# THE UNIVERSITY OF NIGERIA, NSUKKA

## METALLIC MATERIALS: CHALLENGES IN THE 21ST CENTURY NIGERIA AND DIDACTIC LESSONS FROM THE 18TH CENTURY INDUSTRIAL REVOLUTION

***An Inaugural Lecture of the***
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**By**

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**THE VICE CHANCELLOR… PROFESSOR BARTHO OKOLO**
**MEMBERS OF THE GOVERNING COUNCIL**
**DISTINGUISHED COLLEAGUES**
**LIONS AND LIONESSES**
**LADIES AND GENTLEMEN**

## PREAMBLES:

I am honoured today by the Grace of God to pay the debt I owe the University Community as a Professor of this great University.

Inaugural Lecture is a time-honoured tradition adopted from the Western Universities when and where Professors deliver academic sermons from the academic pulpit to the curious audience, eager to pick something from perhaps an abstract academic discourse on an unfamiliar discipline.

I am confident that at the end of this academic sermon your life will surely not be the same and that you will be fulfilled and the exercise will be worthwhile.

## THE BEGINNING OF THE ACADEMIC JOURNEY:

I crave your indulgence to tell this story of my experiences so that our young people who are aspiring for higher degrees in Nigeria or overseas should note that life is not a bed of roses and that you can attain any level in life with God and determination.

It started in 1976 when I was awarded the Federal Government of Nigeria Scholarship for a PhD degree in Engineering in the United States of America after graduating in Second Class Honours Upper Division from the University of Nigeria, Nsukka in 1975.

In 1977 in the United States of America, I was enrolled in a conversion engineering program because my first degree was not in Engineering.

I was required to pass some prerequisite engineering courses to qualify as an engineering graduate before starting the post graduate program in Metallurgical Engineering.

With determination I passed the pre-requisite engineering courses with distinction and I became an engineering graduate in 1978.

In the same 1978 I proceeded for the Masters' degree program.

Being the only black student in the Masters' degree class and working extremely hard, I performed so well at my first examination in the College of Engineering that the Professor that taught one particular course reported that he did not see my answer scripts and that he did not see me in the examination hall and for that he scored me an incomplete grade.

That was my first shock but eventually that particular Professor graded me an outstanding student at the end of the Masters' degree program and at the end of the Masters' Program I worn the University Scholarship as the best graduating student in my Department.

These experiences in this University made me to change to another University despite persuasions, awards/scholarships and exceptional automatic admission to the PhD program as a PhD applicant by the Professors in the College of Engineering. My automatic admission to the PhD applicant status was exceptional because my mates in the Masters' degree program on graduation were placed on post masters status.

When I was preparing for the PhD qualifying examination, I remember a Professor that joined the College of Engineering newly who promised to quench his academic sword in me during the PhD qualifying examination. He learnt a bitter lesson when he marked the papers to see that I scored highest in his course. I became a PhD Candidate but decided to change University. This shocked the Professors in my Department.

I doff my hat and count myself a vessel for God as I remember how my PhD thesis was stolen or lost in my second University. My two PhD Professors, one an American , the other a Japanese and myself were discussing my finished PhD work in my workshop for the final public defense in two weeks' time already advertised all over Engineering College. After hours of discussion, we all went for a short break leaving my PhD documents on the work table in my workshop.

On coming back, lo and behold my PhD finished work was no where to be found. Some people were saying that "the Soviets" have dealt with me by stealing my PhD finished and classified work

Confused I entered my car, drove to my apartment and ransacked every where for copies, manuscripts etc but there was no luck.

Still confused, I stayed for a moment, composed myself and I remembered God's promise to me as a small boy in 1959 when I saw Jesus. I immediately invoked that promise and miraculously a voice told me softly, "check your wardrobe".

When I checked the wardrobe, lo and behold, all the pages, calculations, data, diagrams, designs etc were in tact in rough manuscript. I did not know that the Spirit of God made me to be throwing the papers into my wardrobe.

The next problem was, “how could Mrs. Sorenson, the woman that typed the document originally, finish typing this document with all the equations, diagrams etc so that I would defend it publicly in the College of Engineering in two weeks’ time as advertised”. With the cooperation of Mr. Sorenson, the husband, the work was finished in five days by 2.00am of the fifth day….it was then I knew that sleep is not necessary in emergencies. I and Mrs. Sorenson did not sleep or close our eyes until the job was completed.

I checked with my Professors and everything was alright and on the D-day I successfully defended my PhD and here I am today in my home country.

Who says that we are on this conscious plane alone!!! God, the Almighty is always with us watching and performing miracles!

I am happy and grateful to God Almighty for the continuous protection.

## METALLIC MATERIALS: CHALLENGES IN THE 21ST CENTURY NIGERIA AND DIDACTIC LESSONS FROM THE 18TH CENTURY INDUSTRIAL REVOLUTION

### INTRODUCTION:

In this Inaugural Lecture my contributions on the development and use of Metallic Materials especially Steel will be discussed. This is based on the burden I have for years that most Nigerians and some Africans are living the life of yesterday today.

Metallurgy or Metallurgical Engineering which is the study of science, engineering and technology of metals is as old as man.

Man started living by learning how to use materials to feed, clothe and defend himself from his environment and enemies. Tubal Cain, a descendant of Cain in the early biblical times from the Christian Bible in Genesis Chapter 4 verse 22 was reputed as an instructor in brass and iron.

Most people do not realize the dominant role Metallic Materials had played in the life of man over the ages. Our feeding, clothing, transportation and the gamut of human life and living depend on Metallic Materials.

It is surprising that this aspect of Engineering that forms the bedrock of Engineering practice is just entering the University of Nigeria, Nsukka as a full-fledged programme of study in the Engineering Faculty.

As we shall see in course of the Lecture, the use and the development of Metallic Materials had stood out as the man's major activity that really industrialized man since the 18th century industrial revolution. It is doubtful whether Nigeria and some African countries realize this fact.

Most Nigerians and some Africans exist in the 21st century but really live in the 17th century…….this is evident from the standard of living of most Nigerians and some Africans where almost everything is imported, nothing is 100% indigenous.

It is embarrassing that with all the Universities, Faculties of Engineering and Allied Fields, Research Centres etc, machines, engineering components and systems are being imported in their thousands.

There must be something that is seriously wrong with the development or civilization of the so-called less-industrialized countries like Nigeria and some other African countries.

## INFORMATION ON MATERIALS: WHAT ARE MATERIALS?

The word,"Materials" does not refer to all matter in the Universe. It refers to matter that is useful to man. To an Engineer, materials are that part of the inanimate matter that the Engineer uses to solve problems.

Materials Studies draw heavily from the Engineering Sciences such as Metallurgy, Ceramics, Polymer science, Mechanics and Thermodynamics.

Structurally speaking Metals and Metallic Materials may be understood as IDEAL MATERIALS and the other MATERIALS, namely CERAMICS and POLYMERS are derivatives of METALLIC MATERIALS. Under various conditions like temperature, stress and strain, Ceramic and Polymeric materials behave like Metallic Materials so discussing Metallic Materials is like discussing Materials as a whole.

Engineering Materials fall into two broad groups

- Metals and Alloys.... .......Metallic Materials
- Ceramics )
- Polymers ) ....................Non-Metallic Materials

All Engineering Structures, Machines and Devices are developed from these Metallic and Non-Metallic Materials.

Ferrous Materials (iron-base materials) and Non-Ferrous Materials (non-iron base materials) are all Metallic Materials.

Steel the key driver of civilization and industrial development belongs to the class of Metallic Materials.

Luckily on the earth's crust, God made Oxygen, Silicon, Aluminum and Iron to exist in the highest relative abundance. While Oxygen is about 50% of the earth's crust, Silicon is 26%, Aluminum 8% and Iron a little above 4% of the earth's crust.

Of all these four elements, Iron stands out as the King of the elements and materials based on Iron are to date the Pillar of industrial materials and civilization.

Iron occurs majorly as reddish brown hematite ($Fe_2O_3$) and black magnetic Magnetite ($Fe_3O_4$) at various places in Nigeria like Itakpe near Okene and Agbaja in the northern part, Nsude and Ishiagu in the southern part. The brown sand occurs commonly in Nigeria but in small amounts.

Carbon the other element that combines with iron to form the carbon steels occurs as wood, graphite, coke and charcoal.

Other types of Steel abound depending on the element that combines with iron to form a particular grade of steel.

## METALLIC MATERIALS AS MILESTONES OF CIVILIZATION:

Metallic Materials are so important that they set milestones for the civilization and industrialization of man, namely

- Stone Age,
- Bronze Age
- Steel Age.

Even in the World's Technological Trends the corner stone is the Metallic Material, namely

- 1740-1840: Industrial Revolution in the $18^{th}$ Century England. Iron and Steel Works.
- 1850-1900: Steel Making—Railways
- 1900-1950: Electricity, Internal Combustion Engine. Materials are driving all these.
- 1950-1980: Petrochemicals, Electronics, Computing, Aerospace. Materials are the driving force.
- 2010-2015: Next Technology (Nanotechnology). Nano-materials are driving this new technology.

Metallic Ferrous Material, most especially Steel had been the key and foundation of meaningful industrialization right from the Industrial Revolution in the late seventeenth century, throughout the ages to the modern times and without the development and exploitation of Steel, the people though existing in the $21^{st}$ Century really live in the $17^{th}$ Century… only gulping imported goods, using second-hand everything because they cannot produce anything… the problem is how can such people adapt to new technologies and new ways of life… where do such people start?

## STEEL, THE KING OF MATERIALS AND DRIVER OF CIVILIZATION

Steel is an alloy of Iron and Carbon majorly.

As alloys most metals exhibit their expected engineering properties.

In Steel for example the carbon atom comfortably resides in the tetrahedral and octahedral holes in the iron lattice to give birth to myriads of materials that support the following industries:

- The Construction (buildings etc)
- Transportation (cars, ships, trucks, aviation, railway structures etc)
- Machinery and metal products
- Flat steel products (sheets, plates, bars, wires etc)
- Pipes and Tubes.
- Power

Other elements manganese, nickel, chromium etc called alloying elements are also added in minute amounts for desired engineering properties.

This metallurgical marriage is expected to satisfy these conditions:

- The atomic size factor: The more the solute atom differs in size from that of the solvent , the smaller is the range of primary solubility. Precisely if the atomic diameters differ by more than 14 per cent of that of the solvent the solubility is small and the size factor $\partial = 1/a(da/dc)$ is then unfavourable, a=inter-atomic spacing, c=atomic concentration of solute.
- The electrochemical factor: The more electropositive is one component and the more electronegative is the other the greater the tendency to form compounds rather than solid solutions and the smaller is the solubility.
- The relative valency factor: Other things being equal, a metal of lower valency is more likely to dissolve in a metal of higher valency than vice versa. This rule is valid for alloys of copper, silver or gold with other metals of higher valency.

These Hume-ROTHERY Rules for understanding alloying are good guides but the phase diagrams using thermodynamic properties of the phase give the ranges of compositions and temperatures in which the various phases are stable.

## IRON &STEEL AND MAN OVER THE AGES

Here we see in pictures where Nigerians are at the present time in Metallic Materials especially Iron & Steel Materials. Studies have shown that every Developed Country has a fair share of imported engineering products in Nigeria: cars, canned food items, clothing, engineering systems and technology.

It is not an overstatement that all Nigerians are laboring for imported goods and services. In Nigeria there is scarcely any engineering component or system that is produced. Almost all engineering components, systems and even services are imported.

One wonders what we Engineers are doing!!! Without much brain twisting one can categorically state that it is not the fault of the Nigerian Engineers.

I devote a large part of my Lecture on my contributions and effort in equipping the Nigerian youth with the knowledge and skills in using Metallic Materials to produce engineering components and systems that will improve man's standard of living. This is the message of the Metallurgical & Materials Engineering Department.

Figures 1 to 20 show Iron and Steel Works over the ages from primordial through the Industrial Revolution to the modern times.

*Fig 1: Iron Works (smelting and forging using mallet etc) in Great Britain in the late 17th Century*

*Records of Iron works from archaeological finds were located at Otobo Dunoka, lejja, Aku and Opi, Owerre-Elu, Umunda Amaoba in Nsukka Enugu State. Iron smelting was practiced in these places as early as circa 400-20 BC and 765-120 BC) Iron smelting furnaces were found in these places but were destroyed during the Nigerian Civil War (Okafor et al)*


*Fig. 2: Iron Works at Awka, Nigeria in the $19^{th}$ to the $21^{st}$ Centuryusing bellows.*

*In Nigeria, this early $17^{th}$ Century Practice in Great Britain is being practiced in the $21^{st}$ Century, living the life of yesterday and existing today.*

*The bellows supply the oxygen to burn the charcoal to produce the hot gas rich in carbon monoxide, COfor the progressive reduction of the iron oxides to liquid iron which picks carbon as impurity to form a type of steel cast iron because of the high level carbon absorbed.*

$2C + O_2 = 2CO$

*The commonly occurring haematite $Fe_2O_3$ at Ishiagu Awka goes through this reduction sequence by carbon monoxide and carbon to produce iron:*

$Fe_2O \rightarrow Fe_3O_4 \rightarrow FeO$

$FeO + C = Fe + CO$

*Fig 3: Firing charcoal to melt the brown sand(iron ore) using bellows$21^{st}$ century in Nigeria. The environment belongs to the $17^{th}$ century period.*

*Fig 4: Canons produced from the cast iron to be filled with gunpowder for burying the dead $21^{st}$ Century, $17^{th}$ Century practice.*

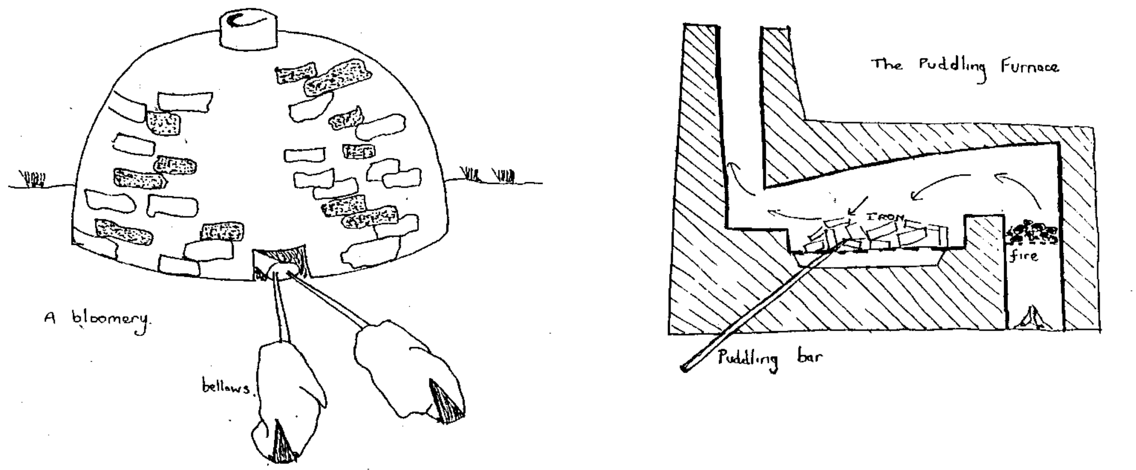



*Fig 5: Furnace for Smelting the brown sand (iron ore) during the Industrial Revolution in Great Britain 18th Century, the first figure was the type destroyed during the civil war at Awka. It was Awka fashion of Blast Furnace.*

*Fig 6: Forging to produce implements, 17th CenturyPractice being practiced at Awka at the present time.*

*Fig 7: Steel Scraps and tools for iron works at Awka, Nigeria in the 21st Century. The tired and famished Workman ponders on his life and tools.*

*Fig 8: Blacksmith's Furnace for Smelting the brown sand $21^{st}$Century in Nigeria, $18^{th}$ Century Practice.*

*Fig 9: Iron Works in Nigeria, $21^{st}$ Century, $18^{th}$Century Practice.*

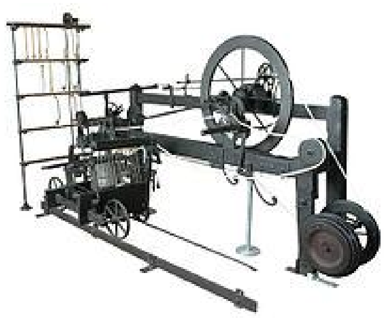


*Fig. 10: Result of the Industrial Revolution, Steel invented was used to produce textile processing systems during industrial revolution $18^{th}$ Century in Britain. Nigeria is in the blacksmith shop in the $21^{st}$ Century*

*Fig. 11: Steel was used to produce the textiles and cloths making machines in Britain during the Industrial Revolution $18^{th}$ Century.*

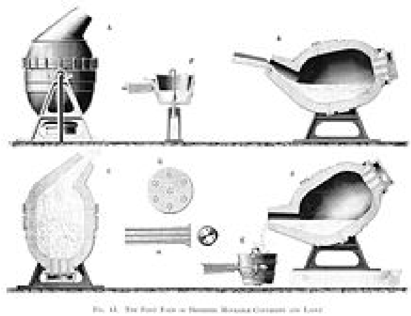


*Fig. 12: In the late 18$^{th}$ Century in Britain cast iron and poor quality steel were improved by modifying the carbon content to produce better steelfor more applications.*

*Fig. 13: The improved steelwas usedto produce bridge materials to span rivers and canals during industrial revolution, 18$^{th}$ Century.*

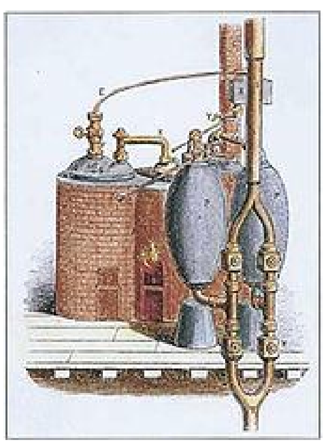


*Fig 14: Steam Power System developed from the Steel produced during industrial revolution in Britain in the 18$^{th}$ Century.Newcomer developed the first practical steam engine to pump water out of mines and soon James Watt improved Newcomer's work to power machinery, locomotive and ships during the industrial revolution.... 17$^{th}$ to 18$^{th}$century with the invention of Steel.*

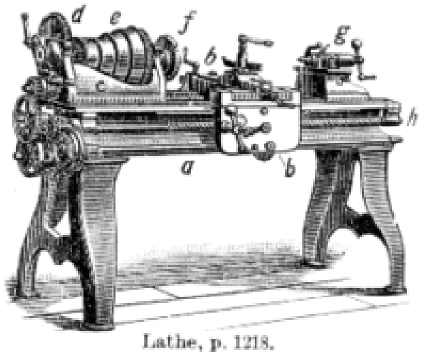



*Fig15: Lathe for Machine Tools Production was invented during industrial revolution in the 18th Century. Metal parts used to maintain the textile machines, clocks and watches etc were produced in the machine shops using lathe machines invented during the industrial revolution. Some Engineering Faculties in Nigeria have no operating modern lathe machines for teaching engineering students in this 21st Century.*

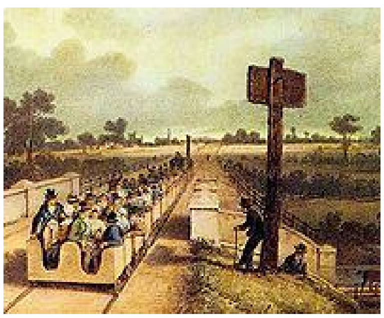


*Fig. 16: Railways developed with Steel invented during the Industrial Revolution.*

*Fig. 17: Standard of Living of man improved during the 18th Century during the industrial revolution, man was civilized(clothed, travelled comfortably in train operated with steam,lived well). The Steel Industry was in operation to produce spares etc to maintain the industries and the existing infrastructures.*

*Fig. 18: Comfortable accommodation for man's habitation during industrial revolution built with steel and other materials.*


*Fig 19: Modern Iron Making Plantconsisting of 7 Units was Installed at the Delta Steel Company Ovwia-Aladja, Warri, Nigeria in 1979 for Nigerians to operate, how? No wonder there were stories of witches and wizards in the area at a time, because the people did not understand the technology. The Plant was designed and installed by the Germans who experienced the 18th Century industrial Revolution that blazed the whole of Europe and America. Those European Countries that missed the Industrial Revolution like Japan strove and caught up with it. The Company is still a shadow of itself!*

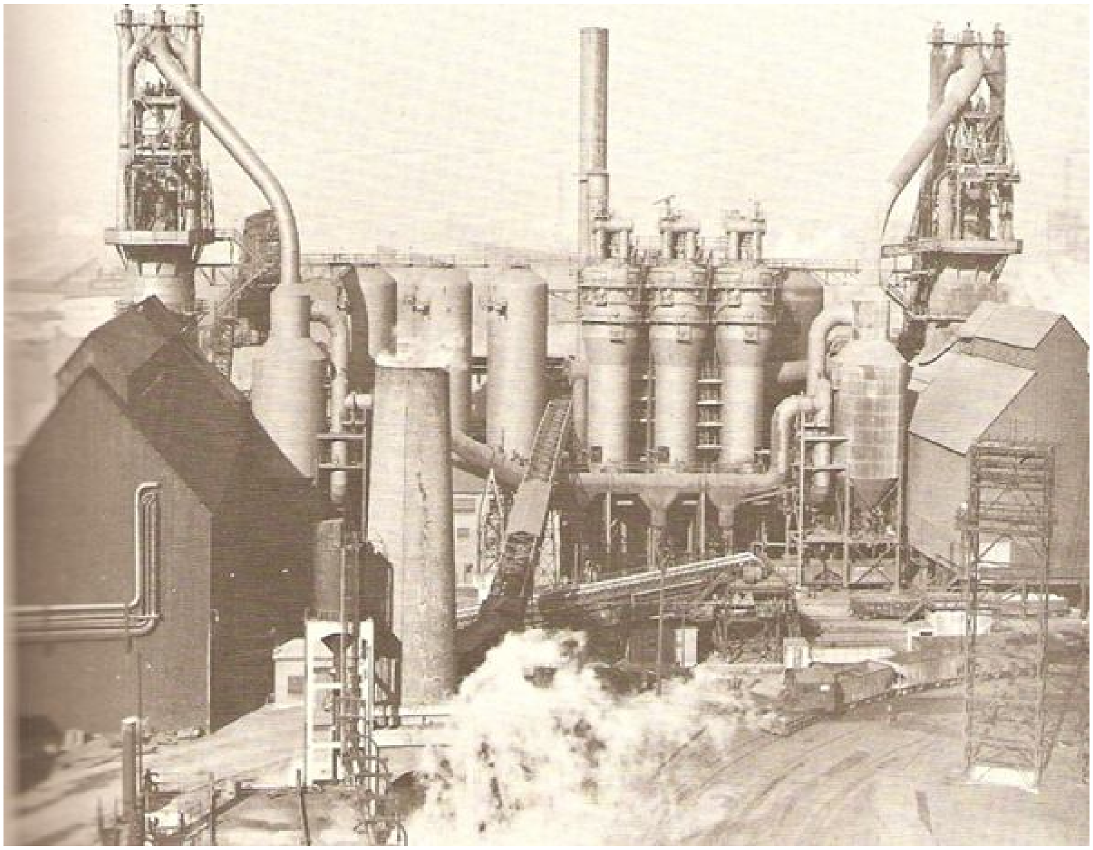


*Fig 20: The Blast Furnace (The type installed at Ajaokuta in Kogi State in Nigeria). This Complex is almost more than twice the Delta Steel Company. The Russians that designed and installed the Plant experienced and/or caught up with the Industrial revolutionand spent years of research and development to reach this level of expertise)*

## LESSONS FROM THE ABOVE FIGURES:

Now Figures 1 to 9 show where Nigerians are at the present time.

Figures 10 to 18 show where Nigerians ought to have evolved to from the blacksmithing phase.

Figures 19 to 20 show where the $20^{th}$ and $21^{st}$ Century technology demands or challenges Nigerians to be.

Before delving into other challenges it is pertinent to have a bird's eye view of what are produced in a Steel Producing Industry.

**THE BIRD'S EYE VIEW OF THE STEEL PROUCTS FROM A STEEL PLANT LIKE AJAOKUTA COMPANY**

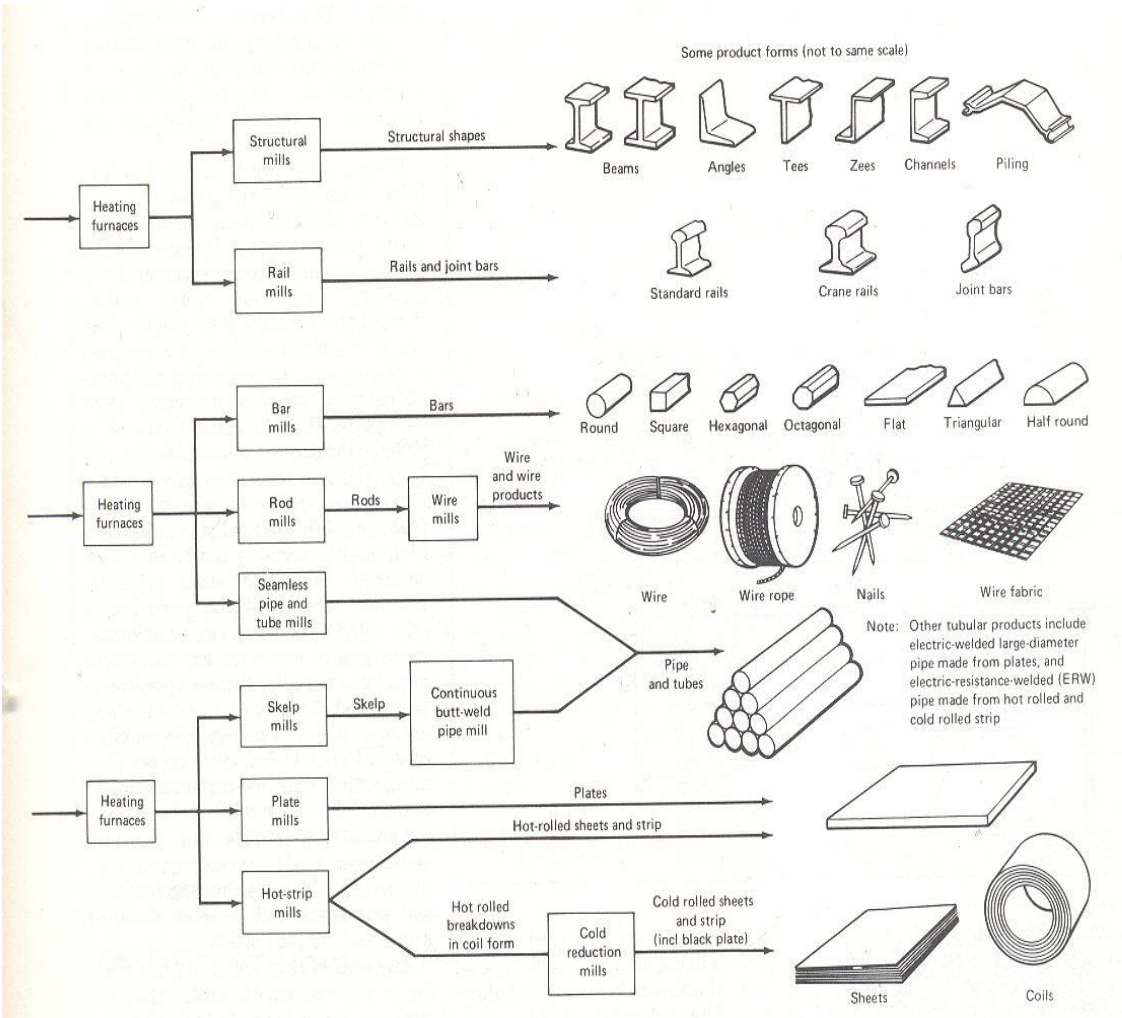



*Fig 20: Steel Products (plates, pipes, sheets, bars etc) from the Modern Steel-Making Furnace.*

From figure 20, there is a gamut of steel products for the downstream and secondary industries. From Carbon Steels alone machine parts, gears, cranes, automobile parts like connecting rods, crankshafts, propellers, springs, building, construction and infrastructural hard-wares etc will be produced.

Stainless steels, tools steels, special alloy steels for producing heavy machineries, kitchen wares, engine blocks, automotive parts, lathes, drills, cutting tools and components for producing machines for industries of all types are manufactured from the Steel Industry.

Carbon Steels account for about 90% of steel products. Realizing how important Metallic Materials are, it is informative to know how important and challenging in our times Metallic Materials like Steel are.

## UNIQUE NATURE OF METALLIC MATERIALS (STEELS):

Steel is produced from iron, carbon and recycled ferrous scraps.

To produce Steel reasonably MAN, MATERIALS AND EQUIPMENT are needed and this can be written mathematically

P = F (M, Ma, E) where P=production, M= Men, Ma= Material and E=equipment (availability, condition, quality, power etc).

Sustainability, S, of producing Steel is a function of Men and available funds (Fa)…. thus S = S(M, Fa). Men (M is a function of quality, management, morale, will etc) and Fa is a function of Policymakers in the Government of the day. So in Metallic Materials production and exploitation there are many variables to be controlled.

Happily once Steel is produced it becomes a permanent resource material because it is 100% recyclable and it has an infinite life cycle.

Metallic Material Production is a no-nonsense business and the Government of the day and people should be directly involved for overall development.

Steel is strategic for industrial development: Steel is central in transport (steel products account for up to 70% of automobile weight, made up of surface treated sheets for vehicle manufacturing as hot dipped galvanized, electro-galvanized and annealed steel sheets, as automobile chassis, doors, bumpers, mufflers, fuel tanks). Special alloy steels are used to produce transmission and suspension systems and engine-related parts of the automobile systems.

The importance of Metallic Material (Steel) products is shown in the World Steel Products data below:

## THE WORLD STEEL PRODUCTS IN PERCENTAGES:

- Structural 7%
- Rails 1%
- Pipes and tubes 8%
- Sheet Metal 31%
- Wire 12%
- Ribbed bar 15%
- Plates 15%
- Rounds 11%

For the Industries that drive industrialization and development, the world percentage production is as follows:

- Construction 50%
- Domestic Appliances 30%
- Machinery 14%
- Electrical 3%
- Metal Products 14%
- Transport 16%

For the Machinery Industry Sector that drives the production sub sector, the World Percentage Production by Countries in 2005 and 2008 is shown below:

| | | 2005 | 2008 |
|---|---|---|---|
| 1. | United States of America | 12% | 14% |
| 2. | Germany | 14% | 14% |
| 3. | Japan | 14% | 12% |
| 4. | China | 12% | 17% |
| 5. | Italy | 6% | 7% |
| 6. | France | 4% | - |
| 7. | United Kingdom | 3% | - |
| 8. | South Korea | 3% | - |
| 9. | Others (developing countries) | 23% | 36% |

(Nigeria is not there, no wonder the developed and developing countries of the world are dumping their products in Nigeria, luckily for these countries there are ever ready consumers and buyers. Nigeria is about 160 million people and there is no functional Metallic Materials Industry under the direct Government Control in Nigeria).

In the Defense Industrial Subsector for the protection of the Nigerian Nation State, there is no effective Industry for the manufacture of simple combatant weapons like rifles, grenades and land missiles. Nigeria is the dumping ground for arms especially pistols and automatic hand weapons used or manufactured elsewhere making the Nigerian Nation State vulnerable to foreign attackers.

At the present time Nigerians (Awka Blacksmiths? Iron Workers fashion their canons from alpha iron (soft steel) for burying their dead chiefs in the community.

Early Defense local industry that developed in the forge shops in what were called blacksmith shops by white men would have sparked off industrial revolution in Nubian Africa and Nigeria if not stopped by the white-man for fear of rebellion and anarchy of the Africans. In Great Britain such practices were encouraged and controlled. The scattered cottage blacksmith shops for weapon manufacture combined to form Foundry Shops and helped to spark off the INDUSTRIAL REVOLUTION in Great Britain. These Blacksmith Shops in Nigeria should be encouraged and controlled to form a Government-Controlled FOUNDARY SHOPS as recommended by Chukukere and Obikwelu in a paper entitled, "Metallurgy ... the Core of Weapon Manufacture" presented in Kaduna in 1988, Major-General Adeniyi of the Defense Industries Corporation of Nigeria (DICON) presided the Session.

Steel touches every aspect of our lives. No other material has the same unique combination of strength, formability and versatility like steel.

That was why Obikwelu in his paper entitled, "The Nigerian Steel Industry...A Dark Page in the history of the Nigerian Metallurgical Society" presented during the 2010 Annual General/Technical Conference of the Society of Metallurgical Engineers at Abuja Nigeria, lamented at the present disgraceful status of the Nigerian Steel Industry.

## IRON & STEEL PRODUCTS AND CIVILIZATION

Over the centuries various peoples including Nigerians have used iron and its products in one form or the other to improve their standard of living.

Awka people in Anambra State (as illustrated earlier) used a type of furnace in the form of anthill (their own fashion of Blast Furnace) to produce pig iron which they forged to domestic implements like knives, hoes and machetes for farm work until they were stopped by the colonial masters (Obikwelu 1983). The colonial masters killed that urge to develop indigenously not only in Nigeria but in Africa.

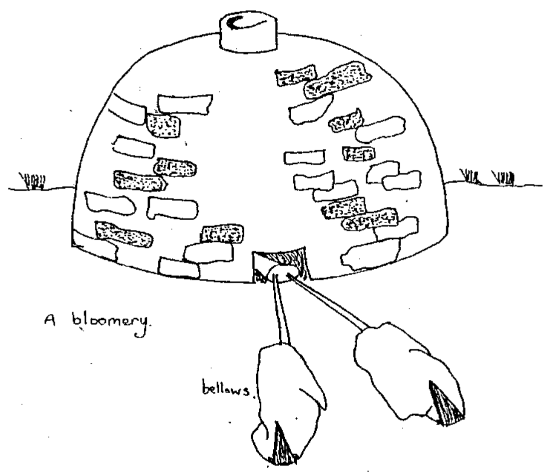
In the Nok, Igboukwu and Benin cultures of the 9$^{th}$ century it was nonferrous metallurgical practices.... Bronzes, brasses because of the tin ore in the alluvial plains of Rivers Niger and Benue. These arts became history because of the colonial masters.

But in Britain about 1760 and sometime between 1820 and 1840, those arts similar to the arts in Awka, Nsukka, Enugu Ezike, Nok region, other parts of Nigeria and Africa, existed and with the discovery of the king of metals, IRON and its alloys STEEL, the Industrial Revolution started, blazing over Great Britain, Europe and America. This experience by these countries created the existing great divide……..the developed and the underdeveloped countries of the World till date.

Industrial Revolution was a phase in human history when the predominant agrarian rural societies in Great Britain, Europe and America became industrial and civilized. Nigeria missed that phase and is paying bitterly and heavily for it now.

It is the realization of this empty space in the industrial history of Nigeria that can revolutionize and change Nigeria for better.

## THE BLAST FURNACE FASHION AT AWKA, LEJJA, OPI AND OTHER LOCATIONS IN NIGERIA DISCOVERED AFTER THE NIGERIAN CIVIL WAR




This was the type found in China and other countries in Europe and developed to the modern Blast Furnace.

In Great Britain in the early 18th century, one Abraham Darby (1678-1717) imitating other Britons like the Awka people and others living in areas that had the brown sand, iron ore used coke in cooking iron ore and produced a harder material called cast iron. This is what the Nigerian Blacksmiths produce now in their shops, using *ICHEKU or* OIL BEAN WOOD CHARCOAL as coke, Obikwelu, 1983. Local clay was used as the furnace or hearth foundation as refractory materials with very low thermal conductivity.

The Blacksmiths knew that the charcoal of the oil bean tree and *icheku* had high heat capacity (ability to retain heat and dissipate it slowly). They also knew that clay had very low thermal conductivity deriving from Fourier"s law of heat conduction in which heat fluxes are directional thus

$q_x = -k\partial T/\partial x$ .... X-direction

$q_y = -k\partial T/\partial y$....... Y direction

$q_z = -k\partial T/\partial z$.......Z- direction

q = heat flux, k= thermal or heat conductivity measured in Joules per meter per degree Kelvin per second (S.I Units).

In 3-D multiplied by the appropriate unit vector the 3-D Fourier Law becomes $q = k\Delta T$ , T is degrees Kelvin.

The whole crude blast furnace assemblage would be covered with clay to conserve heat and the intense firing using bellows directed through earthen tubes into the assemblage would be started for hours.... the holes through which air entered the charge acted as tuyeres in the modern blast furnace. At a time fixed by experience the firing would be stopped and a hole created at the bottom part of the clay covering and the golden yellow molten impure iron would ooze out through the holes.On reaching the cold ground the molten iron congealed and would be flaked out for additional processing.....forging to implements and tools (Obikwelu 1983).

It was impure iron because the molten iron picked carbon from the burning embers of oil bean charcoal to produce cast iron by mistake. It was cast iron because there was no control of carbon that was picked up by the molten iron. Cast Iron contains 1.7 to 4.5% percent carbon, silicon and the base element is iron. More carbon content renders cast iron brittle and unworkable.

From the metallographic examination of the cast irons, five groups namely

- Gray
- White
- Malleable
- Ductile (nodular)
- Alloy cast iron products were identified.

This ingenious practice in Nigeria called black-smiting for some reasonwas also practiced in Great Britain in the early $18^{th}$ century. These scattered practices sparked off the Industrial Revolution in Great Britain and other parts of Europe and America.

These skilled and experienced Nigerian Blacksmiths to date do not use temperature measuring instruments (thermocouples) to know the temperatures of their furnaces. They taught themselves Pyrometry, the technique of knowing temperatures from the amount and colour of radiation emitted thus:

| Colour | Degrees Centigrade | Degrees Fahrenheit |
|---|---|---|
| Faint red | 500 | 930 |
| Blood or dark red | 500-625 | 1022-1157 |
| Dark cherry | 635 | 1175 |
| Fully cherry red | 700 | 1292 |
| Bright cherry | 800 | 1472 |
| Dark orange | 900 | 1652 |
| Orange | 950 | 1742 |
| Fully yellow or lemon | 950-1000 | 1742-1832 |
| Light yellow | 1100 | 2012 |
| White | 1150 and higher | 2102 and higher |

Iron and Steel business is a high temperature affair spanning from low temperatures 400 degrees centigrade to 1700 degrees centigrade and higher. Furnaces and high temperatures are involved in the production of iron and steel materials that are the bedrock of engineering.

If these practices which were widespread in many cultural groups in Nigeria were encouraged, these regions would not have missed this important industrialization phase called the Industrial Revolution.

**BLACKSMITHING IN GREAT BRITAIN SPARKED OFF INDUSTRIAL REVOLUTION BUT REMAINED BLACKSMITHING IN NIGERIA TILL DATE:**

The“Blacksmithing” in Great Britain was special because in Great Britain Henry Bessemer, an Engineer (1813-1898) looked at these practices and developed the first process of producing the stronger and more useful compound of iron and carbon as opposed to the production of cast irons only.

***As soon as this happened in Great Britain, the already technologically curious society was ignited and there was an avalanche of inventions.***

Various engineering systems were devised and invented. In 1770s a Scottish Inventor James Watt improved Newcomer’s work on the Steam Engine and used it to power locomotives and ships.

Goods, raw materials and finished goods that were previously hauled and distributed by horse-drawn wagons and by boats hewed from woods along canals and rivers were transported by locomotives and ships steam-driven using James Watt's Steam Engine.

In Nigeria and other African countries, transportation was by foot.Colonial masters and Warrant Chiefs were carried by strong men to various places for assignments on what was called, "amork??" which was like a framework made of strong wood made in the form of bed or chair.

In the early 1800s an American Robert Fulton (1765-1815) built the first steam boat and by the mid 19$^{th}$ century the steam ships were carrying freights across the Atlantic.

In the same year, the British Engineer Richard Trevithick (1771-1833) constructed the firstrailway steam locomotive and in 1830 England's Liverpool and Manchester Railways started scheduled railway services. By 1850 Britain had more than 6000miles of railtrack.

Around 1820, John McAdam (1756-1836) developed a new process for road construction known as macadam which resulted in roads that were smoother, more durable and less muddy.

In the textile industry, efforts to cover man's nakedness to differentiate man from wild animals followed the invention and the production of pig iron and steel.

Around 1764 James Hargreaves (1722-1778) invented the spinning "jenney" (jenny was the early abbreviation of the word, "engine"… a machine that enabled an individual to produce multiple spools of thread simultaneously). By the time, Hargeaves died there were over 20,000 spinning "jennys" in use in Britain.

By 1830 Samuel Crompton invented the spinning mule for spinning and weaving of wool and linen and clothing materials for man were available in Britain.

Textiles were made in people's homes (giving rise to the term, cottage industries) with merchants often producing the raw materials and basic equipment and then picking up the finished products from the workers after some time.

It is known that in the 1800s Nigeria was being explored by Mungo Park, Clapperton and others.

The seeds of nationalism were being planted by curious Nigerians in the middle nineties and by 1960 Nigeria got its “independence” whatever that meant.

This short historical account creates scenarios and challenges for the 21st Century Nigerians to learn the lessons from the 18th Century Industrial Revolution

## STEEL DEVELOPMENT IN NIGERIA

Henry Bessemer (1813-1898) mass produced steel and this kick-started the Industrial Revolution proper, the first Industrial Revolution being the formation of concepts and theories that were not given legs to walk and wings to fly until steel was produced in mass. It will be interesting to know exactly where Nigeria and some African countries fall in--- forming concepts, ideas and building prototypes (what can be called, the first industrial revolution) or developing the prototypes and commercializing (what can be called the second or real industrial revolution). The scenario in Nigeria is confused, whether Nigeria is still in the ancient stone age or in the first industrial revolution stage or in the real industrial revolution stage proper is not known…. Importing technologies and existing happily in it is not real development because it is not sustainable. It is colossal deceit.

It was in 1958 that an imported Steel Mill was established in Emene Nkalagu, Nigeria extruding all-scrap rounds for construction. The General Manager and the first Metallurgical Engineer of this Mill is here in the person of Engr. Dr. E.U.Chukukere, my mentor and one of the pillars of the Nigerian Steel industry.

The light of Steel came on in 1958 but was extinguished soon. It came up again in 1967 when the Nigerian Federal Government commissioned a Company from the then United Soviet Socialist Republics (USSR), then Soviet Russia to build a completely imported Steel Complex from the then USSR at Ajaotuta in Kogi State of Nigeria. The Steel Company was situated close to River Niger and Itapke iron ore mountains, the source of ample iron ore suitable for iron and steel production.

In 1978, the detailed project report (DPR) was finally accepted from the contractors for the Steel Complex to be set up and commissioned for operation. To date most of the units in the Complex are at some stage of completion and the complex is critically in trouble… to exist or to die. The existing technology in the USSR was “carefully cut and pasted” in Nigeria on the assumption that Nigeria was “a piece of blank paper”. This cut and paste or turn-key project approach is bound to fail in the final analysis. It gives rise to operators, “managing money for personal growth instead of managing industrial projects for the growth of the country” It is a dilemma and portends confusion in national planning for technological growth of a country.

In March 1979 another imported German technology was established in the then Delta Steel Company Ovwia-Aladja near Warri by the Federal Government of Nigeria to use the copious natural gas in this region to reduce imported iron ore from Liberia to produce direct reduced iron (DRI) sponge iron for Steel Making in the Electric Arc Furnace. Over 70% of the raw materials used in running this integrated company was imported and this killed the industry.

It is mind-boggling to a Nigerian Engineer why Russians using the GOSH Unit System and the Germans using the DIN Unit System were contracted to develop and install the Steel Industry in a Country that uses the English and Metric Unit System. The systems were not compatible.

This Cut and Paste or Turn Key approaches to acquire technologies are counter-productive for a country that wants to develop. These approaches make nonsense the reasons and philosophies for establishing Universities and Research Institutes. Yes, some school of thought posits that “we should not waste time to re-invent the wheel” but one has to know and understand the mechanism and the nature of the wheel first.

As Nigeria missed the industrial revolution phase in its development it is better not to be in a hurry, swallowing the dangerous winged bones of foreign technologies and choking. Nigeria should rather go back to the drawing board using the veritable human resources in the Universities and Research Institutes to sincerely develop the indigenous technologies and carefully learn and acquire the existing technologies there-from produce indigenous blue print. This will be sustainable and all the problems plaguing the imported technologies will be things of the past.

## CHALLENGES IN STEEL MAKING IN NIGERIA:

These Challenges center on

- The Problem of the indigenous technology adapting to the complex imported modern technology: the mindset of Nigerians should be repositioned through education and radical policy measures by Government to absorb the local blacksmiths, encourage them, control and equip them. Closing up the Blacksmiths Shops is not the way to develop that skill for the envisaged Industrial Revolution in Nigeria

- Catching up with the experiences of the 18th Century Industrial Revolution: Japan, for example missed the Industrial Revolution like Nigeria but immediately in 1870 caught up with the Industrial Revolution not by being in a hurry or by random importation of goods and services from the developed countries but by
    - ✓ Earmarking the MEIJI PERIOD of incubation to plan, then inaugurating a land reform program to prepare the country for development.
    - ✓ Launching a western-based educational system for all young people.
    - ✓ Sending thousands of Japanese to the United States of America and Europe
    - ✓ Hiring over 3000 Westerners to teach modern science, mathematics, technology an foreign languages
    - ✓ Sending a group of Japanese politicians known as IWAKURA MISSION in 1871 to tour Europe, United States of America to learn western ways
    - ✓ Accessing the Bank of Japan founded in 1877 to use taxes to fund **MODEL STEEL & TEXTILE FACTORIES.**

      Japan did not start hiring and contracting Companies like GLOBAL INFRASTRUCTURES NIG LTD owned by people that Japan did not know their performance records. From reports in a Nigerian Daily, the Company that the Government sold or loaned the Major Nigerian Steel Industries to , did not only strip the Industries down, they borrowed up to 3 billion naira from a local (Nigerian) Bank using the assets of he Company as collateral. The same Company Global Infrastructures Nigeria Ltd was awarded concessions to operate the Itakpe Iron Ores Mines for 10 years. The Report also stated that the Beneficiation Section of the Itakpe Iron Ores Mining Company, which is the main brain of the Plant was cannibalized. The Concession was terminated. The question is," why was this costly mistake made at this time? A Country like Japan cannot make this kind of mistake in a Sector that touches on the life of the Nation (Country).
- The supply of raw materials for the imported technology: This is a serious challenge because the suppliers of the technology from experience specifies raw materials from their home country. Like in the then Delta Steel Company more than 70% of the consumables was imported. This made the Iron & Steel making unprofitable.

Steelmaking requires about 20% ferrous scrap for cooling and 80% iron in the Electric Arc Furnace Steel Making. The iron was imported and iron scraps were locally sourced. With 70% of the consumables imported it was impossible for the Company to break even.

A major problem when attempts were made to produce Steel in Nigeria at Delta Steel Company was to conserve the heat during the Furnace and Ladle metallurgical operations. A Ladle and Tundish insulating covering compound was formulated to solve this problem of profuse heat losses by Obikwelu and Okorie.
Also the correct form and type of carbon to be added to the iron to make it steel was a problem. This was solved with a technique developed by Obikwelu to convert the locally available Enugu coal to coke and it was used to convert the iron to steel. Efforts to replace the imported consumables included the development of foundry core oil for producing high manganese steel castings (Obikwelu et al), replacement of imported *drewfloc* 260 *flocculant* used in iron making with the locally developed causticized starch *flocculant* (Chukwudorue and Obikwelu), the high temperature $Al_2O_3$ mortar for bonding reactor vessel bricks (Obikwelu and Ovwata). These efforts in replacing imported consumables with locally available materials for use in the Nigerian Steel Industry helped in making Steel Production a feasible project in Nigeria.

Typical electric arc furnace system for making Steel is shown below:

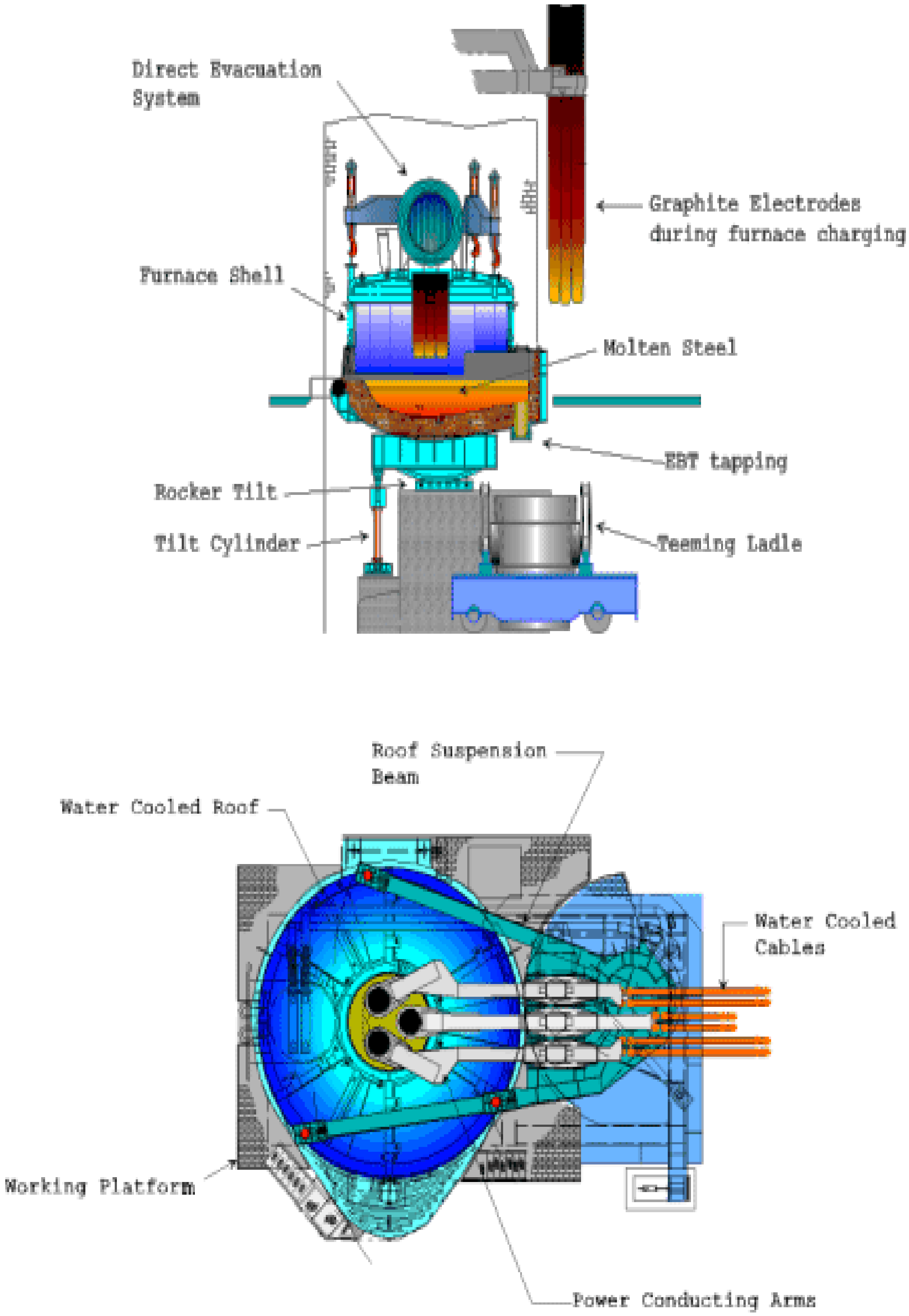



*Fig 22: ELECTRIC ARC FURNACE FOR MAKING STEEL (above furnace is refractory-lined and the furnace below is water-cooled, saving lots of overhead costs in using refractory materials)*

Lives of Production Vessels were made longer by lining the slag zones and radiation zones with magnesite bricks. Some used magnesite bricks were sorted out, specially modified and re-used for the protection of the refractory materials from acidic slag attack. The Refractory Materials mainly $Al_2O_3$ and MgO used in lining Electric Arc Furnace vessels were all imported from overseas and there was no known source of these materials in Nigeria.

These problems which always stopped Steel production in the Steel Industry was solved by the material processing technique developed and applied (Obikwelu, 1986).

The raw magnesite ore located in Bornu for producing the scarce MgO for lining electric arc furnace vessels for making Steel was beneficiated to 36% MgO by Obikwelu et al (1990).

## PROBLEM WITH ITAKPE IRON ORE FOR USE IN MAKING STEEL

With the delay in finishing and commissioning the Ajaokuta Steel Company, tonnes of Itakpe Iron Ore with 52% iron content were wasting at the Itakpe Iron Ore Mining Company. A Research group led by Obikwelu in 1993 beneficiated the iron ore from 52% iron content to 66% iron content for iron making in the direct reduction plant. This is because the Direct Reduction Plant could only process ferrous materials of at least 66% iron content.

This feat made the World Bank to change their stand that Nigeria's iron ore was not good for steel making. The Nigerian iron ore was as from then used for producing billets and then rods thus debunking the World Bank's wrong notion that the country's iron ore could not be used for making steel and therefore the country was not qualified to establish a Steel Company… a notion that could destroy a country economically and industrially.

## MATERIAL PROBLEM FROM THE OFFICE OF NAVAL RESEARCH IN AMERICA

The solution of this material problem: structural and morphological characterization of this difficult Titanium alloy material for marine and engineering applications launched me into the mainstream of my career. Naval operations and the military have the problem of developing a material for marine applications with very stringent requirements…. thick section, strength, ductility, fracture toughness, good corrosion resistance, acceptable strength-to-weight ratio and good low cycle fatigue properties.

A Research Fellowship Grant from The American Naval Research in Washington was awarded for this Work.

For this work a special furnace with inert atmosphere was needed. This type of furnace was not available anywhere in the United States or around. I had to design this furnace system from the scratch, constructed, calibrated and used it for the Naval Research considering the following parameters:

i. Fourier law of heat conduction from the furnace hearth to the refractory (insulator) lining inside the furnace

ii. Heat Transfer by radiation through furnace space.

iii. Heat conduction through the metal shell.

iv. Refractory material and thickness.

v. Heating elements and operating temperatures

vi. Temperature measuring instruments.

vii. Power Requirements.

viii. Furnace atmosphere (argon gas).

ix. Size considerations.

x. Almost zero time quenching mechanism.

Below is the schematic diagram of the two stage coaxial furnace system produced. The system was purged with inert gas argon to avoid oxidation of the special Titanium alloy for the Navy. This Special furnace was named Obikwelu in the College of Engineering. The furnace not only satisfied all the furnace specifications but was used to achieve the objectives prescribed by the American Naval Research Outfit.

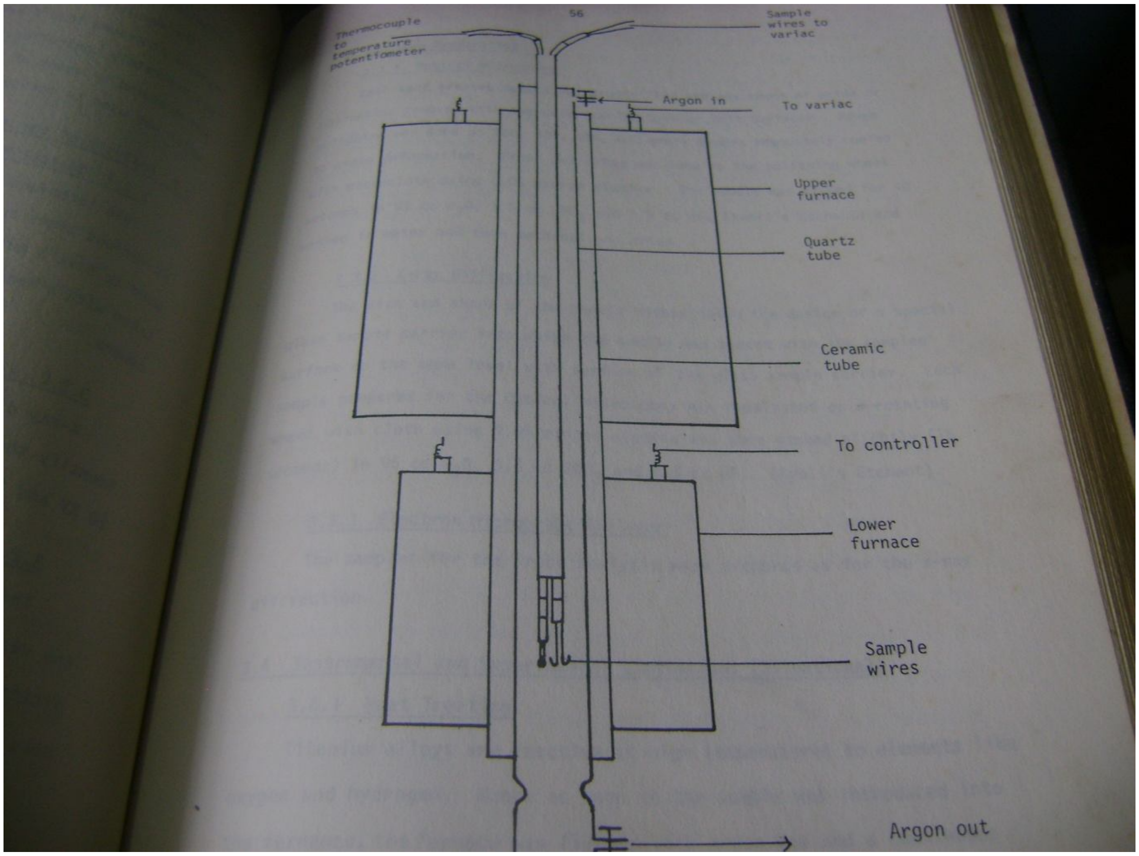



*Fig 23: Two Stage Coaxial Furnace System bathed with inert argon gas, designed and constructed by Obikwelu for special heat treatment.*

A particular type of special material (Titanium base alloy) was developed and characterized by Obikwelu et al, 1980.

This material exhibited the property of having two martensites whose crystal structures were respectively hexagonal (alpha prime) and orthorhombic (alpha double prime). But most importantly the material satisfied the objectives of the Research for the American Navy.

To appreciate the phase changes in this new Alloy, there is need to understand how the phases transform in materials systems.

## PHASE TRANSFORMATIONS IN MATERIALS

Material systems really consist of phases whose stability depends majorly on temperature. If the changes in the system are occurring at constant temperature and pressure the thermodynamic criterion of equilibrium will be $\Delta G = G_\beta - G_\alpha = 0$ where G is Gibb's free energy, α and β are phase components in the system.

Stress state in the initial phase system, the temperature and interfacial energy are the sources of instability of the phase.

At a critical temperature under equilibrium conditions a crystal structure in a material system undergoes phase changes namely:

- Displacive (Martensitic) transformation where the original phase changes to a product phase without motion or shuffling of atoms. The product of this displacive phase change (transformation) produced through quenching or fast coolingof alloys like Steel is called Martensite, a non-equilibrium phase named after Martens that discovered it.

  Martensite is very hard and is of no engineering application until tempered to give a desirable combination of strength and toughness. Metallic Material products go through this process before they are used in any engineering application. The mechanism of this type of phase transformation has been a subject of intense research over the ages and Obikwelu, Murkerjee and Kato developed a model to explain this mechanism in the formation of the hexagonal and orthorhombic martensites in a Titanium alloy, Ti 6211, an alloy of Ti-6w/o Al-2w/oNb-1w/oTa-1w/o Mo.

  Displacive or Diffusionless Transformations are illustrated in the diagram below:

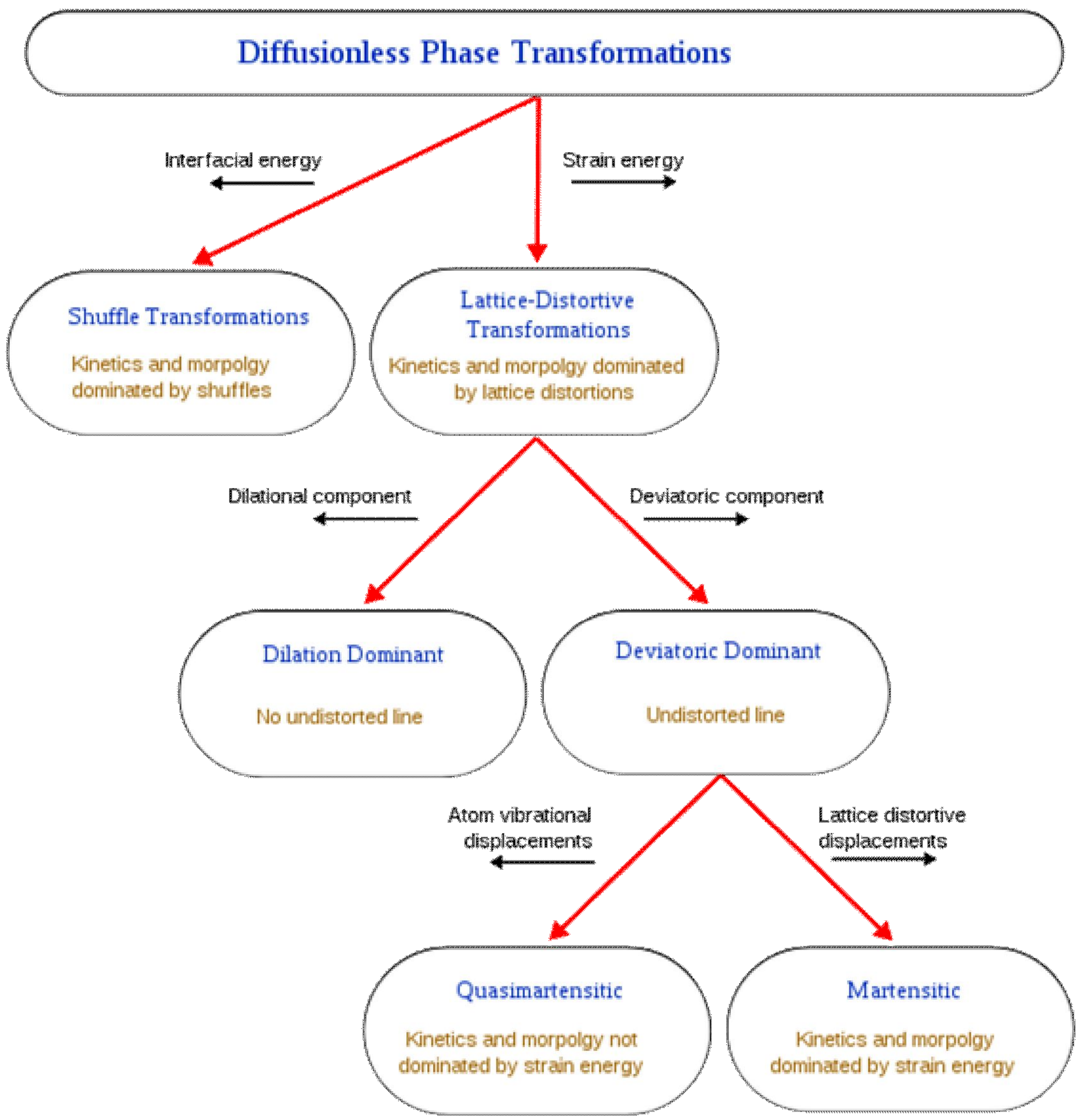
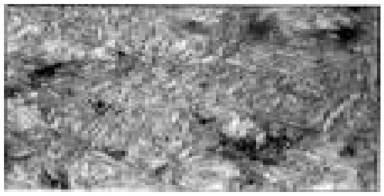
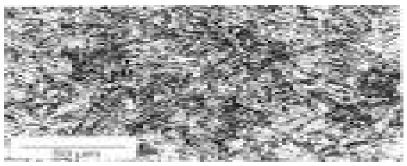


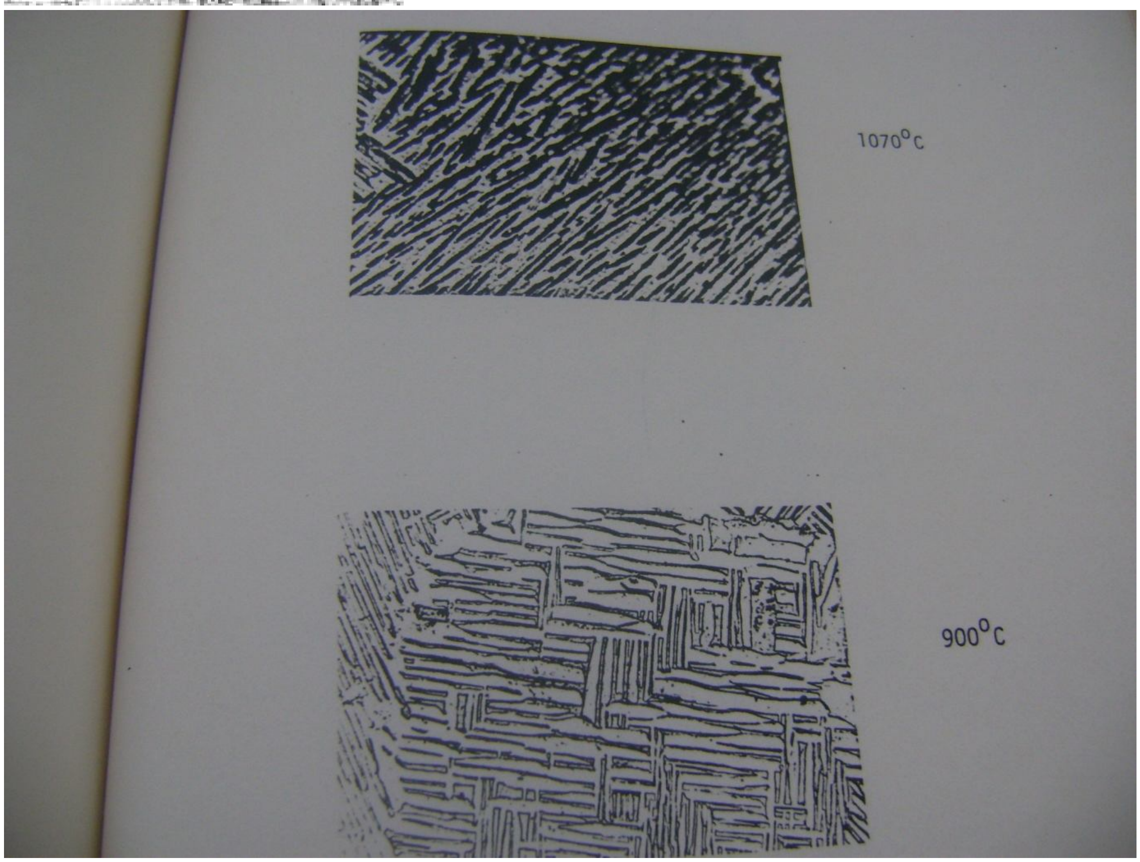

Fig: 24: Diffusionless Phase Transformations

- Reconstructive Transformation where a crystallographic and/or chemical rebuilding of the original phase to the new product phase is required. This occurs through atomic direct motion (diffusion), atom-vacancy exchanges and the resulting phase is an equilibrium product that does not need any annealing or tempering unless it is deformed through secondary processing or fabrication.

  Displacive and Reconstructive phase transformations that obtain in Metallic Materials Production and the microstructure of the non-equilibrium phase, martensite and the equilibrium microstructures of the Titanium Alloy developed are illustrated below:

 Tortured Microstructure of martensite






Microstructures of hexagonal martensite plates in heat treated and quenched Titanium alloy

**OPERATIONAL FEATURES OF THE SPECIAL FURNACE SYSTEM DESIGNED:**

The special furnace system had the lead wires from the variac unit carrying the Titanium alloy sample to be quenched instantaneously in a medium at a specified temperature. Titanium alloy material at high temperature absorbs oxygen as a polymeric sponge absorbs water so the furnace system was purged with inert argon gas. The temperature potentiometer was set at the required temperatures. As soon as the circuit was closed by marching the switch, the sample instantaneously fell into the quenching medium accomplishing the almost zero time quenching required.

All the operations were accomplished in a closed system within seconds. This was the first time such a device and procedure were used in the heat treatment of a material.

The samples were cut into small rectangular blocks of (5x2x2) $cm^3$ polished in 120 grade abrasive and 600 grit and slightly deformed at 1090 degrees centigrade. The final sample of dimensions (3x1x1)$cm^3$ after profuse polishing to remove oxide layer was polished further to 600grit and then heat treated in the specially designed furnace system for X-ray diffraction studies.

The structure factor equations, the extinction rules and the Debye-Schemer camera formulation were used

- To establish the orthorhombic structure
- To calculate the accurate lattice parameters for the structures with

  accurate correction in sample displacement and to evaluate the atom positions in the orthorhombic structure

The structure factor $\mathbf{F}_{hkl}$ is a complex mathematical function describing the amplitude and phase of a wave diffracted from crystal lattice planes characterized by Miller indices *h*,*k*,*l*.

The structure factor may be expressed as

$$\mathbf{F}_{hkl} = F_{hkl}\exp(i\alpha_{hkl}) = \sum_j f_j \exp[2\pi i(hx_j + ky_j + lz_j)]$$

$$= \sum_j f_j \cos[2\pi(hx_j+ky_j+lz_j)] + i\sum_j f_j \sin[2\pi(hx_j+ky_j+lz_j)]$$

$= A_{hkl} + iB_{hkl}$ and it is the resultant wave scattered by all atoms of a unit cell obtained by adding together all the waves scattered by the individual atoms. From the Structure Factor calculation, using some rules, the crystal structure and atomic positions in a unit cell of the orthorhombic phase in the new Titanium alloy material for the American Navy was evaluated.

By applying the principle of the Debye-Schemer Camera to the Diffractometer System using the following formula

$\frac{\Delta d}{d}=\frac{\Delta a}{a}=KCos^2\theta$

Where $KCos^2\theta$ is the extrapolation function

$\frac{\Delta d}{d}$=fractional error in the inter-planar spacing, d

$\frac{\Delta a}{a}$ =fractional error in the lattice parameter, a.

θ=Bragg angle.

K =2∂/R

∂= sample displacement

R =the correct distance for the peak to be if ∂ =0,

it was possible to accurately elucidate the structure of this new material.

Structural Analysis of the X-ray data generated using Cu $K_\alpha$ radiation on the Titanium Alloy samples heat treated at various temperatures produced the X-ray Diffraction Patterns shown in Fig 23 and identified hexagonal, orthorhombic and beta phases in this material for the first time and there from produced a schematic phase diagram of the material for the American Navy.

The X-ray Pattern of this alloy is shown below:

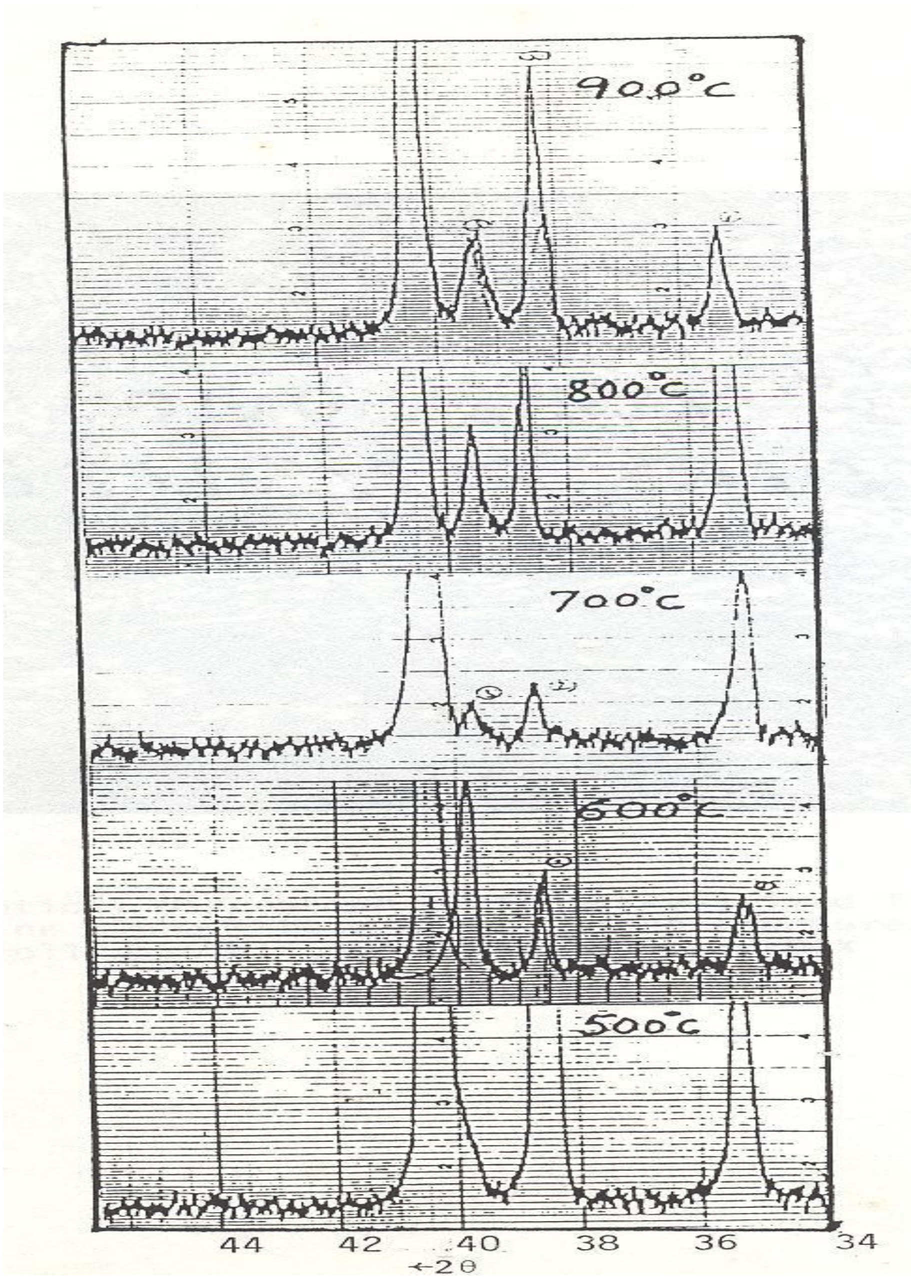



*Fig 23: X-ray Diffraction Pattern at various temperatures for the New Titanium Alloy Material.*

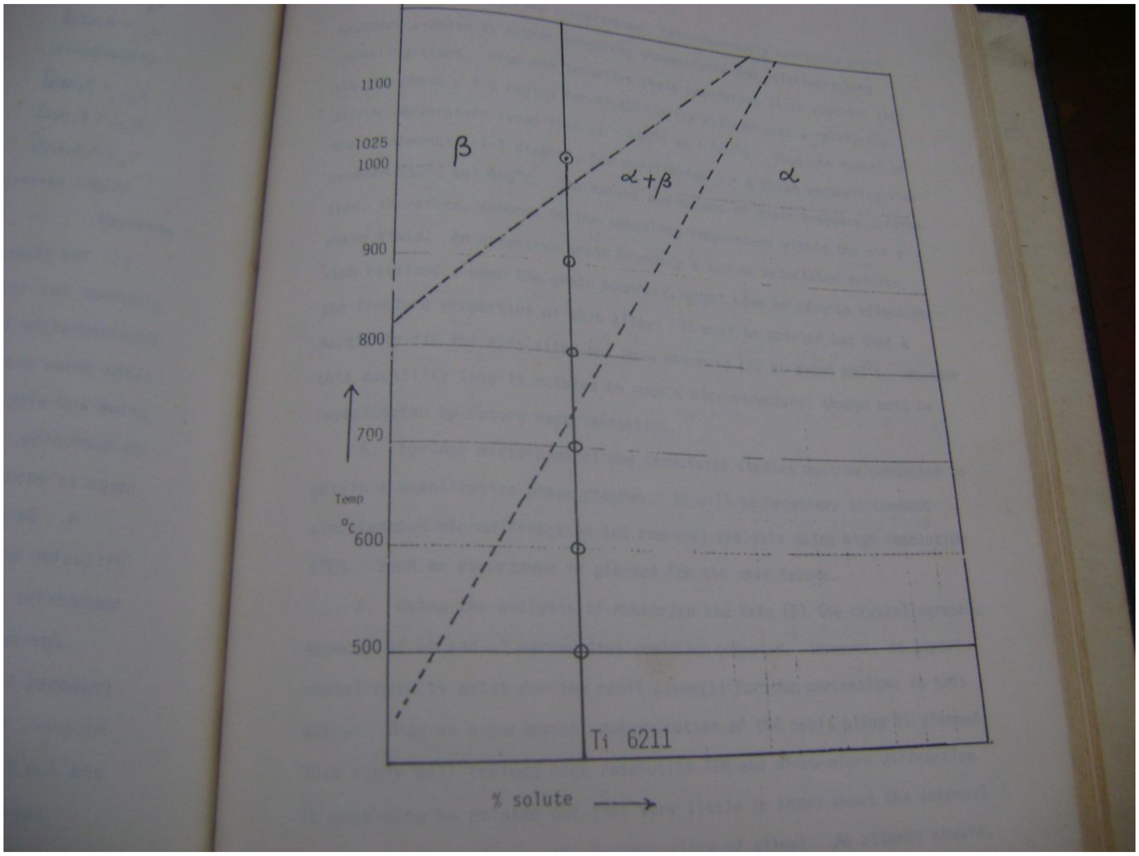
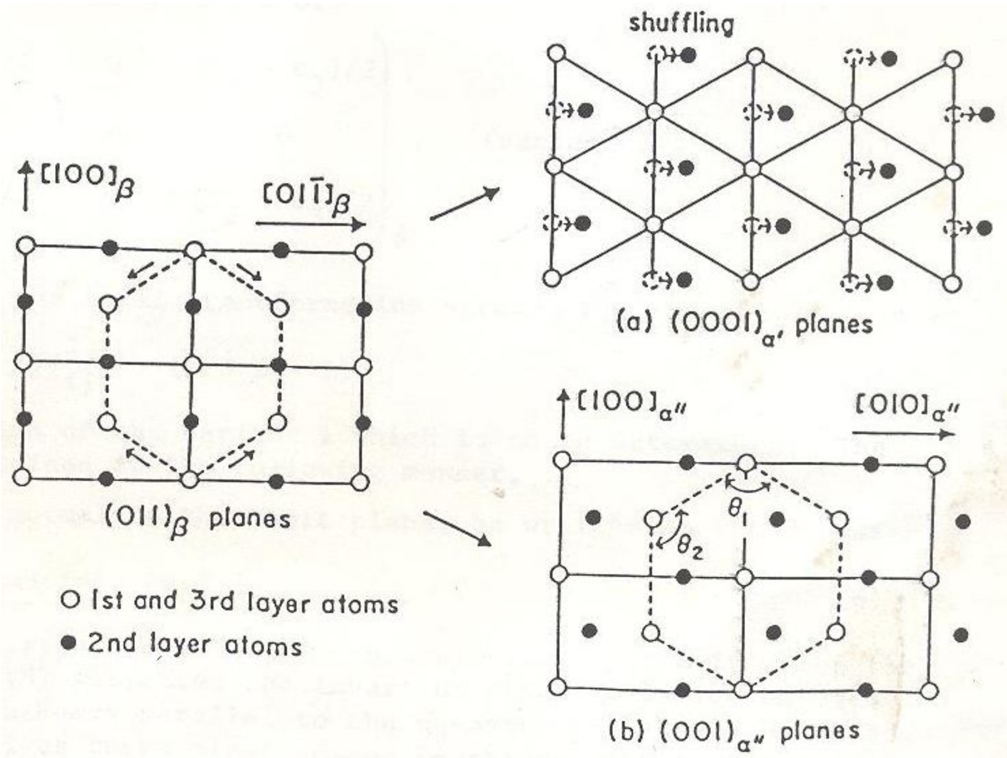



Fig 24: SCHEMATIC PHASE DIAGRAM OF THE SPECIAL ALLOY (Ti62111 special alloy) where the alpha phase is the hexagonal martensite and beta phase is the high temperature BCC phase.

The formation of the hexagonal and orthorhombic phases in this Titanium alloy could only be explained by assuming that the atoms simply shuffled or slightly sheared giving rise to the two martensites simultaneously as shown in the structural diagrams by Obikwelu, Kato and Murkerjee 1982, Fig 25 below:




The orthorhombic martensitic phase developed was represented as shown in Fig 26 below illustrating the structure and the atom positions:

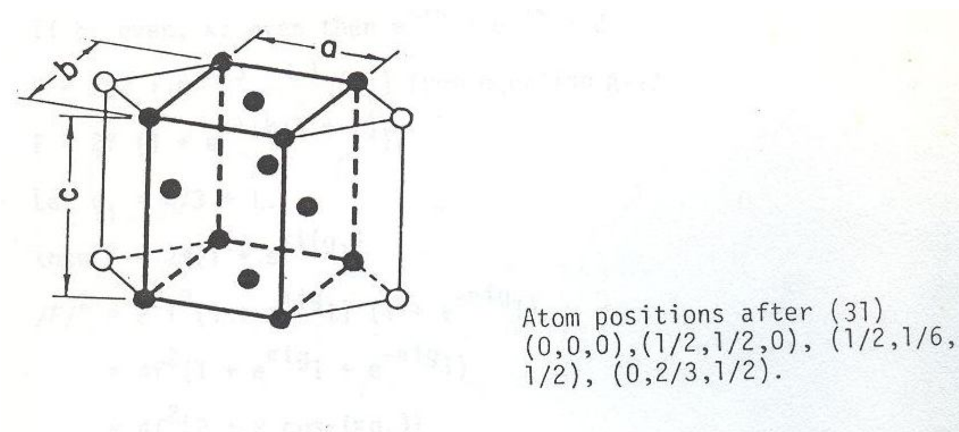



*Fig 26: ORTHORHOMBIC Martensitic Structure and atomic positions.*

Apart from the X-ray methods for developing phase diagrams Computer software packages based on thermodynamic data banks were used to accurately calculate and produce multi-component phase diagrams.

## DUAL-PHASE STEELS

These Steels were developed and modified through special heat treatment for manufacturing principal parts of the automotive systems for high tensile strength, ductility and toughness (Obikwelu et al).

The heat treatment was such that the microstructure consisted of a ferrite matrix with grain boundary iron carbides, a small volume fraction of pearlite and decomposed pearlite and a dense distribution of fine vanadium carbon nitride strengthening precipitates. A recent modification of this microstructure for better strength and ductility was achieved through inter-critical annealing operation to form some volume fraction of ferrite, 10 to 20 % tempered martensite and transformation products of retained austenite Offor and Obikwelu. Tensile strength of 90ksi (620MPa), elongation of 27%, yield strength 3% offset of 70ksi (480MPa) and yield strength 2% offset of 55ksi(380MPa) were achieved.

The future of Dual–Phase Steels is very bright and further work on it is going on.

## MATERIALS IN THE NANO WORLD

Materials in the size range from one nanometer to 100 nanometers are called nano materials, where one nanometer is one billionth of one meter.

The essence of size derives from the ratio of surface area to volume of spherical particle,

$$\frac{surface\ area}{volume} = \frac{4\pi r2}{\frac{4\pi r3}{3}} = \frac{3}{r}$$

As r tends to zero this ratio becomes very large and the energy of the surface is large.

A nanoparticle is of the size range $1x10^{-9}$meters to $100 \times 10^{-9}$ meters.

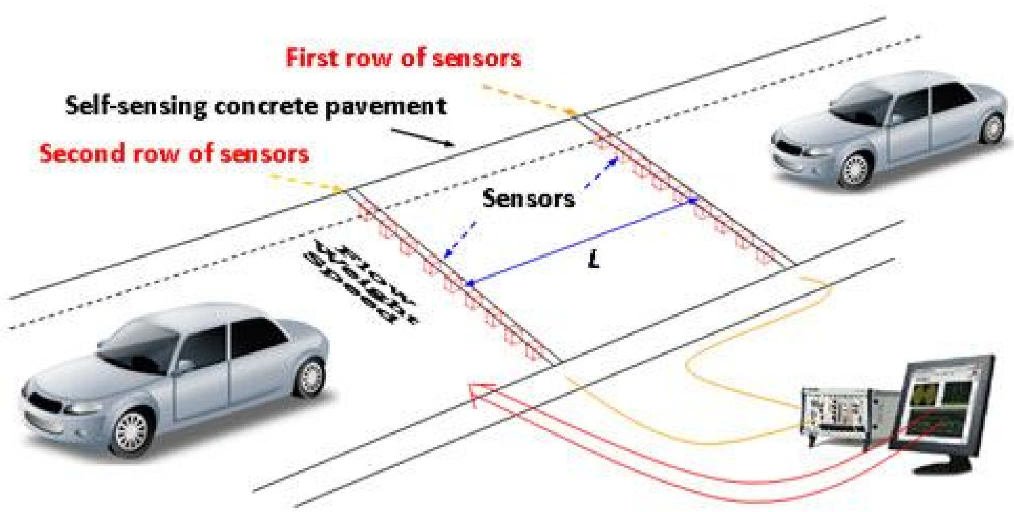
A nano particle material is like a force at a point penetrating or piercing or missile-like particle.

Nanoparticles in materials optimize the properties of the material, Obikwelu and Obayi added definite volume fraction of carbon nanoparticles to local resin and the resin became a very useful engineering material. Further investigation into carbon nano particle strengthening in the excess of 11 volume % of carbon nano-particle is in progress.

Inorganic material nanoparticles in a plant extract medium generates a missile that can shrivel cancer tumour (Obikwelu et al). The preliminary findings were presented at a Materials Research Conference at Victoria Falls Zimbabwe. The finding is being patented. Further work on the topic is still going on.

Substitutional and interstitial poisoning theories were developed as mechanisms for the use of nanoparticles in cancer cure (Obikwelu et al).

Nanomaterials mixed with nano piezoelectric materials and used in concrete road pavement can sense traffic flow and give signals to motorists on the high ways illustrated in the diagram below.




This had been demonstrated in South Korea and could be applied at the Security checks in the University of Nigeria and on the Nigerian high ways. It is an ongoing project.

Sand nanoparticles segregate in concrete application. This was observed in flooring with cement:sand:water mixture where purposely nano particles of some of the components in the mixture were mixed with the other materials. On application nano, micro- and macro-segregation in grain boundary formation results as in a low carbon steel material, polished, etched and observed in an optical micrograph. This can be applied for the optimization of compression strength of concrete.

## NANOMATERIALS IN AUTOMOBILE DESIGN

Obikwelu et al produced an automobile ignition plug by incorporating a nanostructured ceramic material $Al_2O_3$ and MgO into the plug design. This plug if perfected could reduce fuel consumption to the level that a private Toyota car could go to Enugu from Nsukka and back with half the quantity of fuel presently used. Spark plug design using nano particles is an ongoing project.

This spark plug project opens a research door in the application of nano materials in the automobile industry

Fig 27 shows the future of nanomaterials in the automobile industry

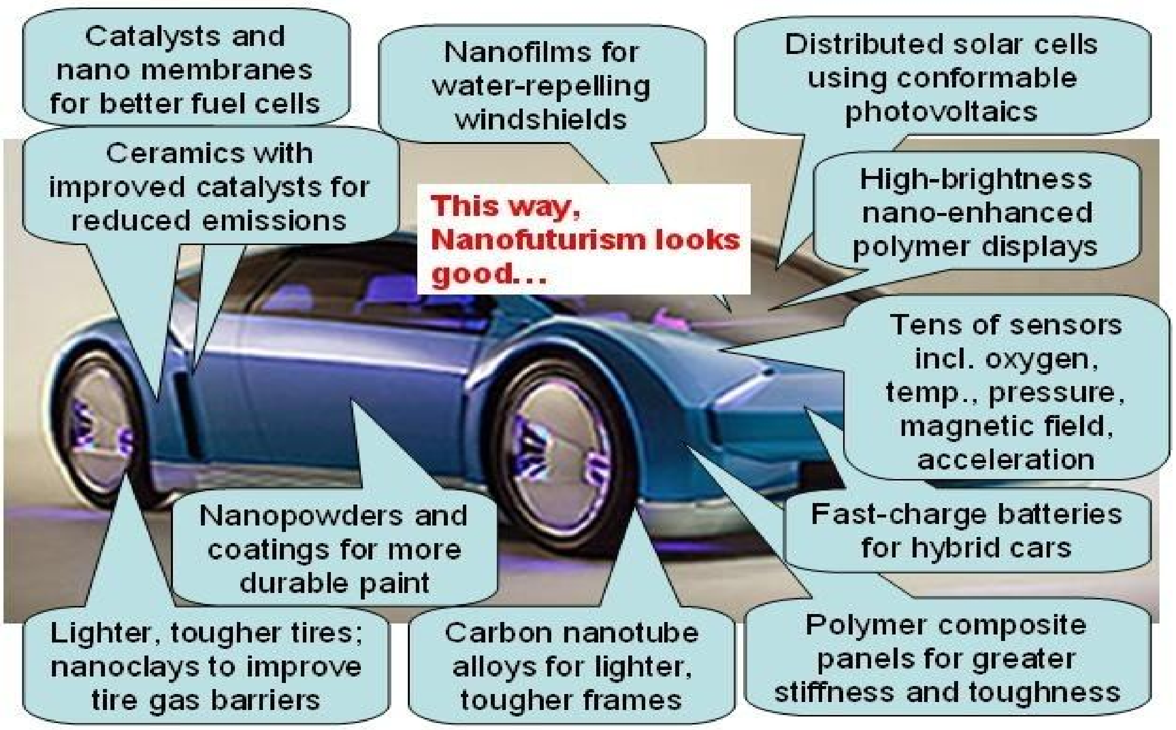



*Fig 27: Future of Nano-materials in the Automobile Industry*

## NANOPARTICLES FROM ELECTRIC ARC FURNACE SLAG

Molten slag from the Electric Arc Furnace was quenched with argon gas and stream of water directed at $90^0$ degree angle to the flow of the molten slag producing nanostructured slag material used for road construction (Obikwelu 1987).

Nanostructured steel was recently produced in the Department of Materials Science and Metallurgy, University of Cambridge by Bhadeshia published in the Science and Technology of Advanced Materials in March 2013. This further shows the great future of nano materials in Materials Research.

## PROBLEM WITH LEAD-BASE MATERIALS

Lead, a low melting metallic material of melting point: $621^0$ Fahrenheit served man in about 2000BC when Chinese made money from it. The Bronze coinage of Ancient Greece and Rome contained up to 30% of Lead. Romans used Lead for water pipes. Its eutectic composition in the Lead-Antimony system is 11.2% Antimony and 88.8% Lead.

Lead and its alloys are used in batteries, x-ray and nuclear shielding. The toxic nature of Lead now limits its use in water pipes etc.

The toxicity of Lead and its compounds led to the study of replacing Lead in solders used in bonding materials during welding operations. Obikwelu and Nwamkpa in 1997 and Obikwelu and Omah in 2009 successfully replaced Lead with Bismuth and with Zinc respectfully in the toxic Lead-Tin soldering material.

## OTHER WORKS IN THE USE OF MATERIALS:

The need to ease transportation for the masses made Obikwelu and some Engineering Students to work on the replacement of the imported fragile *kekenapep* with a locally made one. The long term aim was to provide a low cost mini-automobile that would operate on University campuses. The efforts are hereby highlighted in pictures shown below:

*Fig 28: Concept stage*

*Fig 29: ConstructionStage*

*Fig 30: Construction Stage*

*Fig 31: Commissioning Stage*

Fig 32: Commissioning Stage Continued.

The body of the mini-automobile would be molded with locally available ground palm kernel/cashew resin composite to reduce cost.

From rough structural analysis of the framework of the locally made mini-automobile the automobile framework is statically and aerodynamically determinate. The automobile system called LIONAUTO is equipped with the circular steering system in contrast with the straight bar steering system of the imported one and could carry seven passengers. The imported fragile *kekenapep* could carry barely four passengers.

Its seven horse power petrol engine imparts high traction to the automobile system.

It has low center of gravity and acceptable clearance from the ground while in motion.

## INSTALLATION OF THE ROTARY FURNACE FOR THE PRODUCTION OF CAST IRONS

Obikwelu et al in 2007 installed and commissioned successfully the 100kg capacity Rotary Furnace fabricated by the Engineering Development Institute (EMDI) Akure under the Education Trust Fund (ETF) in the Faculty of Engineering, University of Nigeria, Nsukka. Molten cast iron was produced in the University of Nigeria for the first time in 2007 with this Furnace and some components were produced.

The Rotary Furnace installed in the Engineering Faculty has capacity to produce engineering components like crankshaft and other cast iron units. The Furnace Unit is shown in Fig 33 below:


*Fig 33: ROTARY FURNACE INSTALLED IN THE FACULTY OF ENGINEERING (Obikwelu et al 2007)*

In 1988, A Cupola Furnace shown below, Fig 34 was designed, constructed and put into operation to utilize direct reduced iron fines (which were wastes from the Direct Reduction Plant) to produce iron for steel making in Steel making shops and Foundries.

*Fig 34: Cupola Furnace for Utilizing Iron Fines for Steel making (Obikwelu et al 1988)*

## COMMENTS ON THE NIGERIAN STEEL INDUSTRY

I cannot conclude without commenting on the deplorable state of the Nigerian Steel Industry.

Ferrous metallic material, Steel, has been identified as the king of materials and the driving force for industrialization and civilization of man over the ages.

It kicked off the Industrial Revolution in Great Britain, Europe and America in the 18$^{th}$ Century and sustained the developed countries of the world in their present industrial status and level of civilization.

To date there is no operating Steel Company or Metallic Materials Industry in Nigeria.

From the lessons of the Industrial Revolution it is clear that no country can be fully civilized and industrialized without a robust Steel Industry. A country without Steel will have the unending burden of importing almost every thing from other countries and being at acute disadvantage in all aspects of life and living.

The case in point is the pathetic story of Nigeria in which a country with a population of almost 160million people has no Steel Industry in the 21$^{st}$ Century. Many Nigerians are existing in the 21$^{st}$ Century but living in 18$^{th}$ Century. This can only change if Nigerians copy the Japanese example, stop the importation of engineering systems, goods, people and services.

Unless this is done there is no hope for our young people especially the Engineering graduates who will at best be employable as Maintenance Officers instead of Maintenance Engineers, Engineering Salesmen instead of Engineers, Bankers or even hewers of wood instead of men of timber and caliber.

The Ajaokuta Steel Complex which Nigeria had now successfully and wisely recovered from the Global Steel Holdings/Infrastructure Nig. Ltd (an Indian base company) should be made to operate along the following mindset:

- That Steel is strategic to the Country's socio-economic and industrial development so no opinion of the World Bank and/or International Monetary Fund will be allowed to derail the country in her survival efforts and policies.
- If the Nigeria of Government cannot run the Steel Industries let other people or group of professional persons run the Industry

for the Government on some conditions because without Steel NIGERIA cannot develop at all.

Nigeria cannot have the wherewithal to develop her resources, the resources can only be carried overseas and developed and sold back to us.

That is what is happening to the crude petroleum…. It is carried overseas, refined, they sold what they like to sell to us and keep the better part leaving us outrageously and downright poor living on second hand everything!!!!

- Before proffering solutions to the Government of Nigeria in the short term to redeem the moribund national steel companies, I will recommend that the best option in the long run to redeem Nigeria from dying finally industrially is TO DE-REGULATE STEEL PRODUCTION IN NIGERIA.

  Entrepreneurs should be encouraged to establish mini rolling , billets mills/medium electric arc-furnaces, ferroalloy production industry, refractory production industry, beneficiation plants of low capacity, lime plant, foundry shops, mini iron ore reduction plant and other small units. These units will preferably be located at regions where there are iron ore deposits and where iron smelting were practiced early in history.

  - In the same vein all Materials and Metallurgical Industries should be deregulated. These include Aluminum Smelting industry, Glass Industry and Cement Industry.

As a short term measure Government is urged to make money available to accomplish the following for a final outright selling of the Steel Industries to the prospective entrepreneural persons or consortium

- To commission Billet Mill, Light Section Mill, Wire Rod Mill, Medium Section and Structural Mill, Thermal Power Plant, Forge & Fabrication, Mechanical Repair Shop, Foundry Shop, Power Equipment Repair Shop, Rubberizing and Refractories & Lime Production Plants which have been 100% completed .

- To commission all the Units that are already completed namely the Thermal Power Plant, Power Plant Repair Shop, Refractories & Lime Plant Production Plants, Foundry Shop and Mechanical Repair Shop and sell outright.

- Regarding the Itakpe Iron Ore, Government is urged to repair the Company and sell outright.

- For the Delta Steel Company, the Government should sell all the seven units ought right: the Pellet Plant, Steel Melt Shop, Lime Plant, the Foundry Shop, Central Mechanical Maintenance Shop and the auxiliary plants.

The Government of Nigeria is urged to decide how to define the strategicness of the STEEL AND METALLURGICAL INDUSTRIES and prescribe the conditions for the SELLING OF THE STEEL AND METALLURGICAL INDUSTRIES and the qualifications of the prospective buyers IN ORDER TO SAVE NIGERIA'S INDUSTRIAL LIFE.

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**CONCLUSION:**

May I conclude by

- thanking everybody that endeavored to be here to listen to my story
- urging the Nigerian Government to learn the lessons of the industrial revolution of the $18^{th}$ Century in Great Britain by providing conducive political /industrial atmosphere to conduit the already existing industrial posture in Nigeria to an avalanche of industrial inventions that will eventually lead to the much needed industrial revolution in Nigeria.

  The industrial atmosphere will be the establishment of Metallic Materials industries like the Steel industry. This single achievement will do the miracle in Nigeria….. providing the steel products that will engineer our power, petroleum and various industries thus pulling Nigerians out of the $18^{th}$ Century into the $21^{st}$ Century and beyond.

I thank God for this day and may God bless our University, our Country and all of you in Jesus Name.

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