Productivity Improvement through Casting Defect Analysis and Control

A Project Report

Submitted by

S.Ganesh	-	71202114065
R.Gowsik	-	71202114066
Arun.M.Gaurav	-	71202114067

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of

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DEPARTMENT OF MECHANICAL ENGINEERING

KUMARAGURU COLLEGE OF TECHNOLOGY

COIMBATORE – 641 006

ANNA UNIVERSITY :: CHENNAI 600 025

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ANNA UNIVERSITY :: CHENNAI 600 025

BONAFIDE CERTIFICATE

Certified that this project report entitled "**Productivity Improvement through Casting Defect Analysis and Control**" is the bonafide work of

Mr.S.Ganesh	-	Register No. 71202114065
Mr.R.Gowsik	-	Register No. 71202114066
Mr.Arun.M.Gaurav	-	Register No. 71202114067

Who carried out the project work under my supervision.

Signature of the Head of the Department
Dr.T.P.Mani Ph.D
HEAD OF THE DEPARTMENT

Signature of the Supervisor 27/04/06
Prof.P.Palanisamy.M.E
SUPERVISOR

28/04/06
Internal Examiner

Dr. T.P. Mani
B.E., M.E. Ph.D. DML., MIE. MNIQR. MISTE.
Dean & HoD / Dept. of Mech. Engg.
Kumaraguru College of Technology
Coimbatore - 641 006

External Examiner
28/4/06

DEPARTMENT OF MECHANICAL ENGINEERING
KUMARAGURU COLLEGE OF TECHNOLOGY
COIMBATORE 641 006

CPC (P) Ltd

CPC PREMIER

24.04.2006

TO WHOMSOEVER IT MAY CONCERN

This is to certify that Mr. S.Ganesh,B.E, Mechanical IV Year Student of Kumaraguru College of Technology, Coimbatore, has carried out the Project work titled **"Productivity Improvement Through Casting Defect Analysis and control"** under the guidance of Mr.P.Arulmozhi Devan (Production Manager) and Mr.V.Jaiganesh (DM- Process Control) in our concern during the period February 2006 to April 2006.

The project has been completed successfully and during the project period their character & Involvement were found very good.

We wish them all success.

N.GOPAL
(Manager – Administration).

Registered Office : 207, Mettu palayam Road, Coimbatore - 641 030.
PHONE : +91 422 - 243 2180, 243 2783, 244 1405, 244 3557 FAX : +91 422 - 243 9952
E-mail : cpcltd@eth.net, cpc@vsnl.net Website : www.cpc.in

CPC (P) Ltd

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This is to certify that Mr. R.Gowsik, B.E, Mechanical IV Year Student of Kumaraguru College of Technology, Coimbatore, has carried out the Project work titled **"Productivity Improvement Through Casting Defect Analysis and control"** under the guidance of Mr.P.Arulmozhi Devan (Production Manager) and Mr.V.Jaiganesh (DM- Process Control) in our concern during the period February 2006 to April 2006.

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This is to certify that Mr. Arun. M.Gaurav, B.E, Mechanical IV Year Student of Kumaraguru College of Technology, Coimbatore, has carried out the Project work titled **"Productivity Improvement Through Casting Defect Analysis and Control"** under the guidance of Mr.P.Arulmozhi Devan (Production Manager) and Mr.V.Jaiganesh (DM- Process Control) in our concern during the period February 2006 to April 2006.

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PHONE : +91 422 - 243 2180, 243 2783, 244 1405, 244 3557 FAX : +91 422 - 243 9952
E-mail : cpcltd@eth.net, cpc@vsnl.net Website : www.cpc.in

ABSTRACT

Casting is of one of the oldest and cheapest methods of producing products by metal forming process and found to be the much better way to mass production. On one hand the rapid industrialization and growth in other fields of engineering has placed stringent demands of quality and quantity in foundries where as in other hand the loss of productivity owing to various factors is being concentrated.

As mentioned above, the process of over coming the loss of productivity has been given due importance. In casting industry the major loss in productivity is by rejection of casting to scrap due to casting defects.

In the view this problem we have taken up the project entitled **"Productivity Improvement through Casting Defect Analysis and Control"** which is done at CPC Pvt LTD, Coimbatore.

When we analyzed about the loss of productivity, we came to know that in spite of vast technological developments in various engineering field, the foundry people are following only the traditional approach in analyzing and controlling defects which may not give a permanent solution to prevent the loss of productivity. Hence we have planned to work on with non-traditional approaches which would be effective in improving productivity and finally we have selected the statistical and logical approaches which are used for casting defect analysis and control.

We have taken up a Case Study on two products (rear bearing housing and front bearing housing) and adopted the non-traditional approaches. The adoption of statistical and logical approaches found to be very effective and it arrived us a result of reduction in rejections from 11.5% to 6.86% in rear bearing housing and from 8.6% to 2.28% in front bearing housing. Through this project work, it has been proved that adopting non-traditional approaches will much effectively improve the productivity in casting industry.

ACKNOWLEDGEMENT

We express sincere our thanks to our project guide **Mr.P.Palanisamy**, Assistant Professor, Department of Mechanical Engineering, KCT, Coimbatore and other faculty members whose valuable guidance and continuous encouragement throughout the course made it possible to complete this project well.

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LIST OF ABBREVIATIONS

GCS	Green Compression Strength
DCS	Dry Compression Strength
HCS	Dry Compression Strength
SPC	Statistical Process Control
QC	Quality Control
AFS	American Foundarymen Society
fig.	figure
psi	pounds per square inch
MT	Million Tons

CHAPTER 1 INTRODUCTION

1.1 PROJECT BACKGROUND

1.1.1 Background of the Problem:

Casting industry is one of the oldest industries in human society. But until recently, the industry was considered to be an art rather than a science. It is considered to be the cheapest process of metal forming compared to the other metal forming technologies in mass production.

On one hand the rapid industrialization and growth in other fields of engineering has placed stringent demands of quality and quantity in foundries where as in other hand the loss of productivity owing to various factors is being concentrated.

1.1.2 Importance of Project:

A report published on a journal "Indian foundry" reveals that in producing one million tons of castings, it is estimated that about 75000 tons of additional castings are made and scarped due to defects. The productivity loss also includes the post machining cost apart from the cast on casting it in foundry. Some times even entire batches of castings are returned to the foundry due to the problems exposed during machining.

In the view of the above mentioned problem, encountering castings defects has been found playing key role in improving the productivity of casting industry Even a two or three percent reduction in scarp by proper elimination castings defects will save a lot on salvage cost, man-hours, machine- hours and there by improves productivity. This is how the analysis of casting defects and controlling it becomes important in foundries which made us choose this topic for our project work.

1.2 SCOPE OF THE PROJECT

The rate of newly emerging foundries and rate of increase in the turn over of existing foundries has gone up drastically in the past decades and the high level of competition persuaded the casting industry to concentrate on quality control. But, in site of vast technological development in engineering field the foundry people are following only the traditional approach in analyzing and controlling defects which may not give a permanent solution.

In the view of this constraint, in this project we dealt about adoption statistical approach for defect analysis and logical approach for defect identification and control.

The scope of our project is to complexly replace the traditional approach with the statistical and logical approach so as to achieve a permanent solution by adopting sequential methodology.

Though the modernization of foundries are not that viable for many small and medium scale casting industries, the adoption of the methodology we have followed will help a lot in improving productivity.

For our project, we have taken up a case study at CPC Pvt, Ltd. and used the statistical approach for analyzing rejection due to various categories of defect and adopted a logical approach in identifying causes and controlling the defects.

1.2 COMPANY'S PROFILE

CPC, from modest beginnings in 1946, has today established itself as a leading manufacturer of grey iron castings in India. The company is part of the KG group, the leading industrial conglomerate of Coimbatore, in South India. CPC manufactures a wide range of quality grey iron castings to international standards at its state of the art foundry. The installed capacity is 9600 MT, of which 4500 MT supplied in machined form. CPC's castings have found approval from international automobile majors for their Indian operations. Castings are also being exported to original equipment manufacturers as well as replacement makers in countries like Germany, Italy, Spain, France, UK, USA, Canada, Japan & Australia. CPC has one of the most modern foundries in India and has received the coveted ISO 9002 cetification in November 1995 itself with upgradation of quality system from time to time. The CPC's annual turn over is about 40 crores.

Specialty product of CPC are flywheels, pulleys, manifolds, transmission cases, brake drums, brake discs, axle carriers, brake parts, plug, cap, cover, gland, pump casing, gear box housing , gear box parts, bearing housing. Its major clientele are Maruti Udyog Ltd.Ashok Leyland Ltd., Hosur, Ashok Leyland Ltd., Chennai, Mahindra & Mahindra Ltd Amalgamation Group, Ingersoll Rand Ltd Audco India Ltd., Iljin Automotive New Holland Tractors (India) P.Ltd .,Delco Remy Electricals India Ltd.,Same Deutz – Fahr(India)P.Ltd., Hindustan Powerplus Ltd., Bonfiglioli Transmissions (P) Ltd.,

The available resources are,

- Arpa 300 BMD Simultaneous Jolt Squeeze- 2 pairs
- Arpa 450 BMD Simultaneous Jolt Squeeze- 1 pair
- Induction Furnace (Main Frequency) – 2 ton
- Induction Furnace (Main Frequency) – 1.5 ton
- CO2 Core process -1 Nos
- Shell Core Shooter- 2 Nos
- Cold Box Core Shooter- 2 Nos
- Twin Table Shot Blasting Machine-2 Nos

1.4 LITERATURE SURVEY

1.4.1 Defects in Castings:

Several types of defects may occur during casting, considerably reducing the total output of castings besides increasing the cast of their production. It is therefore essential to understand the causes behind these defects so that they may be suitably eliminated. Casting defects as those characteristics that create a deficiency or imperfection contrary to the quality classifications imposed by the design and the service requirements.

1.4.2 Classification of Defects:

Defects in castings may be of three basic types.

(1) Major defects, which cannot be rectified, resulting in rejection of the casting and total loss. It includes the following defects,

(a) Blow holes, gas holes, porosity, pinholes, and blisters.

(b) Scar, seams, plates, cold shots.

(c) Shrinkage cavities and depressions

(d) Hot tears and cracks

(e) Hardness defects –mass hardness, hard spots, chilled spots etc.

(f) Misrun and cold shuts

(g) Inclusions of dirt, slag and other materials

(h) Sand defects like erosion scabs, cuts, washers, expansion scabs, buckles, rat-tails, blacking scabs, pull downs.

(i) Mould metal reaction defects like sticker or rat, rough surface, metal penetration, fusion.

(2) Defects that can be remedied but whose cost of repair may not justify the salvage attempt.

(3)Minor defects, which clearly allow the casting to be economically salvaged and thereby leave a reasonable margin for profits.

1.4.3 Causes Of the Defects:

a) the castings design which includes pattern equipment flask equipment and rigging gating and risering moulding sand cores

b) the methods of casting that includes pouring practice melting and moulding practice

c) faulty workmanship

1.4.4 Description of Defects:

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 moulding of patterns plates, and checking of pattern flasks, locating pins, etc, before use.

WARPED CASTING:

Warpage 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.

The warpage may occur also due to,

(i) Too small flasks, which may cause rapid cooling of the edges.

(ii) Weak flasks, which may allow movement of the sand mould walls;

(iii) Insufficient getting system, which may not allow rapid pouring of metal,

(iv) Sand with too low green strength, which may cause it to move:

(v) Non-provision of camber allowance on the pattern, wherever necessary.

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 weighting of the moulds during pouring may also cause the cope to lift giving a swell.

FIN:

A thin projection of metal, no 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 or improper clamping of flasks may again produce the fin defect or, if the trouble is more critical, run-out may result in a weak spot and give rise to run-out, may result.

The 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.

BLOWHOLE:

Blowholes 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 pf 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.

PINHOLES:

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 melting and fluxing practices, by reducing the moisture content of moulding sand and increasing its permeability, and by promising a faster rate of solidification.

GAS HOLES:

Gas holes are those holes that appear when the surface of the casting is machined or when the casting is cut into section. If the core prints are of inadequate size, gap 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 meta;, the lack of controlled solidification, and excessively moist sand may also create gas holes.

SHRINKAGE CAVITY:

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 seized gating system, inadequate risers, or poor design of casting involving abrupt changes of sectional thicknesses. Shrinkage may also be produced of the pouring temperature is too high. The defect can be eliminated by applying the principles of directional solidification in mould design and by judicious use of chills, denseners and padding.

POROSITY:

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 defects 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 send mixes can help in minimizing this defect.

DROPS:

When the upper surface of the mould cracks and pieces of sand fall into the molten metal, "Drops" occurs. Sand having too low green strength, soft ramming or insufficient reinforcement of the mould may cause this defect.

DIRT:

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 presence of slag in the mould due to its incomplete separation from molten metal.

SLAG HOLES:

These are smooth depressions or cavities on the upper surface if the casting or near it, usually near the 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.

SCABS:

Scabs are assorted of projection on the casting which occur when a portion of the mould face or core lifts and the metal beneath in a thin layer. Scabs can be recognized as rough, irregular projection on the surface containing embedded sand.

Scabs are of two types:

(i) Expansion scabs.

(ii) Erosion scabs.

As expansion scab is caused by the expansion of the layers of the sand mould. It may occur on any part of the mould, but more often it is found where the sand gets 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 serve and it eventually cracks.

Molten metal enters through the crack and flows behind the layer of sand. It appears as a shallow flat topped projection on the casting

An erosion scab may occur when metal where metal has been agitated or has partly eroded the sand, leaving behind a solid mass of sand and metal at the spot where erosion took place. The sand that is eroded may find its way to the top part of the mould as dirt inclusion. Erosion scabs may thus be caused by hard and uneven ramming, improper selection of gates such that metal impinges on the mould or core and its flow is not streamlines, too high a moisture content in san, too low permeability of sand, intermittent pouring of metal, or insufficiently baked cores or moulds.

HOT TEARS:

Hot tears are internal or external ragged discontinuities or cracks on the casting surface, caused by hindered contraction occurring immediately after the metal has solidified. They may be produced when the casting is poorly designed and abrupt sectional changes take place, no proper fillets and corner radii are provided, and chills are inappropriately placed. Hot teas may also be caused when the mould and core have poor collapsibility or when the ramming is too hard and the casting is thereby under severe strain during cooling. Incorrect pouring temperatures and improper placement of gates and risers can also create hot tears. Methods to prevent hot tears may entail improving the casting design, achieving directional solidification and even rate of cooling all over, selecting proper mould and core materials to suit the cast metal and controlling the mould hardness in relation to other ingredients of sand.

COLD SHUT AND MISRUN:

A cold shut is a defect in which a discontinuity is formed due to the imperfect fusion of two streams of metal in the mould cavity. The defect may appear like a crack or seam with smooth rounded edges. A Misrun casting is one that remains incomplete due to the failure of metals fill the entire wall thickness, improper gating system, damaged patterns slow and intermittent pouring, poor quality of metal cavity is not completely filled because of insufficient metal, the defect is called "Pour short".

1.4.5 Defect Analysis:

When a defective casting is produced it is necessary to analyze the defect or defects observed and determine the causes for their occurrence, so as to arrive at appropriate remedial measures.

Often, there are a large number of inter-related factors affecting the occurrence of any defect and it becomes difficult to determine the exact causes. In order to assist analysis of defects cause and effect diagrams can be prepared showing major causes and all the possible reasons for those causes.

Inspection of castings:

Two basic objectives of inspection are

(1) To reject castings that fail to meet the customers' requirements.

(2) To serve as a means of maintaining the quality of workmanship and materials used in the foundries.

Inspection of castings broadly covers a large number of methods and techniques used to check the quality of castings. These methods may be classified into five categories.

1. Visual inspection
2. Dimensional inspection
3. Mechanical and chemical testing
4. Flaw deduction by non-destructive methods.
5. Metallurgical inspection

CHAPTER 2 SELECTION OF PRODUCT

2.1. DEFINING THE PROCESS OF SELECTION

The process of identifying appropriate product becomes important so as to make the case study effective. The product identification becomes important because a case study done on a inappropriate product would deviate the project work and effort beyond the scope of it. So synchronizing the project case study along with the scope of project becomes essential.

The project identification involves,

(1) Setting up criteria for project selection,

(2) Product data collection (based on criteria)

(3) Selection of product variety.

2.2. SELECTION CRITERIA

The various criteria on basis of which product for case study is identified has been selected keeping in mind, the project in phase with its scope.

2.2.1 The Selection Criteria with Its Reason:

The various criteria selected based on the requirement of project are as follows,

(1) Frequency of rejections:

REASON- so as to consider the man hour, machine-hour and post-machining cost & time.

(2) Weight of the product:

REASON- in order to reduce the salvage so as to control the product yield cost and to improve casting yield.

(3) Number of defects encountered:

REASON- based on consideration of making the analysis effective and to expand the scope to be generalize it for all foundries.

(4)Production consistency:

REASON- as the production in the industry is a batch production type the consistency in production of selected product till the implementation and conclusion phase is important.

2.3. PRODUCT DATA COLLECTION

Data on product is collected based on the above mentioned criteria and products are short-listed on consideration of criteria in stage.

First of all, on consultation with the production manager, certain product varieties are selected based upon two criteria namely,

(1) Consistency in production

(2) Number of defects involved.

2.3.1 First Stage of Selection:

It is ensured that the following products would have production for the next six months consistently. Also these products have been identified to be involved with a number of complications and more number of defects causing rejections.

- Power lift housing
- Sump
- Exhaust manifold
- Gearbox housing
- Thermostat
- Pump casing
- PTO Bearing support
- Pulley
- Flywheel housing
- Flywheels
- Front bearing housing
- Pump parts
- Adopter
- Bearing housing rear

2.3.2 Second Stage of Selection:

In second stage of selection, the criterion of "REJECTION FREQUENCY" has been considered. In consultation with Quality control manager and in reference to past rejection report, the products with high rejection frequency along with the data on weight of the product has been listed below,

Table 2.1 PRODUCT WEIGHT

S.NO	PRODUCT	WEIGHT (in kg)
(1)	Power lift housing	33
(2)	Sump	41
(3)	Front bearing housing	54
(4)	Thermostat	07
(5)	Adopter	21
(6)	Rear bearing housing	73
(7)	Pulley	16

2.4 PRODUCT SELECTION

The final selection of product variety has been based on the criteria of "PRODUCT WEIGHT" so as to benefit the industry in saving the scarp cost (or) salvage loss. Also the defect variety has been taken into account along with the process involved so as to make analysis effective. The product varieties chosen for the case study are as follows,

(1) Bearing housing – front(product code-2343594)

(2) Rear bearing housing (product code-39890546)

The products are selected with similarity so as to make the process analysis easier and simpler. Also the rejection frequency is comparatively more (around 8% and 10% respectively).

These two products are the part of a screw compressor. These bearing housings enclose the front and rear part of the two mating screws and support it with a set of bearings to ensure smooth operation. The customer of the product is Ingersoll Rand.

The products are represented in the following photographic figures,

Bearing housing – front (product code-2343594) - figure 2.1

Rear bearing housing (product code-39890546) – figure 2.1

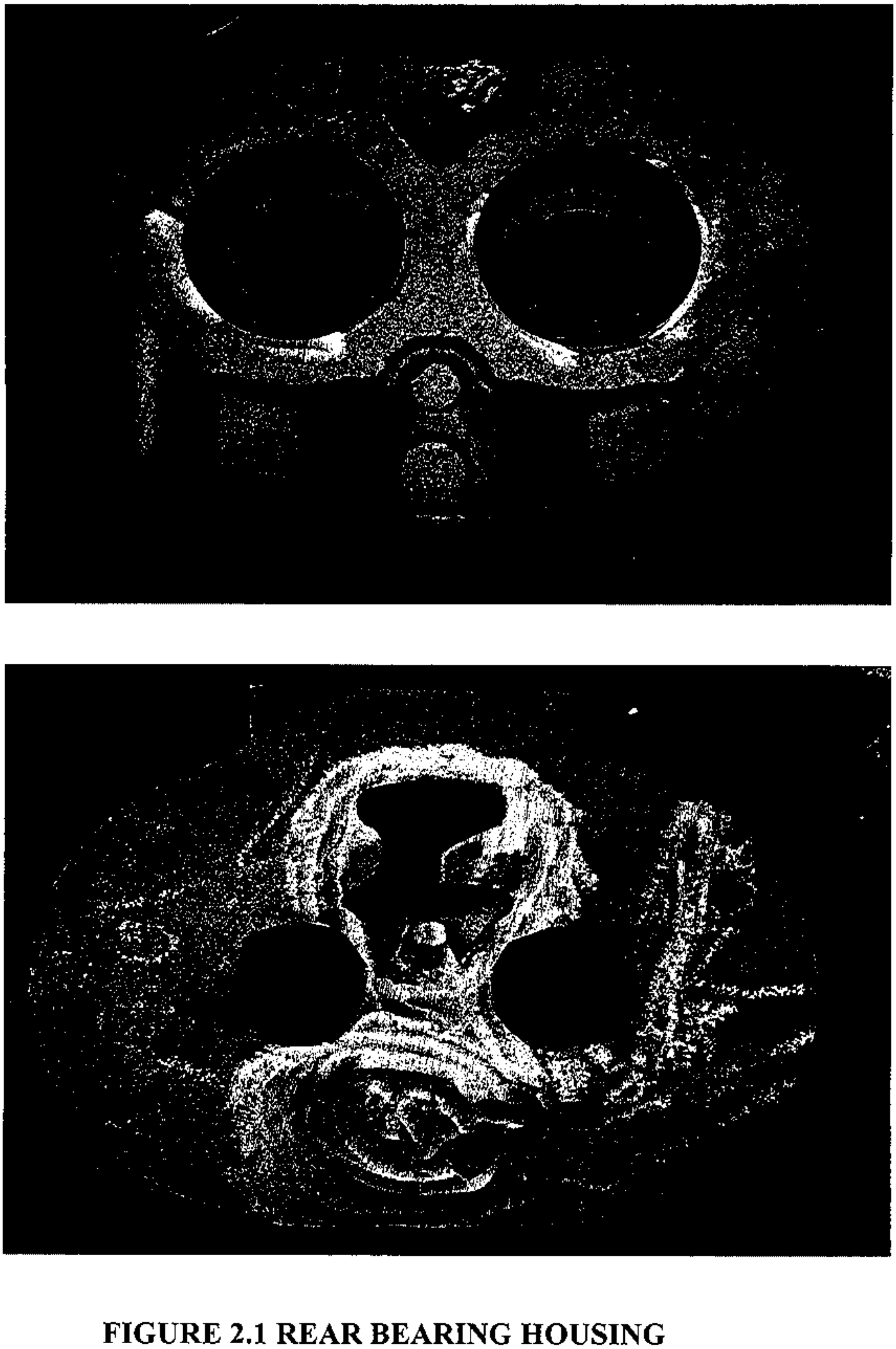

FIGURE 2.1 REAR BEARING HOUSING

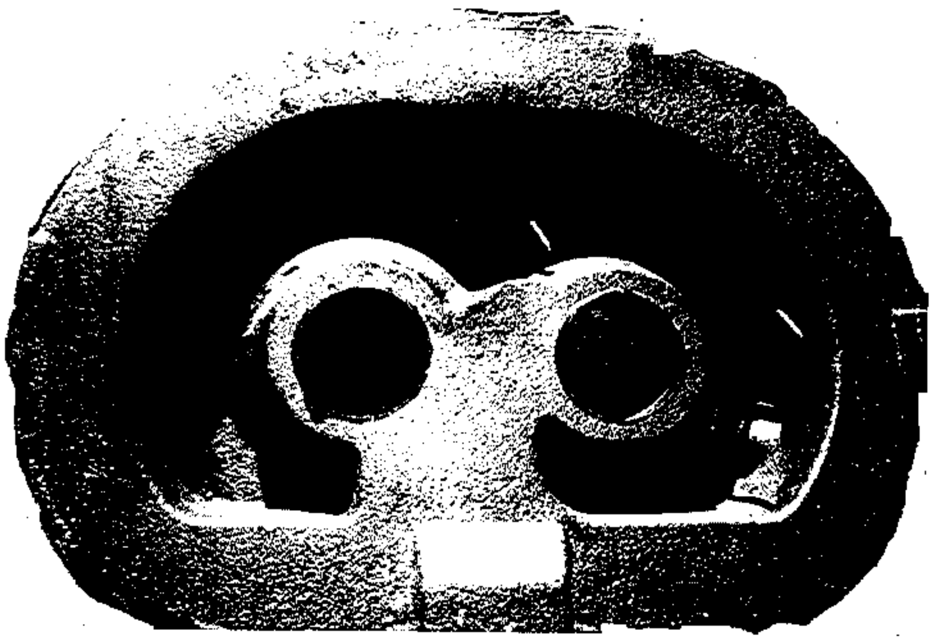

FIGURE 2.1 FRONT BEARING HOUSING

CHAPTER 3 ADOPTING STATISTICAL APPROACH

3.1. IMPORTANCE OF STATISTICAL APPROACH

3.1.1 Methods of Solving Problems:

There are two main approaches to solving problems. They are,

1. Theoretical approach
2. Statistical Problem solving approach

THE THEORETICAL APPROACH:

The approach also known as the deductive methods is employed to solved problems by using relevant physical, chemical, economical (or) other scientific theories (or) by analog with similar past occurrences.

THE STATISTICAL PROBLEM SOLVING APPROACH:

In this approach could be described as inductive. In this approach we trace the causes of the phenomenon by repeatedly asking "why"? and identify the root causes of the problem from the facts.

3.1.2 The Problem Solving Process:

The conventional method of solving problems is based on trial and error. It consists of examining problems in the light of experience intuition, nerve (or) random inspiration, planning and implementing countermeasures based on this, and starting over again if things do not go well. This approach, however does not work with matters in which we lack experience and fail to solve the problem if our intuition is off the mark.

The statistical approach to tackling problems can be split into three main stages and the differences between this and the conventional approach lie in stage 2 in the statistical approach, we do not rely merely in experience and random inspiration, but analyze the process based on factual data and accurately identify the factors adversely affecting the results.

3.1.3 The Seven Step Formula:

(Solving Process the Statistical Way)

Step 1. : Selection of topic

Step 2. : Understanding situation and setting targets.

Step 3. : Planning of activities

Step 4. : Analyzing causes

Step 5. : Consider action and implement action of counter measures.

Step 6. : Checking of result

Step 7. : Standardize and establishment of control.

3.1.4 Benefits of Statistical Problem Solving Approach:

(1) It enables problems to be saved more rationally, scientifically, efficiently and effectively then any other method.

(2) It lightens every persons problem- formulating and problem- solving abilities and enables every body to fulfill an important role in the workplace.

(3) It enables people to acquire the statistical view point through solving problems.

(4) It enables people to become competent in applying the statistical tools and allows them to master the scientific approach.

(5) It gives tangible benefits, mainly in terms of quality, but also in terms of cost delivery safety, morale, sales and so on.

(6) It improves work practices and raises management standards.

(7) It boosts the leadership and management abilities of workplace leaders.

(8) It promotes the personal growth of individual workplace members.

(9) It improves workplace communication and moral and greats cheerful, effective workplaces.

(10) It stimulates QC circle and quality term activities.

3.2. APPLICATION OF STATISTICAL APPROACH

3.2.1 Identifying the Facts:

In statistical approach we try as far as possible to make our various judgments based on the facts, not on guesswork. Our slogan is "speck with facts". If we are going to take the correct action it is essential to have a constant accurate grasp of the facts. When we go out and collect data. New facts come to light, and it often becomes clear that our vague guesses based on experience were way off the mark. Checking the facts enables us to devise effective countermeasures leading to good results. It is important to be constantly in command of the facts and to accept them for what they are.

Management by fact" means not making decisions based on experience and intuition alone but acting in accordance with the facts.

3.2.2 Process of Application:

In order to make our decisions and actions on the facts we have to first quantify the situation in the form of data and convert our subjective judgments to important to follow the procedure described below.

Step 1: closely observe the actual location and actual objects.

Hint: Target the 4M (men, material, methods, machine)

Step 2: Decide on characteristics to be investigated.

Hint: select from among quality, cost, and quantifiable characteristics.

Step 3: Clarify the objectives of collecting the data.

Hint: for analysis? for adjustment?, for control?, for inspection?

Step 4: Collect accurate data

Hint: use check sheets, answer the 5W&1H

(What? where? when? why? who? how?)

Step 5: Carefully analyze the data using Q-7 tools.

Hint: seven QC tools, statistical method.

Step 6: Consider the results and produce accurate information.

Hint: proper transformation of info to next stage.

3.3. SELECTION OF Q-7 TOOLS

3.3.1 The list of Q-7 Tools:

The seven QC tools used for statistical approach of problem solving are as follows,

(1) Cause and effect diagrams.

(2) Pareto diagram

(3) Graphs

(4) Check sheets

(5) Histograms

(6) Scatter diagrams

(7) Control charts

3.3.2 Selection Of Q-7 Tools To Be Used In This Study:

The following quality control tools are used in this study.

1. Check Sheets
2. Pareto Charts
3. Cause and effect diagram

The specific reason for selecting the above Q.C tools is shown in the table. The cause and effect diagram and Pareto diagram are giving the effective result in quality and the control charts are giving the effective result in process control.
Based on the effectiveness of Q-7 tools for a particular application and in comparison with requirement in this project, the above mentioned Q-7 tools have been selected. The table showing the effectiveness of Q-7 tools with respect to the application is given below,

TABLE 3.1 QC TOOLS SELECTION

NAME AND APPLICATION	NEW PRODUCT DEVELOMENT	QUALITY IMPROVE -MENT	PROCESS CONTROL	ADMINIS -TRATION	SALES MANAGE -MENT	SAFETY MANAGE -MENT
CAUSE AND EFFECT DIAGRAM	O	X	O	X	X	X
PARETO DIAGRAM	O	X	O	X	X	X
GRAPHS AND CHARTS	O	O	O	X	X	X
CHECK SHEETS	O	O	X	X	X	X
CONTROL CHARTS	O	O	X	-	-	O
HISTOGRAM	O	X	X	X	X	X
SCATTER DIAGRAM	O	X	O	O	O	O

X	*MOST SUITABLE*	O	*APPLICABLE*

3.4. DESCRIPTION & METHOD OF USING THE Q-7 TOOLS

3.4.1 Description on Check Sheets:

The main purpose of check sheets is to ensure that the data is collected carefully and accurately by operating personnel. Data should be collected in such a manner that it can be quickly and easily used and analyzed. The form of the check sheet is individualized for each situation and is designed by the project team. Also it helps to segregate data properly.

3.4.2 Description on Pareto Diagram:

Alfredo Pareto (1848-1923) conducted extensive studies of the distribution of wealth in Europe. He found that there were a few people with a lot or money and many people with little money. This unequal distribution of wealth became an integral part of economic theory. Dr. Joseph Juran recognized this concept as universal that could be applied to many fields. He coined the phrases vital few and useful many.

The vital few are on the left, and the useful many are on the right. It is sometimes necessary to combine some of the useful many into one classification called other". When this category is used, it is placed on the far right.The vertical scale is dollars (or frequency), and the percent of each category can be placed above the column. In this case, Pareto diagrams were constructed for both frequency and dollars.

Pareto diagrams are used to identify the most important problems. Usually, 75%of the total results from 25% of the items. This fact is shown in the figure, where coating machines 35 and 51 account for about 75%of the total.

Actually, the most important items could be identified by listing them in descending order. However, the graph has the advantage of providing a visual impact, showing those vital few characteristics that need attention. Resources are then directed to take the necessary corrective action.

3.4.3 Description on Cause and Effect Diagram:

A cause and – effect (C & E) diagram is a picture composed of lines and symbols designed to represent a meaningful relationship between an effect and its causes. It was developed by Dr. Kaoru Ishikawa in 1943 and is sometimes referred to as an Ishikawa diagram or a fishbone diagram because of its shape.

Cause and Effect diagrams are used to investigate either a "bad" effect and to take action to correct the causes or a "good" effect and to learn those causes that are responsible. For every effect, there are likely to be numerous causes. Figure 18.3 illustrates a C & E diagram with the effect on the right and causes on the left. The effect is the quality characteristic that needs improvement. Causes are sometimes broken down into the major causes of work methods, materials, measurement, people, equipment, and the environment. Other major causes could be used for service- type problems, as indicated in the chapter on customer satisfaction.

Each major cause is further subdivided into numerous minor causes. FOR example under work methods, we might have training knowledge ability physical characteristics and so forth. C&E diagrams are the means of picturing these entire major and minor causes figure 18-4 shows a diagram for house paint peeling using four major causes

3.4.4 Construction of Cause and Effect Diagram:

The first step in the construction of a C&E diagram is to identify the effect or quality problem. It is placed on the right side of a large piece of paper by the team leader. Next, the major causes are identified and placed on the diagram.

Determine all the minor causes require brainstorming by the project team. Brainstorming is an idea – generating technique that is well suited to the C & E diagram. It uses the creative thinking capacity of the team.

Attention to a few essentials will provide a more accurate and usable result:

1. Participation by every member of the team is facilitated by each member taking a turn giving one idea at a time. If a member cannot think of a minor cause, he or she passes for that round. Another idea may occur at a later round. Following this procedure prevents one or two individuals from dominating the brainstorming session.
2. Quantity of ideas, rather than quality, is encouraged. one person's idea will trigger someone else's idea, and a chain reaction occurs. Frequently, a trivial, or "dumb," idea will lead to the best solution.
3. Criticism of an idea is not allowed. There should be a freewheeling exchange of information that liberates the imagination. All ideas are placed on the diagram. Evaluation of ideas occurs at a later time.
4. Visibility of the diagram is a primary factor of participation. In order to have space for all the minor causes, a 2 – foot by 3 – foot piece of paper is recommended. It should be taped to a wall for maximum visibility.
5. Create a solution – oriented atmosphere and not a gripe session. Focus on solving a problem rather than discussing how is begun. The team leader should ask questions using the why, what, where, when, who, and how techniques.
6. Let the ideas incubate for a period of time (at least overnight) and then have another brainstorming session. Provide team members with a copy of the ideas after the first session. When no more ideas are generated, the brainstorming activity is terminated.

Once the C & E diagram is complete, it must be evaluated to determine the most likely causes. This procedure is to have each person vote on the minor causes. Team members may vote on more than one cause. Those causes with the most votes are circled and the four or five most likely causes of the effect are determined

Solutions are developed to correct the causes and improve the process. Criteria for judging the possible solutions include cost, feasibility, resistance to change, consequences, training and so forth. Once the team agrees on solutions, testing and implementation follow.

CHAPTER 4 PROCESS ANALYSIS

PROCESS ANALYSIS ON TWO BEARING HOUSING

(FRONT-595 & REAR-546)

The various process involved in converting raw grey cast iron into bearing housing (rear & front) has to be analyzed thoroughly. In this process analysis various parameters influencing the process and factors that affects quality of product causing rejection of components have to be identified and evaluated so as to correlate with the data on defects, in order to facilitate eliminate the causes by appropriate remedial measures. The various stages of process has been analyzed in steps and are as follows:

4.1. ANALYSIS ON SAND PREPARATION

Sand, the principle molting material in foundry shop, is prepared with care so as to ensure that it possesses the important characteristics like refractory nature to withstand high temperature, chemical resistivity, and high degree of permeability to allow gases to escape.

4.1.1. Analysis of Sand Composition:

The principle ingredients of molting sand prepared are silica sand grains, clay (for bonding), moisture, bentonite, Bentocol and Lustron. The data on ingredients of molding sand collected from moulding shop is as follows:

Table 4.1 SAND INGREDIENTS COMPOSITION

S.NO	INGREDIENT	WEIGHT(kg)	PERCENTAGE%
(1)	Return sand	450	85.0
(2)	New sand	60	11.3
(3)	Bentonite	16	03.0
(4)	Bentocol	2	0.35
(5)	Lustron	2	0.35

4.1.2. Process of Preparation:

The knock out of the mould is done on the vibrator plate and holes are provided to collect the moulding sand. Then the return sand is passed through a conveyor over a magnetic separator. This device consists of a drum which is magnetized half a side when return sand comes in contact and attracts the magnetic impurities contained in the sand and while it comes to the opposite side it gets demagnetized and hence the magnetic particles fall down on a collector drum. Then the sand will be poured over a to and fro moving plate to extract dust which will be absorbed through a vacuum blower. The sand is then passed through the sand sieve to filter out the day lumps and other tiny metal piece escaped from magnetic separator. The sand sieve is a polygon shaped drum to a length of 6 mts provided with a mesh for filtering. Then it is passed through a cooler (water spray type) and then through conveyor it is poured into the bunker.

Dust collector connected along with a blower is provided whenever the sand is poured onto next stage. Then the bunker is brought through the conveyor to the mixer. The opening of the bunker is closed by means of the conveyor with a required amount of clearance. The movement of the conveyor is properly controlled with so as to obtain the required amount of sand to the mixer.

In mixer the required proportion of new sand and other additives are added manually and mixed well. The well mixed sand will be ready to use and it is transferred to corresponding jolting machine through a centralized conveyor which includes bucket elevator , horizontal conveyor system and fish mouth hopper. The fish mouth hopper is used to pour sand over the moulding box .The a lever and link mechanism is used in operating fish mouth hopper.

4.1.3. Testing Of Sand: The prepared green sand is tested periodically before using it for moulding. The testing of sand is done at regular intervals. The following tests are carried out. The testing equipments are listed in table 4.2 and the testing results are given in 4.3

Table 4.2 TESTING EQUIPMENTS

S.NO	NAMES OF TESTING	NAME OF TESTER
(1)	Testing of moisture content	Infra-red moisture teller
(2)	Compatibility test	Compatibility tester
(3)	GCS test	Universal testing machine
(4)	GSS test	Universal testing machine
(5)	Permeability test	Permeability air flow meter.
(6)	Grain size(AFS number)	Sieve shaker.
(7)	Active clay content	Methylene blue test.
(8)	DCS test	DCS testing

Data collected on the results of testing of sand specimen of block dimension 2" x 2" x dia.2" (149.4gms) at sand temperature of 47 c (Muller) and 35 c (moulding) are as follows:

Table 4.3 TESTING RESULTS

S.NO	TESTING PARAMETER	TESTING VALUE
(1)	Moisture content	3.3%
(2)	Compatibility	43
(3)	Green compression strength	1.25kg/cms2
(4)	Green shear strength	350gms/cms2
(5)	Permeability	Permeability number 163

4.2. ANALYSIS ON MOULDING

4.2.1. Data on Moulding Equipments:

The data collected from the moulding department is given in table 4.4,

Table 4.4 MOULDING EQUIPMENTS

S.NO	NAME OF EQUIPMENT	EQUIPMENT IN USE
(1)	Type of pattern	Single piece pattern
(2)	Pattern material	Aluminium
(3)	Size of moulding box	600x650x225mm
(4)	Moulding type	Green sand mould
(5)	Moulding method	Machine moulding
(6)	Flasks	One cope and one drag box (Prepared on separate m/c)
(7)	Reinforcements	M.S.nails (four in number)
(8)	Transportation of moulds	Manual transportation

4.2.2. Moulding Process:

The moulding sand prepared in the sand muller is transferred to the moulding box through a centralized conveyor on the roof. The moulding machines are arranged in-line and hopper is provided over every machine with electro-mechanical controlled opening & closing provisions. Two machines are placed opposite to each other to prepare cope and drag simultaneously. These boxes are later transferred to the box rail and matched together and clamped.

The moulding process carried out in the simultaneous jolting and squeeze type moulding machine is described below.

First of all the pattern plate will be placed on the table of jolting and squeezing machine. Then the fish mouth of the hopper is opened and sand is poured over the pattern jolting action is started to consolidate the sand on the face of the pattern and thus initial sand packing is achieved. Then consecutively the squeezing action is made to impart the desired density in the upper portion of the mould. Following this again some sand is poured over the mould surface and then simultaneous jolting and squeezing is made to finish the mould at required degree of mould quality which includes mould hardness, bonding of mould, etc.,

This process is carried out simultaneously for cope and drag boxes and then finished drag box is first transferred to assembling rail through the trolley. Then the finished cope box is held in over head box lifter. Then the formation of pouring mouth is done. After this it is cleaned with compressed air and is placed over the drag box and aligned properly and finally the boxes are clamped together. The prepared moulding boxes are passed on to the melting section by means of trolley on rails.

4.3. ANALYSIS ON MELTING AND POURING

4.3.1 Data on Melting Equipments:

The following are the data collected from melting and pouring department,

1.	Furnace type	--	electrical induction furnace
2.	Capacity of furnace	--	a. 2 ton
			b. 1.5 ton
3.	Power requirement	--	a. 450 kw
			b. 1000 kw
4.	Induction frequency	--	a. Main frequency (60Hz)
			b. Medium frequency (about 600 Hz)
5.	Melting time	--	about one and half hours

6. Charge mix:

Table 4.5 CHARGE MIX

S.NO	INGREDIENTS	PERCENTAGE
(1)	pig iron	13.34 %
(2)	borings	33.34 %
(3)	steel scrap	26.67 %
(4)	recycling scrap	26.67 %

7. Metal composition:

Table 4.6 METAL COMPOSITION

S.NO	COMPONENT	PERCENTAGE
(1)	carbon	3.3%
(2)	silicon	1.9%
(3)	manganese	0.9%
(4)	chromium	0.3%
(5)	copper	0.4 - 0.5%
(6)	sulphur	0.6 – 0.8%
(7)	phosphorus	0.15%

8. Cast iron grade -- F G 260
9. Tapping temperature -- 1530 ° c
10. Pouring temperature -- 1390 -1400 ° c
11. Pouring type -- manual pouring.
12. Pouring equipment used -- ladles (double handled type)

13. Pouring time -- about 16 – 18 seconds

14. Transportation of molten metal -- manually transported in ladles (100mt)

4.3.2. Melting and Pouring Process:

The medium frequency 450 kw furnace has normal melting rate and high frequency 1000 kw has high rate of melting and it is of dual track type i.e., the electrical supply is connected to two furnace which are ten metres apart but however only one furnace could be supplied with power . the advantage of this set up is that when melting is carried out in one furnace loading is done in another. This helps to reduce time in loading the charge mix. During finishing stage of melting the metal sample will be tested in spectrometer for checking up the composition. If it deviates from standard, then additional amounts of deficit components would be added. The metal is tapped out of furnace in ladles and transported to the moulding box rails (at a distance of about 100 – 150 mts) and poured through sprue at a timing of about 14 seconds per moulding box. After pouring the mould is allowed to settle and it gets cooled.

4.4. ANALYSIS OF CORE PREPARATION

4.4.1. Data about Core:

The following data are collected from the core shop about the preparation of core.

- number of cores -- a. rear bearing housing – 3

  b. front bearing housing –2
- Process used – cold box process
- Core sand – silica sand (silicon- di- oxide)
- Binder used – polyisocyanate and alkyd phenolic resin.
- Vapour passed -- TEA(tetra ethyl amine)
- Core curing – passing air.
- Core box -- split core box.

4.4.2 Preparation of Core:

The core is being prepared by means of cold box process which is the latest development in moulding using organic binder. Its overwhelming advantage is that no heating of core is required after the process of preparation. Also it provides good collapsibility of core during knock out.

In this process first the fine dry silica sand s mixed with the organic resin polyisocyanate which is used as binder along with alkyd phenolic resin. Then the prepared sand is poured into the core box and rammed well. Then it is transferred to gassing station. There the catalyst vapour which is TEL will be passed on to the core for a few seconds. As TEL is used in the atomized form it will quickly set the core.

Then it removed from the core box and either dry air or carbon-di-oxide gas is passed the remove the excess of catalyst vapour. As there is no need of finishing process the core will be ready to use.

4.5 RESULT OF ANALYSIS

The process of casting the front and rear bearing housing is thoroughly analyzed. This analysis would be helpful in finding out the reason for rejections and in planning to overcome it. The data collected on various process stages will be compared with the rejection data and root cause of the defects will be identified.

CHAPTER-5 DATA COLLECTION

The rejection data of the components are systematically collected using check sheets, one of the QC tools. The data are collected separately from each department in -charge in separate check sheets. The following tables from 5.1 to 5.12 illustrate the rejection data.

5.1 DATA OF REAR BEARING HOUSING (546)

The following tables from table 5.1 to table 5.5 gives the rejection data from various departments on rear bearing housing and the table 5.6 includes the overall rejection data.

TABLE 5.1 CHECK SHEET-1

Product Name: Rear Bearing Housing Product Code : 39890546		Product Weight: 73 kg Production Lot:2873 units (total quantity)	
Duration : APR-05'—FEB-06'		Department: General	
S.NO	DEFECT	REJECTIONS	TOTAL
(1)	Broken / crack	///// ///// /	11
(2)	Box lift	//	02
(3)	Core broken	/	01
(4)	Scabbing	///// ///// //	12
(5)	Sand drop	///	03
(6)	Shrinkage	///// ///// ///	13

TABLE 5.2 CHECK SHEET-2

Product Name: Rear Bearing Housing Product Code : 39890546		Product Weight: 73 kg Production Lot:2873 units (total quantity)	
Duration : APR-05'—FEB-06'		Department: Moulding	
S.NO	DEFECT	REJECTIONS	TOTAL
(1)	Core lift	///// //	07
(2)	Mould broken	//	24
(3)	Scabbing	///// ///// ///// ///// ///// ///// ///// ///// ///// ////	49
(4)	Sand drop	///// ///// ///// /////	20

TABLE 5.3 CHECK SHEET-3

Product Name: Rear Bearing Housing Product Code : 39890546		Product Weight: 73 kg Production Lot:2873 units (total quantity)	
Duration: APR-05'—FEB-06'		Department: Core Shop	
S.NO	DEFECT	REJECTIONS	TOTAL
(1)	Core fusion / Scabbing	///// ///// ///// ///// ///// ///// ///// ///// /////	45
(2)	Core broken	///// ///// /////	15

TABLE 5.4 CHECK SHEET-4

Product Name: Rear Bearing Housing Product Code : 39890546		Product Weight: 73 kg Production Lot:2873 units (total quantity)	
Duration : APR-05'—FEB-06'		Department: Pouring	
S.NO	DEFECT	REJECTIONS	TOTAL
(1)	Broken / crack	///// /	06
(2)	Box lift	/////	05
(3)	Blow holes	///// ///// ///// ////	19
(4)	Leakage	///// /	06
(5)	Misrun	///// ////	09
(6)	Slag inclusion	///// ///// ///// /////	20

TABLE 5.5 CHECK SHEET-5

Product Name: Rear Bearing Housing Product Code : 39890546			Product Weight: 73 kg Production Lot:2873 units (total quantity)
Duration : APR-05'—FEB-06'		Department: Melting	
S.NO	DEFECT	REJECTIONS	TOTAL
(1)	Broken / crack	//	02
(2)	Leakage	/	01
(3)	Blow holes	///// ///// ///// ////	19
(4)	Shrinkage	///// ///// ///// ///// ///// ///// ///// ///// /	41

The rejection data collected from various departments have been merged together and aligned in order of rejection percentage in the following table.

TABLE 5.6 REJECTIONS OF REAR BEARING HOUSING

S.NO	DEFECTS	REJECTION QUANTITY	REJECTION PERCENTAGE%
(1)	Core Problems	68	20.61
(2)	Scabbing	61	18.48
(3)	Shrinkage	54	16.36
(4)	Blow Holes	38	11.52
(5)	Mould Broken	24	7.27
(6)	Sand Drop	23	6.97
(7)	Sand Inclusion	20	6.06
(8)	Broken Crack	19	5.76
(9)	Misrun	09	2.73
(10)	Box Lift	07	2.12
(11)	Leakage	07	2.12
(12)	TOTAL	330	---
TOTAL PRODUCTION QUANTITY :		2873	
DURATION OF DATA COLLECTION :		APR-05' TO FEB-06'	
PRODUCT WEIGHT :		73.0	
OVERALL REJECTION % :		11.49%	

5.2 DATA OF FRONT BEARING HOUSING (546)

The following tables from table 5.7 to table 5.11 gives the rejection data from various departments on rear bearing housing and the table 5.12 includes the overall rejection data.

TABLE 5.7 CHECK SHEET-6

Product Name: Bearing Housing -Front Product Code : 2343594		Product Weight: 54.25 kg Production Lot:3252 units (total quantity)	
Duration : APR-05'—FEB-06'		Department: Moulding	
S.NO	DEFECT	REJECTIONS	TOTAL
(1)	Blow holes	///// ///// ///// //// /////	22
(2)	Mould broken	///// ///// ///// //// /////	29
(3)	Mould fusion	///// ///	06
(4)	Sand drop	///// ///// ///// ///// ///// ///// ///// ///// /////	59
(5)	Scabbing	//	02
(6)	Core missing	/	01
(7)	Core lift	///// ///	08

TABLE 5.8 CHECK SHEET-7

Product Name: Bearing Housing -Front Product Code : 2343594		Product Weight: 54.25 kg Production Lot:3252 units (total quantity)	
Duration : APR-05'—FEB-06'		Department: Melting	
S.NO	DEFECT	REJECTIONS	TOTAL
(1)	Blow holes	///// ///// ///// ///// //	22
(2)	Shrinkage	///// ///// ///// ///// ///// ///// ///// ///// ///// ///	48

TABLE 5.9 CHECK SHEET-8

Product Name: Bearing Housing -Front Product Code : 2343594		Product Weight: 54.25 kg Production Lot:3252 units (total quantity)	
Duration : APR-05'—FEB-06'		Department: Pouring	
S.NO	DEFECT	REJECTIONS	TOTAL
(1)	Blow holes	///// ///// /	11
(2)	Broken / crack	///// ///	08
(3)	Leakage	/	01
(4)	Slag inclusion	///// ///	08

TABLE 5.10 CHECK SHEET-9

Product Name: Bearing Housing -Front Product Code : 2343594		Product Weight: 54.25 kg Production Lot:3252 units	
Duration : APR-05'—FEB-06'		Department: Pattern shop, Fettling, Core shop	
S.NO	DEFECT	REJECTIONS	TOTAL
(1)	Core broken	////	04
(2)	Core fusion	/	01
(3)	Excessive grinding	/	01
(4)	Pattern problems	///// ///	08

TABLE 5.11 CHECK SHEET-10

Product Name: Bearing Housing -Front Product Code : 2343594		Product Weight: 54.25 kg Production Lot:3252 units	
Duration : APR-05'—FEB-06'		Department: General	
S.NO	DEFECT	REJECTIONS	TOTAL
(1)	Broken / crack	/	01
(2)	Blow holes	///// ///// ///// //// /////	24
(3)	Sand drop	///// ///	08
(4)	Shrinkage	///// ////	09

The rejection data collected from various departments have been merged together according to the type of defect and aligned in order of rejection percentage in the following table.

TABLE 5.12 REJECTIONS OF FRONT BEARING HOUSING

S.NO	DEFECTS	REJECTION QUANTITY	REJECTION PERCENTAGE%
(1)	Blow Holes	79	28.11
(2)	Sand Drop	67	23.84
(3)	Shrinkage	58	20.64
(4)	Mould Broken	35	12.46
(5)	Core Problems	14	04.98
(6)	Other minorities (scabbing, fettling, pattern	11	03.91
(7)	Broken/Crack	09	03.20
(8)	Sand Inclusion	08	02.86
(9)	TOTAL	281	---
TOTAL PRODUCTION QUANTITY : 3252			
DURATION OF DATA COLLECTION : APR-05' TO FEB-06'			
PRODUCT WEIGHT : 54.25kg			
OVERALL REJECTION% : 08.64%			

CHAPTER 6 ANALYSIS ON DATA

6.1 DESCRIPTION ON PARETO CHART

Pareto chart one of Q-7 tools which used for effectively analyzing the defects and the major defects which cause about 70% -80% of total rejections can be found. The rejection data collected previously plotted in a Pareto chart and analyzed to obtain the major sources of rejection of castings.

The following five steps are followed in drawing the Pareto chart.

(1) Determine the method of classifying the data:
by problem, by cause, by nonconformity, and so forth.
(2) Decide if cost (best), frequency, or both are to be used to rank the characteristics.
(3) Collect data for an appropriate time interval or use historical data.
(4) Summarize the data and rank order categories from largest to smallest
(5) Construct the diagram and find the vital few.

The Pareto chart for rear bearing housing and front bearing housing are given below in fig.6.1 and 6.2 respectively.

6.2 RESULT OF PARETO ANALYSIS

Based on the analysis of rejection data of front and rear bearing housings made with the help of Pareto charts, the following defects are identified to be contributing to major part of the rejections. The defects are as follows,

a. Shrinkage
b. Mould Scabbing
c. Core Fusion
d. Blow Holes
e. Sand Drop
f. Cracks / Broken

As these defects are found to be major defects in front and rear bearing housing, further process will be carried out in view of these six defects.

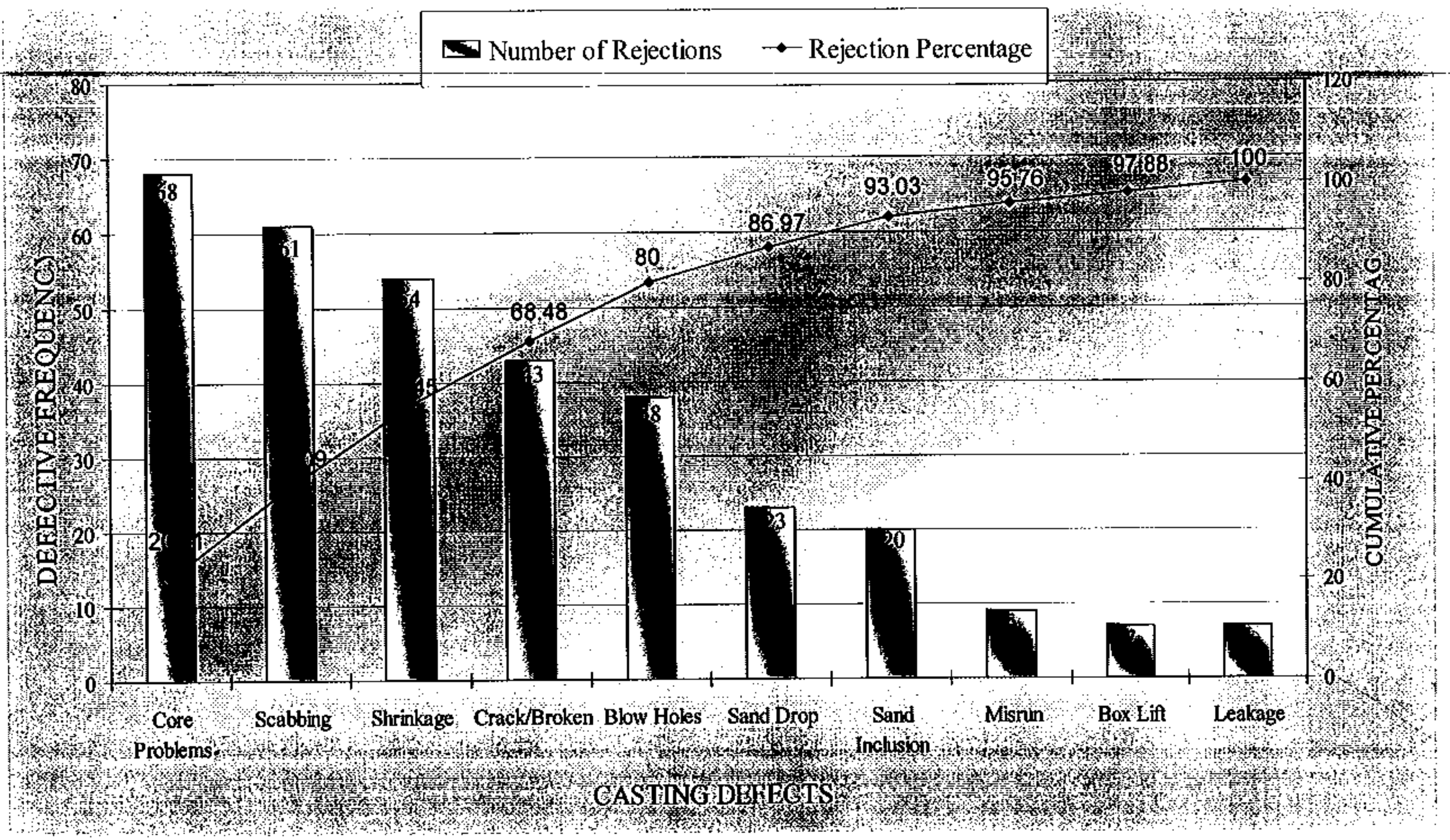

FIGURE 6.1 PARETO ANALYSIS ON REAR BEARING HOUSING

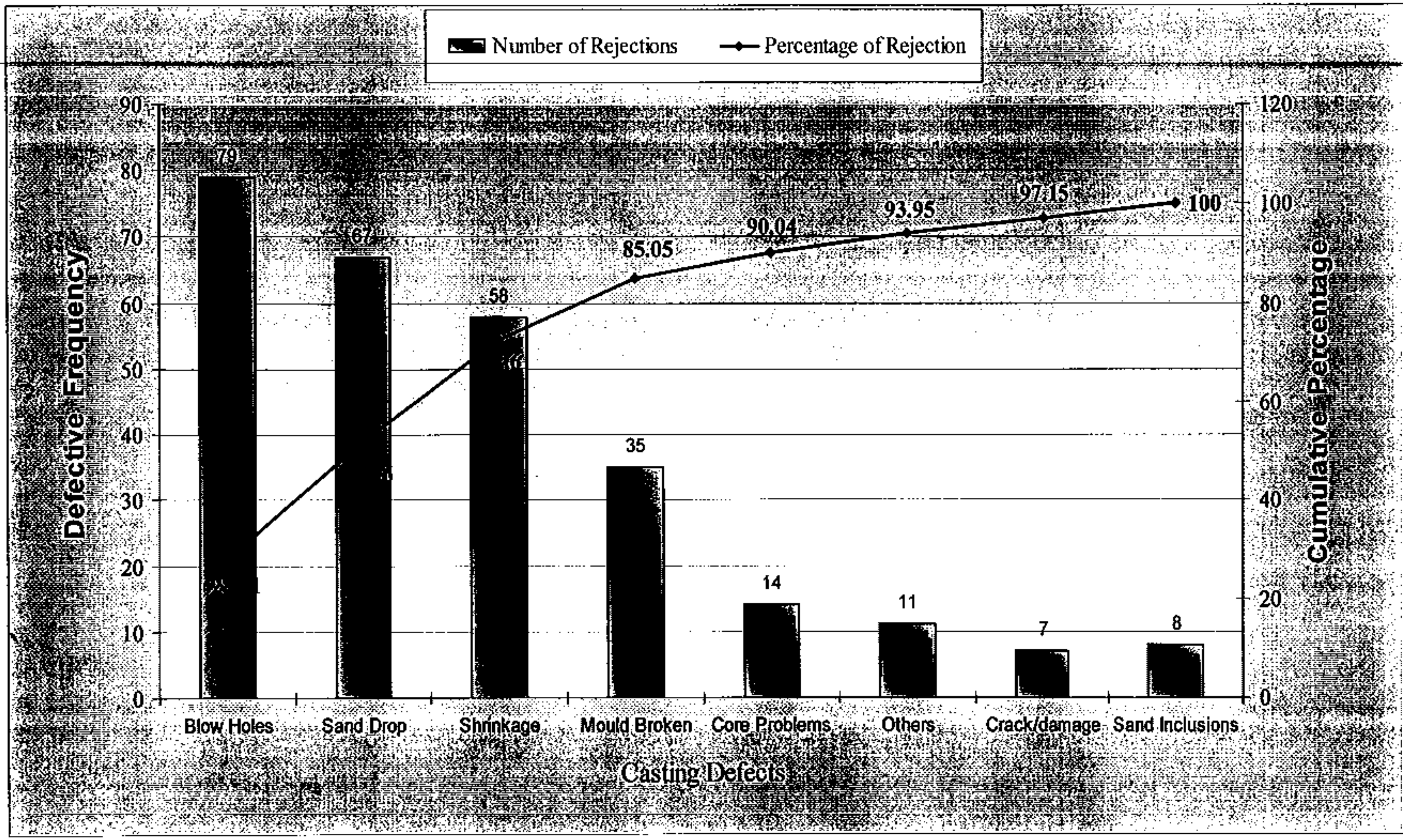

FIGURE 6.2 PARETO ANALYSIS ON FRONT BEARING HOUSING

CHAPTER 7 POTENTIAL CAUSES
AND
REMEDIES BY TRADITIONAL APPROACH

7.1. POTENTIAL CAUSES

7.1.1 Potential Causes for Blow Holes:

The various potential causes identified based on process analysis and cause and effect diagram are listed below,

(1) Insufficient permeability of moulding/core sand.

(2) Presence of dead clay forming clay balls and also not mixing with sand.

(3) Insufficient core print providing no outlet for venting.

(4) Gas accumulation at parting line due to too close cavities.

(5) Too low pouring temperature causing quick cooling of certain portion.

(6) Flask wall too close to mould surface.

(7) Gating system causing turbulence.

(8) Inadequate riser height.

(9) Slow pouring of metal or interrupted pouring.

(10) Ladles too damp.

(11) Late pouring of metal causing mould and core absorbing moisture.

(12) Unclean metal (painted scrap) entering into mould.

(13) Excessive clay binder in sand.

(14) Too high return sand with lot of dead clay.

(15) Too much moisture on core sand.

(16) Under baked cores.

(17) Inadequate venting on core.

(18) Use of wet core without proper drying.

(19) Mould wash too heavy to dry.

(20) Hard spot caused by improper ramming due to misplacement of flask.

(21) Venting through parting line.

7.1.2 Potential Causes for Shrinkage:

The various potential causes identified based on process analysis and cause and effect diagram are listed below,

(1) Change in gating and pouring sprue section too abrupt.

(2) Isolated heavy sections unable to be fed.

(3) Area of feeding is insufficient at isolated sections.

(4) Gates and risers not promoting progressive solidification.

(5) Insufficient number of gating or risering.

(6) Risers too small-no feeding aids.

(7) Thin sections blocking feed path due to worn out section.

(8) Insufficient jolting capacity.

(9) Insufficient box size.

(10) Feed metal requirement not met due to improper gating arrangement.

(11) Pouring passage too long.

(12) Improper ratio of riser neck to casting section.

(13) Over inoculation.

(14) Too low phosphorus content.

(15) Pouring metal either too cold or too hot.

(16) Improper clamping of flasks.

(17) Mould or core having too high rigidity not allowing contraction.

(18) Cope flasks too shallow.

(19) Mould wall movement-no rigidity.

(20) Use of ineffective chills causing rapid cooling.

7.1.3 Potential Causes for Mould Scabbing:

The various potential causes identified based on process analysis and cause and effect diagram are as follows,

(1) Insufficient fillets on gates and section changes.

(2) Bars improperly placed preventing uniform ramming.

(3) Rigging into small flask so that the vertical pattern wall is too close to flask reinforcement bar.

(4) Metal flow causing impingement on mould cavity.

(5) Gating causing localized overheating.

(6) Gating causing interrupted flow.

(7) Improper gating causing interrupted metal flow.

(8) Excessive pouring temperature.

(9) Interrupted pouring of metal.

(10) Too quick poring causing metal impinging on sand surface.

(11) High moisture content causing erosion of sand due to weakness.

(12) Insufficient hot strength.

(13) Excessive carbonaceous material causing boiling.

(14) Improper conditioning of sand.

(15) Dead clay at sand surface causing erosion.

(16) Excessive moisture on skin of core.

(17) Inadequate penetration of core wash.

(18) Insufficient hot strength on sand.

(19) Excessive sticking of sand on mould surface.

(20) Core blow causing scabbing on adjacent mould surface.

7.1.4 Potential Causes for Core Fusion/Broken:

The various potential causes identified based on process analysis and cause and effect diagram are as follows,

(1) Insufficient clearance between dowel pins and bush.

(2) Pressurized gating system.

(3) Flow of metal over one part of core/ from one side of core.

(4) Convergent type ingate system.

(5) Localized heat generation.

(6) Excessive pouring temperature.

(7) Excessive pouring time.

(8) Interruption in pouring of metal.

(9) Short pouring time leading to mould explosion.

(10) Excessive sand moisture due to delay in pouring of metal.

(11) Hot-cold combination of core and mould.

(12) More amount of dead clay present in sand.

(13) Too much of moisture content in core sand.

(14) Low scratch hardness on core.

(15) Insufficient dry compression strength.

(16) Use of improper binder material (tetra ethyl amine) leading to excess gas generation.

(17) Use of hot sand for mixing.

(18) Under curing of core- insufficient curing time.

(19) Lack of reinforcement on core.

(20) Humidity affecting the strength of core due to prolonged storage time.

7.1.5 Potential Causes for Sand Drop:

The various potential causes identified based on process analysis and cause and effect diagram are listed below,

(1) Insufficient permeability of moulding/core sand.

(2) Core print not properly mounted onto the mould cavity.

(3) Insufficient core print to support the cores leading to sand drop.

(4) Weak, loose, springy flasks and bars.

(5) Rough handling of moulding boxes.

(6) Strong backing sand with weak facing sand or vice versa.

(7) Dropping of mould box or some weights over flask.

(8) Insufficient draft / back draft on pattern.

(9) Worn-out / damaged pattern and core boxes.

(10) Lack of crushing strips and sand collector.

(11) Worn-out match plate bushing.

(12) Excessive core wash or wet core.

(13) Insufficient dry strength of core.

(14) Worn-out pins and bushings.

(15) Improper reinforcement of moulding boxes.

(16) Improper blowing of moulds.

(17) Uneven levels of bottom of moulding box.

(18) Wet sand adhering to the inside wall of the moulding box.

(19) Low green compression strength of sand due to insufficient active clay.

(20) The nose of ladle touching the sprue.

(21) Resting of pouring ladles on moulding flask.

7.1.6 Potential Causes for Cracks/ Mould Broken:

The various potential causes identified based on process analysis and cause and effect diagram are as follows,

(1) Isolated heavy section or light section requiring careful handling.

(2) Tie bars or reinforcing ribs not properly used.

(3) Lack of adequate fillets.

(4) Break up notches not provided.

(5) Worn out match plate causing parting line fins.

(6) Gating system promoting stresses.

(7) Too heavy risering.

(8) Poor collapsibility of core.

(9) Not using pre-measured quantity and standard measures for core sand mixing causing poor collapsibility.

(10) More hot strength on sand.

(11) High dry compression strength.

(12) Low green sand deformation.

(13) Hard ramming causing hard mould.

(14) Improper inoculation.

(15) Excessive carbide stabilizer.

(16) Red hot knock out.

(17) Casting failing to destroy binder property due to insufficient pouring temperature.

(18) Too heavy grinding causing crack.

(19) Improper design of shake out grid.

(20) Too much amplitude of vibration in shake out machine.

(21) More accumulation of casting at shot blasting section.

7.2 CAUSE AND EFFECT DIAGRAM

Based on the above given potential causes, a statistical approach is followed by structuring the potential causes in the form of Cause and Effect Diagram, one of the Q-7 tools for making the evaluation of causes more effective. The Cause and Effect Diagram for various defects are given in figures 7.1-7.6,

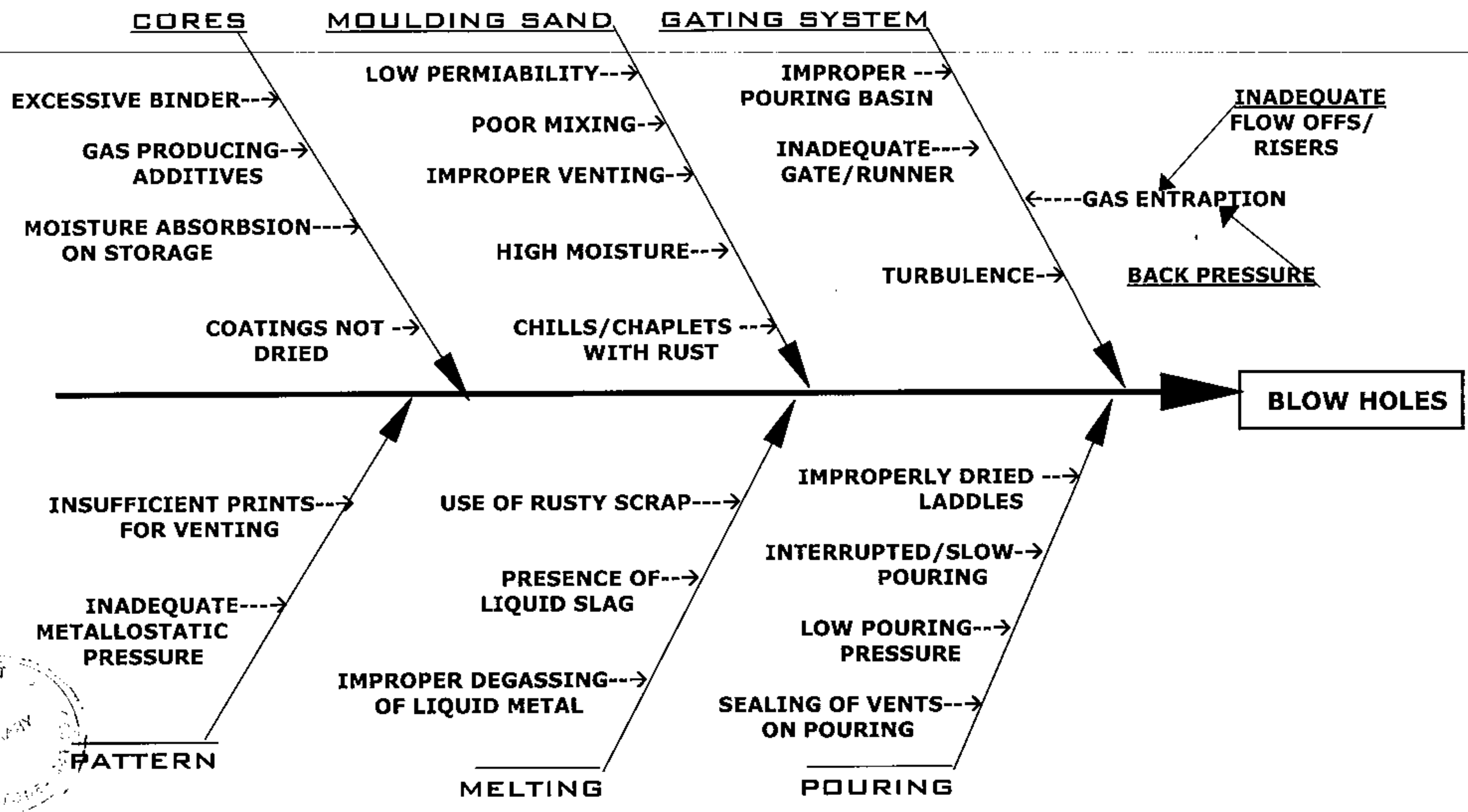

FIGURE 7.1CAUSE AND EFFECT DIAGRAM FOR BLOW HOLES

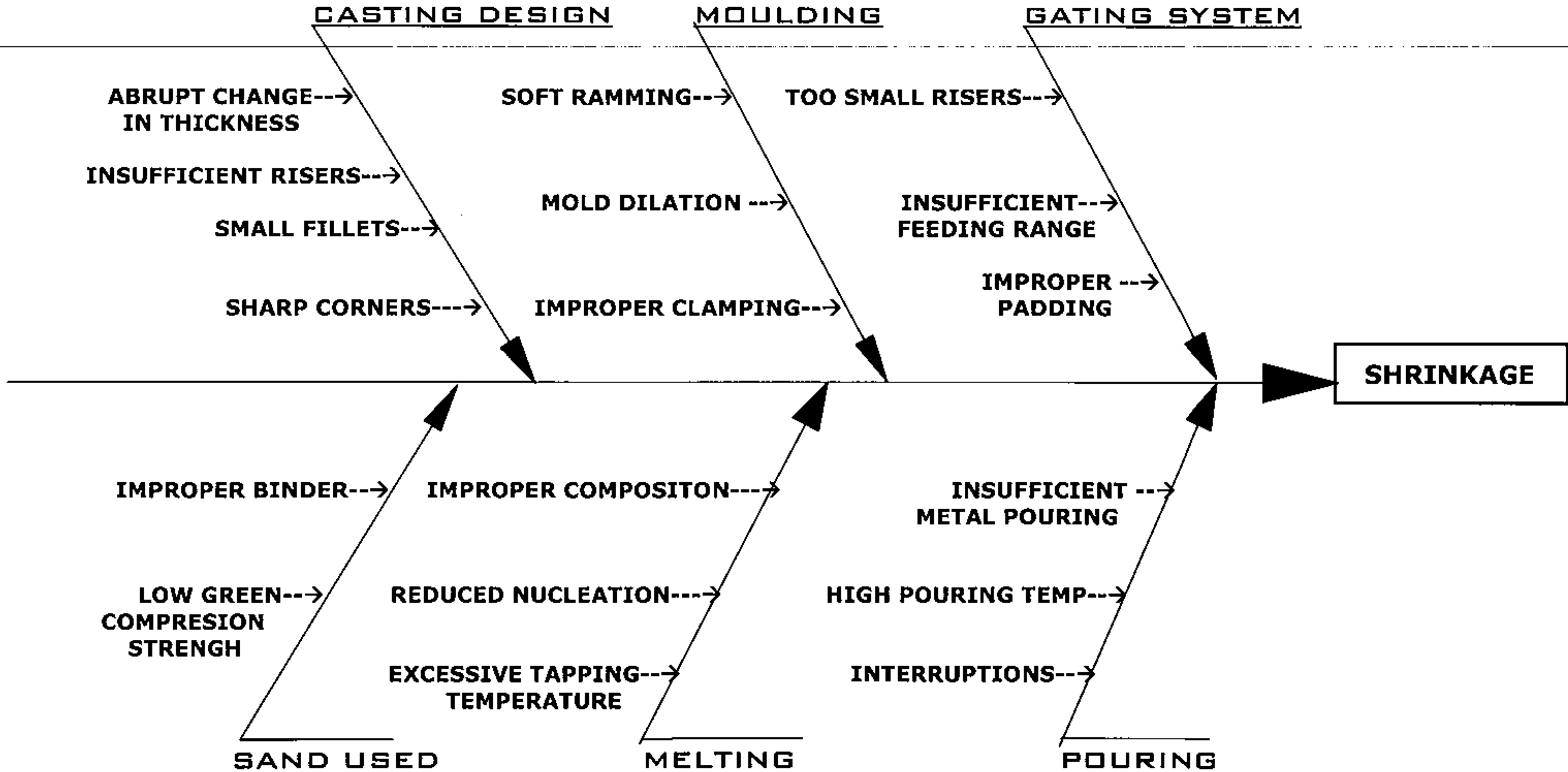

FIGURE 7.2 CAUSES AND EFFECT DIAGRAM FOR SHRINKAGE

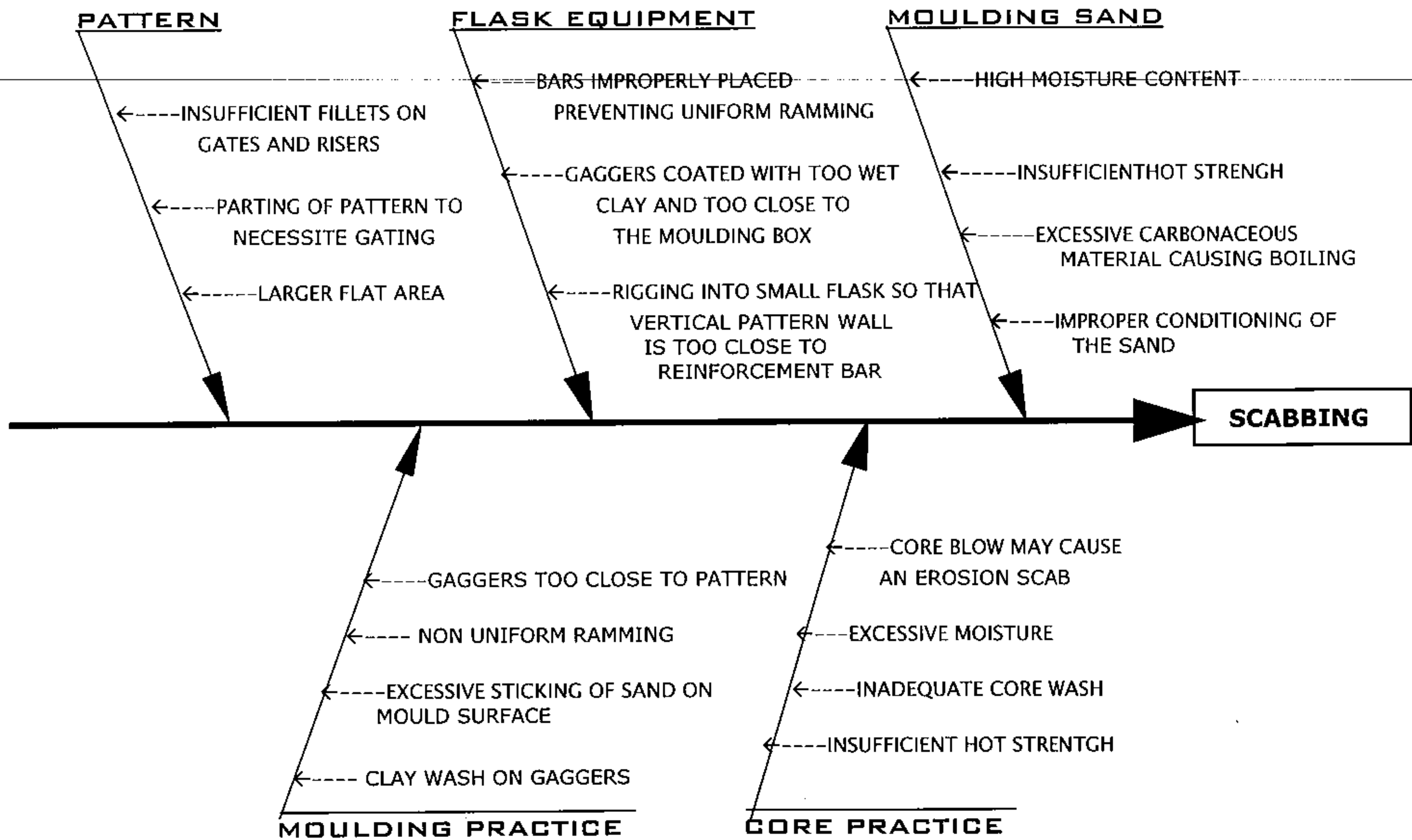

FIGURE 7.3 CAUSE AND EFFECT DIAGRAM FOR SCABBING

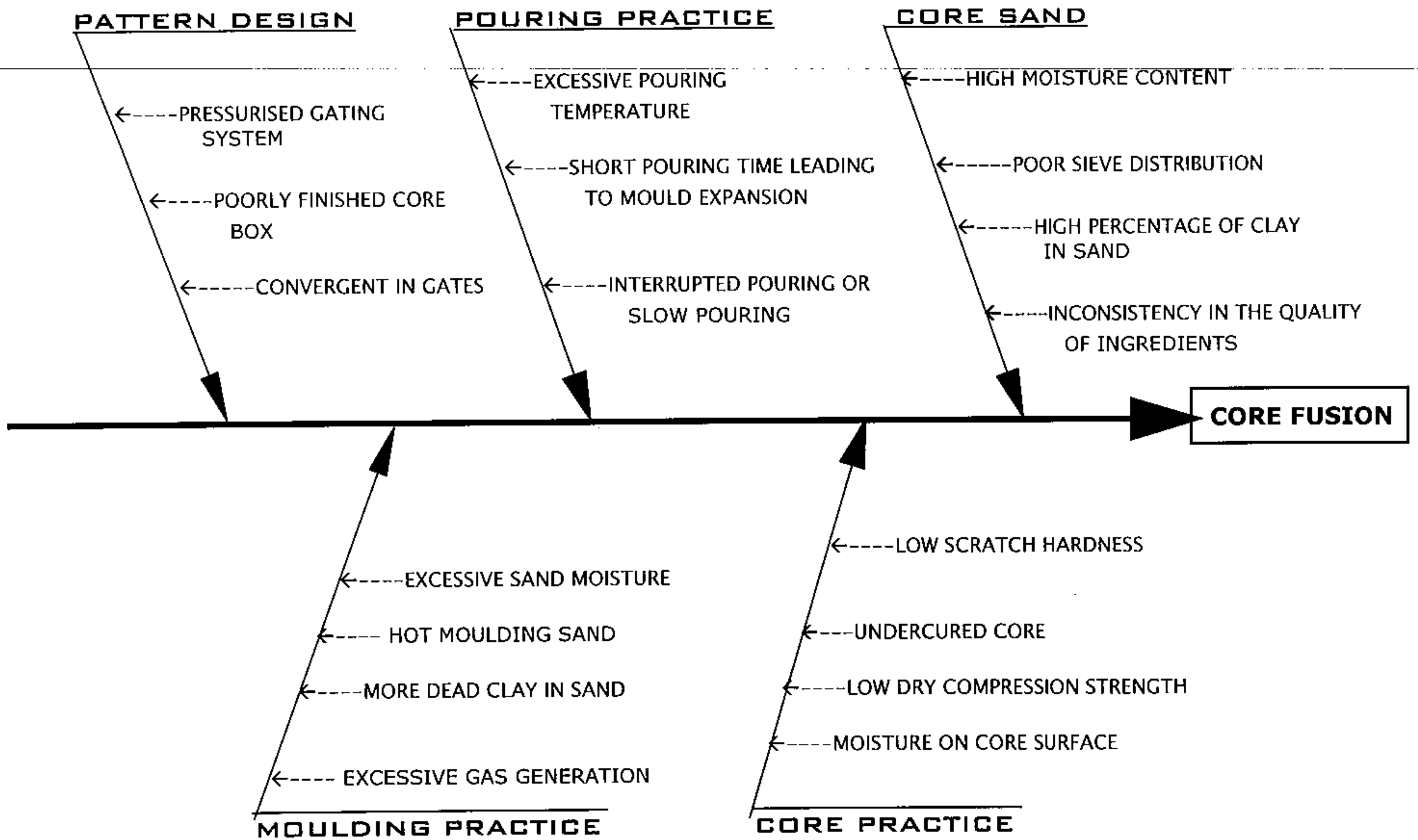

FIGURE 7.4 CAUSE AND EFFECT DIAGRAM FOR CORE FUSION

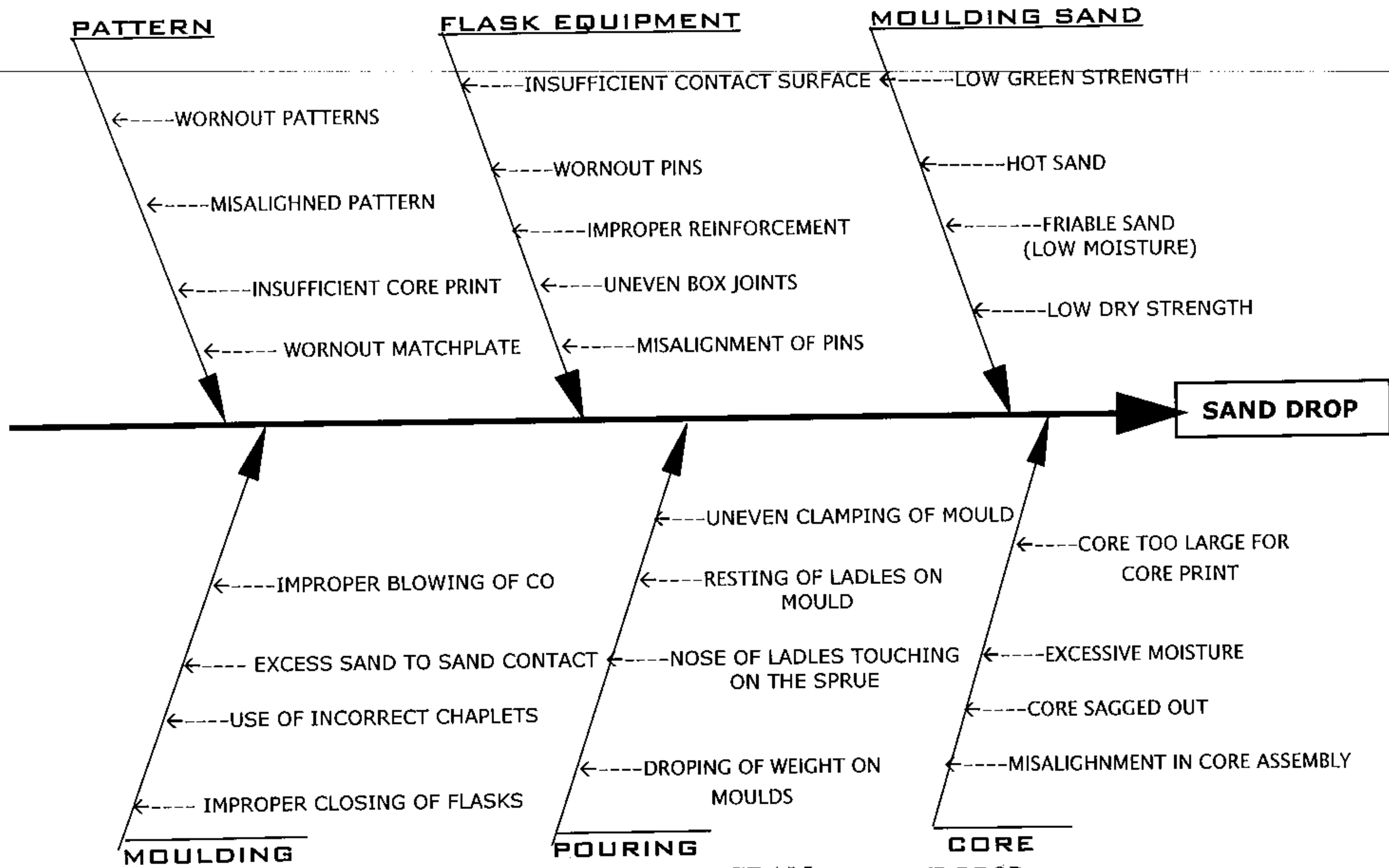

FIGURE 7.5 CAUSE AND EFFECT DIAGRAM FOR SAND DROP

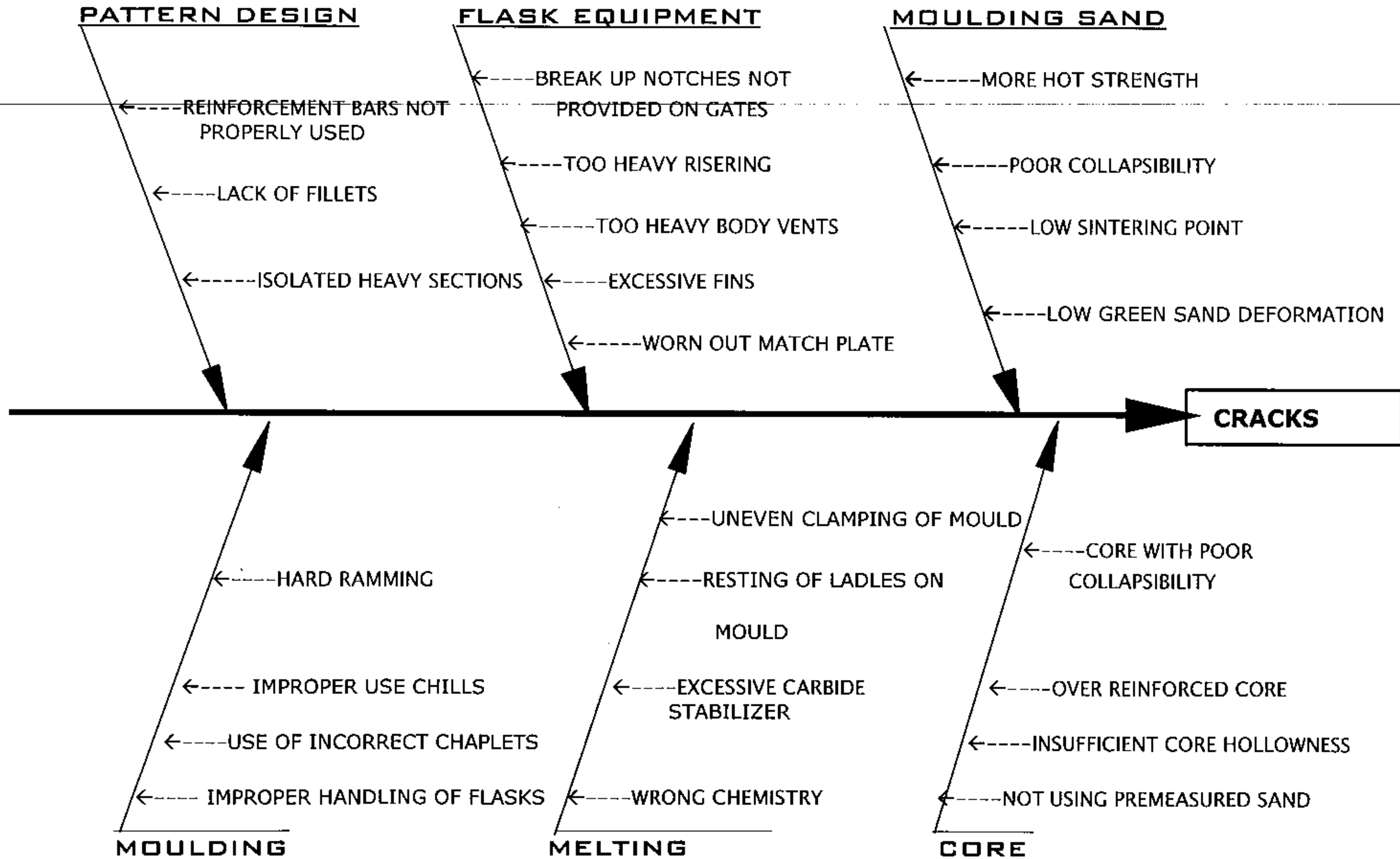

FIGURE 7.6 CAUSE AND EFFECT DIAGRAM FOR CRACKS

7.3 REMEDIES BY TRADITIONAL APPROACH

Based on the analysis made on the potential causes of the major defects and in comparison with the process analysis made on two bearing housing a set of remedial measures has been listed in a traditional approach of theoretical base. Though the traditional approach is found to be ineffective, this approach has been followed in order to provide a comparison with the non-traditional approach adopted in this project. However the remedial measures of traditional approach can also be taken into account as it can also contribute considerably in eliminating the causes so as to bring down rejections.

7.3.1 Remedies for the Defect Shrinkage:

The remedial measures to eliminate the causes for the defect shrinkage suggested based on process analysis and potential causes are as follows ,

(1) Ensure that risers are properly filled with hot metal.
(2) Ensure that risers are properly located and sufficient in size.
(3) Mouth of risers can be enlarged so as to ensure sufficient metal flow.
(4) Feeding flux can be used for proper flow of molten metal by avoiding rapid cooling.
(5) Adjust silicon and/or carbon equivalent in cast iron.
(6) Insulated risers can be introduced to prevent premature cooling
(7) External chills can be introduced when needed.
(8) Distribution of metal flow through sufficient number of in-gates must be ensured.

7.3.2 Remedies for the Defect Scabbing:

The remedial measures to eliminate the causes for the defect scabbing suggested based on process analysis and potential causes are as follows ,

(1) Proper positioning or centering of moulding boxes in machine so as to avoid uneven ramming.
(2) Gating area can be increased so as to avoid slow flowing of metal.
(3) Sand grain size should be properly maintained or else wood powder can be added.
(4) Moisture cum coal dust content should be properly controlled.
(5) Mould dressing (like refractory) should be properly used.
(6) Sand erosion can be controlled by increasing bonding by
(7) Addition of active clay with new sand.
(8) Additives in sand should be in proper proportion.
(9) Proper bonding between facing sand and baking sand must be ensured.
(10) The runner system has to be modified.
(11) Slow pouring of metal should be avoided by improving the gating system.

7.3.3 Remedies for Core Problems:
(Core Fusion, Scabbing)

The remedial measures to eliminate the causes for the defects core fusion / core scabbing suggested based on process analysis and potential causes are as follows ,

(1) Scratch hardness of core should be maintained at about 55-65.
(2) Dry compression strength of sand should be improved.
(3) Presence of moisture in core surface should be completely eliminated.
(4) Storage of core for prolonged period should be avoided.
(5) Core should be properly dried by heating before use.
(6) Binder percentage should be properly ensured.
(7) Finishing of core surface should be done properly.
(8) Proper venting should be provided.

7.3.4 Remedies for the Defect Sand Drop:

The remedial measures to eliminate the causes for the defect shrinkage suggested based on process analysis and potential causes are as follows ,

(1) Soft ramming should be enabled so as to allow casting to contract freely.
(2) Cores should be properly dried to avoid oil content.
(3) Necks should be properly designed so as to ensure proper breaking of risers.
(4) Casting should be sufficiently cooled before removing it out of the mould.
(5) Proper care should be taken while making the pouring mouth.
(6) Mould should be cleaned to remove loose sand particles.
(7) Core print has to be confirmed to be sufficient.
(8) The positioning of reinforcement should be proper.

7.3.5 Remedies for the Defect Cracks:

The remedial measures to eliminate the causes for the defect mould broken/ cracked suggested based on process analysis and potential causes are as follows ,

(1) Soft ramming should be enabled so as to allow
(2) Casting to contract freely.
(3) Cores should be properly dried to avoid oil content.
(4) Necks should be properly designed so as to
(5) Ensure proper breaking of risers.
(6) Casting should be sufficiently cooled before removing it out of the mould.
(7) Pouring temperature of metal should be properly maintained.
(8) Thermal gradients can be established by gates / risers.
(9) Binder content should be properly maintained.
(10) Labour could be insisted for proper handling of castings.

7.3.6 Remedies for Blow Holes:

The remedial measures to eliminate the causes for the defect blow holes suggested based on process analysis and potential causes are as follows ,

(1) Permeability of sand can be increased by using vent wire properly.
(2) Control over mesh size of sand particles by ensuring proper new sand proportion and mulling time.
(3) By providing extra in-gates in the gating system.
(4) Excessive ramming can be avoided by taking care of jolting time on machine.
(5) Moisture content has to be maintained at minimum level consistently.
(6) The pouring ladles must be properly dried before use.
(7) Pouring temperature can be increased.
(8) Cores should be properly dried before use.
(9) Ensure that reinforcement nails are dry.
(10) The gating system should be altered enabling gases to escape.
(11) Proper connection between core vent and mould vent should be provided.
(12) Skilled labour should be employed for pouring.
(13) Ensure ladles are dried before tapping.
(14) The presence of moisture content in core should be eliminated.
(15) The number venting provided can be increased.
(16) Manganese content should be taken care.

The above mentioned remedies are suggested as such in a traditional approach but however it can be considered while finalizing the remedial measures before implementation. The following is the non-traditional approach of using logical methodology for finding remedial measures and implementing it. This sequence could help in finding the importance and effectiveness of logical approach.

CHAPTER 8 REMEDIAL MEASURES BY LOGICAL APPROACH

8.1. LOGICAL APPROACH

In traditional approaches after inspecting the component visually defect would be identified and theoretically the cause would be predicted. Where as in logical approach, the repetition of occurrence of defects and location of defect occurrence will be taken into account and accordingly causes would be decided and corrective action will be properly implemented so as eliminate the occurrence of defect entirely. This methodology would be more effective than the traditional trail and error method.

The Logical approach to defect diagnosis before any effective action can be taken in the foundry, it is imperative that the defect under consideration is accurately diagnosed .Effort should therefore, be directed in diagnosing a defect accurately, since after this has been done, the correct course of action is generally clear. The actual form or Shape of the hole is an important characteristic when diagnosing a defect. When considering blow-hole & shrinkage type defects collectively, they may be clearly divided into three main groups:

(1) Smaller spherical holes

(2) Larger rounded holes

(3) Irregular hole.

8.1.1 Spherical Holes:

Let us consider now the possible ways in which spherical holes may be disposed through a casting. There are three main location of this class of hole, firstly on the top surface revealed during machining, they are some times revealed lodging underneath a core; secondly, on casting faces adjacent to moulds, again revealed on machining and thirdly those on cored faces sometimes seen prior to machining.

When the holes appear a top surface only, and are clear and bright, it is almost certain that they are due to low pouring temperature, and possibly high sulphur or manganese, or a combination of both. Metallographic examination will indicate gross manganese sulphide segregations, as well as associated iron-manganese silicate slag. The basic problem is one of low pouring temperature together with the dirty ladles, lack of skimming or the use of poor refractory materials. This type of defect often occurs in only several casting in particular batch, often the last few poured from one ladle, having the lowest temperature.

Higher metal temperature is necessary for the established and if both, or one of them is high, a reduction should take place. Where low metal temperature is unavoidable, for example in the production of very heavy castings, it is advisable to lower the manganese content and so reduce the tendency of the defect to occur. Clean ladles should be used, together with good skimming practice.

If the small spherical holes occur on all faces of the casting s adjacent to the mound and are slightly smaller than the previous type and have very shiny surfaces, they are most likely to be caused by contamination of the metal with aluminium. Metallographic examination will indicate continuous, graphite lining to the cavities. The presence of small quantities of aluminium in an iron even as little as 0.005% increases its tendency to pick up hydrogen from water vapour and during solidification of the casting, the hydrogen is rejected in the form of small holes .Sources of aluminium must be sought and one of the most common is from the scrap. Inoculants containing silicon normally have aluminium present, and should therefore be used sparingly. The moisture content of the sand must also be controlled, since if this is high the greater is the tendency for the defect to occur. It may be found that only those castings most remote from the down gate are affected and if so, this is a strong indication, and means of shortening the runner system should be investigated.

The third possible position for small spherical holes is adjacent to cores. These often are revealed after knockout and they tend to be more elongated than those holes due to aluminium contamination, and in some cases may even in some cases may even be slightly irregular. When holes of this type are seen, the type of binder used should be investigated. If a resin binder containing nitrogen is used, this is most likely the cause of the defect.

8.1.2 Rounded Holes:

Rounded holes result either from shrinkage of the metal, or from gas evolved from the mould, cores or inserts, these holes are normally larger than those previously discussed.

The surface sinks, which often have an excluded bead of metal inside them, and sometimes have small rounded holes underneath. In addition, small depressions may often occur at hot spots and when on sectioning, generally reveal an associated subsurface hole. Both types of defect generally occur in the heavy sections of castings. These defects are due to shrinkage and the major factors affecting their formation are:

a. The rigidity of the mould
b. High pouring temperature
c. High levels of inoculation

If the mould is insufficiently rammed it will yield under Ferro static and solidification pressures and give rise to a swollen casting or one which is larger than pattern dimensions. Normally the greater the amount of over sizing, the greater is the volume of shrinkage. When therefore this defect is experienced, castings should first be examined, either visually or dimensionally, to assess whether any swelling has taken place. Casting weight is also an indication of casting swelling. If swelling has taken place, then attention should be given to improving the compaction of a mould and may be the cores.

Pouring temperature is a known factor in contributing to these defects and therefore the question of lowering the pouring temperature should be considered. Occasionally, very low carbon contents can be responsible for both defects and if more rigid moulds and cores, together with lower pouring temperature fail to overcome the problem, the carbon content should be investigated. Inoculation increases the tendency for such defects to occur and should preferably be limited to a maximum of 0.3% by weight of metal treated. We come now to rounded holes which are generally in the body of the casting, although they do in certain cases come through to the surface. If the hole is adjacent to the mould face, and has a very thin shell of metal surrounding it, it is most probably due to a blow from the mould. Direct blows from moulds are rare, and normally only occur when excessively wet sand is used, or a mould coating is not being correctly dried.

It is, however, possible in very thin sections where one side of the section is mould and the other core, to confuse a blow from the mould or core. However, this may often be confirmed by examining castings prior to fettling. If a blow from the core is suspected, all core prints should be examined, since it is possible that metal may be entering the prints and thus blocking the vents.

Blow from cores in heavy sections are often associated with the core the sectioning may reveal a series of holes obviously traveling from the core. The question of improving the venting system of the core should be considered and an inspection procedure of all core vents should be established. The cores should be correctly baked and excessive binder contents should be avoided.

Cavities associated with the inserts such as denseners and chaplets are almost certainly due to rust, dirt or condensation. All inserts should be inspected prior to assembly in the mould, since any products of corrosion will most certainly result in some form of blow-hole. Chaplets should be coated with high purity tin or copper and denseners should be shot blasted prior to use. Continued use produces an oxide film and it is preferable to discard the denseners after they have been used four or five times.

8.1.3 Irregular Holes:

There are two distinct types of irregular holes. In several cases and in heavy sections, this type may occur as large voids and have a dendrite or fir tree like surface, This type of defect generally occurs in the heavier sections of castings or at hot spots, such as adjacent to in-gates and feeders, or changes in section. Should the defect have the above characteristics, it is most certainly internal shrinkage, and the major factors affecting its formation are;

1. Lack of mould rigidity
2. High pouring temperatures
3. High degree of inoculation
4. The phosphorous content of the iron

As mentioned previously, when considering top surface shrinkage defects, variations in casting weight or dimension will quickly indicate whether variations in mould or core rigidity are occurring. If so, efforts should be directed to produce castings of greater dimensional accuracy to improve soundness.

High pouring temperatures also give greater casting dimensions a greater tendency for unsoundness, and this factor should be controlled. Inoculants, whilst having certain metallurgical advantages can, if carried out excessively, promote this type of defect. Therefore, if inoculation is being carried out, the amount used should be checked and if possible reduced.

Rarely the chemical composition of an iron has a significant effect on the formation of internal shrinkage but phosphorous is the only element, which does affect the extent to which it occurs. The question of phosphorous should be considered as a likely cause, since fluctuations in the element can give rise to sporadic out breaks of internal shrinkage. Irons having phosphorus contents above 0.10% are prone to this defect, particularly in heavy sections, and where high degrees of soundness are necessary, such as in hydraulic values, levels of below 0.055 are desirable. If therefore attention to the above factors dose not alleviates the problem, the question of phosphorus should be considered.

The second type of irregular holes as shown in the lower illustration, occur as discrete fissures rather than areas of interconnected porosity. There are two forms – the more widely dispersed and more isolated, generally larger fissures.

The more widely dispersed fissures are often associated with cupola melted, low carbon equivalent irons produced from high steel scrap charges, and are due to high nitrogen content in the metal. During the past few years there has been a tendency to use more steel in cupola charges and the incidence of this defect has become more prevalent.

Should this type of defect be experienced and the cupola charge containing in order of, or above 50% steel, then it is highly probable that the defect is caused by high nitrogen content in metal.

In electrically melted irons this defect can result from the use of low grade, high nitrogen in the iron. Titanium can neutralize the effect of the nitrogen and additions of up to 0.03% either as ferrotitanium, titanium metal. Or incorporation of a titanium bearing pig iron in the charge should overcome the problem.

Metallographic examination will most likely indicate the graphite flakes in a compacted form, this being an important diagnostic indicator.

Fissure defects in the more isolated form are generally attributed to the evolution of hydrogen during solidification, they may therefore occur in irons produced from low steel scrap charges. It is often difficult to differentiate clearly between the two. If metallographic examination reveals the presence of a continuous graphite film with evidence of also compacted graphite flakes.

If the defect is suspected to be due to hydrogen, the aluminium content must be reduced, since this will promote hydrogen pick-up and all sources of water vapour, particularly in the furnace and ladle refractoriness, must be eliminated.

This defect often occurs in castings poured from the first few taps when the hydrogen content of the metal is higher than in subsequent taps.

It must also be appreciated that such defects can be the result of high nitrogen bearing resin systems and consideration should always be given to this possibility.

8.2. ROOT CAUSE EVALUATION

Though there are number of potential causes identified and remedial measures have been suggested, implementing the remedial suggestions on trail and error /traditional approach is rather difficult and will be ineffective. Hence a logical approach/ methodology have been adopted to find the root cause which considerably contributes to rejections. In this methodology , the root cause has been found by elimination of non critical causes is done through a brain storming session conducted by experts from various departments. In particular for the defects blow holes and shrinkage the key points of logical approaches given in the previous chapter has been followed to identify the critical causes. The causes are made non-critical by validation of the causes and by evaluation of feasibility of implementing the remedial measures. Sometimes voting system may also be adopted for concluding a cause as non-critical. After eliminating the non-critical causes, out of the remaining critical causes one would be evaluated as root cause for remedial measure will found and implemented.

The root evaluation is done only for the four defects out of the six selected defects. The two defects of mould broken / crack and sand drop were neglected because most of the causes involved in those two defects are related to labour which cannot be taken as critical cause and its other causes are also involved in the rest of four defects; so finding remedial measures for those four defects' causes could reduce the rejections due to mould cracks and sand drop. However causes related with the carelessness of labour can be avoided only to a certain extend. The four defects to which root cause evaluation has been done are as follows,

(a) Blow Holes
(b) Shrinkage
(c) Mould Scabbing
(d) Core Fusion/scabbing

Table 8.1 ROOT CAUSE EVALUATION FOR THE DEFECT SHRINKAGE

S.NO	CAUSES	VALIDATION	EFFECT
(1)	Change in section too abrupt.	Customer related process. Cant be modified	Non-critical
(2)	Area of feeding is insufficient at isolated sections.	Remedy not feasible	Non-critical
(3)	Gates and risers not promoting progressive solidification.	Kalpour system found ineffective	Critical (root cause)
(4)	Insufficient number of gating or risering	Single side pouring not sufficient	Critical
(5)	Insufficient jolting capacity.	Moulding machine with adequate capacity has been used.	Non-critical
(6)	Feed metal requirement not met due to improper gating arrangement.	Ineffective feeding system	Critical
(7)	Improper ratio of riser neck to casting section.	Section modulus verified to be correct	Non-critical

(8)	Risers not providing feeding aids.	Sleeves are to be introduced	Critical
(9)	Over inoculation	Calibrated cups for inoculant addition in use	Non-critical
(10)	Too low phosphorus content.	Percentage checked using spectrometer	Non-critical
(11)	Pouring metal either too cold or too hot.	Pouring temperature checked using pyrometer	Non-critical
(12)	Improper clamping of flasks	No feasible remedy since dependent on labour	Non-critical
(13)	Mould or core having too high rigidity not allowing contraction.	Composition verified	Non-critical
(14)	Cope flasks too shallow	Trailed to be sufficient	Non-critical
(15)	CO slag reaction	Manganese and sulphur content checked before tapping.	Non-critical

Table 8.2 ROOT CAUSE EVALUATION FOR THE DEFECT BLOW HOLES

S.NO	CAUSES	VALIDATION	EFFECT
(1)	Insufficient permeability of moulding/core sand	Too much of clay content causing low permeability	Critical
(2)	Presence of dead clay forming clay balls and also not mixing with sand	Low proportion of new sand	Critical (root cause)
(3)	Insufficient core print providing no outlet for venting.	Already evaluated to be correct	Non-critical
(4)	Gating system causing turbulence	Proper runner system has to be provided	Critical
(5)	Too low pouring temperature causing quick cooling of certain portion	Checked with pyrometer	Non-critical
(6)	Excessive clay binder in sand.	Proportion to be changed	Critical

(7)	Under baked cores.	Core process to be taken care	Non-critical
(8)	Inadequate venting on core.	Proper venting provided	Non-critical
(9)	Venting through parting line.	Not feasible	Non-critical
(10)	Hard spot caused by improper ramming due to misplacement of flask.	Labour dependent	Non-critical
(11)	Inadequate riser height.	Sleeve has been introduced	Non-critical
(12)	Flask wall too close to mould surface	Sufficient flask size provided	Non-critical
(13)	Ladles too damp.	Properly dried before tapping	Non-critical
(14)	Slow pouring of metal or interrupted pouring	Labour dependent	Non-critical

Table 8.3 ROOT CAUSE EVALUATION FOR THE DEFECT SCABBING

S.NO	CAUSES	VALIDATION	EFFECT
(1)	Insufficient fillets and section changes.	Customer related	Non-critical
(2)	Rigging into small flask so that the vertical pattern wall is too close to flask reinforcement bar.	No feasible remedy	Non-critical
(3)	Unidirectional metal flow from causing impingement on mould cavity	Metal flow to be distributed	Critical
(4)	Improper gating causing interrupted metal flow.	Runners may be increased	Critical
(5)	Excessive pouring temperature	Incorrect cause	Non-critical
(6)	Wrong proportion of binder and coal dust	Proportion has to be changed	Critical (root cause)
(7)	Too quick poring causing metal impinging on sand surface	Labour dependent	Non-critical

(8)	High moisture content causing erosion of sand due to weakness	Too much binder	Critical
(9)	Dead clay at sand surface causing erosion during pouring	Too high return sand and too much clay content	Critical
(10)	Excessive moisture on skin of core	Delayed pouring or uncured core	Non-critical
(11)	Inadequate penetration of core wash	Core process dependent	Non-critical
(12)	Core blow causing scabbing on adjacent mould surface	No feasible remedy	Non-critical
(13)	Excessive carbonaceous material causing boiling.	Composition checked	Non-critical
(14)	Insufficient hot strength	Additive ratio to be checked	Non-critical
(15)	Non uniform ramming	Incorrect since machine moulding	Non-critical

Table 8.4 ROOT CAUSE EVALUATION FOR THE DEFECT CORE FUSION

S.NO	CAUSES	VALIDATION	EFFECT
(1)	Convergent type ingate system	Kalpour system found ineffective	Non-critical
(2)	Flow of metal over one part of core/ from one side of core	Single side poring system	Non-critical
(3)	Excessive pouring temperature	Checked with pyrometer	Non-critical
(4)	Interruption in pouring of metal	Labour dependent	Non-critical
(5)	Short pouring time leading to mould explosion	No feasible remedy	Non-critical
(6)	Excessive sand moisture due to delay in pouring of metal	Moulding time and availability of pouring has to be managed	Non-critical
(7)	Low scratch hardness on core	Core sand property has to be improved	Critical (Root cause)

(8)	Insufficient dry compression strength	Core process has to be taken care	Critical
(9)	Lack of reinforcement on core	Proper reinforcements provided	Non-critical
(10)	Humidity affecting the strength of core due to prolonged storage time	Pre-heating can be suggested	Non-critical
(11)	Hot-cold combination of core and mould.	------------	Non-critical
(12)	Localized heat generation	------------	Non-critical
(13)	Pressurized gating system	Gating design to be taken care of	Non-critical
(14)	Use of hot sand for mixing	Totally avoided by proper recycling	Non-critical
(15)	Use of improper binder material leading to excess gas generation	Binder proportion has been verified	Non-critical

8.3. FINALISED CAUSES AND REMEDIAL SUGGESTIONS

As a result of Root Cause Evaluation, certain causes have been short listed for which remedies can be implemented. The finalized causes that are found to be contributing to the major part rejections are as follows,

8.3.1 Gating and Risering System Related Critical Causes:

The critical causes related to gating system are as follows,

a) Gates and risers not promoting progressive solidification.
b) Insufficient number of gating or risering.
c) Feed metal requirement not met due to improper gating arrangement
d) Risers not providing feeding aids.
e) Unidirectional metal flow from causing impingement on mould cavity
f) Improper gating causing interrupted metal flow.
g) Insufficient permeability of moulding/core sand
h) Gating system causing turbulence.
i)

These causes serve as the critical cause for defects blow holes shrinkage, core fusion and scabbing. This factor reveals that Kalpour gating system in existence is not that effective and found to be causing lot defects .Hence it has to be modified and alternative gating has to be implemented.

Also the risers found to be not feeding the metal properly leading to shrinkage and hence an alternative for avoiding the rapid cooling of riser leading to insufficient metal feeding.

8.3.2 Sand Related Critical Causes:

The critical causes related to moulding sand are as follows,

a) Wrong proportion of binder and additives
b) High moisture content causing erosion of sand due to weakness
c) Dead clay at sand surface causing erosion during pouring
d) Insufficient permeability of moulding/core sand
e) Presence of dead clay forming clay balls and also not mixing with sand
f) Excessive clay binder in sand.

These critical causes are found to be contributing to the sand related defects like blow holes, sand drop, scabbing. From the Root Cause Evaluation it is clear that the existing proportion of sand is not proper and binder proportion has to be modified.

8.3.3 Core Process Related Causes:

The various critical causes relating to core preparation process are as follows,

a) Low scratch hardness on core.
b) Insufficient dry compression strength.
c) Excessive moisture on skin of core
d) Inadequate penetration of core wash
e) Core blow causing scabbing on adjacent mould surface
f) Humidity affecting the strength of core

The above mentioned critical causes reveal that the existing cold box process creates core related problems due to moisture content. Binder used in this process also contributes to some defects. Hence it has been suggested to alter the core preparation process.

CHAPTER 9 IMPLEMENTATION OF REMEDIAL MEASURES

The remedial suggestions has been analyzed by the quality control department and representatives from each department .Then after a series of evaluation the following remedies are found to be effective and are implemented .The implementation of remedies for eliminating critical causes are as follows,

9.1 DOUBLE SIDE POURING GATING SYSTEM

The followings chief requisites as mentioned by American Foundarymen Society has been taken into account before altering the gating system,

(i) Metal should be able to flow through the gating system with a minimum of turbulence and aspiration of mould gases so as to prevent sand erosion and gas pick-up. Turbulence is the most important single factor affecting the design of the gating. Excessive turbulence results in the aspiration of air and the formation of dross.

(ii) The metal should be so introduced in the mould cavity that the temperature gradients established on the mould surfaces and within the metal facilitate directional solidification towards the riser.

(iii) The metal cavity should be completely filled with molten metal in the shortest possible time, the gating system therefore be so designed that the rate of entry of metal into the mould cavity is well regulated.

(iv) The casting should be produced with a minimum of excess metal in gates and risers.

(v) Loose sand, oxides, and slag should be presented from entering the mould cavity by providing a proper skimming action on the metal as it flows through the gating system.

(vi) Erosion of the mould wall should be avoided.

9.1.1 Modification in Rear Bearing Housing:

Kalpour gating system has been replaced by the double side pouring gating system. This system consists of two pouring sprue placed at diagonally opposite corners.

Two runners are provided for each pouring sprue and correspondingly two in-gates are provided so as to enable distributed flow of metal so that it won't cause any impingement on sand surface. Because of the provision of two pouring sprue the mould cavity will be filled equally and temperature of metal flown into the cavity will also be evenly distributed enabling simultaneous filling of molten metal. The divided runner system avoids the turbulence caused due to convergent in-gates. Previously there were four vents provided where as because of double side pouring system two vents are found to be sufficient. This reduction in number of vents to half compensate for the loss of yield due to double side gating. The modified gating arrangement on pattern of cope box is shown in fig.9.1. Also the knocked-out casting is shown in fig9.5

9.1.2 Modification in Bearing Housing- Front:

In front bearing housing previously single side pouring with only three in-gates was provided. The runner was provided along one side of poring sprue. Now it has been modified with a distributed runner system with number of gates increased to six based on certain calculations by the pattern design department after a series of trails .Also now the pouring sprue has been placed at centre and metal flow is made to distribute along the runner on both sides of pouring sprue .This system will facilitate even distribution of metal flowing into the mould cavity so as to counteract several critical causes of defects. The modified gating arrangement on pattern of cope box is shown in fig.9.4. Also the knocked-out casting is shown in fig9.6

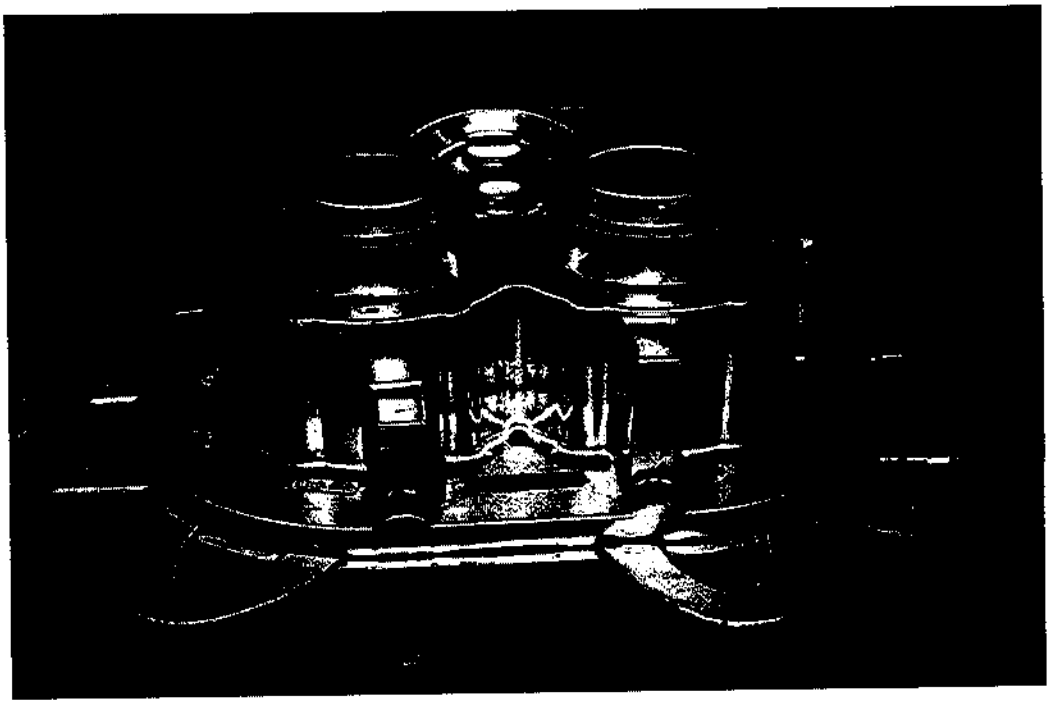

FIGURE 9.1 DRAG PATTERN OF REAR BEARING HOUSING

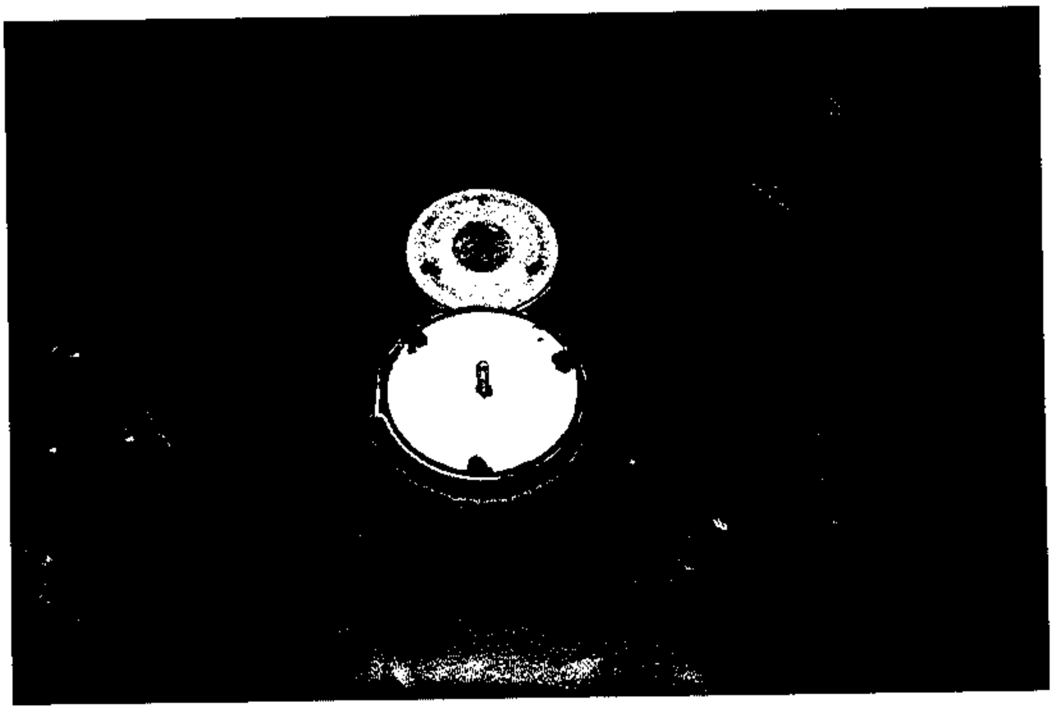

FIGURE 9.2 COPE PATTERN OF REAR BEARINGHOUSING

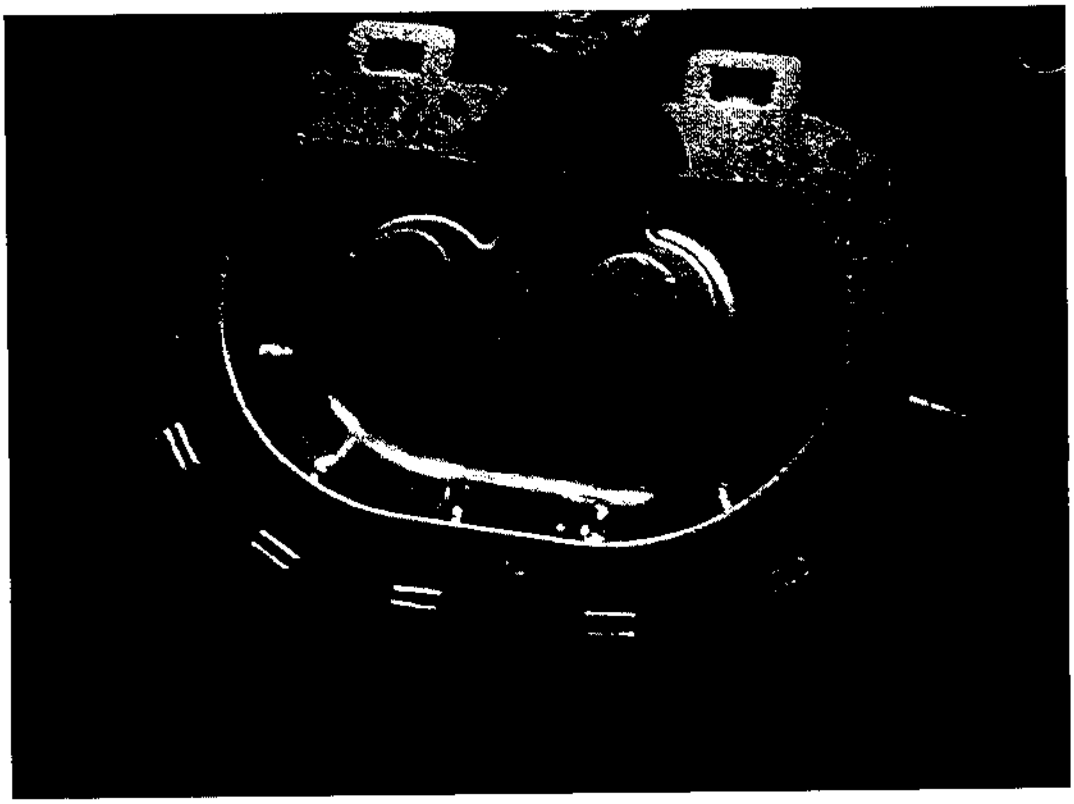

FIGURE 9.3 COPE PATTERN OF FRONT BEARING HOUSING

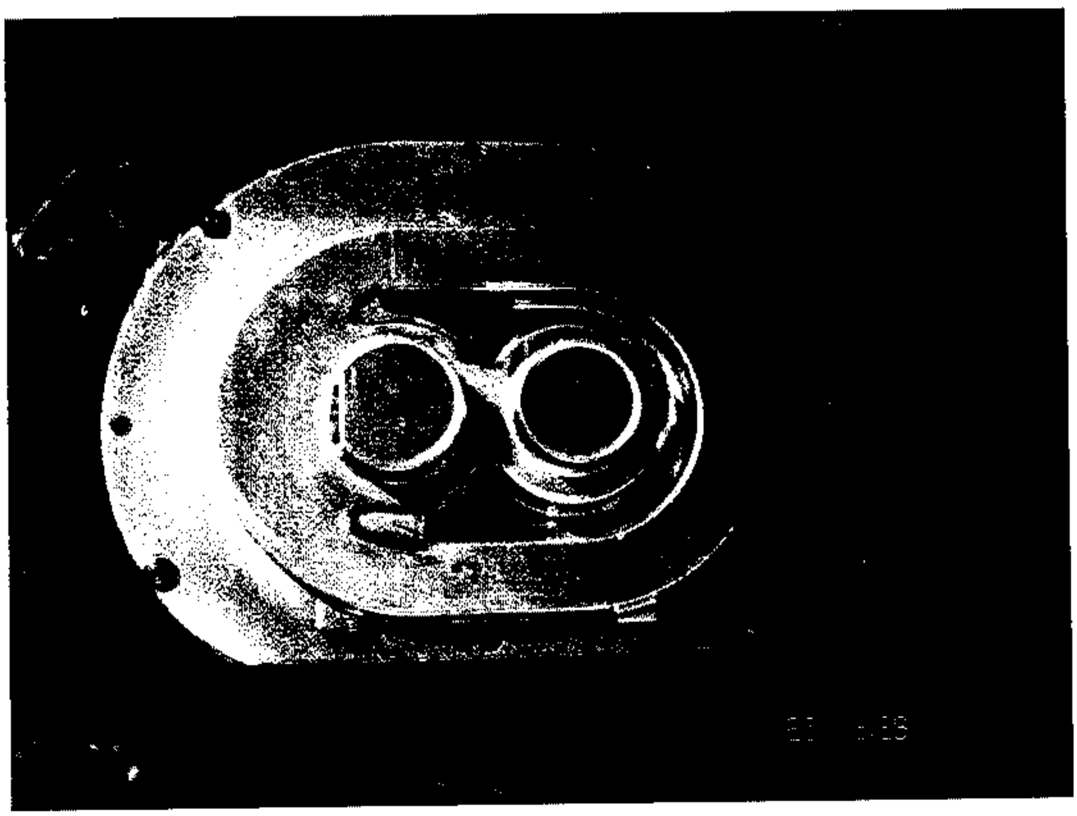

FIGURE 9.4 DRAG PATTERN OF FRONT BEARING HOUSING

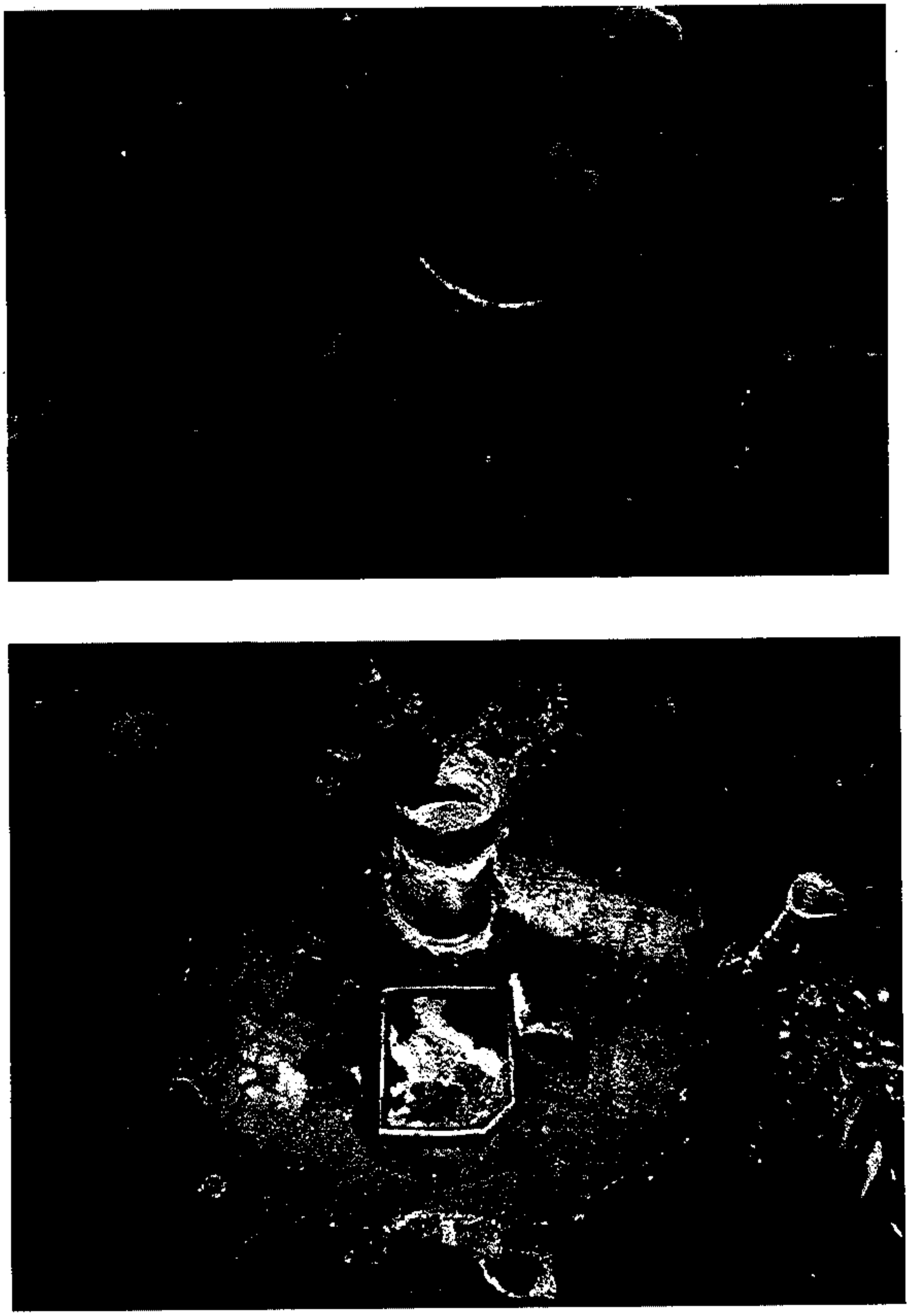

FIGURE 9.5 KNOCKED OUT COMPONENTS

9.2 MODIFICATION OF RISERS

The directional solidification can be controlled by the following ways,
(As per suggestions listed in "Risering of Castings" by 'AFS')

a) Proper design and positioning of the gating and risering
b) By properly adjusting the section modulus of riser with respect to that of the casting.
c) By insertion of insulating sleeves for risers.
d) By the use of padding to increase the thickness of certain sections of casting.
e) By adding exothermic materials in the risers or along with facing sand around the required sections of castings.
f) By employing chills in the mould.
g) By providing blind risers.

Based on suggestions some of the remedies have been implemented which are as follows,

9.2.1 Modification in Rear Bearing Housing:

The risering previously provided did not fed metal properly because of rapid cooling of riser due to exposure on atmosphere leading defects like shrinkage. Also the quick solidification prevented the escaping of hot gases leading to blow holes. Hence the section modulus of the riser has been changed from 1.9 to 2.6 in comparison to the section modulus of the casting of value 2.5.

9.2.2 Modification in Bearing Housing- Front:

The front bearing housing has been previously provided with chills which found to be ineffective. Also the provision of two risers with dimension of diameter 80 mm and length of 150 mm with a neck of diameter 40mm creates more probability of chances of cracks during removal of risers and hence a single Kalpour riser has been provided with a dimension of diameter 70 and length of 175mm. Also the neck of 40 mm diameter found to be insufficient and hence neck diameter has been modified to 55mm which is also due to change in riser dimension modification.

The new riser is found to feed at range of 100 to 160 kg of metal as per data provided by the 'Institute of Indian Foundries'. Thus the modified system proved to be effective. The knocked-out casting along with modified riser is shown in fig9.5

9.2.3 Insulated Sleeve and Exothermic Compound:

The one more modification done is that insulation sleeve has been introduced at the base of the riser based on certain calculations by the pattern design department. This sleeve acts as a barrier to atmospheric exposure so that rapid cooling of riser will be prevented. But still the top part of the riser would however be exposed to atmosphere.

To avoid this exothermic compound which serves to produce directional solidification by the generation of heat is being used. The exothermic material is usually a mixture of oxide of metal to be cast and powdered aluminium.

Here iron oxide and aluminium powder is used. The exothermic compound is being sprinkled over the top of the risers after pouring out the molten metal. The exothermic compound will react with molten metal and will continuously generate heat which will avoid cooling of risers before solidification of mould cavity. This can also be applied along with facings at the section where slow cooling is preferred. Thus the rejections due to shrinkage and blowhole defects are brought down.

9.3 MODIFIED SAND PROPORTIONS

The inadequacy of coal dust serves as a cause for defect 'scabbing' and presence of high dead clay content also serves as causes for certain defects and hence the proportion of new sand has to be increased . Also the lustron proportion needs to be increased. The presence of more dead clay on return sand indicates that clay content is more and excessive binder also causes some defects like blow holes. The actual and modified sand proportions are given in table 9.1 and 9.2.

Table 9.1 THE ACTUAL SAND PROPORTION

S.NO	INGREDIENT	WEIGHT(kg)	PERCENTAGE%
(1)	Return sand	450	85
(2)	New sand	60	11.3
(3)	Bentonite	16	3
(4)	Bentocol	2	0.35
(5)	Lustron	2	0.35

After a series of evaluation meeting in the production department, the cost factor has been analyzed and finally through a set of trails the following sand proportion has found to be effective in controlling sand related defects. The modified sand proportion is tabulated below.

Table 9.2 THE MODIFIED SAND PROPORTION

S.NO	INGREDIENT	WEIGHT(kg)	PERCENTAGE%
(1)	Return sand	400	76.8
(2)	New sand	100	19.2
(3)	Bentonite	15	2.88
(4)	Bentocol	3	0.56
(5)	Lustron	3	0.56

9.4 ALTERATION IN CORE MAKING PROCESS

9.4.1 Existing process and modification of process:

The existing core making process is cold box process. In spite of having an advantage of quick core making and ready to use , the lack of curing or heating of core leads to number of core defects like core fusion and excessive moisture defects like blow holes. This may also contribute to mould scabbing rejections. Also proper care has to be taken to prevent leakage of gas from apparatus because it is injurious to health if inhaled. Hence after considering many factors it has been decided to change the core making process to CO_2 process which already available.

In CO2 process certain specification has been regulated to see that it does not contribute to any rejections. Sodium silicate is chosen to be the binder and as per AFS specification and over a set of trails, binder is optimized to be maintained at 3.5% and also laborers are instructed to strictly check and maintain 3.5% of binder every time so ensure excessive binder defects wont occur.

Then after core is removed from CO_2 process, the core is coated with graphite paste and then it coated with zircon solution. It has been suggested that zircon solution is to be prepared with spirit as dispersion medium instead of water to avoid moisture. The spirit can easily be evaporated. Also after applying zircon-spirit solution the core will be fired and kept for one or two minutes so as to obtain required dry compression strength and to completely eliminate moisture. Its scratch hardness (55-65) is also comparatively more than that of cold box core. Its dry compression strength is around 400psi compared to cold box core strength of 280psi.

9.4.2 Limitations of Co_2 Process:

During humid climate CO_2 core absorbs moisture during delay in pouring of molten metal and during prolonged storage of core before installing it in moulding flask. To encounter this problem it is advised to preheat the core before placing it in mould cavity.

9.5 RESULTS OF IMPLEMENTATION

After the successful implementation of remedial measures, the process has been keenly observed and further casting rejections have been analyzed through rejection data analysis on data collected after a week's time and following results have been arrived.

Table 9.3 REJECTION DATA OF REAR BEARING HOUSING

S.NO	DEFECTS	REJECTION QUANTITY	REJECTION PERCENTAGE%
(1)	Blow Holes	08	3.43
(2)	Core Fusion	02	0.86
(3)	Scabbing	04	1.72
(4)	Sand drop	02	0.86
(5)	TOTAL	16	6.87
TOTAL PRODUCTION QUANTITY : 217			
DURATION OF DATA COLLECTION : MAR-06---APR-06'			
PRODUCT WEIGHT : 73.00kg			
OVERALL REJECTION% : 06.86%			

Table 9.4 REJECTION DATA OF FRONT BEARING HOUSING

S.NO	DEFECTS	REJECTION QUANTITY	REJECTION PERCENTAGE%
(1)	Mould Broken	01	0.46
(2)	Core Broken	01	0.46
(3)	Shrinkage	01	0.46
(4)	Sand drop	02	0.91
(5)	TOTAL	05	2.29
TOTAL PRODUCTION QUANTITY : 219			
DURATION OF DATA COLLECTION : MAR-06---APR-06'			
PRODUCT WEIGHT : 54.25kg			
OVERALL REJECTION% : 02.28%			

CHAPTER 10 CONCLUSION

10.1 CONCLUSION OF THE PROJECT

The remedial measures have been successfully implemented and rejection data are found to be considerably reduced. The reduction of rejections has been clearly shown in the following histogram.

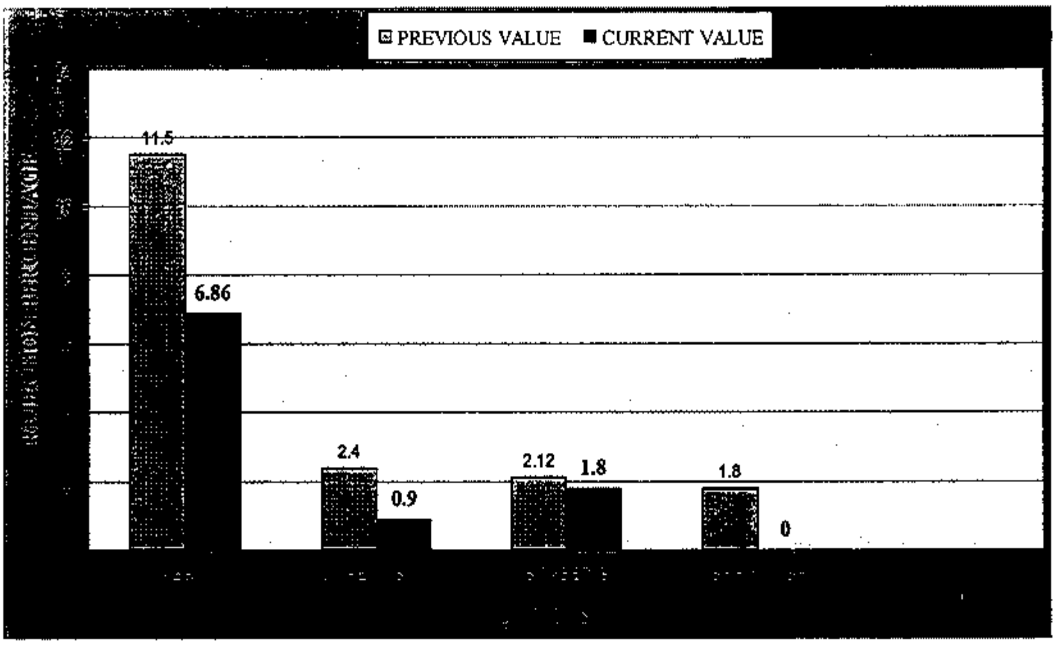

FIGURE 10.1 RESULT ON REAR BEARING HOUSING

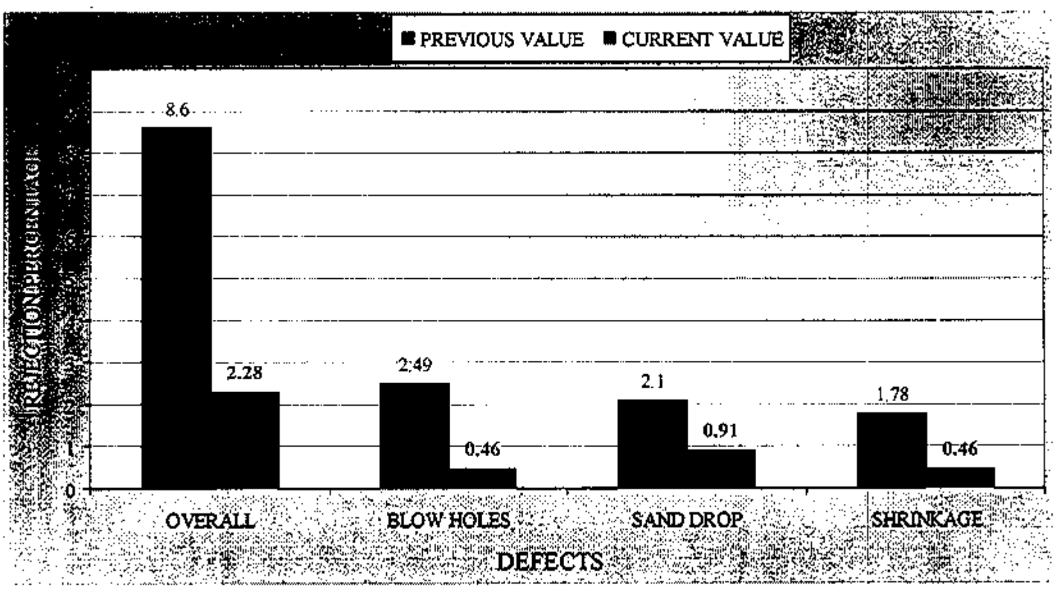

FIGURE 10.2 RESULT ON FRONT BEARING HOUSING

The histogram obviously reveals the reduction in the percentage of rejections of the components Rear Bearing Housing (546) and Bearing Housing-Front (594) from the previous value of 11.5% and 8.6% to a new value of 6.86% and 2.28% respectively.In particular the identification of major defects through statistical approach and root cause evaluation through logical approach are found to be more effective and accurate which contributed to the reduction in rejections.

Thus as we have mentioned earlier the non-traditional technique of adopting statistical and logical approaches is proved to be an effective tool for productivity improvement. Through this project it has been suggested that replacement of traditional approaches with non-traditional techniques should be concentrated by each casting industries for their productivity improvement. We assure that adopting the approach and methodology followed in this project will give good result.

10.2 LIMITATIONS OF THE PROJECT

The major limitation in adopting these kind approaches is the requirement of QC personnel with thorough process knowledge and awareness about statistical and logical approaches.

Another main disadvantage is that the implementation of remedial measures is not that easier in a rejection sensitive process industry. Implementation is possible only if the remedies are strongly believed to be worth while. The one more limitation is that most of foundries are labour dependent and to a maximum extend it could be semi-automated and hence the critical causes related to the labour carelessness or due to unskilled labour are not able to be rectified and remedial measures found to be ineffective in spite of using the non-traditional techniques.

10.3 FUTURE WORK

In order over come the limitations mentioned above, some way has to be found so as to tackle the causes related to labour which may include automation of foundries. Also appointing QC personnel for adopting non-traditional will has to be done in foundries where it is not in practice.

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