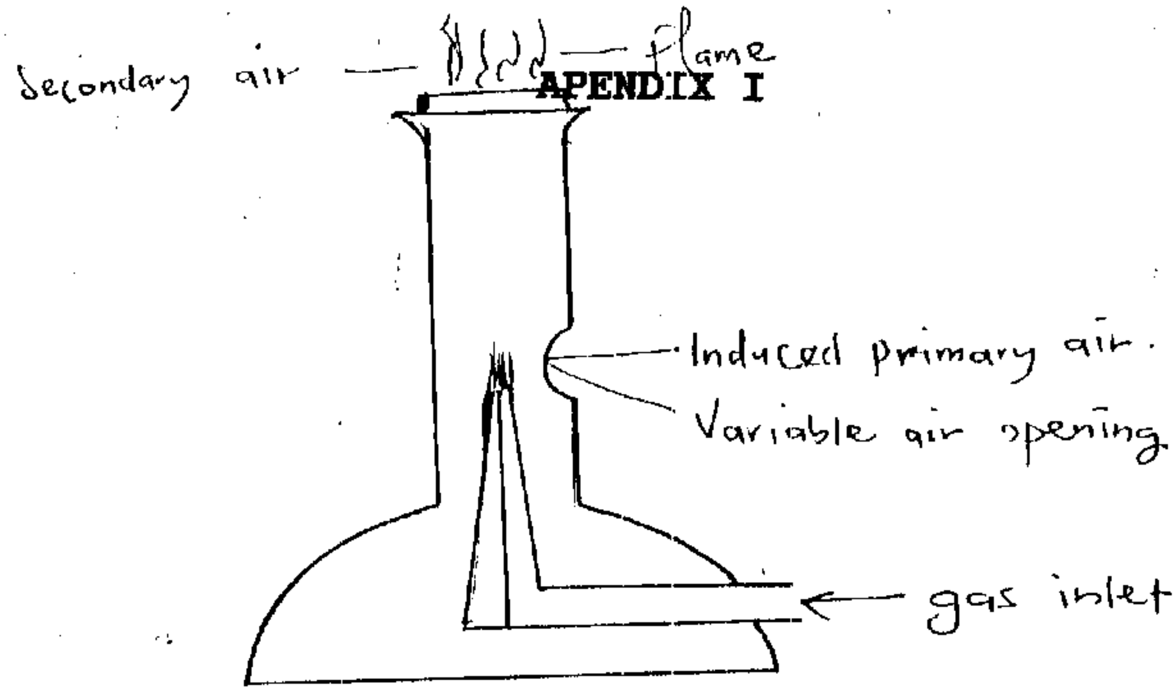
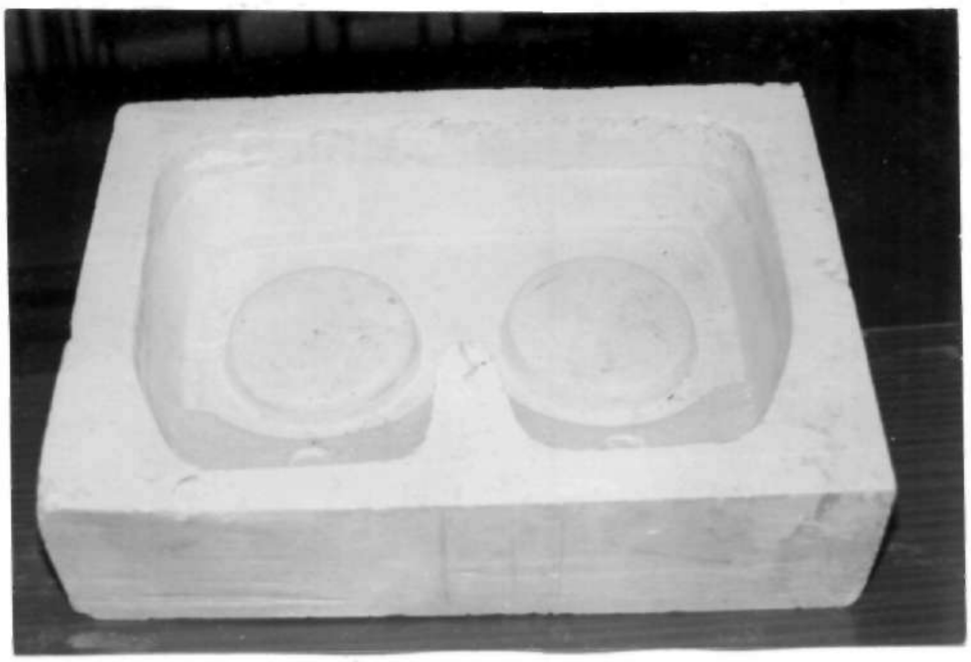


Figure 5

APENDIX II



APENDIX II

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