Federal University of Technology, Minna

METAL CASTING TECHNOLOGY IN NIGERIA – PRESENT STATUS AND FUTURE PROSPECTS

by

Professor R. H. Khan, B.E., M.E., Ph.D.
FICME, LMAAI, LMIISAA.
Professor of Mechanical Engineering

Inaugural Lecture Series 8

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FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA.

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METAL CASTING TECHNOLOGY IN NIGERIA PRESENT STATUS AND FUTURE PROSPECTS

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Preamble

I feel honoured and privileged to deliver the 8th Inaugural Lecture of the Federal University of Technology, Minna and the second in the series from the School of Engineering and Engineering Technology. The lecture is titled "Metal Casting Technology in Nigeria Present Status and Future Prospects".

Metal casting is one of the oldest and most important manufacturing technologies. Without manufacturing, there would be little need for engineers and technologists or, indeed, for many of the people who are engaged in supporting activities. Manufacturing is a central function of most technically educated people. The ultimate purpose of all engineering activity is to produce something tangible and salable, hopefully for the benefit of humanity. It is the lifeline of all industrialized society. Without it, few nations could afford many of the amenities that improve the quality of life for their citizen.

Metal casting is vital to the economy and security of a nation. In addition to transportation, aerospace, and defence, cast metal products are found in virtually every sector of economy including energy exploration and conversion, mining, construction, maritime, fluid power, instrumentation, computers and myriads of household products. Cast metal components include: engine blocks; suspension parts for railcars, trucks and autos; fluid flow and power components including valves, pumps, faucets, pipes and fittings; mining and oil field, and energy producing equipment; surgical equipment and prosthetic devices; and components for many of the household and electronic devices we all use everyday. The future holds great promise for the metal casting industry. But to remain competitive and maintain a viable domestic industry, challenges must be overcome in industry recognition, casting design, processing efficiency, and employment attractiveness.

1.0 INTRODUCTION:

Casting is one of the earliest metal shaping methods known to mankind. It generally means pouring molten metal into a mould with a cavity of the shape to be produced, and allowing it to solidify. When solidified, the metal object is taken out from the mould either by breaking the mould or taking the mould (die) apart. The solidified object after removal of gates and risers is called casting. Casting or founding process is extensively used for the manufactures of products/components for almost all industries such as agriculture, construction, cement, chemical, petro-chemical, air-craft, ship-building, machine tool industries, etc. And hence, foundry industry is rightly said to be the mother of all industries, as it feeds all industries with the components produced as castings.

The strength of the foundry industry rests on the fundamental nature of casting as a process for causing metals to take shapes that will serve the needs of man. Certain advantages are inherent in the metal casting process:

The most intricate of shapes, both external and internal may be cast.

It is possible to cast practically any material whether ferrous or non-ferrous.

Extremely large, heavy metal objects may be cast when they would be difficult or economically impossible to produce otherwise. Large pump housings, valves and hydroelectric power plant parts weighing up to 200 tones are examples.

There are certain metals and alloys which can only be processed by casting due to their metallurgical nature. The highly useful and low cost cast irons, which exceed the total of all other metals in tonnage cast, illustrate this fact.

Castings generally cool uniformly from all sides and they have no directional properties.

Highly adaptable for mass production

Necessary tools required for moulds are simple and relatively inexpensive. As a result, trial production or production of a small lot, it is an ideal method.

Construction may be simplified. Products may be cast in a single piece which would otherwise require production in several pieces and subsequent assembly if made by other methods.

A decided economic advantage may exist as a result of any one or a combination of above mentioned points.

It is also true that conditions may be such that the casting process must give way to other methods of production. For example, machining produces smooth surfaces and dimensional accuracy not obtainable by other processes; forging aids in developing the ultimate of fibred strength and toughness in steel; welding provides a conventional method of joining or fabricating wrought or cast products into complex structures; and stamping produces lightweight sheet metal parts.

Metal castings have been practiced in the middle belt of Nigeria over 2000 years ago through iron melting during the Nok-culture. Iron smelting was also known to be in practice in Kano City over 1000 years ago. Bronze castings were made on the South-Western plains of Benin, Ife and Egboukwu for over 1000 years (Inuwa, 1995).

Although, Nigeria has lots of the metal casting industry, it has remained underdeveloped. The present status of the metal casting technology vis-à-vis the industry has been discussed and the future prospects have been outlined.

2.0 HISTORY OF METAL CASTING

2.1 Metal Casting Through the Ages in the World:-

A casting is the essential foundation of civilization. With it, man unlocked his future, placing him on the path toward conquering his environment. History tells us this started in Mesopotamia, today's modern Iraq. The oldest casting in existence today is believed to be a frog, cast in Copper in 3200 B.C. The frog's complexity indicates that it was preceded by other simpler castings. According to biblical records metal casting technology reached back almost 5500 years B.C. Gold, pure in nature, most likely caught prehistoric man's fancy as he probably hammered gold ornaments out of the gold nuggets he found. Silver would have been treated similarly. Copper was found next as it appeared in the ash of his camp fires from Copper bearing ore that he lived his fire pits with. Man soon found that Copper was harder than gold or silver. Alloys that could be easily melted followed and hence came the use of bronze and brass, not only for cooking pots and utensils, but also to make tools and implements such as axes and arrow heads.

The use of iron was relatively unknown except in areas where iron bearing minerals were abundant. Steel followed much later.

Since its discovery, metal casting has played a vital role in the development and advancement of human cultures and civilization.

After more than 5000 years of technological advances, metal casting plays a greater part in our everyday lives and is more essential than it has every been. A brief timeline of metal casting history is presented below:-

3200 B.C.	-	A Copper frog is cast in Mesopotamia.
2000 B.C	-	Iron is discovered
645 B.C	-	Earliest known sand molding (Chinese)
500 A.D	-	Cast crucible steel is first produced in India, but the process was lost until 1750, when Benjamin Huntsman reinvents it in England..
1455	-	Cast Iron pipe to transport water (Germany)
1794	-	First use of Cupola in Iron founding. (England)
1809	-	Development of Centrifugal Casting. (England)
1815	-	Introduction of Cupola in US foundry.
1826	-	Production of Malleable Iron (USA)
1837	-	First dependable molding machine (USA)
1845	-	Development of Open Hearth Furnace
1863	-	Development of Metallographic (England)
1870	-	Sandblasting is first used to clean large castings. (USA)
1896	-	American Foundrymen's Association (now called American Foundry Society) is formed.
1897	-	Investment casting is rediscovered to cast dental inlays (USA)
1906	-	Use of first electric arc furnace

1913	-	First true stainless steel melted (England)
1923	-	Formation of the International Committee of Foundry Technical Associations in Zurich, Switzerland
1930	-	First use of spectrographic for metal analysis (USA)
1947	-	Invention of Shell Process (Germany)
1948	-	Development of Ductile Iron (SG Iron)
1953	-	Development of Hot Box Process for Core making.
1958	-	Full mould process development
1965	-	Invention of Scanning Electron Micro-Scope (England)
1965	-	Development of Cast Metal Matrix Composites.
1968	-	Introduction of Cold Box Process for coremaking.
1970s	-	Development of Semi-Solid Metalworking Process
1971	-	V- Process Development (Japan)
1972	-	First Austempered Ductile Iron (ADI) Component production.
1974	-	In mould process for ductile iron treatment.
1976	-	Compacted Graphite Iron (CGI) development
1982	-	Introduction of Warm box binder system
1993	-	First foundry application of a plasma ladle refiner.

1995	-	Lost Foam vacuum casting process to produce stainless steel castings with low carbon content.

2.2 History of Metal Casting in Nigeria:

Metal casting technique was known to have been practiced in the middle belt of Nigeria through iron melting during the NOK culture. Iron smelting was also known to be in practice in Kano City over 1000 years ago. Bronze castings were made on the South-Western plains of Benin, Ife and Egboukwu for over 1000 years (Inuwa, 1995).

In the city of Benin, brass casters continue to produce lost wax castings (Investment casting) using a method passed down through the ages from one generation to the next. A study of their methods provides a living example of the early history of the investment casting process.

The brass casters at Benin begin with a core of clay kneaded into a mass. They shape the clay into the approximate shape and size of the article to be made. These cores are allowed to dry thoroughly in the sun for several days. A pattern for the casting is created by covering one of these cores with beeswax and carefully modeling it into the exact shape desired. When the wax form is finished to the artist's satisfaction, it is covered in a thick coating of clay. The first layer of clay is applied as a very fine slip. Before the pattern is fully sealed in this coating, a thin roll of wax is added to form a channel into which molten metal will be poured. Subsequent layers of a thicker clay are added, gradually investing (Covering) the form completely creating a mould. This mould is allowed to air dry thoroughly. When a batch of moulds have been created and are ready for casting, they are placed in a fire and heated so that the wax will melt and can be poured off. The clay moulds are further heated to a point where they are sufficiently fired to permit the pouring of the molten metal without causing the shell to burst. Meanwhile pieces of brass are melted in crucibles on a nearby forge fire. Immediately prior to pour, the moulds are taken from the fire and placed upright in spaded earth. A crucible of metal is taken from the forge with long tongs and the molten bronze/brass is poured into the open mould. The caster holds a wooden stick in his other hand during the pour and places it on the edge of the crucible to help ensure a smooth flow of metal into the shell. Soon after solidification, the moulds are broken open, the shell knocked off and the final object is cleaned, filed and polished. Benin lost wax castings can be found in museums throughout the world. Over the centuries Benin art style have changed slightly, however, certain characteristics still remain common. A bronze version of the Oba of Benin weighing 15lbs (size 25 x 7 x 6 inches) is priced at US $ 475 + $80 as air freight in the world market. A small Benin Bronze Sculpture is shown in Fig. 1a and Fig. 1b.

BENIN SCULPTURE

Fig. 1a

BENIN KING OBA

Fig. 1b (source: www.vbelt.co.za)

Before colonization, many basic tools were locally manufactured by artisans; iron ore was mined and smelted around Ajaokuta (Kogi State) and Ojirtami in Edo State. These include basic agricultural tools (cutlasses and hoes), surgical tools (scalpels), domestic tools (pots, pans, plates) and military tools (guns and arrows). All the products mentioned above were either cast or forged (Adejuyigbe, 1998).

Barberopoulos cited in Foundry chronicle (1995) the estimated number of foundries at 80 which produced specialized industrial components for cement, mining, manufacturing, agriculture, road construction, water supply and automobile industries. He further observed that Nigeria could afford over 1000 foundries provided proper climate for industrial growth is established.

Peters and Esekobe (1997) observed that a survey conducted by National Agency for Science and Engineering Infrastructure (NASENI) between 1993 and 1995 put the total expected domestic production of all types of castings at 153,000 tonnes annually, made up of 60,178 tonnes of cast Iron; 41,465 tonnes of steel and 51,327 tonnes of non-ferrous castings. Ironically the survey put the Nation's total demand for cast automobile components alone at 820,000 tonnes a year confirming the fact that enormous potential market opportunities exist for cast products.

The Nigerian foundry industries like other industries in the country are not without its own problems, which tend to restrain the growth and development of foundries. An attempt has been made to discuss the present status of the metal casting technology in Nigeria and the future prospects for the growth and development of the technology vis a vis the Nation

3.0 METAL CASTING PROCESSES:

Good castings cannot be made without good moulds. Because of the importance of the mould, casting processes and castings are often described by the materials and methods employed in moulding. The term casting process conveys a broader meaning, often including the molding /co remaking process, the method of introducing the metal into the mould cavity, or all the processes used making the casting. The various moulding/coremaking processes differ primarily in the method of forming the mould/core and in the granular refractory and method of bonding it. Based on type of bonding, the moulding processes could be divided into two groups:

1. In-organic Binder Processes
2. Organic Binder Processes

A detailed classification of various processes is presented in Fig. 2.

A brief description of some commonly used but important processes is outlined below:

3.1 Sand Casting (also called Green-Sand Moulding):

It is the most commonly used casting process throughout the entire Casting Industry, World Wide. The maximum tonnage of casting is produced by this process even in most developed nations. Green sand moulding may be defined as a plastic mixture of sand grains, clay (as a binder), water (as activator) and other materials (as additive) which can be used for moulding and casting purposes. The sand is called "green" because of the moisture present and to distinguish from dry sand.

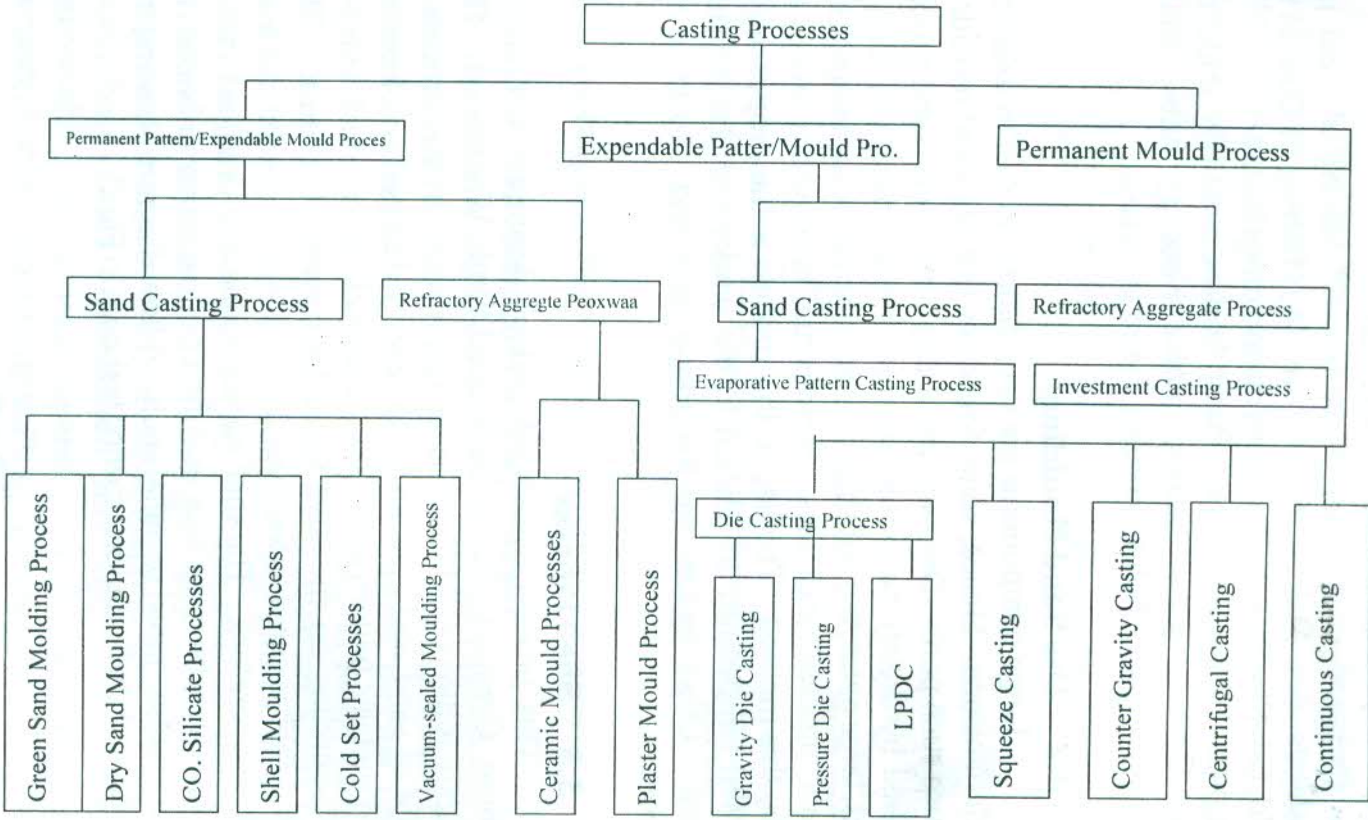

Fig. 2: Classification of Casting Processes {Source: Raji (2004)}

The basic steps in green sand moulding are:-
(i) Preparation of Pattern/Core box (ii) Mixing of sand mix ingredients (iii) Making Mould/Core (iv) Setting of Core in the mould. (v) Closing and Weighting the moldings boxes.
Examples of usage would be: Pump bodies, housings, impellers, Sewer Covers, gears, blanks, motor housing, hubs, shafts, rectangles, squares, holes, no holes, the list is endless.

3.2 Dry Sand Moulding:

Large components are very difficult to cast to exact size and dimensions. Hence, some foundries use dry sand moulds to produce such parts. Dry sand moulding is the green sand process modified by drying the mould at prescribed temperature. Engine blocks, large gears, big housing, construction parts, are examples of dry sand process candidates. Ferrous and non-ferrous metals are cast by this method. The key to this process is the proper drying time and temperature in relation to the binder and the moisture content. Other factors are the shape, size and weight of the component.

3.3 Shell Process:

This process was developed by Johannes Croning of Hamburg, Germany, during the Second World War period. This technique is also called Croning or 'C' Process. In this process, a mixture of sand and thermosetting resin is dumped or blown on heated metallic pattern for a definite period (30 sec. to 1 min.) of time depending on the shell thickness desired (6-12mm). The invested shell is cured in the oven and the shell is ejected out from the pattern/core box. The shell halves (Cope and drag) are joined together after setting the core and then poured either unbacked or backed in sand, gravel or metal shots. A flow diagram showing the production of shell moulded casting is shown in Fig. 3.

Typical applications of shell moulded castings are cylinder and cylinder heads for air cooled IC engines, automobile transmission parts, cast tooth bevel gears, track rollers for crawler tractors, gear blanks, transmission cases, valve bodies, small crank shafts, chain seat bracket, etc.

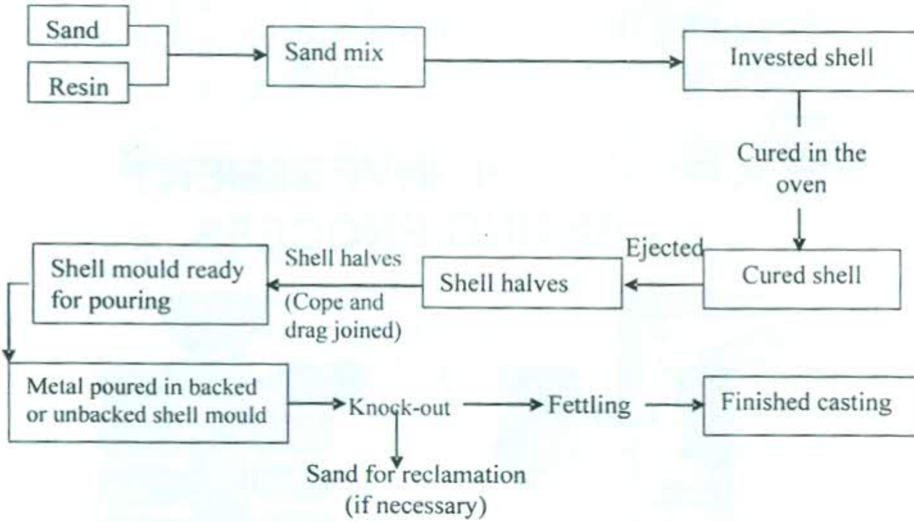

Fig. 3: Flow-Diagram for Shell Moulding Method of Casting Production.

3.4 Investment Casting Process:

The Egyptian, and Chinese and Nigerians used the process in their early history to make statues and jewelry. The investment Casting method was largely ignored as an industrial process until the demand for rapidly finished parts during World War II created the need for near net shape components that could readily be put into their final form. Then new inorganic high temperature ceramic mold binders were developed to industrialize the process applications to include high strength and corrosion resistant materials such as alloy steel, tool steel, stainless steel, and nickel and cobalt base alloys. Aluminium and copper alloys are used, extensively. It is a process capable of producing intricate shapes weighing from a few grams up to 20 kg or more.

The Basic steps of the Investment Casting Process are (Figs. 4a, 4b, 4c and 4d)

1. **Wax Injection**: Wax replicas of the desired castings are produced by injecting wax in the die. These replicas are called patterns.

2. **Assembly**: The patterns are attached to a central wax stick, called a sprue, to form a casting cluster or assembly.

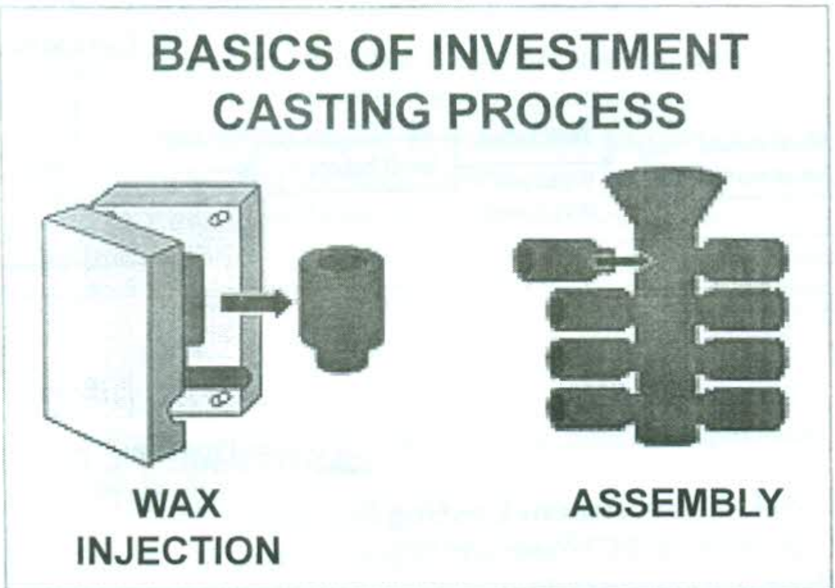

Fig. 4a: {Source: www.hitchiner.com}

3. **Shell Building**: The shell is built by immersing the assembly in a liquid ceramic slurry and then into a bed of extremely fine sand. Up to eight layers may be applied in this manner.

4. **Dewaxing:**- Once the ceramic is dry, the wax is firing and melted out, creating a negative impression of the assembly within the shell. The shell is then fired in a furnace to develop the required strength.

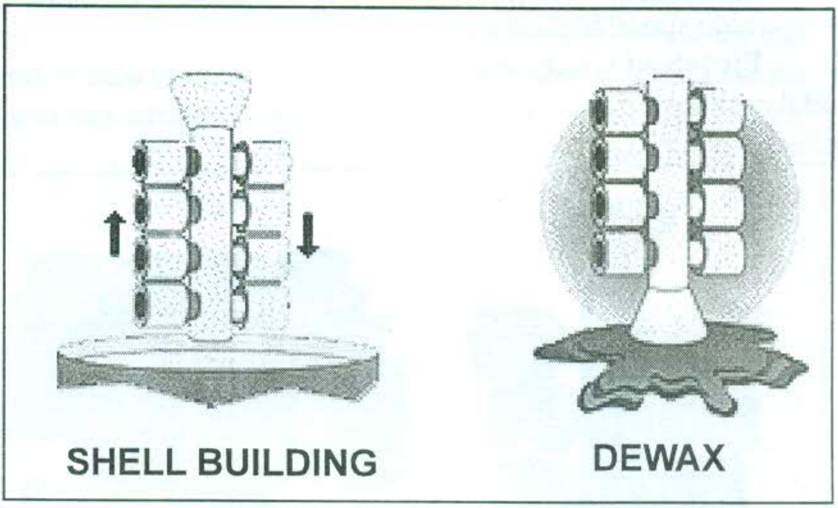

Fig. 4b: {Source: www.hitchiner.com}

5. **Pouring and Solidification** Process: the shell is filled with molten metal by gravity pouring. As the metal solidifies, the parts and gates, sprue and pouring cup become one solid casting.

6. **Knockout:** When the molten metal has cooled and solidified, the ceramic shell is broken off by vibration or water blasting.

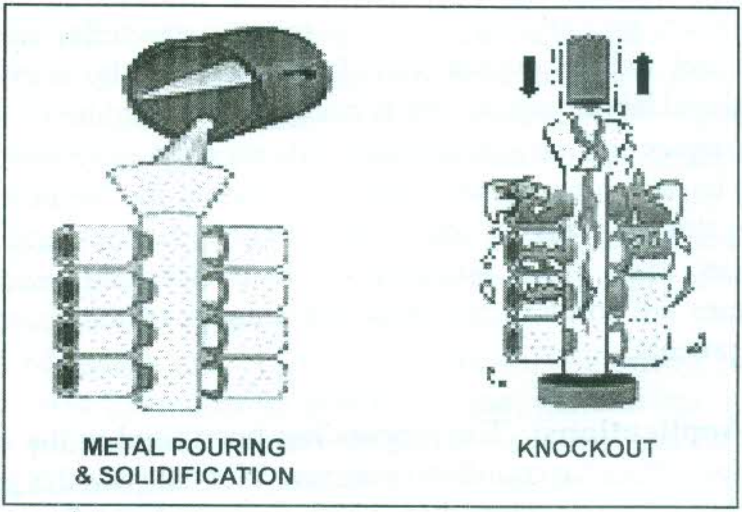

Fig. 4c: {Source: www.hitchiner.com}

7. **Fettling:-** The parts are cut away from the central sprue using a high speed friction saw.

8. **Finished Castings:-** After minor finishing operations, the metal castings identical to the original wax patterns are ready for delivery to the customer.

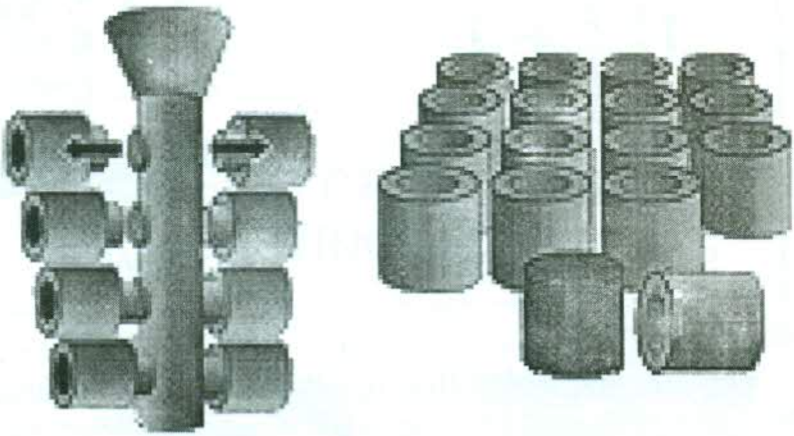

Fig. 4d: {Source: www.hitchiner.com}

When properly applied, the process can offer near net shapes that reduce overall manufacturing costs by minimizing material and labour inputs. Parts designs can be lighter in weight, more complex and are available in a wide range of alloys than those offered by other processes. Stronger materials, better surface finishes, thinner walls, difficult internal configurations and closer tolerances than those available through alternate processing techniques are some of the other advantages of the investment casting process.

Applications: The process has been used in the arts by many civilizations for countless centuries. Not only was this process in use, but it was developed to a high degree of excellence, as is attested to by many beautiful and finely detailed statues, jewelry and artifacts from antiquity. Presently the products made by this process are vanes and blades for gas turbines, shuttle eye for weaving, pawl and claws for movie camera, wave guides for radars, bolts and triggers for firearms, stainless steel valve bodies and impeller for turbochargers, surgical instruments and dental implants, etc.

3.5 Die Casting Process:-

This process is for high volume, high detail, value added, economy priced cast parts. The process involves the production of components by injecting molten metal at high pressures into a metallic die. Die casting is closely related to Permanent Mould Casting (Gravity Die Casting), in that both the processes use reusable metallic moulds called Dies. In die casting as the metal is forced in under pressure compared to permanent moulding, it is also called "Pressure Die Casting". Because of the high pressure involved in die casting, any narrow sections, complex shapes and fine surface details can easily be produced.

In die casting, the die consists of two parts. One called the stationary die or cover die which is fixed to the die casting machine. The second part called the Ejector die is moved out for the ejection of the casting. The casting cycle starts when the two parts of the die are apart. The lubricant is sprayed on the die cavity manually or automatic lubrication system. The two die halves are closed and clamped. The required amount of metal is injected into the die. After casting is solidified under pressure, the die is opened and the casting is ejected. Schematics of hot chamber and cold chamber die casting machines are shown in Figs. 5 and 6.

Examples of usage are:- cabinets for electronic industry, hand and power tools for industrial and home use, general hardware appliances, pump parts, plumbing parts, parts for automotive industry, sports and leisure, home appliances, all general hardware type parts, hardware for doors, drawers, and furniture, parts for lighting industry, a lot of communication equipment, the list is endless.

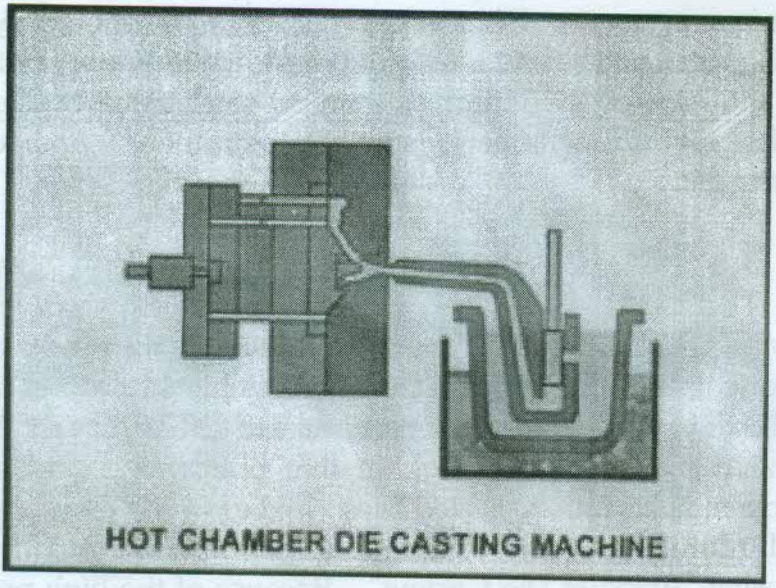

Fig. 5: {Source: clegg (1991)}

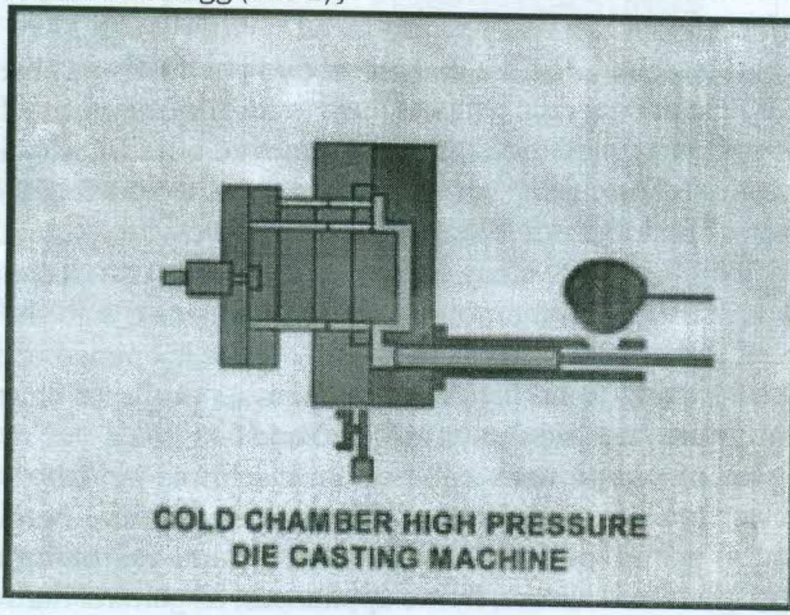

Fig. 6: {Source: clegg (1991)}

3.6 Centrifugal Casting process:

This is a process where the mould is rotated about its central axis as the metal is poured into it. Because of the centrifugal force, a continuous pressure will be acting on the metal as it solidifies. The slag, oxides and other impurities being lighter, get separated from the metal and segregates toward the centre. There are three main types of centrifugal Casting processes:- True centrifugal casting, semi centrifugal costing and centrifuging.

True centrifugal casting is normally used for the making of hollow pipes, tubes, hollow bushes, etc. which are axisymmetric with a concentric hole. Since the metal is always pushed outward because of centrifugal force, no core needs to be used for making the concentric hole. The axis of rotation can be horizontal, vertical or any angle in between. Very long pipes are normally cast with horizontal axis whereas short pieces are more conveniently cast with a vertical axis.

A comparison of the various casting processes discussed above are presented in Tables 1 & 2.

Table 1: Characteristics of some moulding processes. {Source: Heine et al (1967)}

Name of process	Pattern type	Molding aggregate	Molding method	Type and development of aggregate bond	Casting weight	Casting intricacy	Casting dimension and smoothness, general case	Note
Green sand	Wood, plaster, metal; reusable patterns	75%+ sand, 3-15% clay and other binders, water; a moist plastic aggregate; reusable	Collection of sand around pattern, 20-80% reduction in bulk density	Inorganic, green strength due to plastic clay and compaction, dry strength due to water evaporation during casting	Ounces to 1-2 tons	Limited by pattern drawing, no limit with cores	±1/64-±? in., 250-1000 rms μin.	Most common process
Dry sand	Same as above	Same as above	Same as above	Dry strength developed by evaporation of moisture	Heavy castings	Same as above	Same as above or better	Baking of mold required, skin drying being a variant of this process
Core sand	Same as above, or core boxes and driers	90% + sand, 1-3% core oil oar resin, 0.25-1.5% cereal, water	Same as above, core blowing	Organic, polymerization of core oil by baking after removal from core box	Ounces to 500 lb	Same as above	Same as above	Baking of mold required
Floor and pit molding	Same as above	Same as green sand, with added binder	Same as above	Inorganic, same as green sand, maximum strength due to baking	No limit	No limit	±¼ in. or less	For very heavy castings
Shell molding	Heated metal pattern	2.5-10.0% thermo-setting resin, balance sand	Free flow of dry sand around pattern or by blowing	Polymerization of resin by heat from the pattern	Usually less than 250 lb	Limited by pattern drawing, no limit with cores	±0.010 in.-±0.025 in., 100-500 rms μin.	Extensively used for making cores
CO_2 process	Wood or metal patterns or core boxes	2.0-6.0% sodium silicate binder, balance sand	Compaction of sand around pattern, mechanical or by blowing, then CO_2 gassing	Inorganic bond be chemical reaction of CO_2 and silicate	Ounces to several hundred pounds	Same as above	Similar to dry and core sand	
Investment casting	Wax or plastic, expendable	See Table 3.2, slurry with ceramic binder and fine aggregate powder, as ethyl silicate plus silica flour	By dipping pattern in slurry or setting of ceramic binder followed by firing	Gelling, hydrolysis, or setting of ceramic binder followed by firing	Same as above	Limited to wax patterns that can be ejected from dies and their assemblies	0.002-0.005 in./in., 10-85 rms μin.	Casting weight usually under 10 lb, heat and corrosion-resistant alloys

Table 2: Comparison of casting processes {Source: Rao (2001)}

	Metals that can be cast	*Min. and Max mass. Kg*	*Tolerance on dim. %*	*Surface finish. µm*	*Min. Section size. Mm*	*Draft deg*	*Production rate. pcs/hr*	*Min. cored hole. Mm*	*Porosity*
Sand	Aluminium	0.03, 100	0.09	4	3	4	10		
Casting	Steel	0.10, 200,000	to	8	6	to	to	6	5
	CI and others	0.03, 50,000	0.03	8	3.5	7	15		
Permanent mould	Cast iron	0.01, 50	0.01	2	5			4.5 to	
casting	Al and Mg	0.01, 10	min.		3	2	50	6	4
Die casting	Al	0.015, 35	0.0015	1	0.8	2	75 to 150	2.5	
	Mg	0.015, 35	0.0015	1	1.2	2		2.5	2
	Zn	0.05, 80		1	0.5	2	300 to 350	0.8	
Precision investment	Steel	0.005, 25	0.003 to	1	1	1 to	-	0.5 to	
casting	Aluminium	0.002, 10	0.005	1	0.8	3	-	1.25	1
Shell	Steel	0.05, 120	0.01	6	3.5	2	30	3	
moulding	Cast iron	0.03, 50	to	6	3	to	to	to	1
	Aluminium	0.03, 15	0.003	2.5	1.5	3	80	6	
Centrifugal casting	Aluminium	up to	0.002	0.6	0.6		30		1
	Steel	400	0.004	to	to	3	to	-	or
	Cast iron		0.004	3.5	1.2				2

4.0 STATUS OF CASTING TECHNOLOGY IN NIGERIA:

Level of casting technology is considered as an index of growth and development of a nation's technological capabilities and self reliance. It is, therefore, very important for a country to develop its foundry base for rapid industrial growth. There are about 50 foundries which produce an estimated 80,000 tonnes of castings annually. Table 3 shows the 38th Annual Census of World Casting Production 2003. Many countries did not respond to including Nigeria. South Africa re-entered with current data for 2003.

Table 3: 38[th] Census of World Casting Production - 2003 (Metric Tons) {Source: Modern Casting, Dec. 2004}

Country	Gray Iron	Ductile Iron	Malleable Iron	Steel	Copper-Base	Aluminium	Mag.	Zinc	Other Nonferrous	TOTAL
Austria	48,427	113,660[A]	-	13,769	-	104,398	4,749	10,780	-	295,783
Belgium	80,859	15,455	36,075	10,233	537	26,316	-	996	241	170,712
Brazil	1,949,186[AD]	-	-	123,783	15,839	149,990	4,557	6,058	-	2,249,413
Canada['']	684,000[AD]	-	-	152,000	-	76,000[I]	-	-	-	912,000
China	10,800,000	3,630,000	400,000	1,770,000	156,966	1,249,000[I]	-	140,000	-	18,145,966
Croatia	26,578	12,770	50	1,177	745	10,609	-	698	824[F]	53,451
Czech Republic	271,206	45,088	7,674	78,236	1,503	67,545[C]	-	2,148	716	474,116
Denmark	49,913[AM]	37,358	-	-	1,616[I]	-	-	-	-	88,887
Finland	52,116	39,080[G]	-	16,867	3,898	5,287[C]	-	474	8	117,730
France	923,900	1,095,100[A]	-	107,769	28,313	329,078	367	-	-	2,484,527
Germany	2,295,608	1,342,280	38,994	181,393	91,291	677,061	25,987	65,862	4,107	4,722,583
Great Britain	537,000	366,500	-	91,000	15,000	185,000[C]	-	25,000	2,000	1,221,500
Hungary	49,000	30,000	97,000	5,000	5,000	67,000	-	-	-	253,000
India	2,840,000	363,000	39,000	465,000	-	331,000[I]	-	-	-	4,038,000
Iran	310,000	108,000[A]	1,600	32,000	27,000	34,000	-	7,000	-	519,600
Italy	907,000	458,000	9,000	67,000	107,000	805,000	16,000	72,000	-	2,441,000
Japan	2,455,700	1,930,529	81,173	235,352	100,625	1,262,893	97	35,379	9,657	6,111,405
Korea	943,600	539,200[J]	48,400	146,700	22,200	78,000	-	-	5,700[x]	1,783,800
Mexico	790,000[A]	200,000	-	7,980	175,000	550,000	-	100,000	-	1,822,980
Netherlands[']	61,000	60,000	5,000	-	-	-	-	-	-	126,000
Nigeria	-	-	-	-	-	-	-	-	-	**80,000**
Norway	17,000	36,500	-	3,200	2,640	21,923	-	-	-	81,263
Poland	423,000	93,200	15,700	46,500	6,300	134,500	-	8,100	2,100	729,400
Portugal	39,250	52,970	-	10,563	6,000	19,450	300	1,200	115	129,848
Romania[']	400,000[ADM]	-	-	-	-	29,600[E]	-	-	-	365,491
Russia[']	5,700,000[ADM]	-	-	-	-	600,000[I]	-	-	-	2,200,000
Slovenia	68,000	21,000	5,000	22,000	3,000	25,000	3,000	3,000	-	150,000
Spain	497,700	420,000[A]	-	77,300	6,303	131,918	-	13,289	3,168	1,149,678
South Africa	214,500	58,000	1,800	135,000	14,500	39,000	-	2,600	-	465,400
Sweden	157,800	59,000[A]	-	19,100	10,900	37,100	1,400	4,400	-	289,700
Switzerland	27,169	46,125	-	1,381	2,437	15,917[C]	-	1,569	-	94,598
Taiwan	782,463	257,262	1,000	68,930	46,422	250,502	5,313	54,310	1,901	1,468,103
Thailand	82,680	107,640	31,980	3,450	-	3,200	-	-	6,900[F]	235,850
Turkey	592,000	187,000	6,000	112,000	2,840	51,360	-	3,800	-	955,000
United States	4,329,063	3,828,300	105,233	949,817	276,690	1,952,251	73,482	344,728	209,999[K]	12,069,563
Ukraine[']	626,610	40,000	10,000	266,060	11,000	20,500	-	-	-	974,170
TOTALS	40,032,328	15,593,017	940,679	5,220,560	1,141,565	9,340,398	135,252	903,391	247,436	73,554,626

The products range of foundries in Nigeria include municipal castings, water pipe fittings, grinding media, components for cement industries, automotive castings, agricultural casings and industrial spares. Product range of 26 foundries is given in Table 4.

These foundries are broadly grouped into three main categories:

i. Organized Private Sector such as Nigerian Foundries Limited, Lagos; Canplas Ltd. Lagos, Bamford International, Jos; Auto Components Limited, Offa.

ii. Public Sector Captive Foundries such as Nigerian Machine Tools, Oshogbo; Defense Industries Corporation, Kaduna; Delta Steel Company, Aladja; National Metallurgical Centre, Jos; etc.

iii. Small Scale & Cottage Foundries.

Table 4: PRODUCT RANGE OF SOME NIGERIAN FOUNDRIES {Source: RMRDC (2000)}

S/No.	Name of Organization	Type of Castings	Current Range of Products
1.	Nigerian Foundries Ltd., Lagos	Iron, alloy, steel casting	Municipal castings, water pipe fittings, grinding media, component for cement industries.
2.	Ajaokuta Steel Co. (Foundry), Ajaokuta	Iron, steel and non-ferrous castings	Grinding media, industrial spares and parts, auto-parts, components for cement industries.
3.	Delta Steel Co. (Foundry) Ovien/Aladja	Iron and steel castings	Grinding media, industrial spares and parts, components for cement industries, etc.
4.	Camplas Ltd., Lagos	Grey iron, alloy iron, higher grey iron, carbon steel and higher alloy steel	Grinding media, automotive castings, components and industrial spares, agric castings, gears, etc.
5.	Nigerian Machine Tools, Oshogbo	Iron, Steel and non-ferrous castings	Machine tools and components, industrial spares, auto components.
6.	Bamfords, Jos	Iron and steel castings	Agric machinery parts, auto components, industrial spares
7.	Olympics, Abagana	Iron castings	Pulleys, sleeves, auto components, industrial spares
8.	Jimex Group Nnewi	Non-ferrous castings	House-hold utensils, aluminium component castings, aluminium ingot
9.	Basic Tech., Kano	Iron and non-ferrous castings	Pulleys, gears, industrial agric and textile spares and components.

10.	Minesfield Eng. Ltd., Jos	Iron and non-ferrous castings	Parts for agricultural machineries.
11.	DIC., Kaduna	Iron and non-ferrous castings	Range of products depending on needs, parts for military vehicles and armament.
12.	Muhayak Co. Ltd., Owo	Iron casting	Water pump housing, impellers, brake disc., etc.
13.	Union Steel Ind., Ajase Ipo, Kwara State	Iron and non-ferrous castings	Spares and parts for textile and breweries industries.
14.	Abayomi Foundry, Ibadan	Iron castings	Grinding discs, industrial components
15.	Systemax Foundries, Otta	Iron and non-ferrous castings	Cast-iron products, bronze castings, industrial spares, deep well hand pumps.
16.	Addis Eng. Ltd., Lagos	Non-ferrous castings	Agric machineries, grinding machines, pounded yam machines, engineering components.
17.	Auto Components Ind., Otta	Non-ferrous castings	Engine support, rear axle support, door handles auto aluminium parts.
18.	Continental Foundry, Lagos	Iron and non-ferrous	Grinding discs, general castings, industrial spares.
19.	NRC, Lagos and Enugu	Iron and non-ferrous	Railways components, spares and parts.
20.	Fed. Institute of Ind. Research Oshodi, (FIIRO), Lagos	Iron and non-ferrous castings	Foundry research materials, R&D centre, industrial components and spare parts.
21.	N.M.D.C., Jos	Iron and steel castings	R&D Centre
22.	Nig. Sugar Co. Foundry, Bacita	Iron and non-ferrous castings	Impellers, pump casting, pulleys, etc.
23.	Leo Engineering Works, Ikeja, Lagos	Iron and non-ferrous casting	General castings, industrial parts and spares.
24.	Associated Tech. & Eng. Ltd., Ikeja, Lagos	Iron and non-ferrous castings	Engineering/machinery spare parts.
25.	Omodamwen & Sons Art Gallery, Benin City	Non-ferrous castings	Traditional Benin bronze castings.
26.	Bisbol Foundries & Eng. Work, Sango-Otta	Iron and non-ferrous castings	Bearing housing pump castings, pipe joints, industrial components and spares.

A. Casting Technology:

Most of the foundries use sand casting technology for their production. Other processes used by some foundries depending on the type of castings are Gravity/& Pressure Die Casting, Centrifugal Casting & Investment Casting. Table 5 shows the use of these processes in 27 foundries.

Table 5: CASTING PROCESSES IN USE IN SOME FOUNDRIES {Source: RMRDC (2000)}

S/N	Firm	Sand	Centrifugal	Investment	Gravity	Pressure
1.	NFL., Lagos	X				
2.	NMT., Oshogbo	X			X	X
3.	Olympic, Abagana	X				
4.	DSC, Warri	X				
5.	Bamford, Jos	X				
S/N	Firm	Sand	Centrifugal	Investment	Gravity	Pressure
6.	Canplas, Ltd.	X				
7.	ASCL, Ajaokuta	X				
8.	DIC, Kaduna	X				X
9.	Addis, Lagos	X			X	
10.	ESEMC., Enugu	X	X	X	X	
11.	Umon Steel, Ajasse Ipo	X				
12.	Jimex, Nnewi		X		X	X
13.	Nig. Sugar Co., Bacita	X				
14.	Minesfield, Jos	X				
15.	Auto Component, Otta		X		X	X
16.	Omodamwe & Sons, Benin	X		X		
17.	Basic Tech., Kano	X				
18.	Muhayak, Owo	X				
19.	Makeri, Jos		X		X	
20.	Systemax, Jos	X				
21.	Associated Tech., Lagos	X				
22.	Bishop Foundry, Lagos	X				
23.	Continental Foundry, Lagos	X				
24.	Leo Engineering Works, Ikeja, Lagos	X				
25.	FIIRO, Lagos	X				
26.	N.R.C., Lagos	X				
27.	NRC., Enugu	X				

The melting equipment is one of the major investments in a foundry and the selection of melting facility depends on product type, fuel availability and cost, casting technique used, daily output requirement, flexibility of melting, etc. The furnaces in use in foundries include crucible furnace, rotary, reverberatory, cupola, induction and arc furnaces

B. Raw Materials Requirement & Availability:

Major raw materials required by foundries include:

1. Foundry grade moulding sand
2. Bonding material such as Bentonite (Clay), Sodium Silicate.
3. Organic binders such as Phenolic Resins
4. Ethyl Silicate/Colloidal Silica for investment shell preparation
5. Additives such as Coal dust, iron oxide, dextrin, molasses, wood flour, etc.
6. Core Oils
7. Waxes
8. Epoxy Resin
9. Pig Irons Product of blast furnace where iron ore is smelted to get pig iron.
10. Metallic Scraps (C. I. Scrap, Steel Scrap, Al-alloy scrap, cu-alloy scrap, etc.)
11. Ferro-Alloys e.g. Ferro Silicon (Fe-Si); Fe Mn;
    Fe Cr; Fe Ti, Fe Mo, Fe V,
    Fe Si - Mn; Fe Si Mg, etc.
12. Aluminium Ingots and Aluminium Master alloys
13. Copper Ingots & Copper Master alloys
14. Limestone & other fluxing materials
15. Grain Refiner/Modifier for Ferrous and Non-ferrous Alloys.
16. Fluxing/Degassing Materials for Non-Ferrous
17. Refractory Materials for Furnace/Ladle Lining and Repair.
18. Black Oil

The above list is not exhaustive.

The materials listed above may not be required by all the foundries. The requirements will depend on the casting alloy used and melting/ casting technique adapted by a foundry. Table 6 lists the requirements of some materials based on the installed capacity utilization. The National demand as per year 1999 have also been indicated. There has not been significant improvement in these raw materials supply and availability over the years.

Table 6.0: RAW MATERIALS REQUIREMENT AT FULL CAPACITY{Source: RMRDC (2000)}

S/No.	Raw Materials	Unit	Full Capacity Requirement (Annual)		National Demand
			1996	1999	1999
1.	Dolomite/Limestone	MT	0.25 m	0.25 m	0.3 m
2.	Bentonite	"	240	270	405
3.	Ferro chromium alloy	"	275	275	412.5
4.	Ferro manganese alloy	"	26	26	39
5.	Ferro silicon alloy	"	22	22	33
6.	Refractory clay & blocks	"	180	180	270
7.	Steel scrap	"	0.126 m	0.126 m	0.22 m
8.	Tin	"	30.25	70.25	205
9.	Ferro alloys	"	60	100	150
10.	Cast Iron	"	9050	18.800	28.200
11.	Zinc Ingot	"	N/A	3.000	4.500
12.	Lead Ingot	"	N/A	210	315
13.	Black oil	Litres	60.000	60.000	90.000
14.	Iron Scraps	Tonnes	500	500	750

The foundries presently source metallic raw materials through the use of local iron and steel scrap collectors. However, when the Ajaokuta and Delta Steel Companies become fully operational, the scrap collectors would not be able to satisfy the foundry sub-sector. Most of the raw materials listed above are available in the country in the crude form. These are required to be processed, characterized and standardized for foundry use.

C. Infrastructural Facilities:

Infrastructural facilities are major source of constraint not only for the foundries but any type of industries. Erratic power supply, poor road and rail network, inadequate water and other facilities limit the growth of the foundries and the development of local raw materials. Metal casting is high energy intensive area and as a result of erratic power supply foundries set aside huge financial outlay in procurement, installation, operation and maintenance of in house power generating facility.

D. Manpower Requirement:

Foundries need skilled personnel for quality production of castings at various level. The manpower requirement of the sector based on the survey conducted by RMRDC indicates 3809 technical and 1424 administrative personnel. These figures are based on the existing foundries alone. However, there is a lot of scope for the increase in foundries and allied industries. Proper skill acquisition, education and training in metal casting technology is vital for the growth and development of this sector. In every state there are institutions at secondary and tertiary levels to impart the required knowledge but the facilities for practical training are grossly inadequate. There is need to equip these institutions with proper laboratory facilities.

E. Research and Development Facilities:

The main groups of organizations involved in Research & Development activities are:

i. Universities & Polytechnics and to some extent Colleges of Technology;

ii. Research institutions such as National Metallurgical Development Centre, Jos; Federal Institute for Industrial Research, Lagos, NASENI, Abuja.

iii. Major Industrial Organizations/ Companies as well as some government parastatals such as DIC, SEDI, NRC, etc.

Many of the Universities have qualitative and high level manpower and specialists in various fields but are handicapped by poor laboratory and workshop facilities and grossly inadequate funding. These institutions are in dire need of urgent and massive infusion of funds for refurbishing and re-equipping the laboratories, libraries and workshops with state of the art facilities. Notwithstanding the inadequate facilities, the Universities, Polytechnics and Colleges of Education have made considerable contributions through R & D in materials characterization, products and equipment development, troubleshooting and are rendering consultancy services to companies, entrepreneurs and governments.

Most industries rely on Universities and Research Institutions for solution of their scientific and technical problems, although under rather casual and informal arrangements. Large government parastatals such as NRC, SEDI, DIC, etc. have good facilities for R & D. Co-ordination and Co-operation between these industries and agencies, universities and research institutes are essential for the growth of the nation.

There are also some other important factors such as finance, markets and marketability, government policies, etc which need to be properly looked into for the improvement of the sector.

5.0 PROSPECTS & RECOMMENDATIONS:

There are great prospects and very wide area for the growth and development of foundry and allied industries in Nigeria. Many developed countries are shifting their foundries to the developing countries where there are sufficient raw materials, low labour cost and well trained personnel. Nigeria has almost all the raw materials required by foundries and large human resources. These 2M

(Materials & Man) have to be utilized to produce Machines and make Money with a better Management of all the resources and activities. Nigeria has all the potentials for becoming a big industrialized nation in the World. Future prospects for development and recommendations are listed below:

5.1 Raw Materials:-

- Many of the raw materials required by foundries are available in the country but they are in crude form. They are required to be explored, mined, processed, characterized and standardized for foundry use.

- Local substitutes for imported raw materials should be identified and developed. Depending on the type of materials, centre of Excellence may be established in Universities and Institutions for raw materials development and utilization.

- Due to capital intensive nature of some local raw materials government should encourage private entrepreneurs to establish joint ventures in those areas.

5.2 Technology Adaptation:-

New technology/processes are being developed and utilized for conserving materials and energy, reducing human labour and fatigue, minimizing machining and other operations, improving quality and reliability of products. These techniques have to be adopted using the locally available materials and facilities. There is also need to design and develop commonly used machines and tools. Development of machines will require many products to be made in foundries.

Many of the most commonly used processes for mould/core making are not well adapted by the foundries. Production of S. G. Iron, C. G. Iron, Austempered Ductile Iron need to be fully developed for which the required raw materials have to be locally sourced and produced. Investment casting process, though used by Benin artisan since centuries, need to be developed for producing engineering components. Very fine quality silica or zircon flour, wax formulation for pattern, ceramic slurry containing ethyl silicate or colloidal silica, standardized dewaxing and firing cycle are the major materials and process requirements for investment shell development.

5.3 Manpower Development:-

Highly skilled and well trained personnel at various stages of production are needed and the demand will keep on growing based on the growth of the sector. There is a need for establishing centre of Excellence in Colleges of Technology, Polytechnics and Universities. Skilled personnel from Colleges of Technology can be employed as technicians, trained personnel from polytechnics can be supervisory staff and the foundry engineers can take the responsibility of research, development, production or management. Training of trainers is also essential for better manpower development. Participation/attendance at international conference/workshop should be encouraged.

5.4 Research and Development:

Laboratories must be well equipped both for training as well as research and development activities. Apart from funds for lab. equipment and facilities, government should provide sufficient fund for meaningful research. The government should influence the established industries to finance the short and long term projects of their need. Close cooperation between industries and institutions must be established through confidence building. Institutions have to build confidence through their expertise, problem solving and facilities available.

6.0 CONCLUDING REMARKS:

Metal casting technology has not developed to the extent it should have. Many of the hurdles facing the growth of this vital industry have been pointed out and recommendations/suggestions have been made to face the challenges and overcome the hurdles to get the dividends in the future. The nation and the industry must view these challenges as opportunities for success, growth and industrial leadership. It must also recognize that collaborative arrangements between the industry and the institutions are necessary for its successful evolution and development.

- Metal Casting industry should strengthen its position in existing market, capture the markets served by imported products and seek new markets.

- Adoption and adaptation of technology using locally available materials is very essential for the industry. Universities and research institutions must characterize the industry's waste streams and research into methods of their elimination. They must develop materials technologies to improve the variety, integrity and performance of cast metal products. They must develop technology to increase productivity, reduce average lead time and reduce energy consumption.

- The metal casting industry realizes that its chief asset (beside its customers) is its people. The industry cannot hope to achieve its goal without trained people in sufficient numbers. There is presently a shortage of skilled labour in the industry. Continued educational programme of various types are needed for the industry to prosper.

- The programs and policies of the governments (Federal, State and Local Governments) must be implemented with honesty, sincerity& integrity. Without time bound implementations progress and development could never be realized.

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