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Rehabilitation of Mini-furnace in the Foundry Workshop

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Abstract
The rehabilitation of mini-furnace in the foundry workshop is undertaking. The mini-furnace assembly among other things has five main components which include; the furnace shell, the refractory lining [wall of the furnace]. The burner and its pipe, full tank scraps. Full tank and crucible pot. The furnace body is enclosed in cylindrical metal sheet measuring 575mm diameter by 500mm high it is lined internally with superior refractory bricks of 65mm thickness. The furnace by calculation has these specifications; circumstance of 942.86mm volume of 0.04m^3, weight of 49.05KN. The melting process is done in a crucial rammed externally with fire-clay and made from heat resistance sheet at temperature of 700^0 C to 800^0 C. An air-blast from electrically powered centrifugal blower is atomized with condemned diesel oil which flows down by gravity and is controlled by throttle valve in the fuel line and form the heat source when they mixed inside the combustion chamber.

Keywords: Burner, Blower, Throttle Valve, Refractory Bricks, Crucible Pot.

1. INTRODUCTION

A foundry is a factory that produces metal castings. Metals are cast into shapes by melting them into a liquid, pouring the metal in a mold, and removing the mold material or casting after the metal has solidified as it cools. The most common metals that are produced by casting process are aluminum and cast iron. However, other metals such as bronze, brass, steel, magnesium, and zinc are also used to produce casting in foundry. In this process parts of the desired shape and sizes can be formed. Casting is the process of creating metal object by pouring liquid metal into molds, where it cools and hardens into the mold's shape. Although the premise is simple there are many variation in metal casting methods. To take an object from idea to reality, designers must specify the physical and aesthetic needs of the final product and from there find the simplest way to produce those qualities. The complexity of the designs, as well as what stresses the final object must withstand, help determine the metal; how the metal behaves in liquid, solid, and cooling states will dictate requirement of the mold.

Good casting design is the matter of knowing all the ingredients and processes involved to get to the final product. Casting is most often used for making complex shapes that would be difficult or uneconomical to make by other methods. The overall objective of this research is to conduct a fundamental investigation on foundry workshop. In this project we seek to understand furnace works and how the mini furnace in the foundry workshop can be reactivated and test run. A furnace is a device used for high-temperature heating. The name derives from Greek word fornax , which means oven. The heat energy to fuel a furnace may be supplied directly by fuel combustion, by electricity such as electric are furnace, or through induction heating in indications materials, for changing shape {rolling, forging etc], for change properties [Heat treatment}. They are used extraction of from ore or in oil refineries for example as the heat source for fractional distillation columns.

Crucible furnace is one of the oldest and simplest type of melting unit used in the foundry. The furnace uses a refractive crucible which contains the metal charge. The charge is heated via conduction of heat through the walls of the crucible. The heating fuel is typically coke, oil, gas or electricity. Crucible furnaces are continuously used where small batches of low melting point alloy are required.
The capital outlay of these furnaces makes them attractive to small non-ferrous foundry. Crucible furnaces are typically classified according to their method of removal which are the tilting furnace, lift-out furnace, bale-out furnace (www.atlasfdry.com)

A crucible is a pot that is used to keep metals for melting in a furnace. Furnace crucibles are designed tp withstand the highest temperature encountered in thew metal casting works. Crucible should essentially be made of materials with a much higher melting point than that pf the materials to be melted. It should also have good strength even when extremely hot. Crucible furnaces are made up of metal the extreme temperatures in typical foundry operations.

Foundry Practice in Nigeria.
Foundry technology is practiced in both urban and rural areas of Nigeria; the local foundry man digs a hole on the ground to tale the shape of an oven, using coal or charcoal as fuel and makes use of a clay or metal pot as crucible. A blower is used to supply the air needed for the combustion process. The local foundry technicians use the crucible furnace for making of casting of different objects such as machines parts, domestic cooking pots of different sizes, serving spoons, flying pans.

Furnace is also a term used to identity a closed space where heat is applied to the body in order to raise its temperature. The source of heat may be fuel or electricity. Commonly, metals and alloys and sometimes non-metals are heated in furnaces. The purpose of heating defines the temperature pf heating and heating rate. It is an apparatus in which heat is generated and transferred directly or indirectly to a molten or solid mass for the purpose of effecting a physical, chemical or metallurgical change in the mass. Furnace equipment is isolated from the surrounding by an insulated wall and is used to heat to the material produced is utilized, this practically is unachievable and there is no thermal processing equipment with efficiency of 100%. A furnace of high efficiency is therefore a system in which energy losses are minimal. In practices however, a lot of heat is lost in several ways. The losses include energy conversion losses, furnace opening losses and the likes. In order to prevent these losses, materials that can retain and conserve heat known as refractory materials are therefore used for lining materials for the furnaces. Refractories are porous, multi-component and heterogeneous materials composed or thermally stable mineral aggregate, a binder phase and addictive. Refractory wall of furnaces is the key to efficiency of a furnace Yoshikawa, (2004).

A furnace is a device in which the chemical energy of a fuel or electrical energy is converted into heat which is then used to raise the temperature of materials. Furnaces operating at low temperature are often called ovens depending on their purposes and there are other furnaces used at higher temperature for various materials and purposes.(Folayan, 2001). Furnaces are refractory lined vessels that contain the material to be melted and provide energy to melt it, Modern furnace types include electric arc furnaces (EAF), induction furnaces, cupolas, reverberatory, crucible furnaces. The furnace choice is dependent on the materials and quantities processed. For ferrous materials. EAFs, cupolas and induction furnaces are commonly used. Reverberatory and crucible furnaces are common for aluminum castings.(Beeley, 2001).

Metals are cast into shapes by melting them, pouring the molten metal into a mold, and removing the molded materials or casting after the metal has and cooled. The most common metals processed are aluminum and cast iron. However, other metals, such as bronze, steel, magnesium, copper, tin and zinc, are also used to produce castings in foundries (Beeley2001).

Folayan (2001), improved on the gas fired crucible type of method of melting by designing a coal fired crucible furnace. He observed that charcoal remains the most available fuel as coal is not available in many parts of the country, whereas charcoal is always available everywhere and is cheaper than both gas and coal.

Charles, (2001) constructed an electric line crucible -type aluminum melting furnace featuring quiet"Buzzer" venturi burners. The furnace offers the cleanliness of gas heat, operates economically, does not require the maintenance of compressed air and will continue to operate during power failures. The furnace consists of sectioned cast iron furnace rings and a steel lined jacket.

Okada, Sasaki and Yoshikawa, (2004) conducted research on the development of an innovative continuous melting and holding crucible furnace.A high performance continuous aluminium smelting and holding crucible furnace was developed. It has a compact single-body combining the features of both a melting and holding crucible furnace. Continuous melting at minimum temperature in a crucible contributes to less generation of aluminum oxide and less metal loss. The ideal temperature for casting is achieved and higher metal quality with a lower number of hard spots is obtained.

Uses of fire-clay

Fire-clay is resistant to high temperatures having fusion points higher than 1,600°C(2,910°F);therefore is suitable for lining furnaces, as fire brick,, and for manufactures of utensils used in the metalworking industries, such as crucibles, saggars, retorts and glassware. Because of its stability during firing in the kiln, it can be used to make complex items of pottery such as pipes and sanitary ware.

Chemical composition of Fire-Clay

The chemical composition typical for fire-clay are 23-34% Al203, 50-60% SiO2 AND 6-27% loss ignition together with various amounts of $Fe2O_3$,CaO, MgO, k_2O,Na_2O and TiO_2 Chemical analyze from two 19th century sources, shown in the table below.are somewhat lower in alumina although a more contemporary source quotes analyses that are closer.

II. METHODS

Fabrication of furnace shell

A 1.5mm mild steel sheet of dimension 600mm x 650mm was cut using cutting machine and rolled to shape using rolling machine to dimension 500mm x 550mm. The rolled plate was joined at the edges by welding using electric arc machine to form a cylindrical shape which serves as the body of the cylinder. The tolerance was cut away to give the actual dimension of 500mm x 550mm. The base of the furnace was also made from the mild steel sheet that was cut into a circular shape diameter 550mm; the circular plate was welded to the body of the furnace to give a solid base. A crucible cover of 80mm x 550mm was also fabricated from the mild steel plate with a hole 115mm made on the cover to serve as an exhaust for the fumes and gases. Handles were attached to the crucible cover to allow for easy removal of the cover from the body f the furnace during loading of charges into the the furnace and during removal of crucible pot from the furnace.

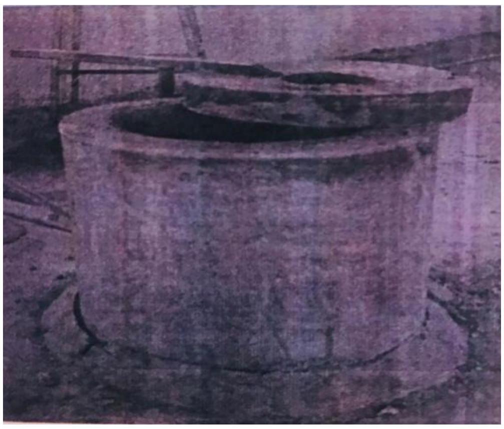

Fig 2.1 Crucible furnace

The following were the designs adopted for this week project work:

Engineering Design of the Furnace

The general layout and profile of the crucible furnace consists of an oil burner, blower unit, fuel tank and its stand and crucible furnace unit. The furnace consists a crucible pot to which the charge to be melted is fed into, a burner which burns the diesel oil and the crucible cover.

Crucible and Furnace specification

The furnace with its cover is 580mm high,the circular base having 550mm base diameter, the furnace lining forms an inner diameter of 300mm and Includes the blower and its mechanisms. Thus the furnace is potable and occupies little space which enables it to be moved from one place to another for easy operations. The designed crucible furnace assembly has five main components as listed below.

1. The Furnace shell.
2. The refractory lining (wall of the furnace).
3. The Burner and its pipe.
4. The fuel tank.
5. Crucible pot.

III. DESIGN CALCULATIONS

i. Calculations for the Internal and External height of the furnace

Internal height of the furnace = height of crucible+height of refractory lining uncovered by crucible
Therefore, 200+210=410mm
External eight = internal height of the furnace + thickness of the base lining
Therefore, external height=410 + 90=500mmVolume=22/7* 0.275* 0.500--e* 0.150^2* 0.410

ii. Circumference of the furnace

The circumference of the circle $2\pi r$,
Where r= radius of the internal diameter of the furnace --22=150mm
Hence, the circumference 2×3.142×150=942.86mm

iii. Calculation of the weight of the metal sheet of the furnace

Recall that the volume of a cylinder Ttr^2h
Volume=(πr^2h)external-(Ttr^2h)internal
I. Volume=22/7* 0.275* 0.500--e* 0.150^2* $0.41m^3$
II. Calculating Weight of the crucible, since the crucible to be used is 2kg
Hence,its weight =2 x 9.81=19.62kn
III. Calculation of weight of the molten metal
Let mass of charged materials equals mass of the molten metal lets say=5kg
Therefore, its weight =5 x 9.81=49.05kn

Relining of the furnace, furnace cover and pot

The method of relining the foundry furnace, furnace cover and pot wherein the refractory material comprises of fire-clay basis containing about 38% of Al2O3 and clay(red sand).

The following methods were adopted for the relining of the furnace:

- Scraping out of remnants of the old refractory using trowel.
- Sprinkling of water on the walls of the furnace to dampen the walls
- Mix the fire-clay(14kg) and clay (red sand) with water with a trowel in a basin, make sure there is no lump in the mixture as shown in the fig 3.3.

- Sprinkling of water on the walls of the furnace before applying the mixture with hand for effective alignment. Start from the bottom of the furnace to cover every holes or cracks very well and for it to align well a shown in fig 3.4.
- Smoothening of the surface using a 40mm hollow cylinder.
- Conical shape is given to the work for effective heatin

IV. RESULTS AND DISCUSSION

Having fabricated the furnace it was test-run in three different ways to determine the time it takes to raise the temperature up to 60°C and above for melting of aluminium in each of the test conducted. The three test that were conducted are:

1. No load test of the furnace.
2. Furnace with the load of 10kg at once test.
3. Continuous load test.

The result obtained are as follow,
No load test

In the no load test carried out, the sequence of testing procedures were followed and the furnace was tested empty without loading aluminium, the following result were obtained from the test.

a. Time taken to raise ht temperature of the crucible to 660°C and above was 30mins.
b. The quality of charcoal consumed for this test was 14kg.

With load test

The load test was carried out with the load of 10kg of aluminium at once the following results were obtained from this test.

a. Time taken to raise the temperature to 660°C and 55mins and the holding time for the aluminium to melt completely was 10min, therefore the total time taken for melting of 10kg of aluminium at once was 1.05min.
b. The quality of charcoal consumed for this test as 2.5kg

With load test continuous method

This test was carried out by adding the load of aluminium, kilogram by kilogram in continuous form, to determine the time taken to melt each kilogram of aluminium in the furnace; the results obtained are given in the table.

a. Ambient temperature =28°C
b. Temperature of the products of combustion(flue gas) T_g = 260°C
c. Initial temperature of the charcoal fuel T_f = 28°C
d. Melting temperature = 660°C
e. Furnace external temperature 105°C
f. Furnace environment temperature 750°C

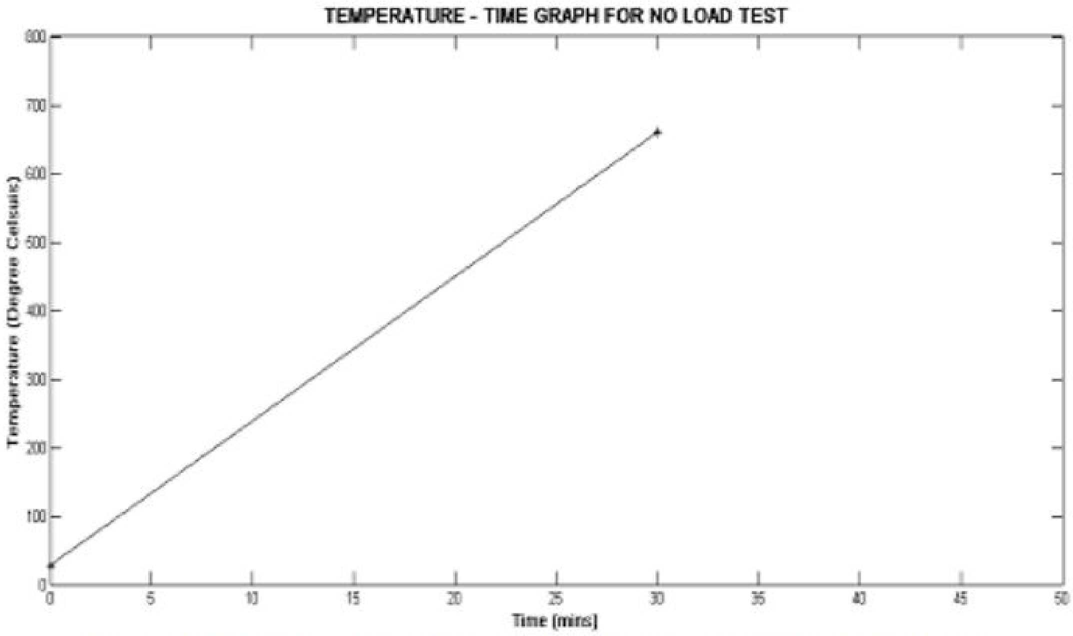

Figure 4.1 Vanatun of temperature versus time for no load test of a furnace.

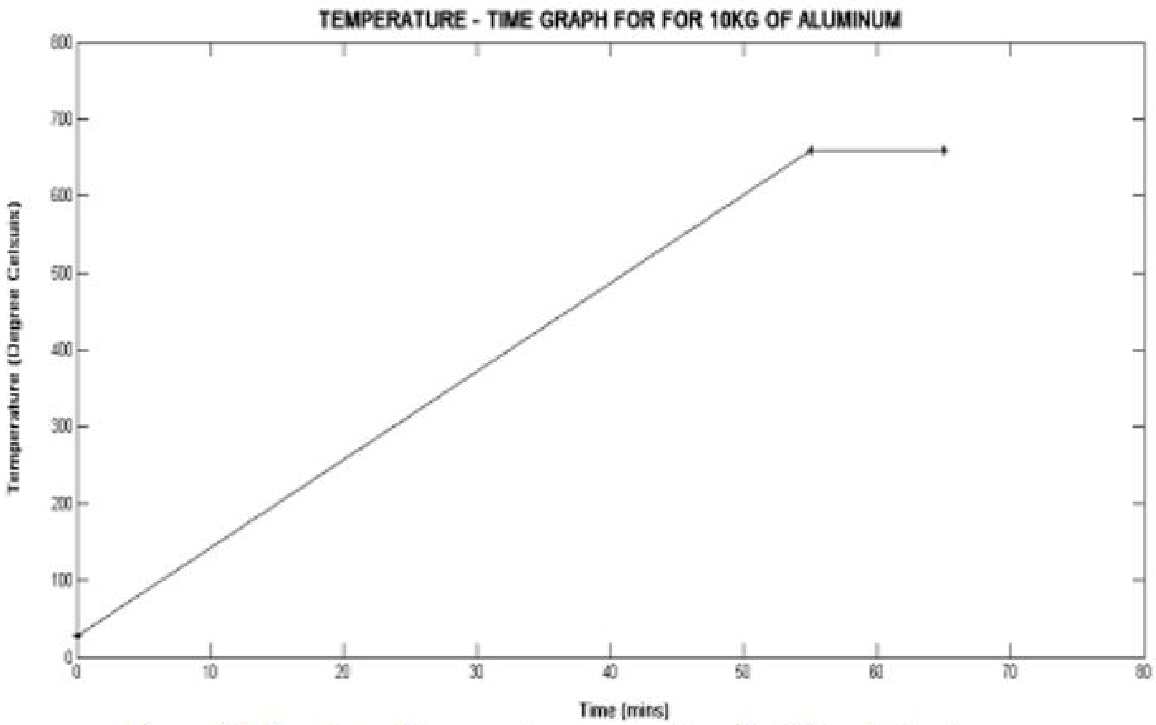

Figure 4.2 Vanatun of temperature versus time for 10kg of aluminum.

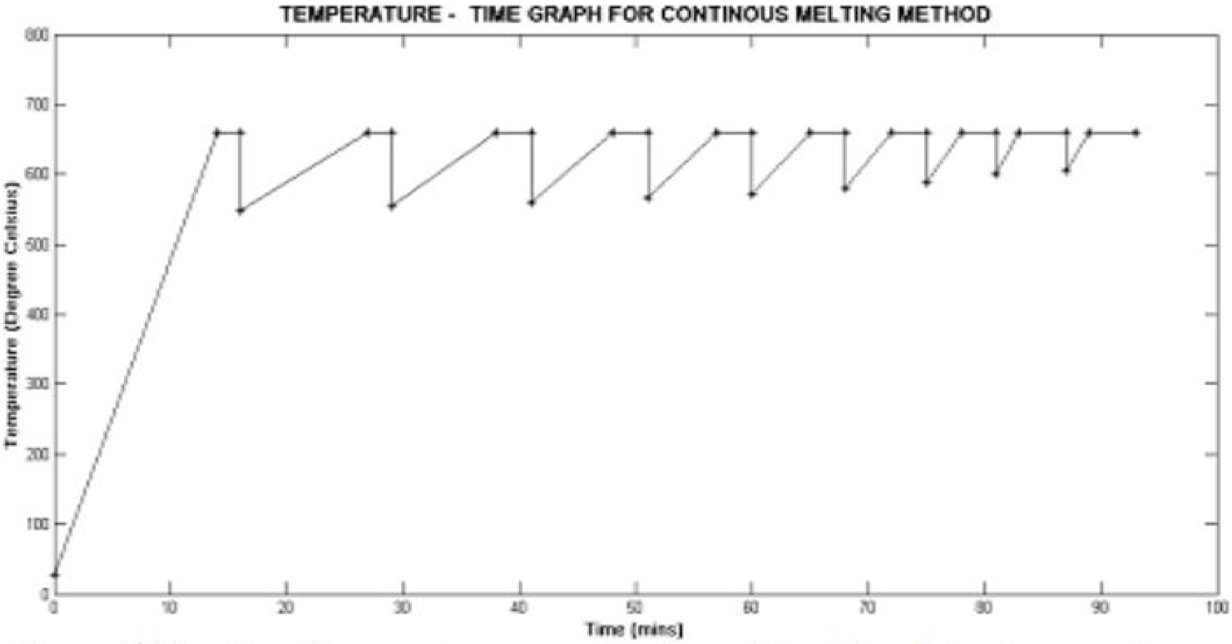

Figure 4.3 Vanatun of temperature versus time for melting 10kg of aluminum continues method.

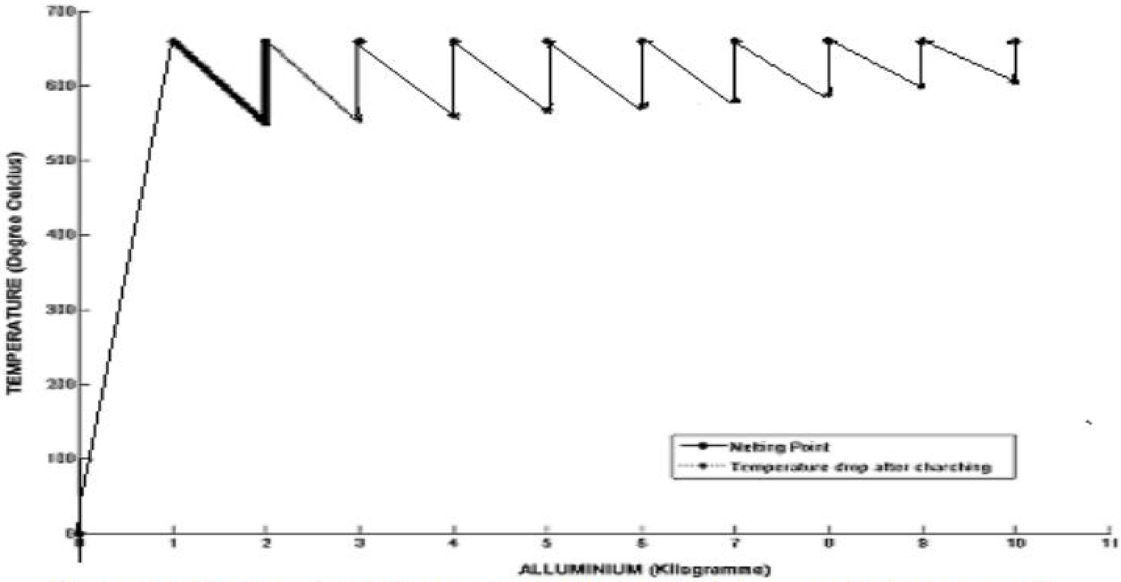

Figure 4.4 Vanatun of temperature versus increase in kilograms of aluminum and temperature dropped.

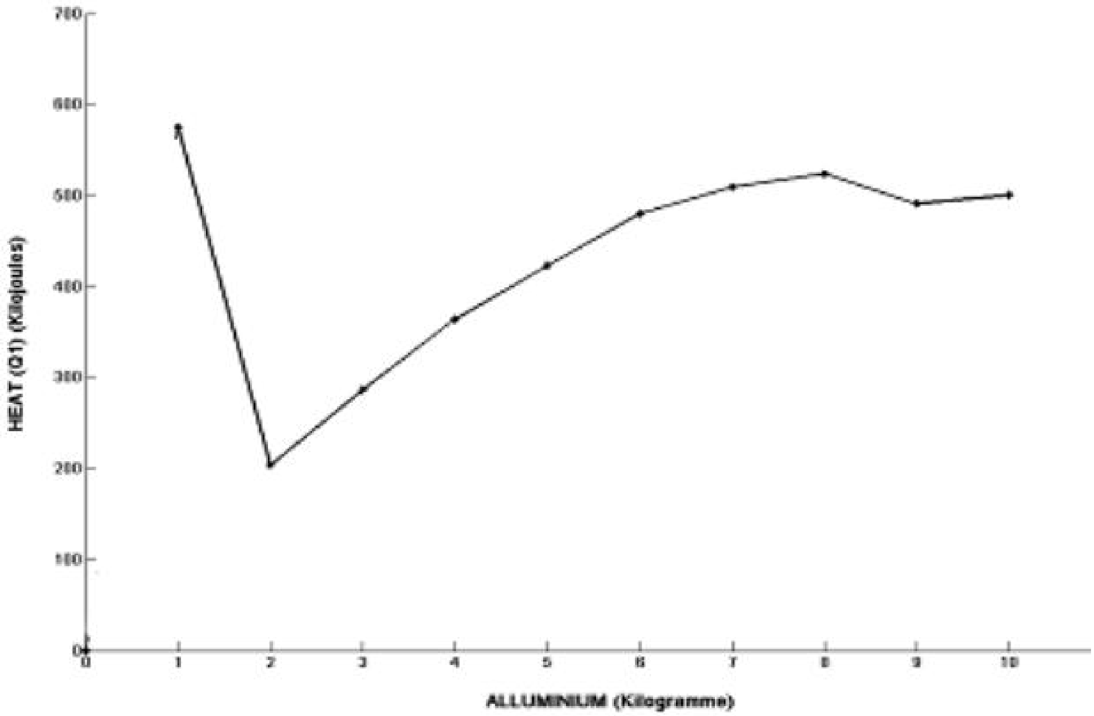

Figure 4.5: Curve of Sensible heat (Q_1) versus increase in kilograms of aluminum.

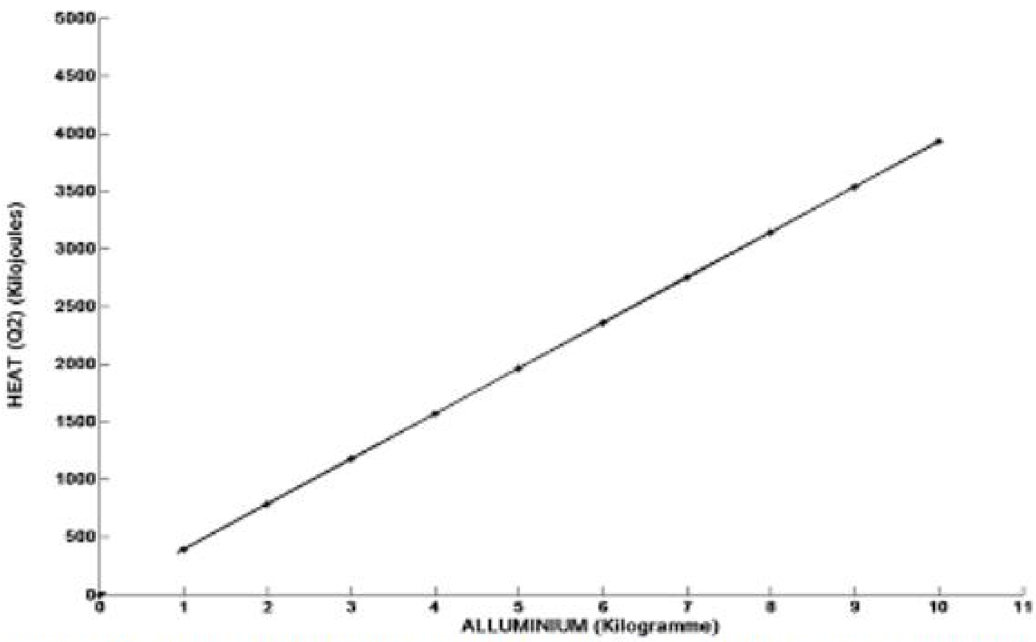

Figure 4.6: Curve of Enthalpy of fusion Heat (Q_2) versus increase in kilograms of aluminum.

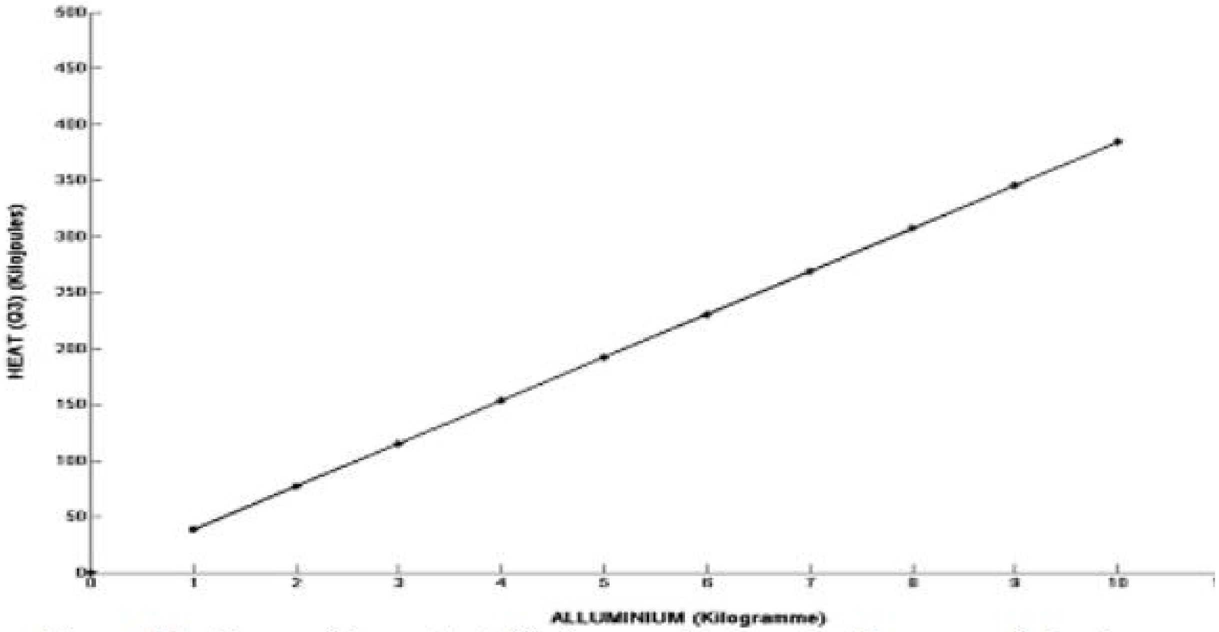

Figure 4.7: Curve of Super heat (Q_3) versus increase in kilograms of aluminum

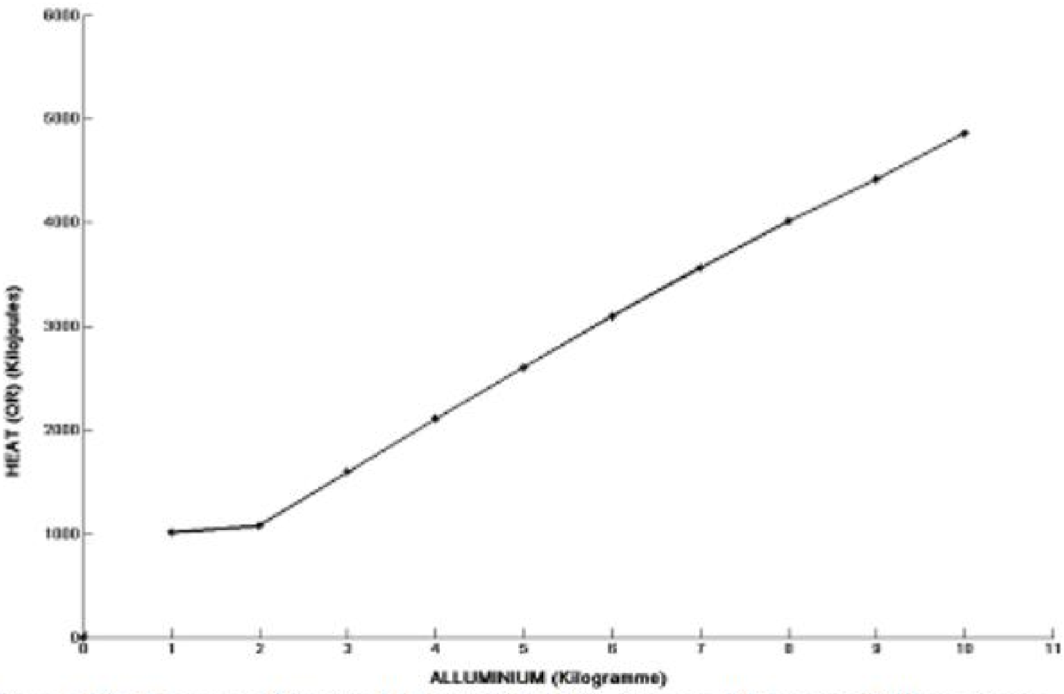

Figure 4.8: the curve of the total Heat required (Q_R) versos kilograms of Alluminiums.

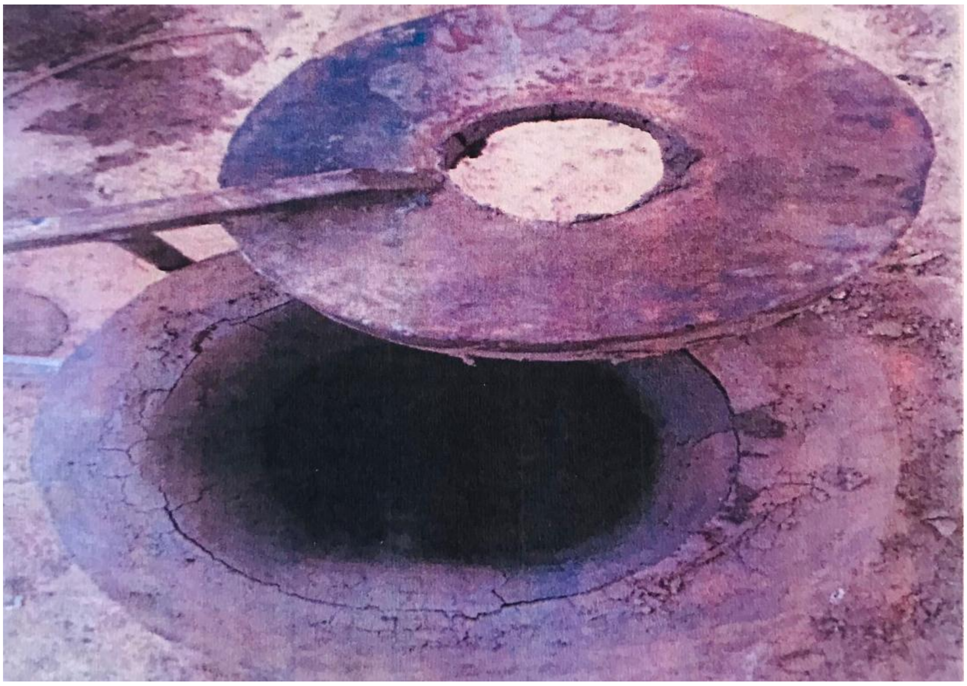

Fig 4.9 The furnace after relining

Fig 4.10 Fabricated tripod stand and the pot

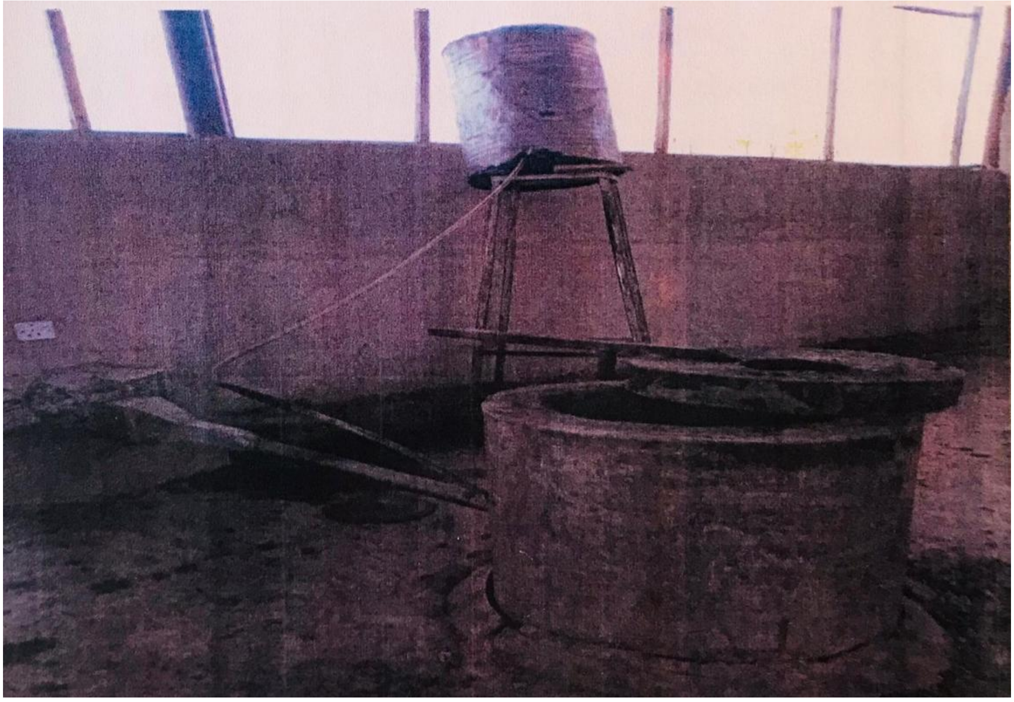

Fig 4.11 Assembly of the furnace, blower and fuel tank.

V. CONCLUSION

In developing countries like Nigeria, where job opportunities are very scarce its not wise to allow the few operating ones to close down. Therefore, Based on the results obtained from the performance test carried pout on fabricated crucible furnace the set objectives of the research was achieved, such as fuel economy, health hazard reduction for the operation, the following conclusions can also be made:

1. The crucible furnace proved to be effective for melting of aluminum.
2. Melting aluminium in the crucible furnace proved to be more economical and time saving during operations
3. It can be concluded that the device is suitable for us in small scale foundries and tertiary institutions.
4. The fabricated crucible furnace reached a temperature of 700°C and produced 67,943.16kJ of heat in 1.33min.
5. The practical performance of the fabricated crucible furnace was in accordance with the efficiency value gotten from the calculation.

This research work has shown that with this simple device, the problem of casting small scale foundries in Nigeria will be solved.

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