Entrepreneurial Approach in Production of Refractory Bricks for Foundry Furnaces

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***Abstract*— The strategic steps involved in production of refractory bricks for lining of foundry furnaces from entrepreneurial point of view have been examined. From the perspective of chemical composition, the three existing types of refractories are discussed with their suitable applications mentioned. The reviewed literatures revealed that appreciable percentage of our refractory needs especially the basic types are sourced abroad. This revelation consequently opens a good opportunity for prospective investors as materials required for production of the refractories are locally available in abundance. The technical steps involved in production of refractory bricks are itemized and discussed. The notable refractory mineral deposits in Nigeria are provided and firing temperatures of common refractory bricks are also provided. The necessary laboratory tests to ascertain the quality and suitability of selected refractory deposits which are expected to meet ASTM standard are also provided. The business procedure is enumerated while the strength, weaknesses, opportunities and threats in refractory bricks production business are examined using SWOT analysis. It was concluded that the potentials of refractory's production business has not been fully explored in Nigeria as foundry industry which is the largest consumer of the product is growing progressively. Hence, this can be a very good business opportunity for interested investors. The information provided in this study shall be very useful in harnessing the solid minerals potential of Nigeria and enhance economic development and diversification**

***Index Terms*— Refractory bricks, Entrepreneurship, Foundry Furnace, Business Opportunity**

1 INTRODUCTION

Foundry is defined as work establishment where ferrous and non-ferrous metals are first of all caused to be molten by the application of heat in a furnace and then cooled in a mould to yield a unit solid mass. The major needs of a foundry-industry ranges from metal scraps, moulding sands, pattern mould, refractory lining among others. Metal scraps are usually bought from scrap dealers who normally collect scraps from industries and scavengers that pick up the scraps from dump sites and along the streets. The geographical location of this country placed her in a position where woods of various varieties are readily available for production of wooden patterns. Moulding sands having variety of properties are also available in abundance. However, refractory lining, which is also a major requirement for foundry industry has been found to be grossly in-adequate. In view of the growing need of Nigeria's metallurgical industry, it is imperative for prospective entrepreneur to explore the opportunity and invest in local production of refractories especially the basic type which for now is largely imported. With the proposed rejuvinisation of Ajaokuta steel complex and Delta steel company (DSC) Aladja and the development of soft solid minerals in Nigeria, there is going to be an intensive increase in the use of refractory materials. For instance, on completion, Ajaokuta steel complex will require about 36,000 tonnes of refractory bricks worth over twenty million naira, just for lining furnaces only (Aderibigbe and Chukwuogo;1984) . Due to large amount of natural resources deposit available in Nigeria, the exploration, mining and exploitation of the nation's mineral resources have not received sufficient research attention and the required technological production capacity. Clay deposit as one of the mineral deposits in Nigeria covers an estimated proven reserves of billions of tons. Refractories are porous, multi-component and heterogeneous materials composed of thermally stable mineral aggregate, a binder phase and additives (Abolarin et-al; 2004).

Refractories are heat resistant materials which can withstand high temperature without rapid physical and chemical deterioration. Generally, products applied at temperatures above 600^0C are referred to as refractories. Refractories are known to be chemically and physically stable at high temperature. They retain their shape, strength, chemical identity and are not deformed at high temperature. They need to be chemically inert and resistant to thermal shock (Atanda and Imasogie; 2009).

Hassan (1990), investigated the effect of some additives like saw dust, graphite and asbestos on Kankara clay. He discovered that a good thermal insulating fireclay brick can be produced from this clay by the addition of graphite and saw dust (15%). It was also found that the density of the fireclay brick with adequate strength at operating temperature can be increased by mixing the clay with up to 25% asbestos.

Hassan and Adewara (1994) carried out investigation on the refractory properties of some of the clays taken from Bauchi, Onibode and Oshiele. Of the four clays studied, Onibode clays produced bricks with the best overall refractory properties. The values of the common physical properties compared very favourably with those for fire clay refractory bricks. This is in respect of low shrinkage, low bulk density and spalling resistance values. It is noteworthy that they all have good refaractoriness qualities. It was noted that while Onibode clays could be suitable for producing refractory

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bricks for the metallurgical furnaces, Oshiele and Bauchi clays would be considered unsuitable because they produced bricks with poor spalling resistance.

The tests conducted by Agha (1998), on the bricks made from kaurandole kujama (Borno), Jankasa-Malali, and Marban-Rido clays in Kaduna State Nigeria revealed that the mouldability of bricks with average water content of 13.00% by weight was found good enough for all the four clay samples, all the samples showed very low shrinkage value. Kujama and Kaurandole clays showed porosity values of'21.7% and 18.90% respectively compared with 20-30% for typical fireclay porosity. Only bricks made from Kaurandole clays showed quite appreciable value of 19.621 and 14.285 KN/m^2 in the direction of forming and normal to the direction of forming respectively. This is good compared with fireclay bricks. The clay samples from Borno and Kaurandole are capable of being used for furnace bricks of which temperature limit would not exceed 1400°C. The other clay sample having low porosity values could be used as insulating refractory materials. Olusola (1998), investigated the properties of Zungeru clay material for high temperature applications. He found the firing shrinkage value to be 9.18%, apparent porosity is 22.0% bulk density is $1.948 g/cm^2$ permeability value of 80.4 and specific gravity is 2.82. These values fall within acceptable standard for fireclays. The thermal shock resistance was found to be 15 cycles and the refractoriness value revealed that the sample could be as material for medium temperature furnaces.

Lawal et al (2008), in their work titled "Characterization of the refractory properties of Osiele clay" revealed that the clay was silicious alumino-silicate with low content of Iron III Oxide. The water absorption, bulk density and apparent porosity decreased with the firing temperatures, whereas the total shrinkage increased as the firing temperature increased. It was concluded that Osiele clay can be used as refractory material for the lining of furnaces particularly for operating temperatures in the pre 1,100°C range.
Comparative study of some Refractory roperties of some selected clay deposit in Biu and Hawul Local Government areas of Borno State was carried out, it was revealed that the highest temperature obtained were for Gula and Kwayabura 1400°C and those for Hema and Mangada 1300°C but fireclay refractory should have refractoriness in the range of 1500°C - 1700^0C (Abdullai and Mahdi;2008), (Chesters ; 1973), (ASTM ;1982) and (Chesti;1986).

Chukwudi (2008), studied the refractory properties of Nsu clay deposit in Imo State. He reported that on the basis of physio-chemical characteristics of this kaolinitic fireclay deposit, it can successfully be processed for use as refractory materials such as ladle brick and ramming mass.

The effect of Agricultural waste ash additives on refractory properties of a blend of two Nigerian clays was investigated. It was discovered that addition of ash residues from agricultural waste gave an improvement in the apparent porosity and water absorption of the blended clays (Odo and Mba; 2008). Fire brick is the most common form of refractory material and is used extensively in Iron and steel industry, non – ferrous metallurgy, glass industry, pottery kilns, cement industries and many others (UNEP/Sida ; 2017).

Aramide and Seidu (2013), in their investigation on locally sourced kaolin and potter's clay for production of refractory lining discovered that material mix of 80% chamotte and 20% raw kaolin is considered to be the optimal. The cost of fire clay is much less than that of non-clay refractory such as thoria and berrylia (Atanda et-al; 2012)
According to Olaiya (2011), the need for appropriate and effective refractory lining is one of the major factors for effective and efficient performance of furnaces. Hence, availability of refractory lining is very paramount for flourishing of foundry industry, which itself is a vital sector for technological development, industrialization and self reliance of any nation.

Olaiya et al (2015), investigated the suitability of Alagutan Dolomite deposit as raw materials for production of refractory bricks. It was revealed that on the basis of physio-chemical characteristics, Alagutan Dolomite is basic and calcitic with a refractoriness of 1778^oC. It was found suitable and then recommended for lining of steel making furnaces as well as other furnaces and kilns requiring basic environment below operating temperature of 1778^oC.

Shuaib-Babata et - al (2018), characterized the fire clays available from Baruten Local Government Area of Kwara State. The researchers posited that the properties of the natural clays obtained from this location are measurable with the international standards established for fire clays and could consequently replace imported clays in some refractory applications.

About 80% of the total refractory materials are used in metallurgical industries for construction and maintenance of furnaces, kilns, reactor vessels and boilers. The remaining 20% are being used in non-metallurgical industries such as cement, glass and hardware industries (Hassan and Adewara; 1994).

1.1 PROPERTIES OF REFRACTORIES

The general properties and requirement of refractory materials are as itemized as follows:
(i) ability to withstand high temperature
(ii) ability to withstand sudden changes in temperature
(iii) ability to withstand action of molten metal
(iv) ability to withstand load at service conditions
(v) ability to withstand load and abrasive forces
(vi) low coefficient of thermal expansion,
(vii) ability to conserve heat
(viii) it should not contaminate or engage in chemical reaction, with the material with which it comes in contact.

1.2 CLASSIFICATION OF REFRACTORIES

Refractories are classified on the following basis
(a) Chemical composition
(i) Acidic (ii) Basic (iii) Neutral
(b) Method of Manufacture
(i) Dry press process
(ii) Fused cart
(iii) Hand Moulded
(iv) Formed (Normal, fired or chemical bonded)
(v) Uniformed (Monolythic - Plastics, Ramming mass, Gunning, Castable, Spraying)
(c) Physical form

(i) Shaped Refractories (ii) Unshaped Refractories

2. METHOD OF PRODUCTION OF REFRACTORY BRICK

The process technology involved in the production of refractory bricks is illustrated by the flow chart shown in Fig l.

2.1 MINING AND GRADING

Raw materials such as clay, dolomite, magnesite, are dug and extracted from identified deposits which is large enough to support a small or medium scale production. Notable Refractory mineral deposits in Nigeria are given in Table 1. The materials are the crushed and ground to obtain proper size of materials and ensure that the ratio of coarse to fine particle is even. Equipments used for this purpose includes various types of crushers, hammer mills, ball mills and press.

2.2 PRE TREATMENT

The main pre-treatment given to refractory raw materials is its firing or calcinations at high temperature for considerable period of time to bring about a complete mineral conversion and hence stabilizes the materials. Firing temperature for various materials is as shown in Table 2.

2.3 MIXING

Ground and sieved refractory material is mixed with the binding materials in such a way that it becomes plastic and the plasticity is equally distributed through the mass to facilitate easy moulding. Mixing can be dry, semi-plastic or wet. 14 to 20% water is used in wet mixing which is usually used for hand moulding. Semi-plastic mixture has lower percentage of water to achieve semi-state of plasticity. Dry mixture includes non-plastic basic mixes and clay mixes containing less than 5% water. Since mixing with so little water is difficult, water as a fine spray is used to achieve proper mixing. Due to requirement of high moulding pressures, semi-plastic and dry mixtures are machine pressed.

Table 1: Notable Refractory Mineral Deposits in Nigeria

No.	Mineral	Location	State	Reserve (If available)
1.	Dolomite	Osara	Kogi	Large
	Dolomite	Elebu	Kwara	
	Dolomite	Burum	Kwara	
2.	Marble	Jakura	Kogi	
	Marble	Okpella	Edo	
3.	Zircon	Jos	Plateau	
	Zircon	Udegi	Plateau	
4.	Kyanite	Birnin Gwari	Kaduna	Large
	Kyanite	Dutsin Fari	Kaduna	
5.	Graphite	Dutsin Ma	Kastina	
6.	Sillimanite	Ibadan	Oyo	
7.	Magnesite	Maska	Kaduna	
		Oban Hills	Cross River	
8.	Bauxite	Mambilla	Gongola	
	(Bauxite Clay)	Plateau		
9.	Chromite	Tugan Kukaku (Anka)	Sokoto	

Source: M.T.F. Report, Non-metallic, Minerals (1989)

Table 2: Firing Temperatures for Various Refractories

Refractory type	Firing Temperature (°C)
Fire clay bricks	1250 – 1400
High Alumina Bricks	1450 – 1550
Silica Bricks	1450 – 1510
Chrome Bricks	1450 – 1650
Dolomite Bricks	1450 – 1750
Magnesite Bricks	1450 – 1760
Direst Bonded baric bricks	1650 – 1760
Silicon Carbide bricks	1370 – 1510

Source: www.PDHonline.org

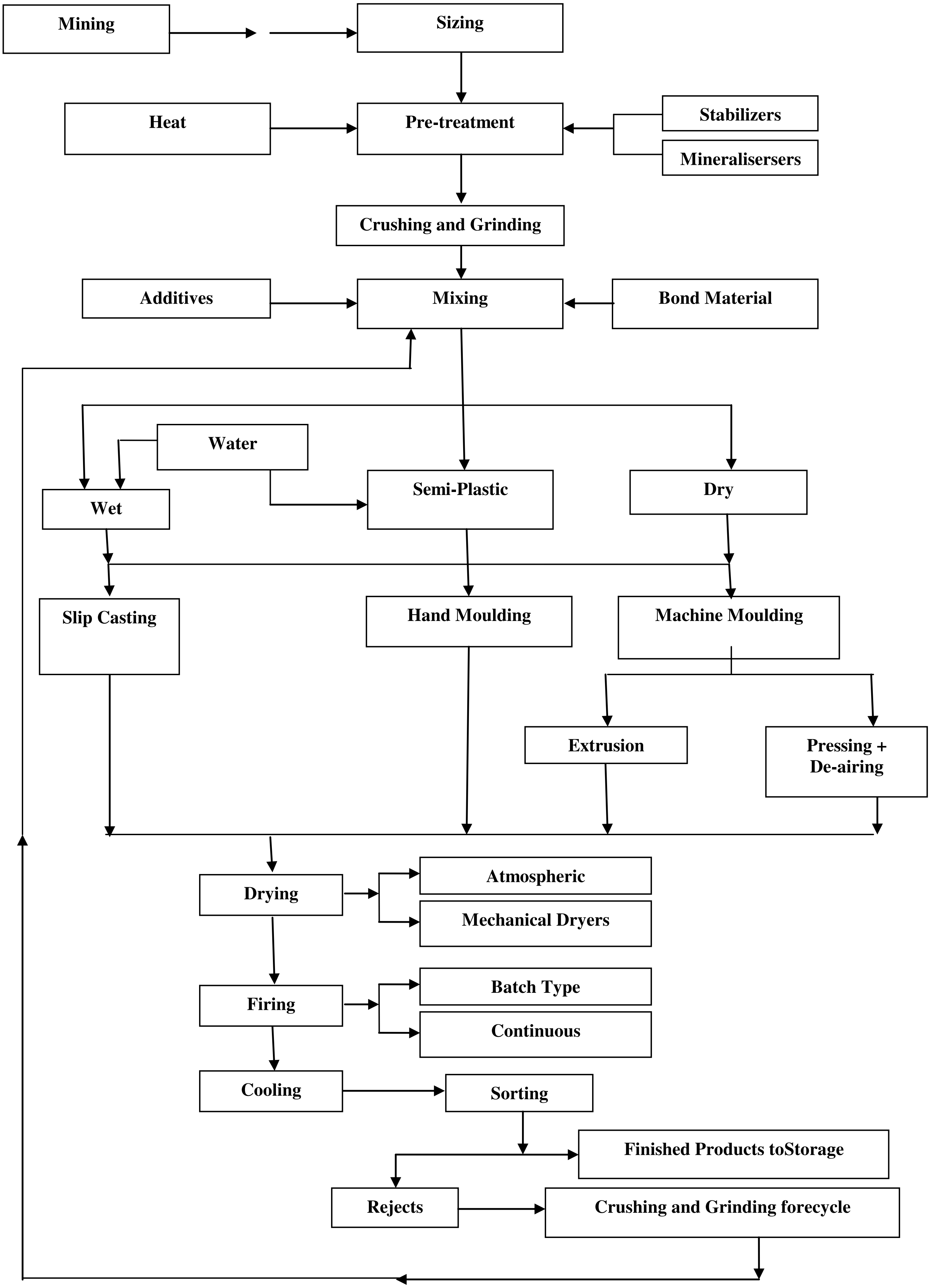

Fig. 1: Flow Chart for Production of Refractory Bricks

2.4 MOULDING

Moulding is done mechanically by using high pressure or by hand to increase density (by de-airing) and strength of the refractory. Moulding process which comes after mixing of refractory materials is done either by hand or machine (by pressing or extrusion). Hand moulding (successful with wet mixtures) is carried out in wooden boxes and is cheaper than machine on a jobbing basis. However, machine moulding has more practical application and is cheaper for mass-production of standard refractory shapes. Machine moulded refractories have higher strength and density than hand moulded refractories. Machine moulding can be used for semi-plastic mixture using moderate moulding pressures. Extrusion is usually used to get the rough shapes of approximate dimensions which are subsequently pressed to exact shapes. Machine moulding of dry mixtures requires a pressure of about 1000kg/cm^{2}or more. Power pressing is used for moulding refractories involving dry compacting or slightly dry refractory powder mixture in metallic dies using sufficiently higher pressure to produce strong and dense refractory shapes.

2.5 DRYING

Drying is done at slow rate to avoid voids and high shrinkage. Drying of moulded refractory increases its green strength by removing moisture and thus making them safe for subsequent handling. Drying is usually carried out under shade (not direct sun light) on large drying floors. Floor heated by waste heat from kilns are also used where refractories are laid out in the open arrays. Drying is carried out in pre-determined set of conditions (of temperature and humidity) and drying rate is kept at minimum to avoid higher shrinkage and crack formations. For faster drying of refractory of constant shape and sizes, tunnel kilns are used where raw materials are stacked or placed on belts moving through a tunnel against a stream of hot air.

2.6 FIRING / BURNING

This involves burning of the moulded bricks in kiln to remove water of hydration, vitrification and development of stable mineral forms. Shrinkage in volume of up to 30% occurs during burning. Burning or firing of refractories following their drying facilitates development of stable mineral forms in them and high crushing strength of finished product. Firing temperatures of some typical common bricks are shown in table 3.

Table 3: Properties of Some Typical Commonly Used Refractory Materials

PROPERTIES	UNITS	1	2	3	4	5	6	7	8	9	10
Bulk Density	kg/m3	1920-2080	1920-2080	1840-2000	1680-1840	2480-2640	2640-2880	2800-3360	2400-2640	2000-2160	60-130
Cold crushing Strength	Kg/cm^3	170-380	170-380	170-380	140-380	410-550	340-550	210-340	>550	340-480	-
Refractoriness	^{o}C	1630-1700	1710-1760	1650-1690	1690-1730	1540-2130	1850	1850	1850	1770-1790	Max. Temp. 1260
Permeability to Air.	mm/s	-	-	36	75	25-90	-	-	-	-	-
Thermal Shock Resistance	Cycles	-	>10	11-14	11-14	23-28	10-15	22-30	-	-	-
Linear Shrinkage	%	-	0.5-1.1	<0.4	<0.5	0-0.2	0.2-0.5	0.2	-	-	-
Apparent Porousity	%	-	11.5	17	26	18.20	19.5	13-16	-	-	-

Source: Chesters (1973) and Gupta (2008)

1. Ordinary Firebricks
2. Aluminous Firebricks
3. Semi-Silica
4. Silica
5. Stabilised Dolomite
6. Magnesite
7. Chrome-Magnesite
8. Silicon-Carbide
9. Silimanite
10. Ceramic Fibre

2.7 COOLING, SORTING AND STORAGE

After firing, the burnt bricks are cooled preferably with the oven or kiln where the firing or burning was done. On cooling the burnt bricks are sorted. The good finished refractory bricks are packages and stored while the rejects are crushed and ground for recycling.

2.8 LABORATORY TESTS

Refractory materials must also be subjected to some laboratory tests to certify that they are of acceptable properties and quality standards. Such tests are as listed below.

(a) Thermal shock resistance
(b) Refractoriness
(c) Cold crushing strength
(d) Linear shrinkage
(e) Bulk density
(f) Apparent porosity

The internationally acceptable standard and properties for some typical commonly used refractories according to ASTM and as cited by Gupta (2008) and Chesters (1973) are given in table 3

3. BUSINESS PROCEDURE

There are two options available to a company or an individual to enter into refractory's Production, in most West African and some other countries of the world.

1. through legitimate acquisition of an existing production plant from the original owner
2. By obtaining due permission or license from appropriate authorities, on application.

The steps involved are as follows

(a) Register a company to produce refractories

(b) Obtain a permit or license from appropriate Authority e.g Local Government

(c) Identify a suitable deposit, extensive enough to sustain a small-medium scale industry

(d) Hand dig a pit on the identified deposit to determine the reserve estimate with the help of a geologist (for a fee).

(e) Carry out simple laboratory tests to determine the mineralogy and physical properties of the refractory materials.

(f) Approach a bank, relative or Government for a loan.

3.1 SWOT ANALYSIS OF REFRACTORIES PRODUCTION

A careful analysis of refractory production venture in Nigeria reveals the following facts SWOT analysis is a useful technique for understanding the strength and weaknesses as well as identifying the available Opportunities and the threats one faces in operating a business venture. It helps an Entrepreneur to focus on his strength, minimize threats and take the greatest possible advantage of opportunities available to the business. It is a very useful tool in producing an action plan for a proposed business venture. The SWOT analysis matrix for Refractory production Entrepreneurship in Nigeria is given as follows:-

Table 4: SWOT ANALYSIS MATRIX FOR REFRACTORY PRODUCTION

	POSTIVE FACTORS	NEGATIVE FACTORS
Internal	Strength	Weaknesses
factors	1 . Availability of raw materials 2. Availability of labour 3. Plant located near deposit of raw materials	1. Working environment usually very hot - people may be scared of working in such environment
External	Opportunities	Threats
factors	1. Increasing number of foundry shops 2. Increase of ceramic plants	1. Continuous mining of raw materials makes the environment to be susceptible to environmental degradation 2. In-consistent economic policy

From the SWOT analysis matrix presented in Table 4, the existing strengths and opportunities of refractory's production in Nigeria are wide enough to provide an enduring business climate. Improved design and construction of production plant can bring the temperature of the working environment to a bearable level; hence this weakness can be converted to strength as more people may be attracted to work in refractory's production plant. According to Oyawale (2008), mined areas are reclaimed by replacing overburden and top soil. The resulting property can provide a wide variety of functions which include farm land, residential and commercial buildings as well as some other useful purposes. Hence, this submission debunks environmental degradation as being a threat to refractory mining and production.

Sincere and credible Government which is in place in developed nations and is being clamoured in most developing nations will obviously usher a consistent economic policy, which will be friendly to local production of industrial needs and entrepreneurship.

4.0 CONCLUSION AND RECOMMENDATION

4.1 CONCLUSION

In view of the above enumerated facts, the following conclusions are drawn.

1. Production of refractory lining materials can flourish in Nigerian business environment as the needed raw materials are widely available and the process technology required is also readily available.
2. The available market for refractory lining materials in Nigeria is in-exhaustible as the foundry industry, which is the largest consumer of this product, is growing progressively.

4.2 RECOMMENDATION

Consequently, it is recommended that prospective entrepreneurs and government take interest in refractory production. This will provide a local source for the refractory needs of our foundry furnaces, conserve our foreign exchange, provide employment opportunity for the youths and consequently enhance economic development of the nation. It is very imperative to focus on establishment of small and medium scale refractory firms within the identified deposits (environments) in order to enhance local capacity building, reduce unemployment in Nigeria and abate the nations over – dependence on single commodity- oil.

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