

Sudan University Of  
Science and Technology  
College Of Graduate Studies



## **Evaluation of the quality control system at Khartoum Central Foundry**

**تقييم منظومة ضبط الجودة في مسبك الخرطوم المركزي**

A thesis Submitted in partial fulfillment of the Requirements for  
the Degree of M.Sc.

In Mechanical Engineering (Production)

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بسم الله الرحمن الرحيم

﴿ لَقَدْ أَرْسَلْنَا رُسُلَنَا بِالْبَيِّنَاتِ  
وَأَنْزَلْنَا مَعَهُمُ الْكِتَابَ وَالْمِيزَانَ  
لِيَقُومَ النَّاسُ بِالْقِسْطِ وَأَنْزَلْنَا  
الْحَدِيدَ فِيهِ بَأْسٌ شَدِيدٌ وَمَنَافِعُ  
لِلنَّاسِ وَلِيَعْلَمَ اللَّهُ مَن يَنْصُرُهُ  
وَرُسُلَهُ بِالْغَيْبِ إِنَّ اللَّهَ قَوِيٌّ  
عَزِيزٌ ﴾

الآية: 25 سورة: الحديد

## Dedication

*To my teachers, my family and friends*

## **Acknowledgements**

I wish to express my deepest gratitude to my supervisor, Dr. Abd Alfattah Bilal, for his support, advice and guidance throughout the course of my research.

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## **Abstract**

Metal casting industries are actively involved to reduce the scrap rejection and rework during the manufacturing process of the components. To achieve this, the production concerns must follow the quality control procedures correctly and perfectly without any negligence. This research addressed the problem of evaluation of quality control system using 5S method, at Khartoum Central Foundry. The method of analysis and comparison of data obtained from the field study has been used. The Research objectives are: reducing losses from the foundry productive, and improve the work environment using 5S, as well as activating the test lab equipment. Among the most significant findings of this research were: 82% of the defects production was due to the quality of the sand used in the work of casting molds, and also because of the lack of skilled technicians and workers as well as the operating system and the path are identical to the output quality. It is recommend to follow the method of 5S to improve the workplace, and raise production efficiency, and train workers and technicians on modern methods of processing templates, and to avoid mistakes in order to increase production and reduce waste, and also to provide the corresponding specifications of sand, by using the scientific method. A number of venues are proposed for future studies, including: Economic impact in following 5S system in an environment of Labor, and use simulation computerized program in foundries operations to improve the design of casting molds.

## المستخلص

تعني عميات المسابك بتقليل الفاقد لإعادة التصنيع وذلك بتقليل عيوب المنتج خلال عمليات التصنيع للأجزاء المسبوكة وللوصول إلى ذلك يجب إتباع إجراءات ضبط جودة صحيحة ومثلي. وتحسين أسلوب وطريقة الإنتاج لتلافي عيوب المنتجات إستنادا علي أبحاث ضبط الجودة. تناول هذا البحث مشكلة تقييم منظومة ضبط الجودة باستخدام طريقة S5 في مسبك الخرطوم المركزي. وقد إستخدم أسلوب تحليل ومقارنة البيانات التي حصل عليها من الدراسة الميدانية. اهداف البحث هي: تقليل الفاقد من إنتاجية المسبك و تحسين بيئة العمل باستخدام طريقة 5S وكذلك تفعيل أجهزة معمل الفحص.و كانت من أهم نتائج هذا البحث : 82 % من عيوب الانتاج تعود الي نوعية الرمل المستخدم في عمل قوالب الصب وأيضا بسبب قلة مهارة الفنيين والعمال وكذلك نظام التشغيل ومسار الانتاج غير مطابق للجودة.ومن الموصي به إتباع طريقة 5S لتحسين مكان العمل ورفع الكفاءة الانتاجية, وتدريب العمال والفنيين علي الطرق الحديثة في تجهيز القوالب, وتلافي الاخطاء وذلك لزيادة الانتاج وتقليل الفاقد, وأيضا بتوفير الرمل المطابق للمواصفات, واستخدامه بالطريقة العلمية.و أقترح عدد من العناوين لدراسات مستقبلية منها:الأثر الاقتصادي في إتباع نظام 5S في بيئة العمل, وإستخدام برنامج محاكاة عمليات السبك حاسوبيا لتحسين تصميم القوالب .

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# **CHAPTER ONE**

## **INTRODUCTION**

### **1.1 General:-**

Metal casting process begins by creating a mold, which is the 'reverse' shape of the part we need. The mold is made from a refractory material, for example, sand. The metal is heated in an oven until it melts, and the molten metal is poured into the mould cavity. The liquid takes the shape of cavity, which is the shape of the part. It is cooled until it solidifies. Finally, the solidified metal part is removed from the mould. A large number of metal components in designs are made by casting. The reasons for this include: Casting can produce very complex geometry parts with internal cavities and hollow sections. It can be used to make small (few hundred grams) to very large size parts (thousands of kilograms), It is economical, with very little wastage: the extra metal in each casting is re-melted and re-used, Cast metal is isotropic it has the same physical/mechanical properties along any direction. Common examples of casting products: door handles, locks, the outer casing or housing for motors, pumps, etc., wheels of many cars. Casting is also heavily used in the toy industry to make parts, e.g. toy- cars, planes, and so on.

### **1.2 Research problem:-**

Khartoum Central Foundry is a one of the biggest and well equipped foundries in Sudan. But the rejections of castings produced compared with the type of castings such as manholes covers, etc. is not acceptable (9% to 26% daily) (Acceptable range to 5%). Also considering the diversity of castings that can be produced for gray cast iron for example piston rings, wear resistant machines components, cylinder walls, machine frames and bases.

### **1.3 Importance of the research:-**

The current research is addressing the quality control system at (K.C.F.) A good quality control decrease the rejection of products and upgrade the product quality, which results in minimizing the time and cost of the products.

### **1.4 Methodology:-**

This research will be accomplished using case study in (K.C.F.) by collecting the data and information from the foundry work place, and the quality control department.

### **1.5 Research objective:-**

The objective of this thesis is to evaluate quality control system at (K.C.F.), and also to estimate the weakness of the working path and Determination the rejection causes of the products.

The specific objectives include:

1. To produce sand castings with minimum level of rejections.
2. To get use of the laboratories facilities at (K.C.F.).
3. To organize (K.C.F.) workplace.
4. To evaluate quality control system using 5S method (sort, straighten, shine, standardize and sustain.)

### **1.6 Hypotheses:-**

1. If adding inspection points in production path, the level of rejections reduced.
2. Efficient use of the laboratories facilities at (K.C.F.) increases the productivity.
3. If used 5S method, the work environmental be comfortable, helpful and effectiveness.

## 1.7 Technical terms:-

**a. Evaluation:** Evaluation is a systematic determination of a subject's merit, worth and significance, using criteria governed by a set of standards. It can assist an organization to assess any aim, realizable concept or proposal, or any alternative, to help in decision-making; or to ascertain the degree of achievement or value in regard to the aim and objectives and results of any such action that has been undertaken. The primary purpose of evaluation, in addition to gaining insight into prior or existing initiatives, is to enable reflection and assist in the identification of future change.

**b. Technological path:** Technology is the making, modification, usage, and knowledge of tools, machines, techniques, crafts, systems, methods of organization, in order to solve a problem, improve a preexisting solution to a problem, achieve a goal or perform a specific function. It can also refer to the collection of such tools, machinery, modifications, arrangements and procedures. Technologies significantly affect human as well as other animal species' ability to control and adapt to their natural environments. The word *technology* comes from Greek *τεχνολογία* (*technología*); from *τέχνη* (*téchnē*), meaning "art, skill, craft", and *-λογία* (*-logía*), meaning "study of-". The term can either be applied generally or to specific areas: examples include *construction technology*, *medical technology*, and *information technology* [1].

**c. Quality control:** Quality control emphasizes testing of products to uncover defects and reporting to management who make the decision to allow or deny product release, whereas quality assurance attempts to improve and stabilize production (and associated processes) to avoid, or at least minimize, issues which led to the defect(s) in the first place [1].

## **. CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.1 Preface:-**

The production of cast items was known from ancient times (second and first millennia B.C.) in China, India, Babylonia, Egypt, Greece, and Rome,

##### **2-1-1 Metal Casting Origins:-**

3200 B.C. A copper frog, the oldest known casting in existence, is cast in Mesopotamia. 2000 B.C. Iron is discovered. 800-700 B.C. First Chinese production of cast iron. 645 B.C. Earliest known sand molding (Chinese). 233 B.C. Cast iron plowshares are poured in China. 500 A.D. Cast crucible steel is first produced in India, but the process is lost until 1750 when Benjamin Huntsman reinvents it in England [2] .

##### **a. Middle Ages to 1800:-**

In 1455 Dillenburg Castle in Germany is the first to use cast iron pipe to transport water. In 1480 Birth of Vannoccio Biringuccio (1480-1539), the "father of the foundry industry," in Italy. He is the first man to document the foundry process in writing. In 1642 Saugus Iron Works, America's first iron foundry (and second industrial plant), is established near Lynn, Massachusetts. The first American iron casting, the Saugus pot, is poured there. In 1709 Englishman Abraham Darby creates the first true foundry flask for sand and loam molding. In 1720 Rene Antoine de Reaumur develops the first malleable iron, known today as "European Whiteheart". In 1730 Abraham Darby is the first to use coke as fuel in his melting furnace in Coalbrookdale, England. In 1750 Benjamin Huntsman reinvents the process of cast crucible steel in England. This process is the first in which the steel is completely melted, producing a uniform composition within the melt. Since the metal is completely molten, it also allows for alloy steel

production, as the additional elements in the alloy can be added to the crucible during melting. Prior steel production was accomplished by a combination of forging and tempering, and the metal never reached a molten state. In 1776 Foundrymen Charles Carroll, James Smith, George Taylor, James Wilson, George Ross, Philip Livingston and Stephen Hopkins sign the Mercian Declaration of Independence. In 1794 First use of the cupola in iron founding. Invented by John Wilkinson of England, the original had metal-cladding and utilized a steam engine to provide the air blast [2].

#### **b. The 19th Century:-**

In 1809 Centrifugal casting is developed by A. G. Eckhardt of Soho, England. In 1815 The cupola is introduced in the United States in Baltimore, MD. In 1818 First cast steel produced by the crucible process in the U.S. at the Valley Forge Foundry. In 1825 Aluminum, the most common metal in the earth's crust, is isolated. In 1826 Seth Boyden of Newark, NJ, is the first to develop a process for and produce "blackheart" malleable iron. In 1831 In Cincinnati, OH, William Garrard establishes the first commercial crucible steel operation in the U.S. In 1837 First dependable molding machine is marketed and used by the S. Jarvis Adams Company in Pittsburg. In 1845 The open hearth furnace is developed. In 1851 Sir Henry Bessemer and William Kelly both invent a simple converter that uses blasts of air to burn out the impurities, silicon, manganese and excess carbon in pig iron. Although Kelly is the first to use a converter, Bessemer obtains the U.S. patents. Kelly proves patent priority in 1857. In 1863 Metallography, the etching, polishing, and microscopic evaluation of metal surfaces, is developed by Henry C. Sarby of Sheffield, England. It is the first process to physically examine the surface of castings for quality analysis. In 1867 James Nasmythe develops a gear-tilted foundry ladle, increasing worker safety and operational economy. In 1870 Sandblasting is first used to clean large castings by R. E. Tilghman of Philadelphia. 1880-1887 the



Sly tumbling mill is developed. It is the first cleaning machine for small castings. This mill greatly reduced the time needed for hand-cleaning operations and produced a finer finished product. In 1896 American Foundrymen's Association (renamed American Foundrymen's Society in 1948 and now called the American Foundry Society) is formed. In 1897 Investment casting is rediscovered by B.F. Philbrook of Iowa. He uses it to cast dental inlays.

### **c. Early 20th Century:-**

In 1906 First electric arc furnace is used in the U.S. at Holcomb Steel Co. in Syracuse, NY. In 1913 First true stainless steel melted by Harry Brearley in Sheffield, England. 1913 Crucible Steel Casting Co.'s Lansdown, PA plant installs the first low-frequency electric furnace for special melting. In 1923 Formation of the International Committee of Foundry Technical Associations in Zurich, Switzerland. In 1924 Dr. W.H. Hatfield invents 18/8 stainless steel (18% chromium, 8% nickel). 1930s University of Michigan professors pioneer Spectrograph for metal analysis. In 1930 First high-frequency coreless electric induction furnace in the U.S. is installed in the Lebanon Steel Foundry in Lebanon, PA. In 1940 Wood flour is introduced into foundry practice as a sand additive. In 1947 The Shell process, invented by J. Croning of Germany during WWII, is discovered by U.S. officials and made public. 1948 Development of ductile iron, a cast iron with a fully spheroidal graphite structure. In 1949 U.S. patent granted to K.D. Millis, A.P. Gagnebin and N.B. Pilling of International Nickel Company for developing ductile iron. In 1953 The Hotbox system of making and curing cores in one operation is developed, eliminating the need for dielectric drying ovens. In 1958 H.F. Shroyer is granted a patent for the full mold process, the forerunner of the expendable pattern (lost foam) casting process. In 1960s Compactibility and methylene blue clay tests are developed for green sand control. Also developed at this time are high-pressure molding processes and fast-setting no-bake binders for

san. In 1964 the first Disamatic molding machine is introduced. In 1965 The Scanning Electron Microscope is invented by the Cambridge University Engineering Department in England. In 1965 Cast metal matrix composites are first poured at International Nickel Company in Sterling Forest, NY, by Pradeep Rohatgi. In 1968 The Coldbox process is introduced by L. Toriello and J. Robins for high production core making [2].

#### **d. Late 20th Century:-**

Early In 1970s The Semi-Solid Metalworking (SSM) process is conceived of at Massachusetts Institute of Technology. It combines aspects of casting with aspects of forging. In 1971 The Japanese develop V-Process molding. This method uses unbonded sand and a vacuum. In 1971 Rheocasting is developed at Massachusetts Institute of Technology. In 1971 U.S. Congress passes the Clean Air Act and OSHA, the Occupational Health and Safety Act. In 1972 The first production Austempered Ductile Iron (ADI) component is produced by Wagner Castings Company. In 1974 Fiat introduces the in-mold process for ductile iron treatment. In 1976 Compacted graphite iron (CGI), an iron with elongated graphite particles with rounded edges and roughened surfaces, is developed in the U.K. It has characteristics of both gray and ductile iron. In 1982 The Warm Box binder system is introduced. In 1993 First foundry application of a plasma ladle refiner (melting and refining in one vessel) occurs at Maynard Steel Casting Company in Milwaukee, WI. In 1995 Babcock and Wilcox, Barberton, OH, patent a lost foam vacuum casting process to produce stainless steel castings with low carbon content. In 1996 Cast metal matrix composites are first used in a production model automobile in the brake rotors for the Lotus Elise. In 1997 Electromagnetic casting processes developed by Argonne and Inland Steel Corporation. Electromagnetic edge containment greatly reduces cost and energy expenditures in steel production. [2]

### **2-1-2 Literature review:-**

Mustafa Ali, Msc. ,2002 ,design and programming of quality control system for Khartoum central foundry, Problem (K.C.F.) is the biggest and well equipped foundry in Sudan but the rejection of casting produced compare with the type of castings such as manholes covers etc. Is not acceptable, Objectives to produce sound castings with minimum level of reject and to get use of the laboratories facilitates at Khartoum center upgrading quality control department throw a programmable system, Conclusion the binding material bentonite dos not conform with the specification requirements resulting in high percentage of defects , using a programmed package , will modernize the system and gives high performance and better efficiency, establishing a quality control system is vital demand, usage of specifications decreases the possibility of defects, daily testing and recording data will give better feed for remedial action.

### **2-1-3 Classification of Cast iron: -**

Cast iron are mainly high carbon iron base alloys, the carbon content of cast iron, are above 1.75% and can be classified mainly as follows:-

#### **a- grey cast iron:-**

Are alloys of iron carbon and silicon in which carbon precipitates as graphite flakes, and it usually contains from (1.7% to 4.5% carbon) and (1% to 3% silicon). The machine ability of most gray cast iron is superior to that of virtually all steel because of the graphite discontinuities in the matrix occupied by the graphite break up the chips, and the graphite serves as a lubricant. It is widely used for machine components resist wear. It can be hardened when cooled rapidly quenched from a suitable elevated temperature, gray cast iron is the most suitable material for piston rings and cylinder walls of reciprocating piston engines [3].

As a result of its graphite flakes, gray cast iron has a high ability for damping out vibration. This makes it desirable for machine frames and bases. It can easily be cast. Some of the thin –wall and complex castings produced would not be practical to cast with other metals [4].

#### **b- White cast iron:-**

Grey cast iron is produced by graphitization in cast iron. However, if the carbon content is kept down to about (2.5%) and the silicon content is kept below (1.5%). The ordinary rate of cooling in a sand mould will not allow time for cementite decomposes into graphite and austenite. As a result white cast iron will be produced. Its principal constituents are pearlite and cementite when broken, its fracture will have silvery metallic appearance. All of the combined carbon in the white cast iron is precipitated as nodules of graphite. The nodules are small, fairly compact aggregations which are much more desirable for strength view point than flakes.

#### **c- Malleable Cast Iron:-**

White cast iron is also cast as the intermediate material for making malleable cast iron.

The casting is first cast as white cast iron, then by suitable heat treatment. Lasting, on the average, 90hr, the graphite nodules allows castings to be bent, and the mechanical properties are generally superior to those of gray cast iron. The maximum section thickness which can be malleablized is about (10 mms).

Each class is designated by a number followed by a letter. The number indicates the minimum tensile strength of the iron in a separately cast test bar, and the letter indicates the size of the test bar, for example (20A) 20 refer to 20(p.si.) and A to test bar size. This is as per American Standard for Testing and Materials (ASTM).

## **2-2 Foundry Industry:-**

It is a branch of industry that produces castings by filling molds with molten alloys, the annual volume of foundry production in the world is more than 80 million tons. Casting is used to produce an average of about 40 percent (by weight) of stock for machine parts, but in some areas of machine building, such as machine-tool manufacture, the proportion of cast parts is 80 percent. Machine building consumes about 70 percent of all cast stock, the metallurgical industry consumes 20 percent, and 10 percent is used in sanitary engineering. Cast parts are used in metalworking lathes, internal-combustion engines, compressors, pumps, electric motors, steam and hydraulic turbines, rolling mills, agricultural machines, motor vehicles, tractors, locomotives, and railroad cars. A considerable volume of cast products, particularly from nonferrous alloys, is used in aircraft construction, the defense industry, and instrument-making. The foundry industry also produces water and sewer pipes, bathtubs, radiators, heating boilers, and furnace parts.

The use of castings is widespread because they may be produced with a shape that approaches that of the finished articles more closely than the shape of blanks produced by other methods, such as forging. Stock of varying complexity may be produced by casting without large machining allowances, which reduces the consumption of metal and the expenditures for machining and ultimately lowers the cost of the articles. Casting may be used to produce articles of virtually any weight, ranging from a few grams to hundreds of tons, with walls a fraction of a millimeter to several meters thick. The most important alloys used in the production of castings are gray, malleable, and alloy cast iron (up to 75 percent of all castings by weight), carbon and alloy steel (more than 20 percent), and nonferrous alloys (copper, aluminum, zinc, and magnesium alloys). The area of use of cast parts is constantly broadening [3].

Foundry production is varied and is divided as follows:

(1) according to the method of filling the mold-ordinary, centrifugal, and pressure-die casting; (2) according to the method of production of the mold-single-use mold casting, casting with multiple-use ceramic or sand-and-clay molds (semi-permanent molds, which last for up to 150 castings, with repairs), and casting with multiple-use (permanent) metal molds, such as chill molds, which can withstand several thousand castings. Production of blanks and billets by casting uses single-use sand molds and self-hardening shell molds. Single-use molds are made by means of a pattern assembly and a mold box.

Production of castings in single-use sand molds is the most widespread method in the industry. It is used for the production of a variety of castings from various alloys. The castings may have any desired size and shape. The industrial process of casting in sand molds (see Figure 2.1) consists of a series of sequential operations: preparation of materials, preparation of the mixtures for molds and cores, production of molds and cores, installation of cores and assembly of molds, melting of metal and pouring into molds, cooling of the metal and knockout of the finished casting, cleaning of the casting, heat treatment, and finishing.

(See Fig. 2.2, Fig. 2.3).

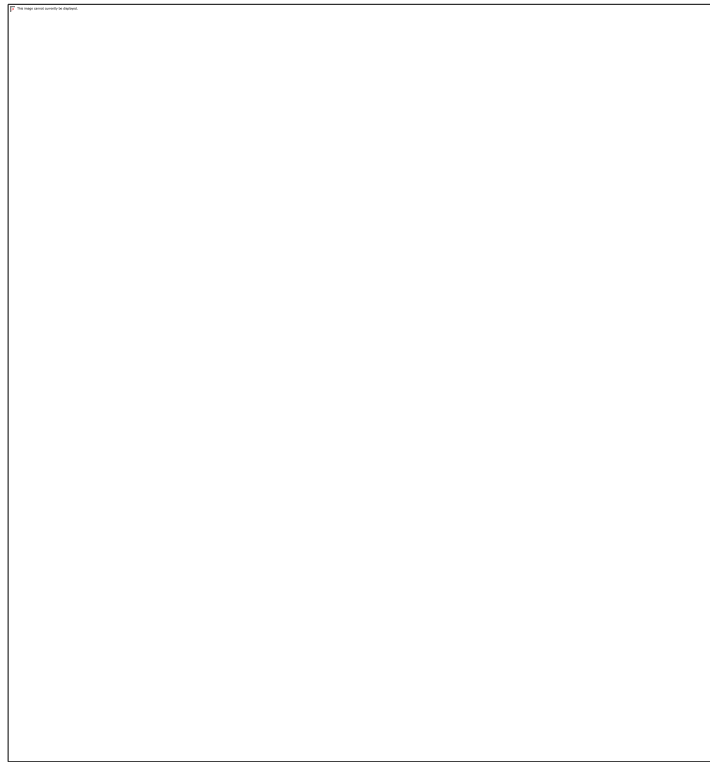


Figure2.1: Basic operations of the industrial process of production of castings in sand molds

The three basic constituents of cast iron that affect strength, hardness and chilling characteristics are total carbon, silicon and phosphorus. The index which combines the effects of these elements is known as the carbon equivalent value and is normally calculated from the simple formula:

$$\text{Carbon equivalent value} = \text{Total carbon \%} + \frac{\text{Silicon \%} + \text{Phosphorus \%}}{3} \quad [3]$$

To meet specification requirements there is an obvious need to know the chemical analysis, carbon equivalent value or chilling characteristics of the metal as soon as it has been tapped from the furnace and before it is poured into the moulds. Chemical analysis is too slow, spectrographic analysis gives only the silicon value unless special techniques too expensive for the majority of foundries are used, and the chill test is open to a number of operational variables. The materials used for the production of single-use molds and cores are divided into the initial molding

materials and molding sands; the average weight of these materials is 5–6 tons per ton of usable castings per year. Spent molding sand knocked out of the mold boxes is used in the preparation of fresh molding sand, which also contains fresh clay-sand or bentonite-type materials, additives to improve the properties of the mix, and water. The core sand mix usually consists of quartz sand, binders (oil, resin, and other materials), and additives. The mixtures are prepared in a fixed sequence in mixing equipment, which includes screens, driers, mills, crushers, magnetic separators, and mixers.

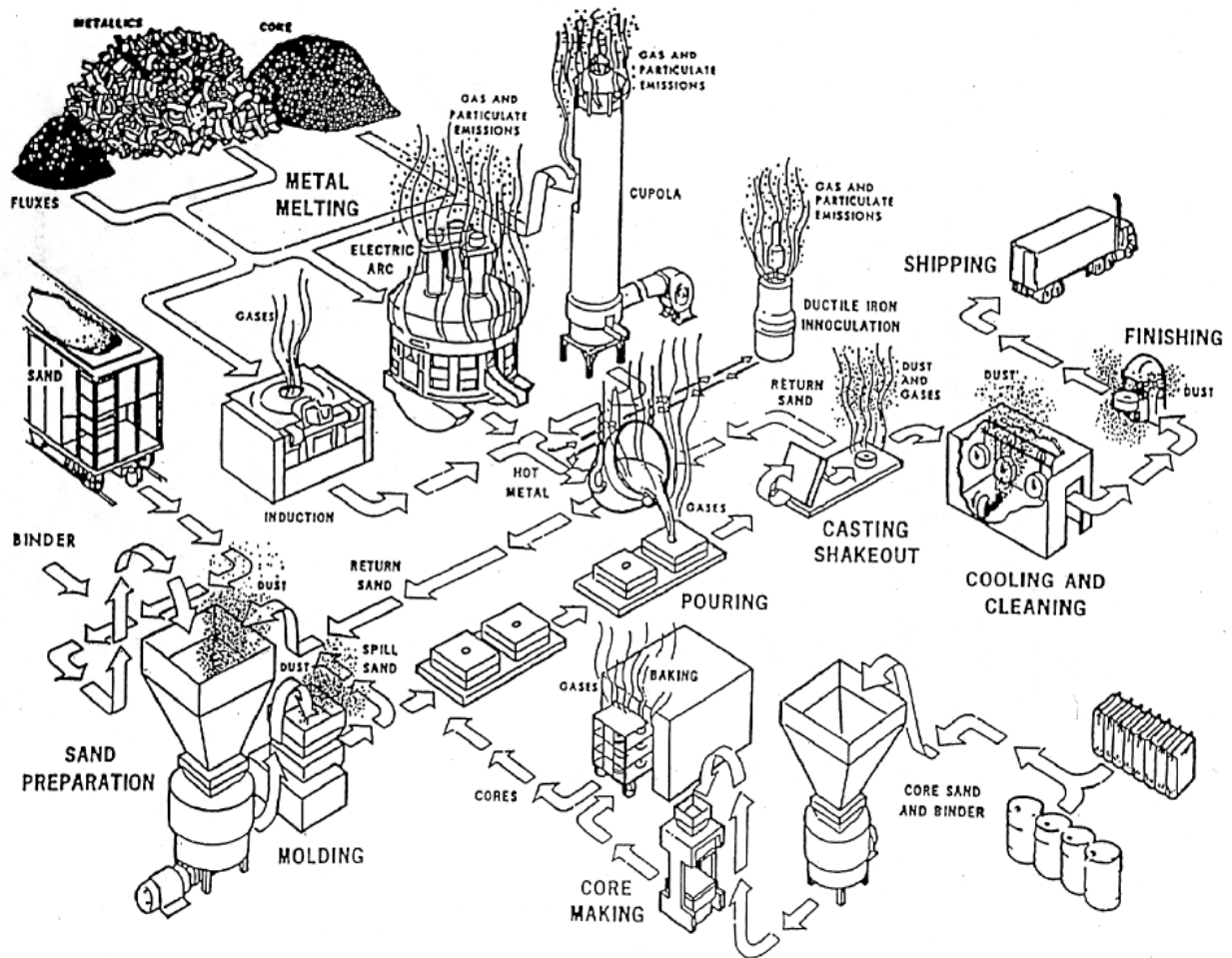
Molds and cores are produced on special molding equipment and machines. The mixture poured into a mold box is compacted by shaking or compression or by both methods simultaneously. Large molds are filled using sand slingers; sand-blowing machines are used less frequently. The molds in the mold boxes and the cores formed in the core boxes undergo heat drying or chemical hardening, for example, in casting in self-hardening molds. Heat drying is performed in foundry driers, and cores may also be dried in the heated core boxes. The assembly of molds consists of installation of the cores, mating of the mold halves, and fastening of the molds with clamps or weights, which are placed on the cope to prevent them from opening during pouring. A pouring basin made of core sand mix or molding sand is sometimes installed on the mold.

Metal is melted in furnaces of various types and having various output levels, depending on the composition of the alloy. Cast iron is most frequently produced in cupola furnaces, but electrically heated crucible, electric arc, induction, and channel furnaces are also used. Some ferrous alloys, such as white cast iron, are produced sequentially in two furnaces, for example, cupola and electric furnaces (the duplex process). The melt is poured into molds from ladles, which periodically receive quantities of melt from the melting furnace. The hardened castings are usually knocked out using vibrating screens or pneumatic knockouts. In the process, the

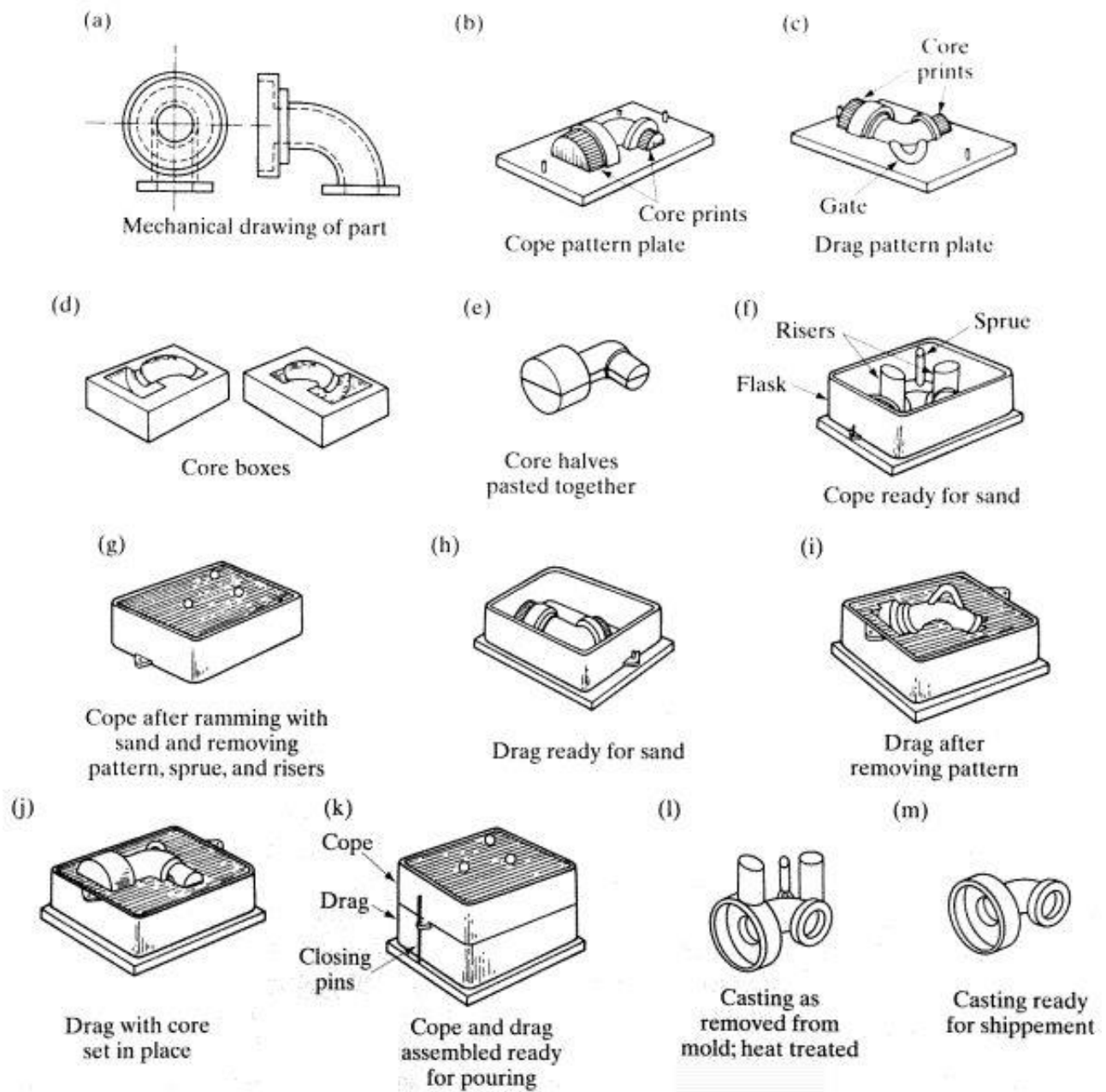


molding sand drops through the screen and is conveyed to the mixture-preparation section for reprocessing, and the castings are transported to the cleaning section. The cleaning procedure involves removal of burned-on molding sand, knocking off (cutting off) the gating elements, and grinding off excess metal and the remains of the gating. These operations are performed in tumbling barrels and in shot-blasting and shot-slinging installations. Large castings are cleaned by the hydraulic method in special chambers. Cutting and grinding operations on castings are performed by pneumatic chisels and abrasive tools. Nonferrous metal castings are finished on lathes.

To attain the required mechanical properties, most steel, malleable cast-iron and nonferrous metal castings undergo heat treatment. After the quality of the castings is checked and any casting defects are repaired, the cast articles are painted and sent to warehouses for finished goods [3].



**Fig. 2.2: Work flow in typical sand casting foundry**

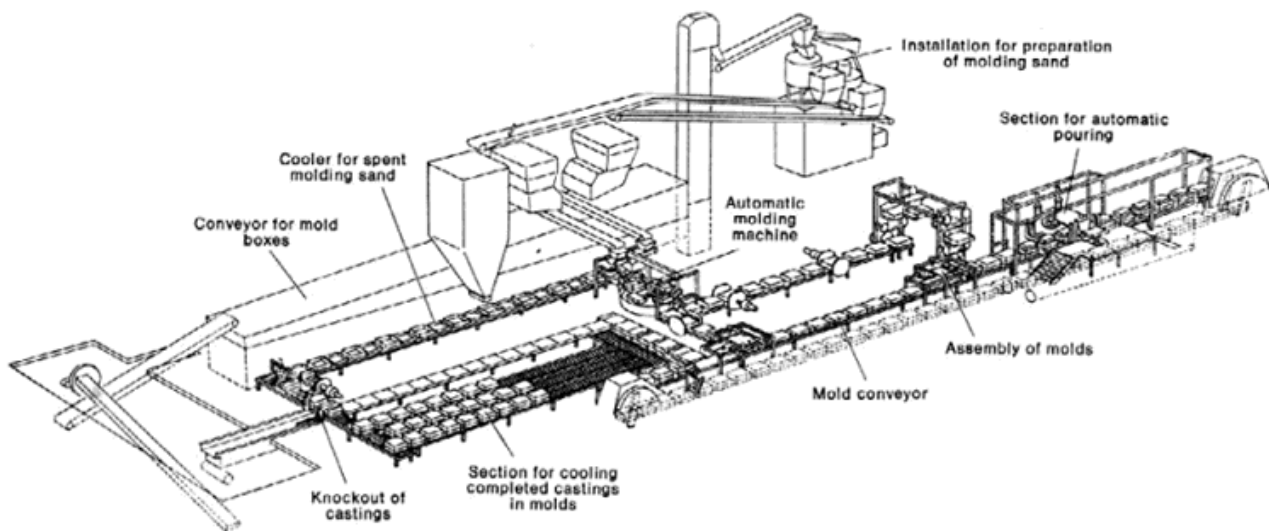


**Fig. 2.3: Schematic showing steps of the sand casting process**

## **2- 2-1 Mechanization and automation:-**

Most of the operations in the foundry industry are very labor-intensive and take place at high temperatures, with evolution of gases and quartz-containing dust. To reduce the labor requirements and create normal sanitary and hygienic working conditions in foundries, various means of mechanization and automation of the technological processes and transportation operations are used. The introduction of mechanization into the foundry industry dates to the mid-20th century, when sand mullers, sifters, and mixers were used for preparing molding mixtures, and sandblasters were used for cleaning castings. Simple molding machines were designed for manual filling of molds; hydraulic presses appeared later. Molding machines with pneumatic shaking appeared in the 1920's and were rapidly adopted. An attempt was made to substitute machines for manual labor in every operation: equipment for the production of molds and cores and devices for the knockout and cleaning of castings were improved; transportation of materials and finished castings was mechanized; and conveyors and methods for flow production were introduced. The subsequent growth of mechanization is reflected in the design of improved machines, automated casting machines and casting production lines, and in the introduction of complete automation in various production areas and foundries. The most labor-intensive operations in foundry production are molding, production of cores, and cleaning of the finished castings. The engineering operations in these areas are maximally mechanized and partially automated. The introduction of integrated mechanization and automation is particularly effective in the foundry industry. Automated lines for molding, assembly of molds, and pouring, as well as cooling and knockout of castings, are promising. For example, molding, pouring, and knockout are automated in the foundry line of the Swiss Bühler-Fischer system (Figure 2.4). Satisfactory performance has been achieved with an installation for

automated pouring of molds on a continuously moving conveyor (Fig. 2.5). The weight of the molten alloy required to fill the molds is controlled by an electronic instrument, which takes into account the capacity of a given mold. The installation is equipped with an automatic system for preparing the molding sand, monitoring its quality, and regulating its preparation (the Swiss Moldability Controller system). Straight-through, continuous-operation drums with shot-slinging devices are used for finishing operations (cleaning and deburring of castings). Large castings are cleaned in continuous-operation chambers, within which the castings are moved on conveyors. Automatic cleaning chambers have been designed for castings with cavities of complex shape. The Omco-Pangborn company (USA-Japan) developed the Robot chambers.



**Fig. 2.4:** Automatic line of the Bühler-Fischer system (Switzerland) for preparation of molds, casting, and knockout of castings.

Each chamber is an independent mechanism for the transportation of castings that operates automatically, executing commands received from the guidance modules, which are arranged on a monorail transportation system. A hanger, from which the casting is automatically suspended, rotates in the cleaning zone with an optimum speed according to a preset program. The doors of the chamber are opened and closed automatically.

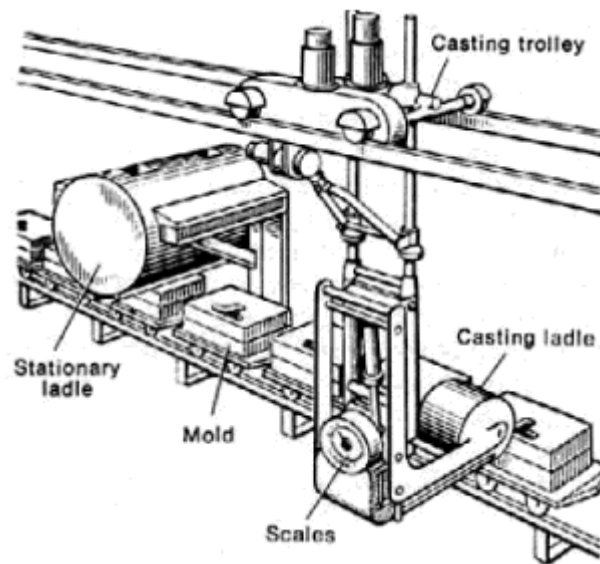


Fig. 2.5: Installation for automatic pouring on a conveyor  
(H. Fischer plant, Switzerland)

In mass production, the preliminary (rough) smoothing of castings (stripping) is performed in foundries. During this operation the reference surfaces of castings for subsequent processing on transfer lines in the machine shops are also prepared.

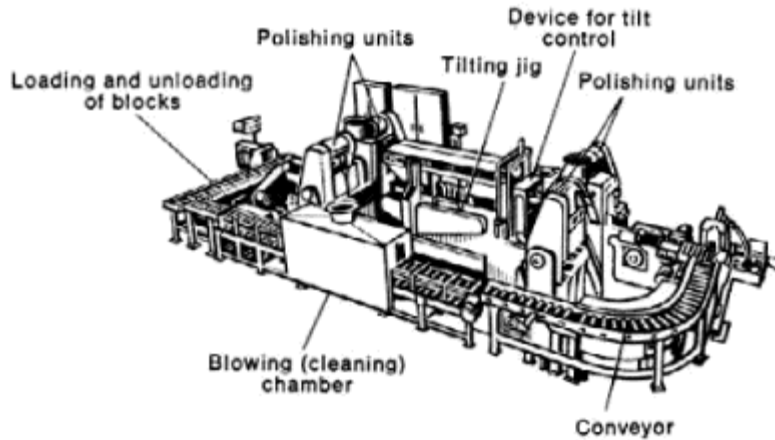


Fig. 2.6: Automatic line for cleaning engine blocks, with polishing assemblies  
(Noritake Company, Japan)

The finishing operations may also be performed on transfer lines. An automatic line of the Japanese Noritake Company for cleaning the blocks of motor-vehicle engines is shown in Figure 2.6. Such a line makes possible the processing of 120 blocks per hour.

Opportunities for mechanization and automation in the foundry industry increased significantly after the development of basically new industrial casting processes, such as production of shell molds, or the ironing process (Federal Republic of Germany, 1940's), fabrication of cores in cold core boxes (Great Britain, 1950's), and fabrication of cores with hardening in hot core boxes (France, 1960's). The use of the lost-wax method in the industry for the production of precision castings began as early as the 1940's. All operations of this process were soon mechanized. Fully automated lost-wax foundry production in the USSR is 2,500 tons of small castings per year (see Figure 2.5).

### **2-2-2 Sand used in foundries:-**

The major use of dune sand is in foundries. The sand is used to make molds and cores. The molds are used to form metal into a variety of shapes. Core sand fills the spaces where metal is not needed or wanted. The requirements are very demanding. Dune sand is particularly suited to foundry use because, it can withstand the high temperatures (from 1,300° to 1,700°C) of the molten metal, it can withstand associated pressure, gasses can escape through the sand, and the sand has the proper texture and composition to make a smooth casting and does not react with the metal. The following average compositions are seen in natural molding sand: 65.5% silica grains, 21.7% clay content, 12.8% undesirable impurities. Sand properties are checked regularly in most foundries. At best, the sand can be recycled only about twice before it can no longer be used and becomes a waste product.

Sand casting and glass making are two of the oldest industrial processes known. There is hardly a manufactured product made or an industrial process used that does not utilize some form of these two industrial techniques in its makeup or in its fabrication. The fixtures and tools used to make almost all manufactured products are made from sand castings. The tools to make these tools were made from sand castings. Therefore, any decision affecting the cost and availability of industrial sand will have a wide reaching, multiple effects on the cost and availability of almost every manufactured product and its competitive advantage in the market place. The elevated financial position of the foundry industry attests to the economic importance of industrial sand and its total impact on all other industries, and ultimately the cost of almost all fabricated goods sold. This type of sand is needed because of its high chemical purity, grain size, shape, and distribution. Sand and sandstone meeting these specifications are used in metal casting. Some sand is also used as a scouring agent, traction sand in rail transportation, lining for high-temperature furnaces, and in the manufacture of metallurgical alloys. Thus, one aspect of sand and gravel



mining that is not often realized is that many sites are simply sand mines. Often we think of sand and gravel operation as one where both are mined at the same time, and through sieving they are separated and sold as discrete products. However, in dune areas clean, pure sand alone is mined and utilized. Early foundries removed natural sand from small pockets along river banks and local sand hills as their needs dictated. These sands were a composite mixture of sand, clay, and other materials. Since the early 1900's, industry demands and its associated advancing technology created the need for unbounded sand. Unbounded sand has very little clay or other impurities present. Dune and coastal strip sands and crushed sandstone are the leading sources of unbounded sand. The industrial advantages of unbounded sand are: more uniform grain size, Greater tolerance to heat, less bonding material and moisture required (additives), workability, and greater suitability for a variety of foundry uses. One of the prime indicators of superior sand quality is fineness of grain size. Grain fineness is a measure of the amount of sand passing through certain screens. Grain size and shape affect both the escape of hot gases from the molten metal poured into the mold and surface texture of the casting. The finer the sand used the smoother the finish. Generally speaking, finer grained sands are used on smaller size castings. Extraneous material, such as clay or broken sand grains, will plug off the pore spaces of the mold causing blistering, pock marks, and weaken the casting. The sand grains themselves must be durable so that the sand may be reclaimed and reused time after time up to 25 times or more depending on the type of casting and technique employed.

The chemical quality of the sand is also important. The sand must contain less than 2% carbonate. If too much carbonate is present it reacts with acid based binding material and causes the prepared mold to lose strength. Other extraneous minerals such as mica and feldspar cause the mold to react with the molten metal causing abrasions and weakening of the cast [5].

## **2-3 Quality controls:-**

### **2-3-1 Definition of quality:-**

The word 'quality' has different meanings under different circumstances. The quality of a product may have greater or lesser significance depending on the need and requirement of the user. The easiest way to define quality would be "the degree to which a product meets the requirements of a customer." Or still simply, "the fitness of a product or service for its intended use' Quality control includes all efforts to manage quality and maintain assurance of continued high quality of product or service. Thus, quality control conveys an idea about determining and maintaining that quality of the product or service which will satisfy the customer by its performance, cost and delivery. An item, even if produced to a level of quality higher than that demanded by the customer will not be appreciated if its cost is too high or if it is delivered too late. Customer satisfaction is therefore the key to effective quality assurance [6].

### **2-3-2 Historical background of quality control:-**

If we look back into the history of human evolution, it will be observed that quality has always been integrated into the development of human society. It is quite possible that ancient builders and artisans were more skilled and quality-conscious than what we profess to be today. However, quality was confined to manual skills, workmanship and proficiency. The entire work of building houses, halls, temples, producing agricultural implements, as well as arms and ammunition was taken as a matter of art. In the period before the industrial revolution in Europe, the entire manufacturing activity was carried out by the cottage industry spread over villages and remote areas away from large towns which relied heavily on the craftsmen. The craftsmen in turn trained apprentices thoroughly who later took over their positions. Thus, skills and quality were passed on from one generation to the next this trend is still very much evident in various trades

which are dominated by specific communities such as textile dyeing and printing for hand loom cloth, lock smithy, statue making, sculpturing, wood work etc.

With the advent of the industrial revolution, manufacturing was broken up into small parts. Craftsmen became inspectors and standards started to emerge. Thus, gradually, three or four classes of workmen were formed; the highly skilled, skilled, semi-skilled and un-skilled. The two World War demanded a further expansion in manufacturing, mass production methods of manufacturing were developed in all areas of engineering and technology. Mechanization and later automation were introduced for faster production. With these changes the demand for skills reduced and industries relied more on inspectors to ensure quality of the product it was realized that quality was the responsibility of everyone right from the drawing board stage through project definition, planning, material processing and production, supply and customer service. Schewart for the first time, brought a statistical approach to quality control in the year 1924. Later during and after the Second World War, statistical quality control became an essential technique to assist in quality control and production. The era of 'quality control' changed to 'quality assurance'. Deming and Juran contributed to a large extent in the late forties by introducing statistical practices and ushering in the modern concept of quality assurance.

In the early fifties, K. Ishikawa introduced a new technique of worker motivation for improving quality and called it 'quality circles'. Training tools, like the cause and effect diagram and Pareto analysis were used. The 'zero defect' concept and 'right first time' concepts were introduced in the west at the same time. The emphasis on the inspection of the final product to achieve the desired quality was shifted to controlling quality at every stage of production and thus, the term "total quality control" was introduced by Fiegenbaum in the year 1983, which was later changed to "total quality management",

The year 1987 saw the introduction of quality standards at an international level and the ISO 9000 series was brought out as a guideline for developing a quality system. This could help a company in designing, building, and maintaining quality of a product thus satisfying the requirements of the customer on a consistent basis. These standards have been revised in view of the experiences gained over these years and a large number of companies, not only in the manufacturing sector but also in the service, education and training sectors all over the world have accepted these standards and have got the necessary accreditation from authorized agencies.

Inspect of the fast evolution of quality requirements, the business and industry are facing a challenges, which has to be faced with confidence. The challenges are, Increasing demand by the customer for quantity, More stringent demand for quality, Increasing competition in the market, squeezing profit margins, Changes in technology and materials used, Increasing wages and labor costs, More laws for environment control.[6]

### **2-3-3 Need for quality improvement and control:-**

The need for quality control and quality assurance in all areas of industrial production as well as in the foundry industry is greater today than ever, it is not possible to produce a desired quality and maintain it consistently over a length of period unless adequate control is exercised at every stage. Quality management should be taken as a continuous phenomenon, implying that there is no end to improvement; it is an unending process.

The stages can be defined as follows:-

- Set quality standards.
- Plan methods, technology, materials tooling, and personnel to achieve the specified quality.
- Manufacture right the first time.
- Inspect and report any quality shortcomings.

- Carry out corrections in process, controls, tooling, etc.
- Re-plan for long term quality control.

To plan and manufacture right the first time can be further elaborated as follows

- Incoming materials control, supplier maintenance and audit, supplier improvement, supplier rating.
- Employee training and development.
- Process planning, process documentation, new product introduction.
- Gauge and fixture control.
- Equipment maintenance and spare parts control.
- Set-up and first piece control.
- Process capability determination.
- Statistical process control.
- In-process inspection and test.
- In-process audits and finished goods audit.
- Quality data system and documentation.
- Corrective action program.
- Out-going quality level improvement.

Doming has evolved major points for improving quality, which are summarized below:-

- Establish the objective of working towards continuous innovation and improvement.
- Adopt a new philosophy that we cannot accept the old mistakes and defects.
- Cease dependence on mass inspection; require statistical evidence that quality has been built in the process.
- End the practice of awarding business on the basis of price.
- Use statistical techniques to find the trouble spots.
- Institute modern methods of training on the job.

- Improve quality of supervision, doing what is right for the company, not just turning out quantity.
- Break down barriers between different departments, and also with suppliers and customers so that there will be open and effective communication.
- Eliminate posters and slogans. They do not help in solving problems.
- Eliminate work standards that prescribe a numerical quota and disregard quality.
- Remove barriers between workers and their right to pride in workman-ship.

Control of metal quality is becoming increasingly important in the iron founding industry as customers demand tighter specifications and apply more rigorous inspection techniques on the components ordered. Quality mission of a manufacturer is to meet the quality requirement of specific consumer through specifications and the elemental building block out of which quality is constructed is the quality characteristic a physical or chemical property used to define the nature of product or services is a quality characteristic. Foundries all over the world have as a common aim of producing castings in quantity and quality adequate to the market therefore the concept of quality must be used in realistic form. That is to say must be established by management that determines the optimum situation in which the satisfaction of the customers is obtained with the minimum of production and control cost. To achieve consistency in quality, a casting must be produced with the minimum variation in production condition. When this is achieved one of the main problems of the maintenance of high quality production is solved. The maintenance of the quality is assisted by inspection. The function of inspection is to separate well from bad casting and to insure that only the good castings are passed to the customer, then information should be studied to solve the production problems. One of the main important tools used for analysis of data obtained is the statistical tools which are applicable to most of the operations within the foundry” [6].

### **2-3-4 Statistical process control (SPC) in foundries:-**

Quality control involving statistical analysis may broadly be applied in two ways. One is for controlling the quality of materials as they are received and processed through various stages of production till the finished or final product is ready for dispatch to the customer. The control of quality in this case is mainly confined to various materials going into production, may these be raw materials, in-process materials, supplies or finished product. The type and nature of controls exercised and the quality of these controls are not concerned with the processes, methods, operations or techniques being used to carry out production.

The other type of application of statistical control in production is where the quality or consistency of the processes used during all the stages of production is to be controlled and maintained. This control is specifically termed as 'statistical process control.' For example, while pouring molten iron from a ladle into a mould in a foundry, the process parameters which need careful control are composition of metal, particularly, carbon and silicon content, pouring temperature, pouring time or pouring rate.

It is possible to maintain statistical control on some of these parameters which show a tendency to vary so that their values can be maintained throughout and undesirable deviations are highlighted. Statistical controls can be applied to any of these parameters which will control the process quality in order to finally produce the right product. All such controls are grouped for convenience as statistical process controls and these are employed at every stage of production. Statistical process control uses statistical analysis of data collected from a process in order to monitor and control each stage of that process. The aim of SPC is to improve the performance of processes by emphasizing on the prevention of defects rather than on the detection of defects after they have already been produced. Correct application of SPC techniques, therefore, not only

serves to improve and ensure product quality but also helps in minimizing process costs due to wasteful production [7].

## **2-4 Types of defects:-**

Several types of defects may occur during casting, considerably reducing the total output of castings besides increasing the cost of their production. It is therefore essential to understand the causes behind these defects so that they may be suitably eliminated. Casting defects may be defined as those characteristics that create a deficiency or imperfection contrary to the quality specifications imposed by the design and the service requirements. Defects in castings may be of three basic types: (I) major defects, which cannot be rectified, resulting in rejection of the casting and total loss; (II) defects that can be remedied but whose cost of repair may not justify the salvage attempt; and (III) minor defects, which clearly allow the castings to be economically salvaged and thereby leave a reasonable margin for profit.

Broadly, the defects may be attributed to: (I) unsuitable or unsatisfactory raw materials used in moulding, core making or casting; (II) the application of unsatisfactory moulding or casting practice by the individual worker or incorrect advice by the supervisor; (III) the use of improper tools, equipment, appliances, or patterns; and (IV) unprofessional management policies relating to the fixing of incentive plans and setting up of production procedures, faulty organization and poor work discipline, or lack of training.

Castings are born on a designer's drawing board where sections of a casting are assumed to be of metal, uniformly sound, homogeneous and having certain mechanical and other characteristics. The relation between these assumptions and the castings actually produced depends largely on the casting design, materials used, foundry practice, and the nature of the alloys. The common types of defects encountered in castings, their causes and remedies are discussed as follows. [8]



**a. Shift:** A shift results in a mismatch of the sections of a casting usually at a parting line. This defect is usually easy to identify. Unless the error caused due to mismatching is within the allowable variation on the casting, it cannot be rectified and the casting has to be scrapped. Misalignment of flasks is a common cause of shift. The defect can be prevented by ensuring proper alignment of the pattern or die parts, moulding boxes, correct mounting of patterns on pattern plates, and checking of pattern flasks, locating pins, etc. before use. Like the shift of the two or more parts of the moulds, core shift may also occur due to misalignment of cores or core halves during assembly. It may also be the result of undersized or oversized core prints or the failure to use core sets, or if the chaplets used are of the incorrect size. Core shift can be prevented by using prints and chaplets of the proper dimension and design

(See Figure 2.7)



**Fig.2.7: Shift**

**b. Warped Casting:** Warped is an undesirable deformation in a casting which occurs during or after solidification. Large and flat sections or intersecting sections are particularly prone to warpage. A proper casting design can go a long way in reducing the warpage of the casting. A judicious use of ribs can prevent the warping tendency, but an incorrectly placed rib may worsen the defect. Warpage may also be due to (I) too small flasks, which may cause rapid cooling of the edges or ends of the casting; (II) weak flasks, which may allow movement of the sand mould walls; (III) insufficient gating system, which may not allow rapid pouring of metal; (IV) sand with too low green strength, which may cause it to move; and (V) Non-provision of camber allowance on the pattern, wherever necessary.

A warped casting can be straightened wherever the shape permits and where the metal of the casting is not brittle. If warping cannot be altogether eliminated, extra warpage allowance may have to be provided along with the machining allowance so that it can be subsequently machined. (See Figure 2.8)



**Fig. 2.8: Warped Casting**

**c. Swell:** A swell is an enlargement of the mould cavity by metal pressure, resulting in localized or overall enlargement of the casting. It may be caused by insufficient ramming of the sand. If molten metal is poured too rapidly, a swell may occur. Insufficient weighing of the moulds during pouring may also cause the cope to lift, giving a swell.

**d. Fin:** A thin projection of metal, not intended as part of the casting, is called a fin. Fins usually occur at the parting of the mould or core sections. A 'run-out' of molten metal may be considered an extreme type of fin. Moulds and cores incorrectly assembled will cause fins. "Kiss cores" of shorter length than necessary may also give rise to a fin. High metal pressures due to too long sprue, insufficient weighing of the moulds or improper clamping of flasks may again produce the fin defect or, if the trouble is more critical, run-out may result. A pattern that is too large for a given flask or placed too close to the flask edge may result in a weak spot and give rise to run-out. Improper sealing of moulding joints may also produce run-outs.

**e. Blowhole:** are smooth and round holes clearly perceptible on the surface of the casting. They may be either in the form of a cluster of a large number of small holes having a diameter of about 3 mm or less or in the form of one large and smooth depression. Blowholes are caused in a casting by the generation and/or accumulation of gas or entrapped air in the mould cavity. Gas may accumulate when permeability of sand is low, such as when sand contains high moisture, sand grains

are too fine, sand is rammed too hard, or when venting is insufficient. To prevent blowholes, the moisture content in sand must be well adjusted, sand of the proper grain size should be used, ramming should not be too hard, and venting should be adequate. (Fig. 2.9a), (Fig. 2.9b)



**Fig. 2.9a: Blowhole of casting**



**Fig.2.9b: Blowhole of casting**

**f. Pinholes:** are numerous holes of small diameter, usually less than 2 mm. visible on the surface of the casting. They are caused by the absorption of hydrogen or carbon monoxide when the moisture content of sand is high or when steel is poured from wet ladles or is not sufficiently degasified. The defect can be minimized by using good



**Fig. 2.10: Pinholes**

melting and fluxing practices, by reducing the moisture content of moulding sand and increasing its permeability, and by promoting a faster rate of solidification (See Fig. 2.10) .

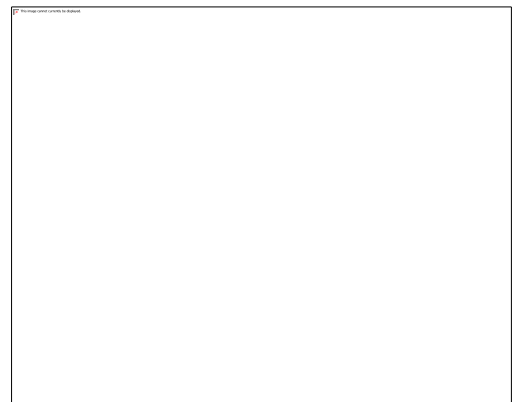
**g. Gas Holes:** are those holes that appear when the surface of the casting is machined or when the casting is cut into sections. If the core prints are of inadequate size, gas cannot escape from the mould as fast as it is generated in the cores. The accumulation of gas from the core may give rise to gas holes in the casting Faulty and poor quality of metal, the lack of controlled solidification.



**Fig. 2.11: Gas holes**

and excessively moist sand may also create gas holes.  
(See Fig 2.11)

**h. Shrinkage Cavity:** is a void or depression in the casting caused mainly by uncontrolled and haphazard solidification of the metal. It may be due to wrong location or an improperly sized gating system, inadequate risers, or poor design of casting involving abrupt changes of sectional thicknesses. Shrinkage may also be produced if the pouring temperature is too high.



**Fig. 2.12: Shrinkage Cavity**

The defect can be eliminated by applying the principles of directional solidification in mould design and by judicious use of chills, denseness and padding.  
(See Fig. 2.12)



**i. Porosity:** is also due to gas formation and gas absorption by the metal while it is poured. Metal may dissolve some gas or air from the mould or core faces. These gases are liberated later when the metal cools, leaving behind porosity in the casting. Obviously, the porosity defect may lead to leaking castings and reduce pressure tightness. Adequate fluxing of metal and controlling the amount of gas-producing materials in the moulding and core-making sand mixes can help in minimizing this defect.

**j. Drops:** When the upper surface of the mould cracks and pieces of sand fall into the molten metal, 'drop' occurs. Sand having too low green strength, soft ramming or insufficient reinforcement of the mould may cause this defect. (See Fig. 2.13)



**Fig.2.13: Sand Drop**

**k. Dirt:** generally appears in the form of foreign particles and sand embedded on the surface of the casting. The causes for this defect may be crushing of the mould due to mishandling, sand wash when the metal is poured because of low strength and soft ramming, insufficient fluxing of molten metal, and the presence of slag in the mould due to its incomplete separation from molten metal. (Fig. 2.14)



**Fig.2.14: Dirt**

**l. Metal Penetration and Rough Surfaces:** This defect appears as an uneven and rough external surface of the casting. It may be caused when the sand has too high permeability, large grain size, and low strength. Soft ramming may also cause metal penetration.

**m. Slag Holes:** These are smooth depressions or cavities on the upper surface of the casting or near it, usually near the in-gates, and are produced when the slag tends to find its way into the mould cavity along with the molten metal. Incorrect gating system and poor fluxing of metal are mainly responsible for this defect.

**n. Scabs:** are a sort of projection on the casting which occurs when a portion of the mould face or core lifts and the metal flows beneath in a thin layer. Scabs can be recognized as rough, irregular projections on the surface containing embedded sand. Scabs are of two types: (i) expansion scabs, and (ii) erosion scabs.



**Fig.2.15: Scabs**

An expansion scab is caused by the expansion of the surface layers of the sand mould. It may occur on any part of the mould, but more often it is found where the sand gels strongly heated, such as the top face of the mould which gets heated first by the radiation of heat from the molten metal rising upwards and then by actual contact with the molten metal. Heating by radiation causes a thin outer layer of sand to dry up and expand, leaving the interior green. This local expansion subjects the layer to severe stress and it eventually cracks. Molten metal enters through the crack and flows behind the layer of sand. It thus appears as a shallow, flat-topped projection on the casting. Olivine or zircon sands, due to their low thermal expansion, are much less prone to scabbing than silica sand. . (See Fig. 2.15)

Defects caused by foundry men (workers) shown in figures (2.16), (2.17), (2.18)



**Fig.2.16: Poring metal is insufficient**



**Fig.2.17: Break (crack)**



**Fig. 2.18: Leakage**

## 2.5 The 5S. Method:-

5S is the name of a workplace organization method that uses a list of five Japanese words: seiri, seiton, seiso, seiketsu, and shitsuke. Transliterated or translated into English, they all start with the letter "S". The list describes how to organize a work space for efficiency and effectiveness by identifying and storing the items used, maintaining the area and items, and sustaining the new order. The decision-making process usually comes from a dialogue about standardization, which builds understanding among employees of how they should do the work. There are five primary 5S phases: They can be translated from the Japanese as "sort", "straighten", "shine", "standardize", and "sustain". [9]

### a. Sort:-

- Remove unnecessary items and dispose them properly
- Make work easier by eliminating obstacles
- Reduce chance of being disturbed with unnecessary items
- Prevent accumulation of unnecessary items
- Evaluate necessary items with regard to cost or other factors
- Remove all parts not in use
- Segregate unwanted material from the workplace. (See Fig. 4.1).



**Fig. 4.1: Example of sorting in work place**



(K.C.F.) work place as shown in the Fig.4.2

- many unnecessary items in
- Many of obstacles Make work harder
- Increase chance of being disturbed with unnecessary items
- Accumulated of unnecessary items
- Many parts not in use
- The unwanted material is not segregated from the workplace.



**Fig. 4.2: K.C.F. work place (Unsorted)**

**b. Straighten or "set in order":-**

- Arrange all necessary items so they can be easily selected for use
- Prevent loss and waste of time
- Make it easy to find and pick up necessary items
- Ensure first-come-first-served basis
- Make workflow smooth and easy

(K.C.F.) work place as shown in the fig.4.3.

- The necessary items not arrange so they cannot be easily selected for use
- loss and waste of time
- Make it hard to find and pick up necessary items
- Make workflow difficult



**Fig. 4.3: Work place (Untidy and insecure)**

### c. Shine or "sweep":-

- Clean your workplace completely
- Use cleaning as inspection
- Prevent machinery and equipment deterioration
- Keep workplace safe and easy to work (See fig.4.4)



**Fig. 4.4: Example of Standardized work place**

### d. Standardize:-

- Maintain high standards of housekeeping and workplace organization at all times
- Maintain cleanliness and orderliness
- Maintain everything in order and according to its standard
- Everything in its right place
- Prominently display a picture or diagram showing the proper layout of the workspace



**Fig. 4.5: Painting**

### e. Sustain:-

- To keep in working order
- Perform regular audits [10].

# **CHAPTER THREE**

## **EVALUATION OF THE QUALITY CONTROL SYSTEM IN KARTOUM CENTRAL FOUNDRY**

### **3-1 Preface:-**

In this chapter the Q.C. system composed of locating nine check points as shown in (fig.3.1). These check points cover the control and testing of raw materials, in process and final castings products at (K.C.F.) where at each check point the characteristics to be tested were mentioned. Also standard methods of testing, .Finally statistical tools were used for results analysis such as average, range, standard deviation and control charts.(P – control chart) and pareto analysis for defects.

For check points two to eight variable inspection method was used, except check point six where only visual inspection was required for mold assembly while attribute inspection was used for final casting products.

### **3- 2. Khartoum Central Foundry:-**

(K.C.F.), was established in 1971 and it was co-financed by United Nations Industrial Development Organization. Since it became a sick factory with a low production of 10 to 12 tons per month, it was transferred to Sudanese Sugar Co. Ltd (S.S.C.) from the Ministry of Industry for rehabilitation. The rehabilitation was envisaged with 3000 tons per year with the same equipment and layout facilities by using latest technologies and aimed at import substitution by producing various castings for local market and particularly for sugar industry viz., boiler furnace grate bars, cane cutting knives, etc. and fully equipped Central Machine Shop.[ 11].

Equipment and facilities at foundry are: -

- Two medium frequency induction furnace of (1.5mt) each.
- Semi automatic sand plant with capacity (6mt) sand processing/hr
- Moulding machines – (box size):

Large moulding line – (70×60cms)

Medium moulding line – (60×50cms)

Small moulding line – (40×30cms)

-Shot plastic machine 500kg

-Overheat cranes (5mt) for materials and metal handling.

-Laboratory – fully equipped laboratory for raw materials and sand testing, metallurgical and mechanical testing.

-Separate substation with (33KV).

-Well equipped pattern shop for wooden and metallic patterns.

Foundry products:

Foundry castings vary and include several requests in the local market

The main castings produced by (K.C.F.) are:-

Spare parts for sugar factories, Links for power cables, Spare Parts for textile factories, Parts grain mills, Manhole covers –light and heavy duty, Pipe joints – 2"up to 14" size, Bushes and shafts, Impellers and other casting.

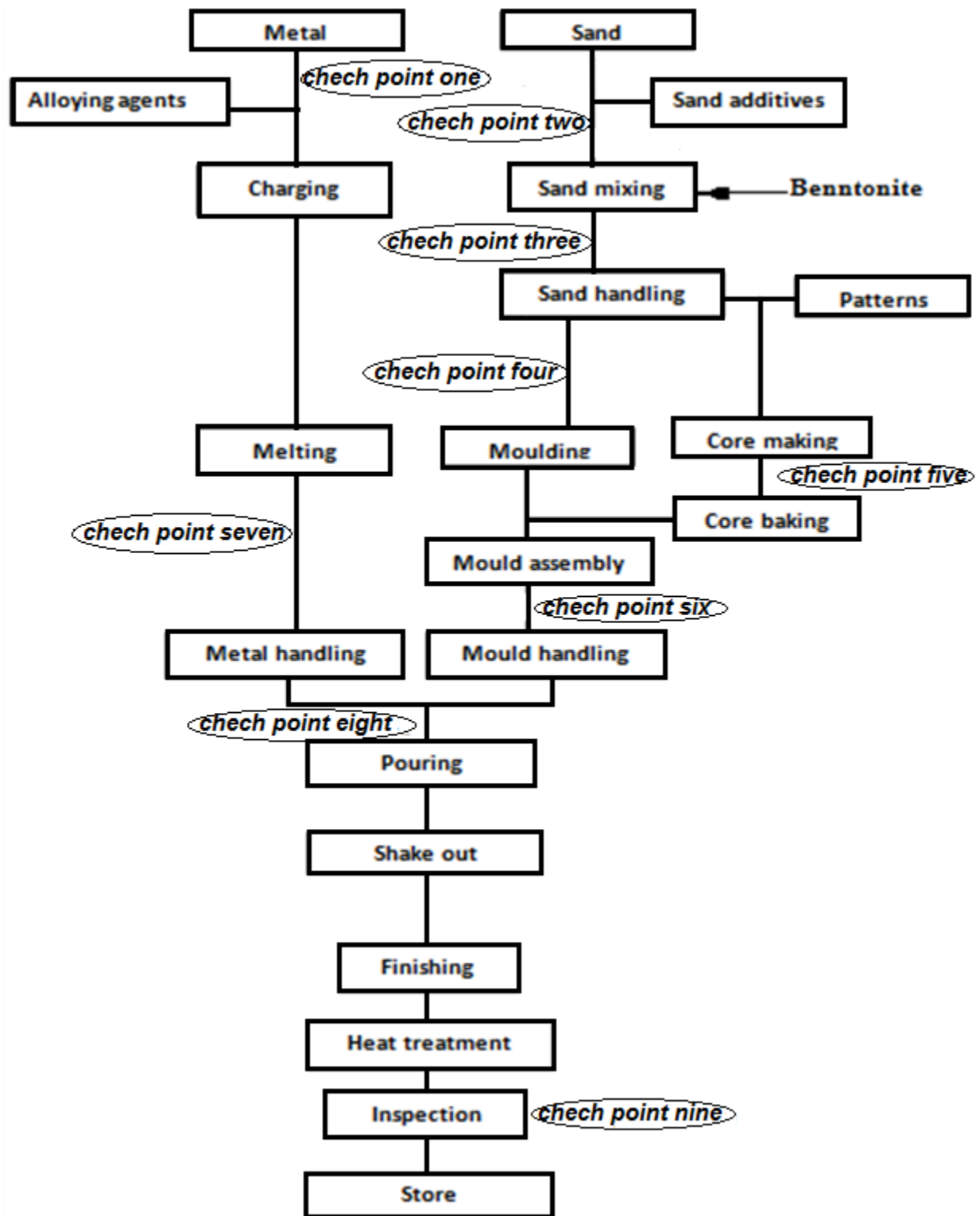


Fig. 3.1: Flow sheet of existing metal casting operation in (K.C.F.)



**The nine check points located at (K.C.F.) are as following:**

**1-check point one:-**

This is where the sorting out of the scrap is done. (Fig.3.2)



**Fig. 3.2: Raw material (scrap)**

**2-check point two:-**

This is where the quality of the national sand is being tested, the measuring parameters are:

2-1 Clay content

2-2 Grain fineness

### 3- Check point three:-

This is where the quality of the bentonite is being tested, the measuring parameters are:

3-1 Loss on drying percentage (Fig. 3.3), (Fig.3.4)

3-2 Gel formation index

3-3 Swelling power

3-4 Loss on ignition and

3-5 Matter soluble in water



**Fig. 3.3: Loss on drying percentage**



**Fig. 3.4: Digital scales for weighing sand**

#### **4- Check point four:-**

This is where the quality mould mixture is being tested, the main measuring parameters are:

4-1 Green compression strength G.C.S  $\text{gm/cm}^2$  (See Fig. 3.5)

4-2 Permeability

4-3 Moisture content percentage and

4-4 Compactability

Testing procedure shown at appendix (1)





**Fig. 3.5: Green compression strength G.C.S gm/cm<sup>2</sup>**

**5- Check point five:-**

This is where the quality of Core mixture is being tested, the measuring parameters are the same as for mould mixture.

Testing procedure is the same as mould mixture.

#### **6- Check point six:-**

This is where visual inspection is being done for the assembly of mold and core to the molding box. (See Fig. 3.6)



**Fig. 3.6: Check the installation**

#### **7-Check point seven:**

This is where the chemical composition of the charged metal is being analyzed,(the device analyzed 25 measuring parameters) the main measuring parameters are:

7-1 Carbon content %

7-2 Silicon content %

7-3 Manganese content %

7-4 Sulphur content % (See Fig. 3.7, Fig. 3.8, Fig. 3.9)

7-5 Measuring temperature, before pouring. (See Fig. 3.11)

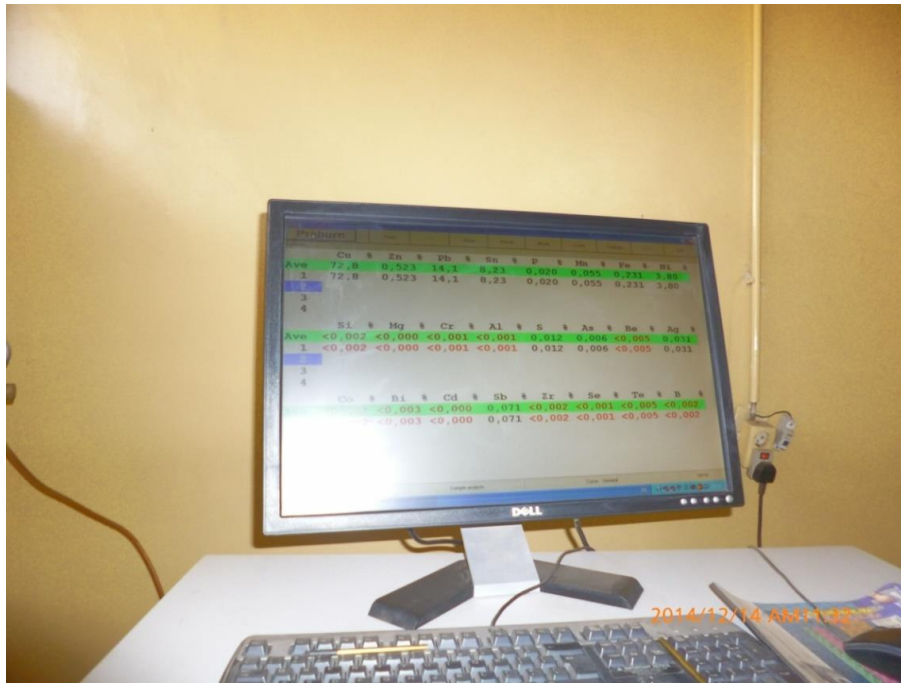
Testing procedure shown at appendix (2).



**Fig. 3.7: Specimen for test**



**Fig. 3.8: Spectrometer**



**Fig. 3.9: Screen show the chemical composition**



**Fig. 3.10: Microscopic Examination, Microstructure Analysis**





**Fig. 3.11: Temperature measuring tool**

**8-Check point eight:-**

This is where the mechanical properties of the cast iron is being tested, the measuring parameters are:

8-1 Tensile strength

8-2 Hardness

**9- Check point nine:-**

This is where finished product is inspected for casting defect.

## CHAPTER FOUR

### RESULTS AND DISCUSSIONS

#### 4.1 The results:-

In this chapter the results are shown after the data analyzed and give the suggestions to improve the foundry products.

The aim of this research to evaluate quality control system for Khartoum Central Foundry the results as shown in the table 5.1, 5.2 and figure 5.1 calculated using an Excel package program. The researcher find that the average rejections of casting products (Bufflow wheel) = 9.2% of the total number of products. It is greater than allowable defects (5%).

A p-chart is an attributes control chart used with data collected in subgroups of varying sizes. Because the subgroup size can vary, it shows a proportion on nonconforming items rather than the actual count. P-charts show how the process changes over time.

The p formula (for the proportion of nonconforming units from subgroups that can vary in size):

$$\bar{p} = \frac{np}{n} \qquad \bar{p} = \frac{\sum np}{\sum n}$$

To calculate control limits for the p-chart:

$$UCL_P, LCL_P = \bar{P} \pm 3 \sqrt{\frac{\bar{P}(1-\bar{P})}{n}}$$

As shown in the table 3 Non-conformance distribution for Bufflow wheel for 9 parameters. They parameters are: - Breaks, Fin, Gas Holes, Sand holes, Dirt, Blowhole, Warped, Shrinkage Cavity and Mold drops.

Table 5.1: Defect units for casting (Bufflow wheel)

No	Item Description	Gross wt Wt	Net wt Wt	Inspected		Pass		Rejected			Y	Re marks
				No	Wt	No	Wt	No	Wt	%		
1	Bufflow wheel	11	7.5	42	462	33	247.5	9	67.7	21.4	5	×
2	Bufflow wheel	11	7.5	65	715	50	375	15	113	23.1	5	×
3	Bufflow wheel	11	7.5	118	1298	102	765	16	120	13.6	5	×
4	Bufflow wheel	11	7.5	115	1265	107	802.5	8	60	7.0	5	×
5	Bufflow wheel	11	7.5	85	935	75	562.5	10	75	11.8	5	×
6	Bufflow wheel	11	7.5	122	1342	116	870	6	45	4.9	5	✓
7	Bufflow wheel	11	7.5	199	2189	189	1417.5	10	75	5.0	5	✓
8	Bufflow wheel	11	7.5	75	825	67	502.5	8	60	10.7	5	×
9	Bufflow wheel	11	7.5	102	1122	94	705	8	60	7.8	5	×
10	Bufflow wheel	11	7.5	202	2222	186	1395	16	120	7.9	5	×
11	Bufflow wheel	11	7.5	240	2640	220	1650	20	150	8.3	5	×
12	Bufflow wheel	11	7.5	234	2574	214	1605	20	150	8.5	5	×
13	Bufflow wheel	11	7.5	150	1716	148	1110	8	60	5.3	5	×
14	Bufflow wheel	11	7.5	208	2508	214	1805	14	105	6.7	5	×
15	Bufflow wheel	11	7.5	234	2574	220	1650	14	105	6.0	5	×
16	Bufflow wheel	11	7.5	220	2420	198	1485	22	165	10.0	5	×
17	Bufflow wheel	11	7.5	234	2574	224	1680	10	75	4.3	5	✓
18	Bufflow wheel	11	7.5	158	1738	145	1007.5	13	97.5	8.2	5	×
19	Bufflow wheel	11	7.5	234	2574	226	1695	8	60	3.4	5	✓
20	Bufflow wheel	11	7.5	172	1892	154	1155	18	135	10.5	5	×
21	Bufflow wheel	11	7.5	102	1122	95	712.5	7	52.5	6.9	5	×
22	Bufflow wheel	11	7.5	132	1452	119	892.5	13	97.5	9.8	5	×
23	Bufflow wheel	11	7.5	102	1122	96	720	6	15	5.9	5	×
24	Bufflow wheel	11	9	34	374	27	243	7	63	20.6	5	×
25	Bufflow wheel	14	10	44	616	44	440	0	0	0.0	5	✓
26	Bufflow wheel	11	7.5	102	1122	100	750	12	90	11.8	5	×
27	Bufflow wheel	11	7.5	73	803	66	496	7	52.5	9.6	5	×
28	Bufflow wheel	11	7.5	54	594	52	390	2	15	3.7	5	✓
29	Bufflow wheel	11	7.5	68	748	59	442.5	9	67.5	13.2	5	×
30	Bufflow wheel	11	7.5	76	836	68	570	8	60	10.5	5	×
31	Bufflow wheel	11	7.5	216	2376	201	1507.5	15	113	6.9	5	×
32	Bufflow wheel	11	7.5	144	1584	128	960	16	120	11.1	5	×
33	Bufflow wheel	11	7.5	214	2354	179	1342.5	35	263	16.4	5	×
34	Bufflow wheel	11	7.5	212	2332	190	1425	22	165	10.4	5	×
35	Bufflow wheel	11	7.5	35	385	29	217.5	6	45	17.1	5	×
36	Bufflow wheel	11	7.5	192	2112	172	1290	20	150	10.4	5	×
37	Bufflow wheel	11	7.5	84	924	82	615	2	15	2.4	5	✓
38	Bufflow wheel	11	7.5	112	1232	106	795	6	45	5.4	5	×
39	Bufflow wheel	11	7.5	92	1012	84	630	8	60	8.7	5	×
40	Bufflow wheel	11	7.5	90	990	71	532.5	13	97.5	14.4	5	×
41	Bufflow wheel	11	7.5	96	1056	80	600	16	120	16.7	5	×
42	Bufflow wheel	11	7.5	147	1617	120	900	27	202	18.4	5	×
43	Bufflow wheel	11	7.5	125	1375	112	840	13	97.5	10.4	5	×
44	Bufflow wheel	9	7.5	201	1809	180	1350	21	158	10.4	5	×
45	Bufflow wheel	9	7.5	134	1206	108	810	26	195	19.4	5	×

46	Bufflow wheel	9	7.5	192	1728	174	1305	18	135	9.4	5	×
47	Bufflow wheel	9	7.5	150	1350	135	1012.5	15	113	10.0	5	×
48	Bufflow wheel	9	7.5	222	1998	206	1545	16	120	7.2	5	×
49	Bufflow wheel	9	7.5	140	1260	125	937	15	113	10.7	5	×
50	Bufflow wheel	9	7.5	141	1269	130	975	11	82.5	7.8	5	×
51	Bufflow wheel	9	7.5	216	1944	198	1485	18	135	8.3	5	×
52	Bufflow wheel	9	7.5	218	1962	201	1507.5	17	128	7.8	5	×

Table 5.2: Defect units for p-chart calculated using an Excel program.

sample no	defect units	sample size	P	UCL	+2 Sigma	+1 Sigma	Average	-1 Sigma	-2 Sigma	LCL
1	9	42	0.214	0.226	0.182	0.137	0.092	0.048	0.003	0.000
2	15	65	0.231	0.200	0.164	0.128	0.092	0.056	0.020	0.000
3	16	118	0.136	0.172	0.146	0.119	0.092	0.066	0.039	0.012
4	8	115	0.070	0.173	0.146	0.119	0.092	0.065	0.038	0.011
5	10	85	0.118	0.186	0.155	0.124	0.092	0.061	0.029	0.000
6	6	122	0.049	0.171	0.145	0.118	0.092	0.066	0.040	0.014
7	10	199	0.050	0.154	0.133	0.113	0.092	0.072	0.051	0.031
8	8	75	0.107	0.193	0.159	0.126	0.092	0.059	0.025	0.000
9	8	102	0.078	0.178	0.150	0.121	0.092	0.064	0.035	0.006
10	16	202	0.079	0.153	0.133	0.113	0.092	0.072	0.052	0.031
11	20	240	0.083	0.148	0.130	0.111	0.092	0.074	0.055	0.036
12	20	234	0.085	0.149	0.130	0.111	0.092	0.073	0.054	0.036
13	8	150	0.053	0.163	0.140	0.116	0.092	0.069	0.045	0.021
14	14	208	0.067	0.152	0.132	0.112	0.092	0.072	0.052	0.032
15	14	234	0.060	0.149	0.130	0.111	0.092	0.073	0.054	0.036
16	22	220	0.100	0.151	0.131	0.112	0.092	0.073	0.053	0.034
17	10	234	0.043	0.149	0.130	0.111	0.092	0.073	0.054	0.036
18	13	158	0.082	0.161	0.138	0.115	0.092	0.069	0.046	0.023
19	8	234	0.034	0.149	0.130	0.111	0.092	0.073	0.054	0.036
20	18	172	0.105	0.158	0.136	0.114	0.092	0.070	0.048	0.026
21	7	102	0.069	0.178	0.150	0.121	0.092	0.064	0.035	0.006
22	13	132	0.098	0.168	0.143	0.117	0.092	0.067	0.042	0.017
23	6	102	0.059	0.178	0.150	0.121	0.092	0.064	0.035	0.006
24	7	34	0.206	0.241	0.192	0.142	0.092	0.043	0.000	0.000
25	0	44	0.000	0.223	0.180	0.136	0.092	0.049	0.005	0.000
26	12	102	0.118	0.178	0.150	0.121	0.092	0.064	0.035	0.006
27	7	73	0.096	0.194	0.160	0.126	0.092	0.058	0.025	0.000
28	2	54	0.037	0.210	0.171	0.132	0.092	0.053	0.014	0.000
29	9	68	0.132	0.198	0.162	0.127	0.092	0.057	0.022	0.000
30	8	76	0.105	0.192	0.159	0.125	0.092	0.059	0.026	0.000
31	15	216	0.069	0.151	0.132	0.112	0.092	0.073	0.053	0.033
32	16	144	0.111	0.165	0.141	0.116	0.092	0.068	0.044	0.020
33	35	214	0.164	0.152	0.132	0.112	0.092	0.072	0.053	0.033
34	22	212	0.104	0.152	0.132	0.112	0.092	0.072	0.053	0.033
35	6	35	0.171	0.239	0.190	0.141	0.092	0.043	0.000	0.000
36	20	192	0.104	0.155	0.134	0.113	0.092	0.071	0.051	0.030



37	2	84	0.024	0.187	0.155	0.124	0.092	0.061	0.029	0.000
38	6	112	0.054	0.174	0.147	0.120	0.092	0.065	0.038	0.010
39	8	92	0.087	0.183	0.153	0.122	0.092	0.062	0.032	0.002
40	13	90	0.144	0.184	0.153	0.123	0.092	0.062	0.031	0.001
41	16	96	0.167	0.181	0.151	0.122	0.092	0.063	0.033	0.004
42	27	147	0.184	0.164	0.140	0.116	0.092	0.068	0.045	0.021
43	13	125	0.104	0.170	0.144	0.118	0.092	0.066	0.041	0.015
44	21	201	0.104	0.154	0.133	0.113	0.092	0.072	0.051	0.031
45	26	134	0.194	0.167	0.142	0.117	0.092	0.067	0.042	0.017
46	18	192	0.094	0.155	0.134	0.113	0.092	0.071	0.051	0.030
47	15	150	0.100	0.163	0.140	0.116	0.092	0.069	0.045	0.021
48	16	222	0.072	0.151	0.131	0.112	0.092	0.073	0.053	0.034
49	15	140	0.107	0.166	0.141	0.117	0.092	0.068	0.043	0.019
50	11	141	0.078	0.165	0.141	0.117	0.092	0.068	0.044	0.019
51	18	216	0.083	0.151	0.132	0.112	0.092	0.073	0.053	0.033
52	17	218	0.078	0.151	0.131	0.112	0.092	0.073	0.053	0.033

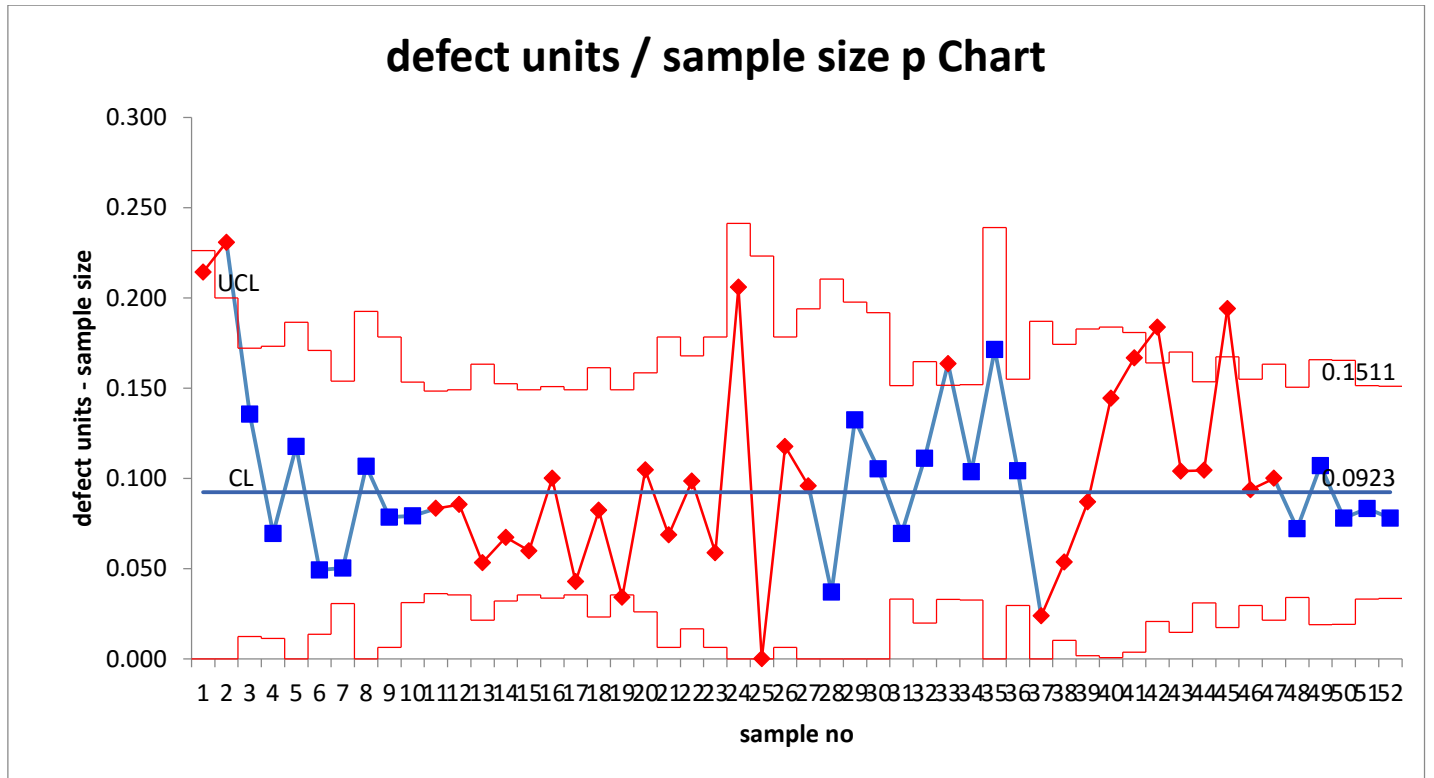
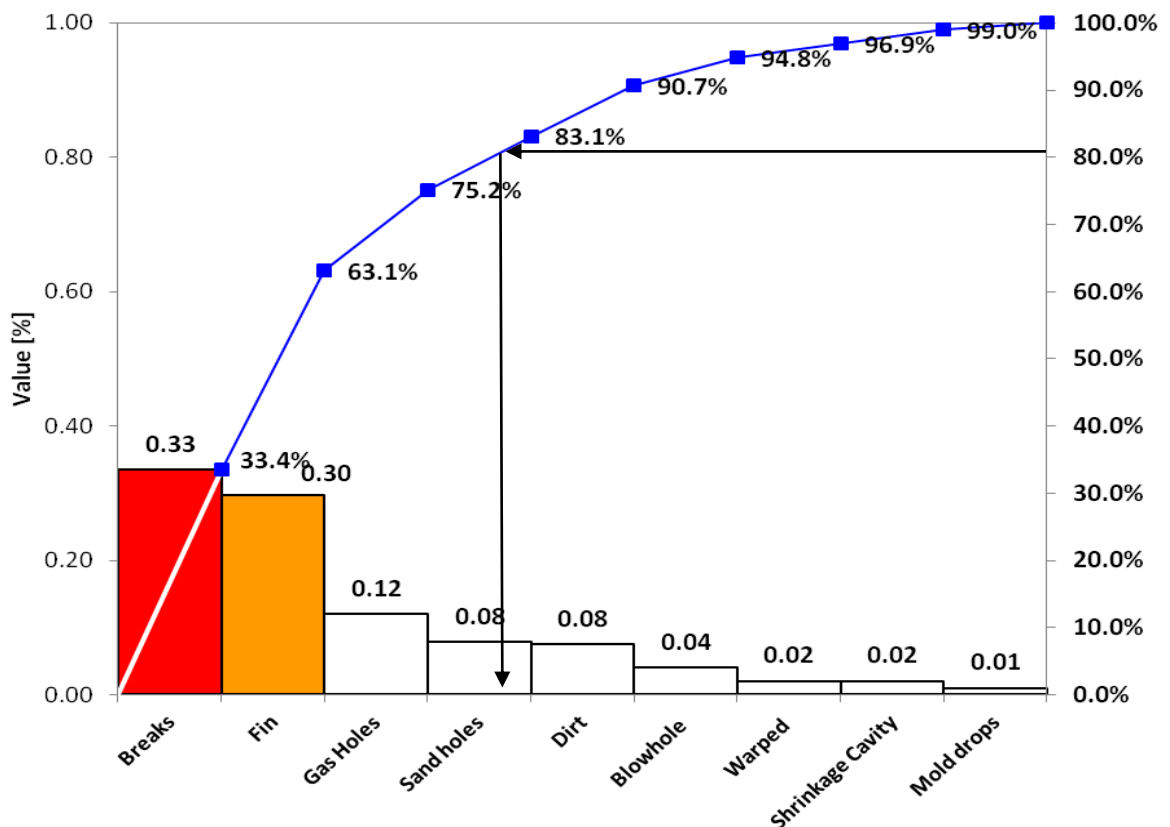


Fig. 5.1: P- Chart for defects

**Table 5.3: Non-conformance distribution for Bufflow wheel**

No	Non-conformance	No of units	Value [%]	cumulative
1	Breaks	97	0.334483	0.334483
2	Fin	86	0.296552	0.631034
3	Gas Holes	35	0.12069	0.751724
4	Sand holes	23	0.07931	0.831034
5	Dirt	22	0.075862	0.906897
6	Blowhole	12	0.041379	0.948276
7	Warped	6	0.02069	0.968966
8	Shrinkage Cavity	6	0.02069	0.989655
9	Mold drops	3	0.010345	1



**Fig. 5.2: Parito chart Non-conformance Diagram**

. Defects were analyzed by using Pareto analyses, and identify the important causes using 80/20 rule find that:

- 1- 82% of defects related to 4 parameters, Breaks, Fin, Gas holes and sand holes,
- 2- 62% of defects related to two parameters Break and fin, the two parameters caused by weakness of workers skills.
- 3- 20% of defects related to gas holes and sand holes, because the sand is nonconforming.
- 4- The most effective parameters on the quality of the products are weakness of worker skills, and quality of the Sand.
- 5- The operating system and the production path are not clear and not systematic.
- 6- The work place environment is untidy and unsecure.

## **CHAPTER FIVE**

### **CONCLUSIONS AND RECOMMENDATIONS**

#### **5-1.Conclusions:-**

- 1- The quality of the sand does not conform to the specification requirements resulting in high percentage of defects.
- 2- The workers and technicians need to training for improve their skills.
- 3- Daily testing and recording data will give better feedback for remedial actions.
- 4- Organizing K.C.F. workplace is a vital demand to prevent accidents and errors.

#### **5-2 Recommendations:-**

Based on the results of this research, the specific contributions can be summarized as follows:

- 1- Applied method of 5S to improve the workplace, and raise production efficiency
- 2- Training the workers and technicians on modern methods of processing templates, to avoid mistakes in order to increase production and reduce waste.
- 3- And also to provide the corresponding specifications of sand, by using the scientific method.

#### **5-3 Suggestions:-**

The researcher has proposed a number of addresses for future studies, including:

- 1- Economic impact in the follow 5S method in an environment workplace.
- 2- Using simulation computerized program in foundries operations to improve the design of casting molds.

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## Appendix A. Chemical composition

SUDANES SUGAR CO LTD

KHARTOUM CENTRAL FOUNDRY

Samle ID heat no.4 on 9-12-2014

Customer f -sample

Lab no. 833

Date 09.12.2014

Grade

cr. 3.57

	Fe	C	Si	Mn	P	S	Cr	Mo
1	93,5	2,01	2,42	0,621	0,287	0,0915	0,234	0,0735
2	93,5	2,02	2,41	0,669	0,276	0,0762	0,232	0,0687
3	93,5	2,04	2,34	0,638	0,298	0,0886	0,231	0,0782
Ave	93,5	2,02	2,39	0,643	0,287	0,0854	0,232	0,0735

	Ni	Al	Co	Cu	Mg	Nb	Ti	V
1	0,125	0,0065	0,0158	0,174	0,0029	0,0838	0,0420	0,0498
2	0,127	0,0105	0,0153	0,201	0,0028	0,0610	0,0355	0,0501
3	0,136	0,0112	0,0140	0,158	0,0025	0,0740	0,0405	0,0502
Ave	0,129	0,0094	0,0150	0,177	0,0027	0,0729	0,0393	0,0501

	Pb	Sn	B	Ce	Zr	Zn	Bi	As
1	0,0252	0,0658	0,0033	0,0044	0,0494	0,0048	< 0,0070	0,0352
2	0,0248	0,0419	0,0029	0,0061	0,0478	0,0043	< 0,0070	0,0300
3	0,0250	0,0815	0,0032	0,0098	0,0380	0,0049	< 0,0070	0,0378
Ave	0,0250	0,0630	0,0031	0,0068	0,0451	0,0046	< 0,0070	0,0343

	La
1	0,0020
2	0,0019
3	0,0014
Ave	0,0018

Khartoum Foundry Tel. 462890 - 462230 - Fax. 465996 - P.O.Box 511 KRT

**Appendix B. Laboratory analysis, sand testing**

Quality Assurance Log Sheet / Daily QA Report Date .....

**SAND TESTING  
LABORATORY ANALYSIS**

Time		standard	Remarks
Process			
G.C.S gm/cm <sup>2</sup>		1100 -1300	
Permeability		140 - 180	
%Moisture		3.2 - 3.8	
Compactability		35 -40	
Total Clay		12 -13	

Laboratory

Production, Planning & Control