IMPLEMENTATION OF AN AVAILABILITY IMPROVEMENT METHODOLOGY IN THE SEAMLESS TUBE MINI-MILL ENVIRONMENT – A CASE STUDY.

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ABSTRACT

The maintenance management environment of a mini-mill in the steel processing industry, provides unique opportunities for developing and applying methodologies to optimise availability of plant equipment for production. Creating an incremental improvement culture within the maintenance department can prove to have a major impact when a focused approach is followed.

This dissertation presents a non-traditional, but practical approach to improve the performance of the plant maintenance team. It is complementary to both total productive management (TPM) and reliability centred maintenance (RCM) whilst providing a methodology to apply the data generated by computerised maintenance management systems (CMMS) in a productive manner.

The technologically advanced environment of a modern seamless tube mini-mill was used to evaluate the implementation results of the availability improvement drive. This dissertation is limited to the hot-mill section of the plant due to the opportunity for improvement that was identified in this department.

A systematic time based delay analysis methodology was applied to identify the sub-systems of the major equipment groups responsible for abnormal high downtime contributions. At the time of formulating and applying the methodology, the most recent data from the already established maintenance control system was used to establish the downtime root causes.

It was found that the results achieved by applying this approach to improve the plant's availability, were extremely positive. In one case, mechanical availability of a major equipment group was improved by 35% through focused implementation of engineering solutions to the problem areas identified. One important conclusion made by this maintenance team was that "redesign" proved to be the most effective way to improve both availability and reliability.

OPSOMMING

Die instandhoudingsbestuur omgewing van 'n mini-wals in die staal vervaardigingsbedryf bied unieke geleenthede vir die ontwikkeling en implementering van metodologië om die beskikbaarheid van aanleg toerusting vir produksie doeleindes te optimiseer. 'n Deurslaggewende impak kan gemaak word deur 'n kultuur van inkrementele verbetering te vestig in die instandhoudingsdepartement.

Hierdie skripsie bied 'n nie-tradisionele, maar praktiese benadering om die prestasie van die aanleg instandhoudingspan te verbeter. Dit komplementeer byvoorbeeld filosofië soos "total productive maintenance (TPM)" en "reliability centered maintenance (RCM)" terwyl dit ook 'n metode bied om data, wat deur gerekenariseerde instandhoudingbestuur pakette genereer word, doeltreffend aan te wend.

Die tegnologies gevorderde omgewing van 'n moderne mini-wals wat naatlose staal buise produseer is gebruik om die implementeringsresultate van die beskikbaarheid-verbetering projek te evalueer. Hierdie skripsie is beperk tot die warmwals gedeelte van die aanleg omdat 'n besliste verbeteringsgeleentheid in dié departement geïdentifiseer is.

'n Sistematiese metodologie van tydgebasseerde vertraginganalise is gebruik om subsisteme van die hoof toerusting groepe te identifiseer wat verantwoordelik was vir abnormale hoë vertragingbydraes. Die jongste beskikbare data vanuit die reeds bestaande instandhoudingsiteem is gebruik om grondliggende vertragingsoorsake te identifiseer tydens die formulering en implementering van die metodologie.

Besonder positiewe resultate is bereik met die toepassing van hierdie benadering om die aanleg beskikbaarheid te verbeter. In een geval is die meganiese beskikbaarheid van 'n hoof toerusting groep verbeter met 35% deur die implementering van gefokusde ingenieursopossings op geïdentifiseerde probleem areas. Een belangrike gevolgtrekking wat deur hierdie instandhoudingspan gemaak is, was dat "herontwerp" die mees effektiewe manier blyk te wees om aanlegbeskikbaarheid en -betroubaarheid te verbeter.

PREAMBLE

This dissertation should be informative to maintenance managers in the heavy engineering industry. As a young mechanical engineer in the steel industry, it was enlightening to see the impact of applying the knowledge gained from this MBA-course.

Acknowledgements:
Recognising that it was not a solo achievement, credit must be given to the maintenance personnel at Iscor's Seamless Tube plant in Vereeniging, South Africa. This improvement drive was made possible with the help of my colleague, Mr Johan Schutte, Electrical Engineer at IST.

I appreciate the support and collegiality offered by Mr Pieter Geldenhuys, my supervisor for reviewing this dissertation. In the same sentence, I have to thank Mrs Backeberg for her attentive and highly professional support in grammatically reviewing the text.

My sincere appreciation to my wife Cora and our daughter René for their continuous support during the final year of my studies.

To our heavenly Father, I give praise for leading me each step of the way.

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LIST OF ABBREVIATIONS

AM	Autonomous Maintenance
API	American Petroleum Institute
CBM	Condition Based Monitoring
CMMS	Computerised Maintenance Management System
CTP	Cone Type Piercer
FMEA	Failure Mode and Effect Analysis
FU	Functional Unit
IST	Iscor Seamless Tubes
JIT	Just In Time (philosophy)
MPM	Multi-stand Pipe Mill
MRP	Material Requirement Plan
MTBF	Mean Time Between Failure
MTTR	Mean Time To Repair
PLC	Programmable Logic Controller
PM	Plant Maintenance (module in SAP R/3)
RCM	Reliability Centred Maintenance
RHF	Rotary Hearth Furnace
SAP R/3 ®	System Application Program, Revision 3
SRM	Stretch Reducing Mill
TPM	Total Productive Maintenance
TQM	Total Quality Management

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Maintenance management within the context of the steel mini-mill poses enormous challenges to the maintenance manager and his team. The objective is to ensure optimal plant availability for the production of marketable products.

The dilemma of the maintenance manager (Moubray, 1997:5) can be illustrated on a time-line showing three different generations of the maintenance philosophy:

Table1.1: Illustration of the growing expectations of maintenance management.

First Generation	Second Generation	Third Generation
1940 1950	1960 1970	1980 1990
• Fix it when it broke	• More emphasis on plant availability • Longer equipment life expected • Lower cost	• Better plant availability and reliability • Safety awareness • Better product quality • Minimise impact on environment • Longer equipment life expectancy • Better cost effectiveness

With reference to the above Table 1.1, it becomes clear that major development must have taken place in the field of maintenance management over the past 20 years. From a South African point of view, ten different aspects could be identified to have a direct influence on the operation sphere of the modern maintenance manager. These different dimensions are listed in Table 1.2.

Table 1.2: Dimensions of maintenance management.

Dimension	**Quantifier**
1. Safety management	1. Legislation; OHS-act, 85 of 1993.
2. Project management • Ongoing reinvestment • Upgrading / Expansion	2. Capital budget
3. Preventive maintenance	3. RCM, TPM, TQM
4. Supplier management	4. MRP
5. Management of (reconditionable) equipment.	5. Spares / Maintenance strategy
6. Environmental management	6. Environmental legislation
7. Human resource	7. Labour law, Affirmative action
8. Relationship management: mechanical / electrical	8. Mutual co-operation
9. Relationship management: production / maintenance	9. Mutual co-operation
10. Multi-skill of employees	10. Productivity drivers, Change

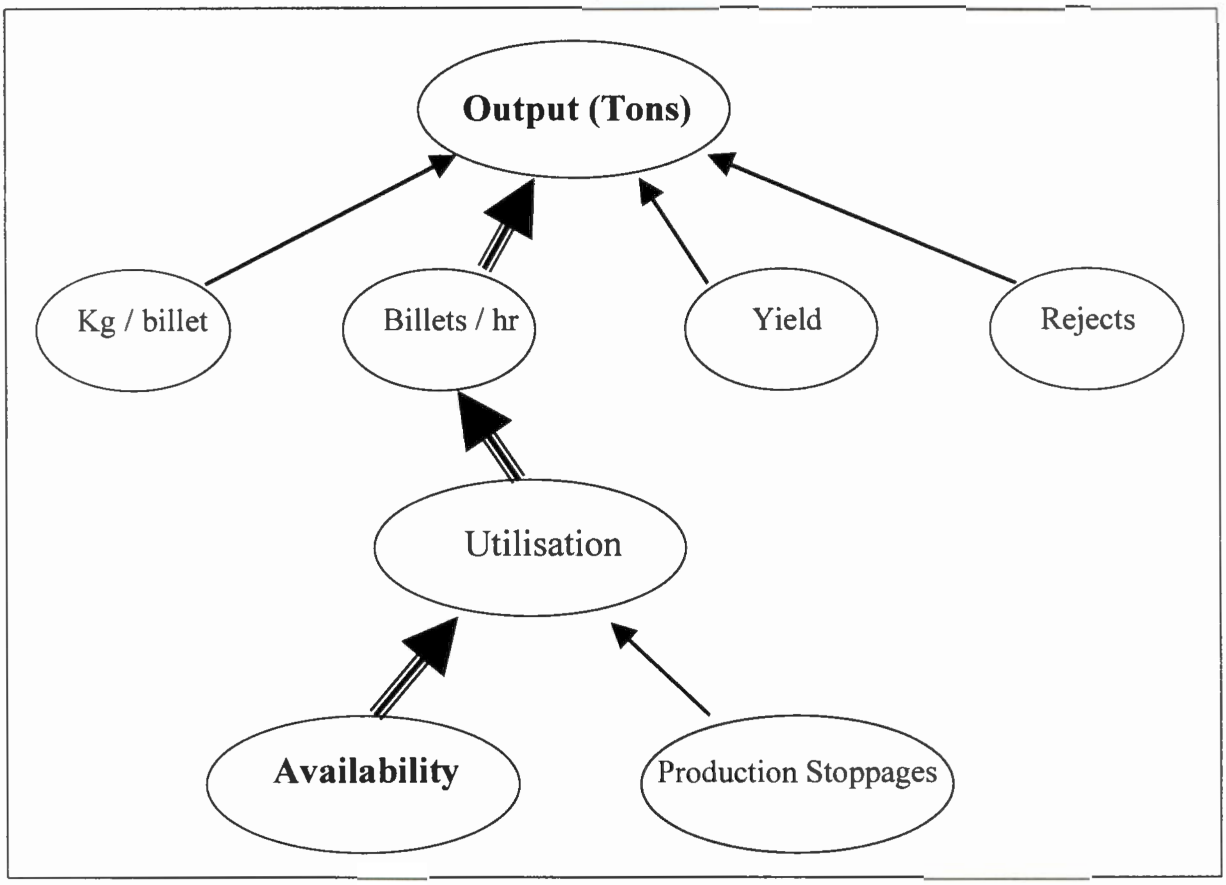
By now, it must have become evident that there is a need for a management tool that can help the maintenance manager to actively manage and control the maintenance requirements of the steel mini-mill's production environment in terms of availability.

When faced with an under performing steel processing plant, management have to use every possible means at their disposal to optimise the production process and ensure a profitable outcome for both the shareholders and other stakeholders. This document outlines the important contribution that can be made by the maintenance department to improve the availability of plant equipment for production.

In order to give the reader some perspective on the overall approach that was taken, figure 1.1 was compiled, showing the relationship between the responsibility area of 1) the maintenance manager, 2) plant availability and 3) the eventual production output of the plant.

The combination of **high availability** of the plant equipment and minimum production stoppages describes the total utilisation of the plant. Since billets are the raw material that is transformed into tubes, it follows that the number of billets that can be produced per hour would determine the annual output in tons. The other factors influencing the final output, are the mass per billet as well as the yield and number of rejects.

Figure1.1: Overview of factors influencing the mini-mill output, showing where the maintenance team's responsibility comes in, ensuring availability.



1.2 PROBLEM DEFINITION

The improvement of plant availability is one of the most cost effective ways to develop a competitive advantage in the manufacturing industry. Implementing a methodology to systematically identify areas for meaningful improvement is the key to improved plant availability. By using data from the plant's computerised maintenance management system, priority areas can be targeted for the implementation of engineering solutions. Until now, the systematic and structured refining of data from the computerised maintenance management system into meaningful information that can be practically applied to improve plant availability, remained a major challenge.

1.3 PURPOSE OBJECTIVE

The primary objective of this document is to develop a series of systematic initiatives to raise the level of maintenance performance in the steel mini-mill environment with the focus on optimised plant availability.

The contribution of this improvement drive would be evaluated in terms of improved machine downtime results achieved and compared over a two-year period in the seamless tube mini-mill environment.

A literature study is included to illustrate the functionality of this methodology when applied in series with other world class maintenance techniques e.g. TPM and RCM.

Since the implementation of this methodology is dependent on downtime data from the plant's computerised maintenance management system, it would be proven that it adds value to the data that would otherwise not have been used.

1.4 RESEARCH METHODOLOGY

It is imperative to have a thorough understanding of the production process and the existing maintenance management infrastructure before applying a remedy to achieve the desired effect of increased availability. A detailed analysis was therefore done to present the production process and the level of technologically advanced equipment used in the manufacturing process.

The next step is to illustrate how the "Scuba" methodology was applied to do a structured analysis of the modes of equipment failures experienced. These failure modes were quantified in terms of machine downtime and then prioritised for implementation of engineering solutions. An empirical investigation is included to illustrate the process that was followed to identify the problem areas. In most of these instances, a redesign approach was followed.

In conclusion, the results of this "Scuba" methodology are then evaluated by comparing documented plant availability results over a one year period to the previous year's figures.

1.5 SCOPE OF THE STUDY

The scope of this document is limited to one dimension of maintenance management with the aim to optimise plant availability. Documenting the critical aspect of systematically identifying equipment which prevents optimal plant availability forms an integrated part of the study. The results achieved by implementing engineering solutions are then evaluated to determine the success of the proposed methodology.

The subject of the study is the Iscor Seamless Tube mini-mill in Vereeniging, South Africa. As an example, a detailed comparison will be presented to indicate the improvement in equipment availability that was achieved. Focus is kept to the methodology that was applied and not on the engineering solutions implemented to achieve these improvements.

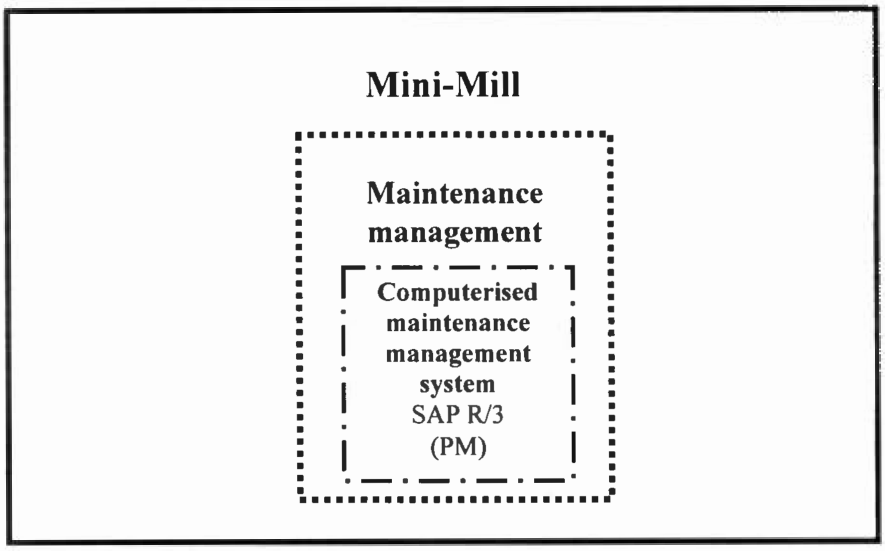
1.6 TERMINOLOGY

To familiarise the reader with the maintenance environment, the following terminology is defined as a basic guideline within the context of this dissertation:

• Steel processing plant:	Seamless Tube mini-mill
• Maintenance management:	Multidimensional discipline with the primary objective to optimise equipment availability.

- Information management system: Systems application program (SAP R/3) Computerised maintenance management system (CMMS)

Figure 1.2: Schematic diagram illustrating the relationship of the relevant areas.



Please refer to the pictogram in Appendix A, illustrating the manufacturing process where this study was done.

1.7 FURTHER DEPLOYMENT OF THE STUDY

This dissertation presents the results achieved by implementing the "Scuba" methodology to improve plant availability. Chapter 2 gives the reader some background to the steel mini-mill plant where seamless tubes are produced. This is necessary to understand the complex technical environment where the maintenance team is continuously striving to improve the plant performance.

Chapter 3 allows the reader to come closer to the field of maintenance management by presenting a literature study on world class maintenance techniques. It is illustrated that the ‘Scuba” methodology adds value to the data generated by computerised maintenance management systems.

Chapter 4 presents the research done to illustrate how the “Scuba” methodology was applied to the Iscor Seamless Tube mini-mill. A discussion of the implementation and initial outcome is tabulated to give a better understanding of the methodology.

Finally, the plant availability results are evaluated in chapter 5 on a comparative basis over two consecutive years. Conclusions are then made about the success and outcome of the methodology implementation.

CHAPTER 2

ORGANISATION BACKGROUND

2.1 INTRODUCTION:

More than 100 years ago (1886), an epoch-making invention by the brothers Reinhard and Max Mannesmann, gave a new dimension to the process of tube making (Anon, 1985:2). Nobody even imagined that seamless tubes could be produced, just by rolling. At that time, a tube had a seam unless it was bored out of solid material. However, it was not until 1890, when the inventors developed the pilger rolling process as a supplement to the pierce rolling process, that they finally reached their main objective: the production of a marketable thin-walled steel tube.

During the first decades of its existence, the seamless tube scored success after success. It was actually far ahead of the contemporary state of technological development in that its properties were so novel and extraordinary that the technology of the 19th century could utilise it only to a limited extent.

The first pipeline made from seamless tubes was intended for the transportation of crude oil and masut; it was 25 km long and was laid in the Ural Mountains in 1890, shortly after the invention of the seamless pipe. Today the seamless pipe is used in applications of extremely high temperature and pressure such as the boilers of coal and atomic energy power stations, the complex and extensive piping systems in the chemical industry and even offshore oil rig drilling – achieving depths of up to 10 000m at 200 Mpa, 300 °C.

2.2 ISCOR SEAMLESS TUBE (IST):

Construction of this modern plant began in 1989 as a Joint Venture between Iscor Ltd and the Dorbyl Group of Companies. During the first two years, the hot-mill section was installed. Full production was reached in 1993 after the completion of the "downstream" processing line. The plant was designed to produce 100 000 Ton per year. This positions

IST in the mini-mill league compared to other European, American and Japanese plants producing up to 500 000 Ton per year.

A range of seamless tubes are produced in accordance with International Standards set by the American Petroleum Institute (API – 5L). Nominal Tube diameters vary between 1" (25.4mm) and 6" (152.4mm). The wall thickness of these tubes is classified as "Schedule" 40, 80 or 160 and includes a range between 3.91mm and 18.89mm, depending on the nominal diameter and application. The tubes are manufactured from steel grades with a low-to-medium carbon content. Due to the limited demand for Seamless Tube on the local South African market, the product is mainly exported to overseas customers. In order to present a product that can compete on the world market, strict Quality control measures are enforced in accordance with in-house or special customer requirements. Preparing the tubes for shipping, necessitated the installation of a paint-line to apply a special rust prevention coating, protecting the tubes in the hostile conditions at sea.

2.3 TECHNOLOGICALLY ADVANCED PLANT EQUIPMENT:

The hot-mill process involves a number of stages to transform a solid round billet of steel into a semi-finished tubular product.

Mechanical handling equipment, operated by integrated control systems, are used to transport the cut-to-length billets to the rotary hearth furnace. The billets are automatically loaded into the furnace by means of "gripper-tongs". Simultaneously the next hot billet is taken out of the furnace by another set of "tongs". This is a continuous process of loading a cold billet and off-loading a hot (1250 °C) billet, ready for piercing at the cone type piercer. An operator monitors the process on television screens, connected to cameras positioned at strategic points on the rollerways and inside the furnace.

At the cone type piercer, the billet arrives at hot-forming temperature (T>1150°C) and is slowly pushed into the "roll-gap" between the two vertically spaced conical piercer rolls. The two large diameter rolls are driven at an angle by two prop-shafts, rotating in the same direction. A piercing mandrel with a specially pointed "plug" which functions as an internal tool is positioned in the roll gap centre, being supported via a rod by an external thrust block. "Guide-shoes" or "Diescher discs" positioned horizontally in the roll gap, prevent the material to deflect out of the "roll-gap". The hot material is forced forward over the "plug" with the motion generated by the conical rolls to produce a rough pierced hollow shell. The result of the piercing is that the shell is elongated to 1.5 to 2 times the original billet length.

Following pierce rolling, the thick-walled hollow body, while still at rolling temperature, is rolled to its final shape in the Multi-stand Pipe Mill (MPM). The MPM consists of four stands with a two-roll arrangement. Each stand of paired rolls is 90° offset one to another. A graphite lubricated cylindrical mandrel, the diameter of which is roughly equal to the desired internal pipe diameter, is inserted into the shell before it passes through the MPM. Here the pipe is rolled to an exactly defined outside diameter and a perfectly round cross section. The main feature of the retained-mandrel continuous mill is the controlled mandrel speed. This makes it possible to obtain a more regular material flow, and hence, tolerances on wall thickness of an average ±6%. The result is an elongation of 5 to 6 times its in-going length is achieved, corresponding to a cross sectional reduction of between 80 to 90%. The extractor stand after the MPM ensures that the pipe is gradually run out and stripped off the mandrel.

Depending on the desired final diameter required, tubes with a nominal diameter below 3.5" are taken through yet another process at the Stretch Reducing Mill (SRM). The SRM is capable of elongating sufficiently hot steel tubing up to 10 times its original length, whereby it is possible to effect a considerable reduction not only in diameter, but depending on the diameter reduction, in the wall thickness as well. In-line induction heaters positioned in front of the SRM, re-heat the tube passing through them within seconds to the required temperature.

Finally the tube is cut in 20m long sections by three “hot-metal”-saws before it is transferred onto the cooling-bed where it is continuously rotated while being transferred to the “downstream” line for further cold processing.

2.4 PROCESS CONTROL SYSTEMS:

Each production unit on the hot-mill is automatically controlled by either a programmable logic controller (PLC) and / or a computer generated modelling program using feedback from online recording instruments.

The Rotary Hearth Furnace has 40 burners fuelled by Sasol Industrial gas. Hot air from the recouperator at a temperature of ~400°C is fed to the burners where it meets with the industrial gas to form a flammable mixture. The ratio of air to gas is kept between the limits of 3.9:1 and 4.2:1 by controlling the flow rate through the orifice of the respective air and gas lines for each group of burners. The differential pressure over the orifice is measured and converted into a 4 - 20 mA signal, which is, transmitted to a recorder unit. This unit is the system interface with the PLC. The return signal from the PLC is again received via the recorder by an “I-to-P”-transducer which then activates a pneumatic actuator to open or close the flow control valve in either the air or gas line. Besides regulating the air to gas ratio, the PLC also maintains the temperature in the furnace at a predetermined set-point for each zone of the furnace. Thermocouples on the furnace’s roof also supply a 4-20mA signal back to the PLC via the recorder where it is evaluated and then “decided” to increase or decrease the energy input of gas.

The PLC controlled charger and discharger “tongs” are used to handle the billets at the furnace. These operations are inter-linked with mechanical gearbox drive units used to incrementally rotate the 300 ton furnace floor through ~ 3° after each charge and discharge operation. Automatic operation of the “tongs” can be overridden to allow for joy-stick and push-button operation.

The Piercing Mill incorporates a number of “interlocks” where certain conditions must be met before the next action can be activated. These conditions are all evaluated by yet another PLC. Standardising on 110V AC, hydraulic and pneumatic valve coils are activated via relays, pulsed from the PLC. Input signals are received from pressure switches, flow switches, proximity switches, infrared optical sensors, hot metal detectors (HMD's) and limit strikers. Actual position feedback from encoders and transmitters is received, electronically interpreted and displayed as operating information.

Electronic motor drives are widely used to control the speed on normal AC-motors by changing the output frequency to the motor. These variable drives also offer a wide range of other features to control electric motors – ramp settings, variable torque control and master-slave configurations.

Online PC-based expert systems on the MPM and SRM, evaluate the recorded results from the encoders and transducers after each tube pass. Graphs are plotted and analysed to show trends and make adjustments to compensate for roll- and/or mandrel-wear.

These control systems are all integrated to create a maize of checkpoints and information resources to optimise the production process. It also minimises safety risks and warning signals are received in order to take precautions.

2.5 MAINTENANCE SYSTEM:

In order to maintain production equipment in the best operable condition, equipment must be inspected on a scheduled basis. It was therefore important to introduce Condition Based Monitoring (CBM) based on the scheduling and execution of repair work that are prepared in accordance with inspection results.

The following technology audit outlines the current maintenance technology employed at the IST hot-mill to produce seamless tubes. The technology level on the "downstream"-equipment is from the same generation as on the hot-mill, but less advanced and therefore not included in this report.

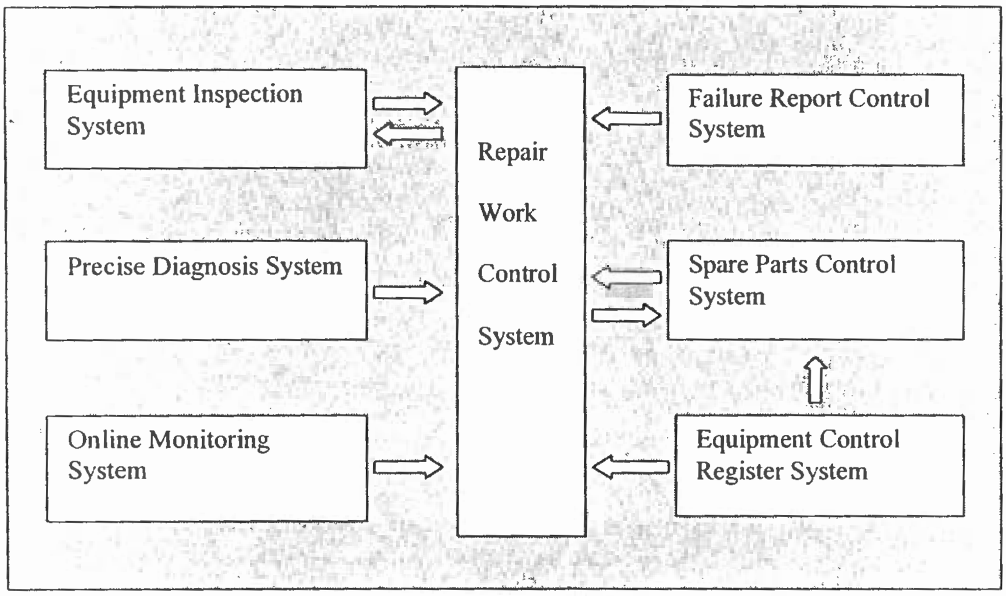
Table 2.1: Maintenance performance assessment.

		Poor	Avg	Good	World Class	Key themes
Effectiveness	Problem Diagnosis & Repair Execution.		●			• Operator involvement in problem communication, repair execution is minimal. • Root cause analysis done on major equipment.
	Equipment Strategy		●			• Moderate use of condition monitoring and preventative maintenance.
	Organisation improvement			●		• Flat and well integrated structure • Strong performance ethic • Emphasis on training is high.
Efficiency	Planning & Scheduling		●			• ~ 50% of total maintenance work is planned. • Overtime around 15%.
	Infrastructure Support		●			• Spares availability and inventory system is moderate.
	Systems support			●		• IT systems in place but not understood by all. • Equipment history not used consistently.

To hold maintenance costs at minimum levels, it is important that the deterioration characteristics of equipment are accurately grasped by working on a time based maintenance system.

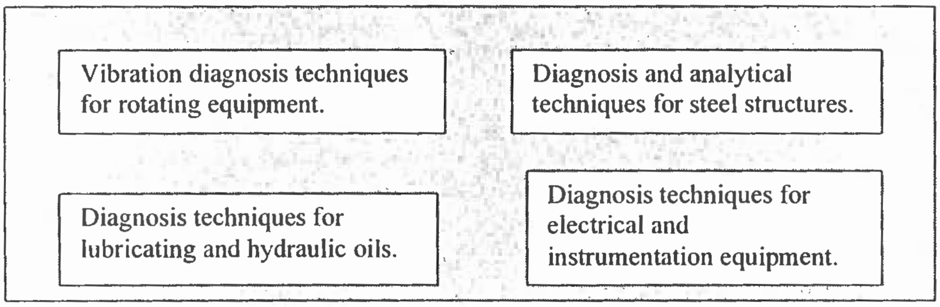
At IST it has been found that plant equipment must be maintained on a 13-day cycle. Plant shutdown-days are thus scheduled for every 14th day in order to do planned-maintenance work according to inspection and CBM reports. The maintenance department is run according to the following control system:

Figure 2.1: Equipment Maintenance Control System



Various machine condition diagnosis techniques are applied to monitor the production equipment and provide useful inputs to the Repair Control System. Four distinct categories can be identified:

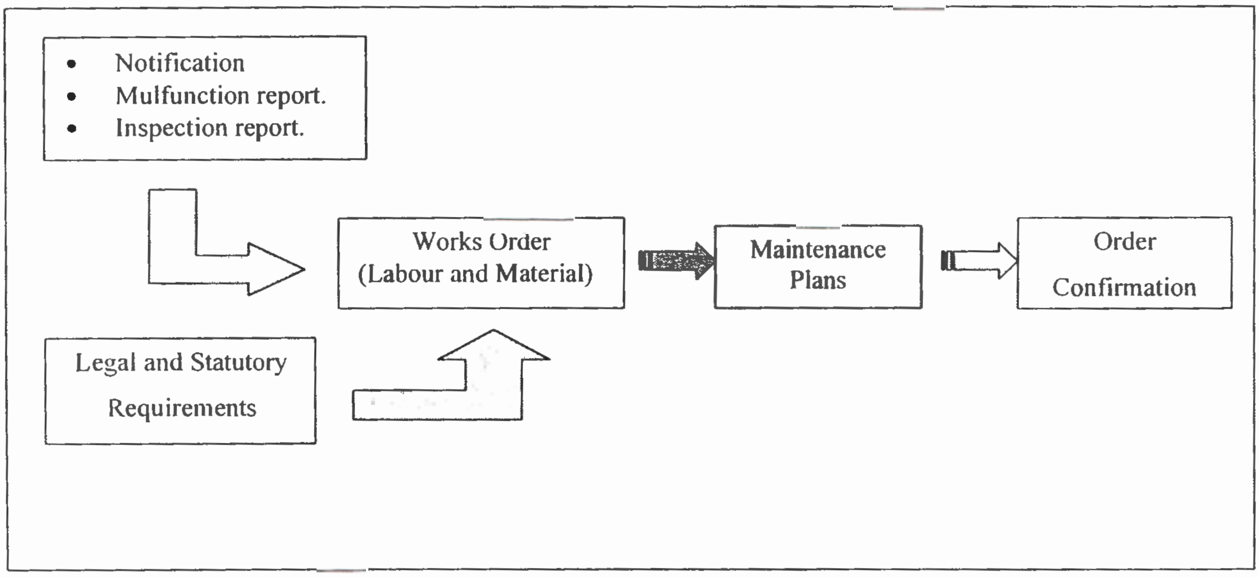
Figure 2.2: Diagnosis categories



Since July 1998, SAP R/3 was implemented at IST with the full Plant Maintenance (PM) module to assist the maintenance team. Through SAP R/3, integrated business process control can be achieved, linking all the different areas of responsibility to one common source for easy access to management information. The addition of the PM module now confirms the fully developed business function of the maintenance department. Figure 2.3 describes the process flow of information in the PM module.

All the work is initiated by creating a notification or malfunction report to the maintenance department's planning office. From this, a works order is then created to ensure that labour and material be scheduled and assigned to perform the required work. Repetitive work is identified for the creation of maintenance plans. Other repetitive work originating from legal and statutory requirements for environmental and safety reasons, is also scheduled for automatic generation of works orders to maintenance personnel. Confirmations are done by the assigned artisan and reconfirmed as technically complete by the relevant section's supervisor after the job was executed. Materials management, costing and other related information are automatically updated through the integrated system.

Figure 2.3: Basic process flow in the computerised maintenance management system, plant maintenance module, SAP R/3.



2.6 MANAGEMENT SYSTEMS:

2.6.1 DAY TO DAY MANAGEMENT:

A comprehensive management report is compiled on a daily basis to outline the plant performance over the past 24 hour period. Since the plant is operated on a 3-shift system, each shift's production detail is reported individually to create a situation where the shifts can compete with one another.

The report is structured to show detail information about:

- Efficiency
- Availability
- Utilisation

A copy of one day's report is included as "Appendix D" and should be read in conjunction with the stoppage analysis detail given for the day. Also included are graphs, updated on a daily basis to show trends on the Production output, Availability, Rejects and Production Stoppages.

- **Efficiency**

... describes the hot-mill production in terms of a predetermined standard of 400 billets to be processed per 8 hour shift. Although the billet length and diameter influence the cycle time to pierce and process it at the MPM, this standard is used across the range of tube sizes.

- **Availability**

... reflects the time spent by the maintenance department to do unscheduled repair work or make adjustments according to unforeseen circumstances. Electrical and mechanical stoppages should be minimised to make the plant available to production for at least 85% of the time over every 24 hour period.

- **Utilisation**

... is a function of the plant availability. The aim is to keep the utilisation within 10% of the availability figure.

2.6.2 MANAGING "COST OF PRODUCTION":

Management cost reports are compiled on a monthly basis to reflect the R/ton cost for the different commodities consumed to produce the tubes to export standards. These reports are based upon information from the computerised purchasing and stock control systems.

The plant is sub-divided in different production units with specific consumables associated to each unit. A budget amount is set as guideline for the R/ton cost per consumable in order to achieve the desired profit margin. Specific attention is paid to consumables like:

- Industrial Sasol Gas (Rotary Hearth Furnace)
- Rolls, Plugs and Guide shoes (Cone Type Piercer)
- Rolls, mandrel bars and lubricating graphite (MPM & SRM)

2.7 TECHNOLOGICAL COMPETITIVENESS STRATEGY

Competing on the world market requires **the timeous delivery of a quality product at the right price**. This necessarily calls for advanced control, information and communication systems to streamline the operation.

Being a relatively new and modern plant, IST is positioned in the mini tube-mill category where the rate of technological development is so fast, that it can become non-competitive with other producers within 10 years after commissioning. Upgrading of electronic control equipment and the expansion of the existing systems are thus important to ensure that production cycle times are continually improved to achieve greater tonnage output per year. Increasing these control capabilities requires better equipment made from more exotic materials to withstand the higher operating temperatures and stresses. One of IST's objectives would therefore be to develop a specialist engineering department to facilitate the implementation of improved designs and special "add-on" equipment to realise the full potential of advanced control equipment.

Maintaining good relations with original equipment manufacturers and suppliers would help to obtain information about new trends of development and how it can be applied in the situation at IST.

Personnel training and exposure to similar overseas plants would lift the level of expertise and the general approach to problem areas. Operating the plant equipment to its full potential is important in order to obtain the maximum output.

On the maintenance side, there is room for improvement to increase the plant availability by better planning for shutdown days. A new goal of 85% should be set. The present "Repair Work Control System" can definitely achieve this by focusing on feedback from preventative maintenance reports. Emphasising the importance of the normal equipment inspection system would also help to improve the plant reliability.

Improving the production planning system with an optimum product mix would prevent time being wasted on changing the mill equipment from one size to the next. Restructuring the product range by eliminating smaller tube sizes with a low profit margin, would help to position IST in a specific tube range.

Monitoring the technology applied by clients in applications using more "thin-walled" seamless tube, made from stainless steel and alloyed steel grades, would necessitate the upgrading of plant technology to meet their future demands. Developments in other applications such as for structural steel work, need to be carefully accessed as possible future market.

The overall technological development of the plant has to be continuously addressed according to projected scenarios of how the world market conditions are going to be affected by the fluctuations in the commodity cycle of low-to-medium carbon steel tube. Updating and reformulating the scenarios on an annual basis and incorporating new technological development information will provide the best guidelines to approach the future.

CHAPTER 3

LITERATURE STUDY

3.1 INTRODUCTION

There was a time in many mills, where everybody in an organisation had a title and knew what they were supposed to do. It is not like that anymore due to organisational development towards flexible systems (Idhammar, 1994:41). In an effort to establish a work pattern in these organisations, different management techniques have been developed.

This chapter is aimed at understanding and comparing only two of these improvement techniques. An overview of availability measurement is given. Then, breakdown and preventive maintenance approaches are also compared to illustrate how an optimum cost based trade-off point is found. Finally, the requirements of a computerised maintenance management system would be discussed based on literature findings.

The aspects included in this literature study forms part of the characteristics to be included in the new availability improvement methodology for implementation in steel mini-mills.

3.2 BASIC DEFINITIONS

Since availability improvement is regarded as part of the maintenance function in the steel mini-mill environment, the following definitions (Stevenson, 1996:750) have to be included:

Maintenance:

> All activities that maintain facilities and equipment in good working order so that a system can perform as intended.

Breakdown Maintenance:

Reactive approach; dealing with breakdown problems when they occur.

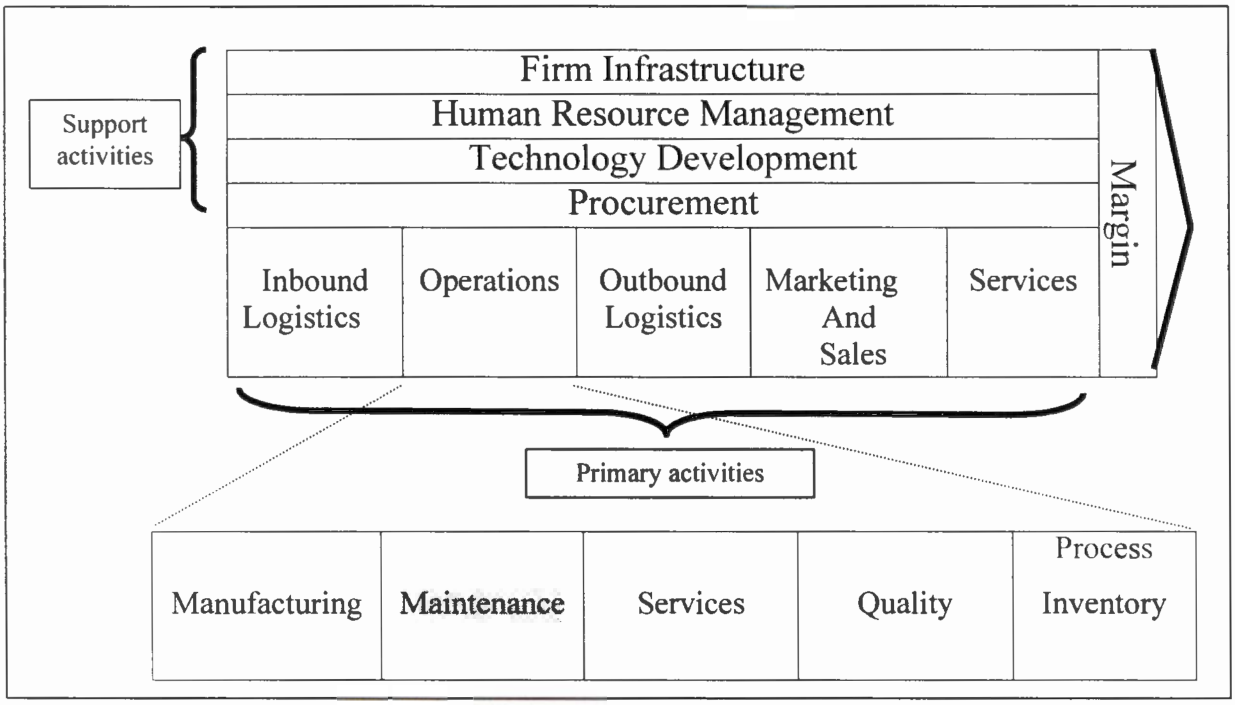
Preventive Maintenance:

Proactive approach; reducing breakdowns through a program of lubrication, adjustment, cleaning, inspection and replacement of worn parts.

3.3 THE MAINTENANCE DEPARTMENT WITHIN THE VALUE CHAIN

Michael Porter (Kotler & Armstrong, 1996:574) proposed the value chain as the major tool for identifying ways to improve the company's competitive position. The value chain breaks the firm into nine value creating activities. This includes five primary activities and four support activities as indicated in figure 3.1.

Figure 3.1: The generic value chain.

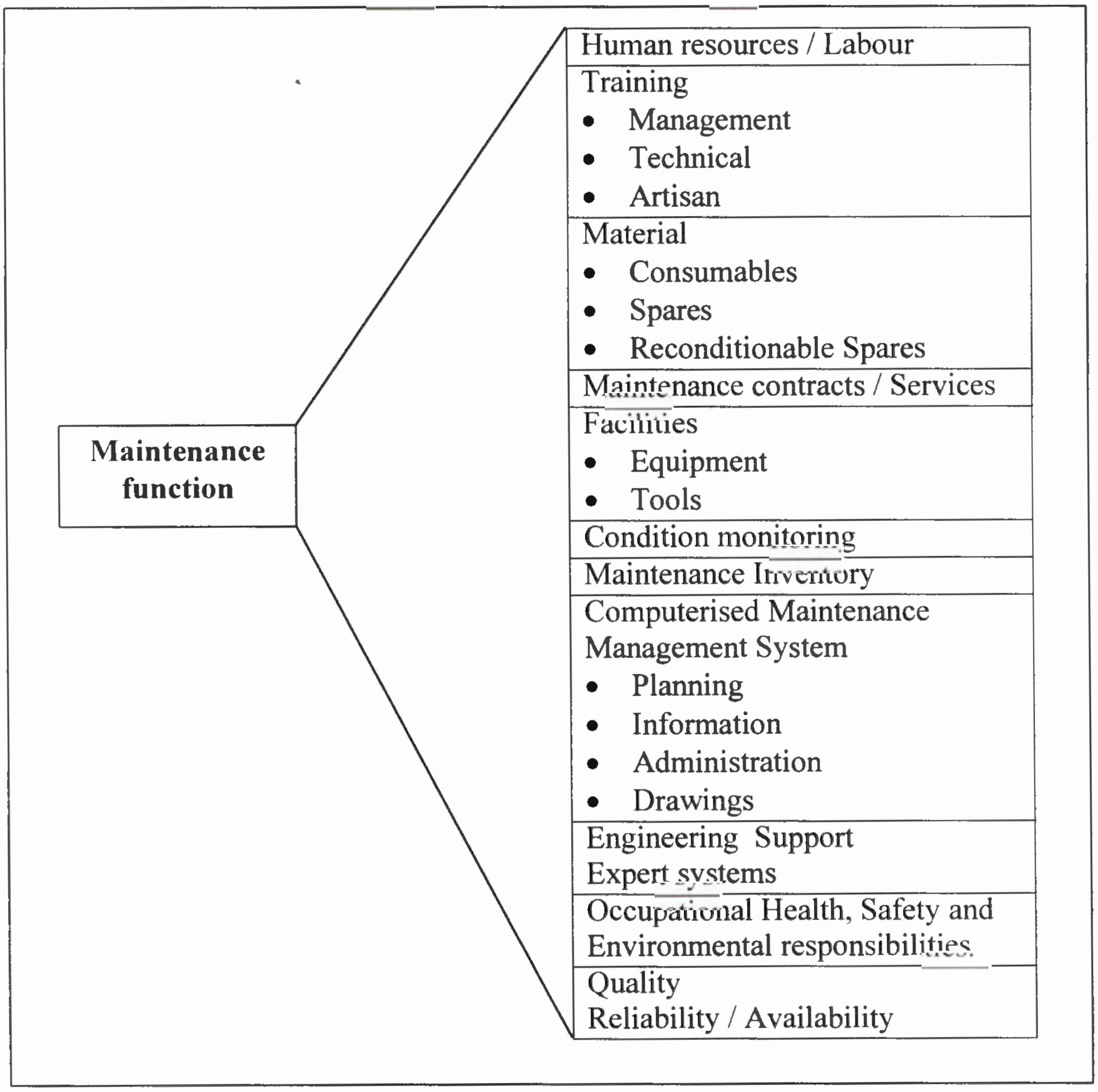


Under the value chain concept, the firm should examine its costs and performance in each value creating activity to look for improvement opportunities. Benchmarks should be used to estimate competitor's performance.

The firm's success depends not only on how well each department performs on its own, but also on how well the activities of the various departments are coordinated. Too often, individual departments maximise their own interests rather than those of the total company.

The maintenance department's responsibility span was introduced by Von Wieligh, (1994: Bylaag A) as an "extension" of the value chain. A total of eleven different aspects were identified and is listed in figure 3.2.

Figure 3.2: The maintenance "value chain".



3.4 AVAILABILITY MEASUREMENT

The term "availability" is associated with process machinery management. It is generally given as a percentage figure and the difference between this figure and the 100% goal indicates the amount of unplanned maintenance time spent on the equipment. Take for example a plant running at 80% availability. This means that the maintenance team performs unplanned maintenance work during 20% of the production time.

Plant availability is a function of two other operating standard determinants:

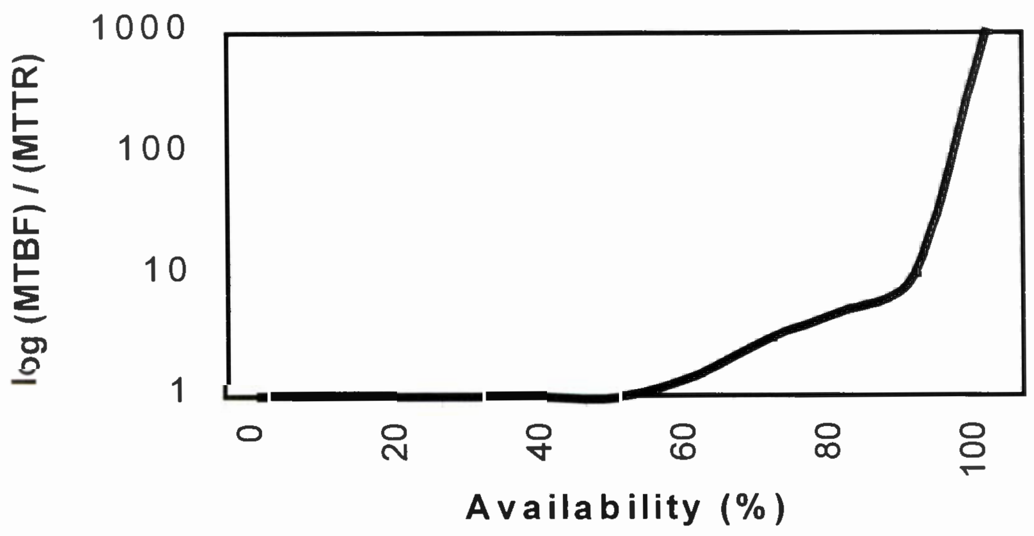
- Reliability (MTBF)
- Maintainability (MTTR)

Bloch (1996:19) indicates this relationship in a graphical format (figure 3.3), using respectively the "mean time between failure" (MTBF) and "mean time to repair" (MTTR) to quantify the above determinants.

The relationship can be equated as follows:

$$\textbf{Availability (\%)} = f\left\{\log \frac{\textbf{Reliability (MTBF)}}{\textbf{Maintainability (MTTR)}}\right\}$$

Figure 3.3: Availability measurement graph.



From the above, it can be concluded that in order to increase plant availability, it should be the objective to maximise technical reliability (MTBF) and minimise the effort required to bring the equipment back to operating standard (MTTR) after failure.

The graph also clearly indicates that it becomes more and more difficult to improve availability toward the 100% goal. The calculated ratio of (MTBF)/(MTTR) increases from 10 to 1000 when the availability is compared at 90% and 100%. Availability above 90% can therefore be regarded as truly "world class".

The effectiveness of plant maintenance is quantified by the availability figure as a percentage of the production time. Availability is extremely sensitive to the industry type and production schedule.

To conclude this section of the literature study, table 3.1 (Humphries, 1998:46) shows "Best-in-class" benchmark figures on availability for North American integrated steel mills. The benchmarks help to highlight improvement opportunities in the plant maintenance function. According to Humphries, these benchmark figures provide a tool to complement the good judgement of those who must manage change in today's competitive business environment.

The shaded blocks in table 3.1 indicate typical metrics for North American integrated steel mills. The over-all effectiveness is in the range of 48 to 78 percent.

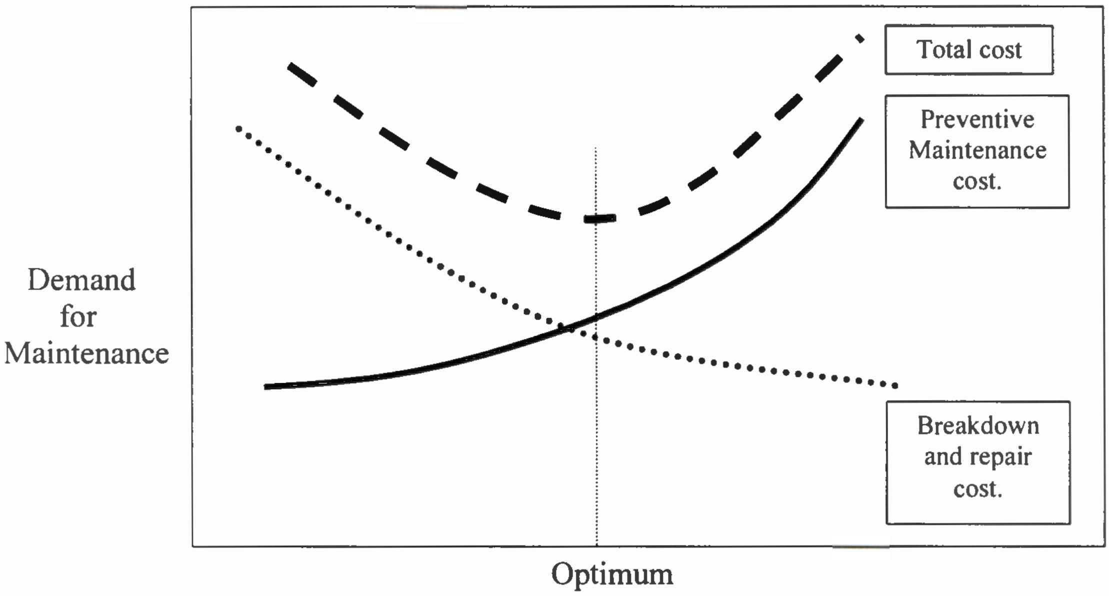
Table 3.1: Abstract of "Best-in-class" availability benchmark of integrated steel mills. (Humphries, 1998:46)

	Quartile			
Availability Benchmark (%)	Bottom	Third	Second	Top
Discrete	**<78**	78 - 84	85 - 91	>91
Batch Process	<72	72 - 80	**81 - 90**	>90
Chemical, Refining, Power	<85	85 - 90	**91 - 95**	>95
Overall Equipment effectiveness	Not Measurable	<48	**48 - 78**	>78

3.5 DIFFERENT MAINTENANCE APPROACHES

Maintaining the productive capability of an organisation is a very important function. It is the responsibility of the maintenance manager to seek a balance between preventive maintenance and breakdown maintenance. This balance is determined on a cost basis to obtain the minimum total cost impact on the budget. Figure 3.4 illustrates how an optimum situation is obtained by plotting the respective breakdown and preventive maintenance cost curves and comparing the total cost at each demand situation. The optimum point is where the total cost curve is at the lowest value.

Figure 3.4: The amount of preventive maintenance required. (Stevenson, 1996:751)



There are a number of factors that influence this balance:

- Age and condition of equipment.
- Degree of technology involved.
- Type of production process.

Against this basic background, the literature study can now be continued to gain a deeper insight into the modern approaches followed in the manufacturing industry.

3.5.1 TOTAL PRODUCTIVE MAINTENANCE

The first technique found in the literature research, was the concept of total productive maintenance (TPM). This technique has been developed by the Japanese manufacturing industry (Kelly & Harris, 1993:9) to provide maintenance that is both effective and efficient, therefore productive, in response to the needs of just in time manufacturing (JIT) and total quality management (TQM).

The basic philosophy is to improve, through radical change, the corporate image of maintenance.

By definition, total productive maintenance is summarised as follows:
TPM is aimed at maximising equipment effectiveness through the optimisation of equipment availability, performance, efficiency and product quality. It establishes a maintenance strategy for the life of the equipment. TPM covers all departments such as the planning department, the users and the maintenance department. All staff members are involved from top management to shop floor workers. Finally, it promotes improved maintenance through small group autonomous activities. A slight variation is found in the "total preventive maintenance" approach where workers perform preventive maintenance on the machines they operate.

Since education is one of the corner stones of the TPM technique, it has made a considerable contribution by fostering the "Kaizen" principle of continuous improvement. Based on this principle, several European companies have implemented the TPM technique. In this context, an autonomous maintenance (AM) concept developed to form the real core of TPM. It depends on developing employees' skills, standards and judgement.

"TPM succeeds not because of its strategy or systems or engineering techniques, but because its adoption indicates a corporate belief in the importance of maintenance and a realisation that some resources have to be expended for long term gain." (Kelly & Harris, 1993:11)

Patterson *et al* (1995:61) analysed western companies to point out that the success of TPM depends on top management's leadership to have everyone in the organisation committed to support the process.

3.5.2 RELIABILITY CENTRED MAINTENANCE

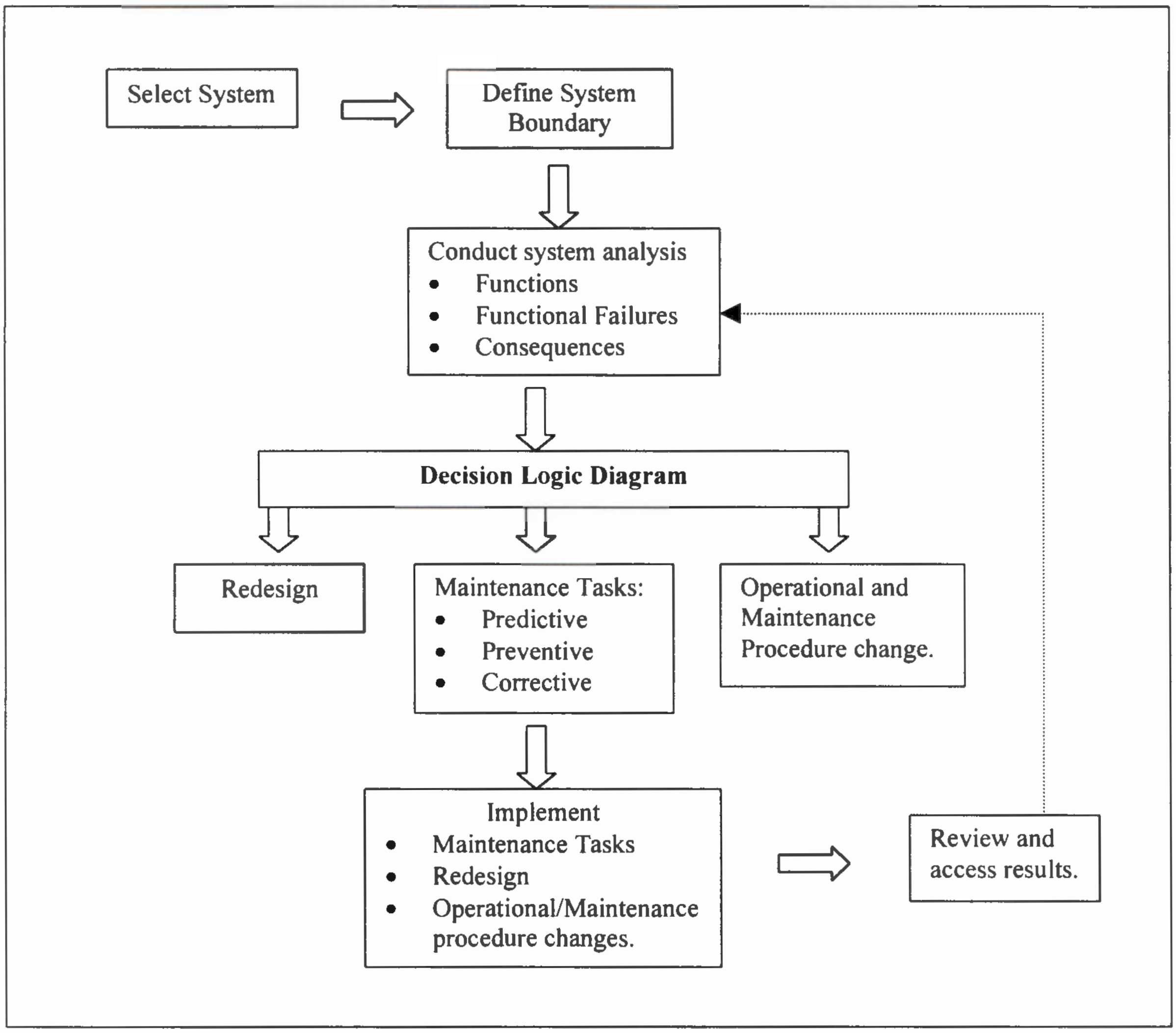
Reliability centred maintenance (RCM) had first been developed by United Airlines to report on processes used by the civil aviation industry. The technique was then extended to the US Navy in the late 70's and ultimately found its way to nuclear power undertakings in the United States by 1984. Since then, RCM became relevant to the mining and manufacturing sectors where it is used to formulate maintenance strategies for production equipment.

Formally defined, RCM is a method for developing and selecting maintenance design alternatives, based on safety, operational and economic criteria. RCM is a multi-disciplinary approach that looks at risk holistically - as a system, rather than individual components. (Jones, 1995:57)

The basic RCM method is presented in figure 3.5.

Once a team has been established for conducting the RCM analysis, the next step requires the establishment of the system boundaries. Focus can then be set to analyse the functions, functional failures and consequences of system failures. In response to the anticipated consequences, the team must decide whether to recommend that the equipment be redesigned, operational and maintenance procedures be changed or the implementation of new maintenance tasks to improve the situation. Each failure mode undergoes a decision logic exercise to decide if a maintenance action is needed and what action to prescribe. Reviewing and assessing the results on a regular basis is important to ensure that the desired improvement results are achieved.

Figure 3.5: The RCM method. (Pradhan, 1993:43)



With reference to figure 3.5, the decision logic diagram examines each failure mode identified in the system analysis and evaluates if a maintenance task will eliminate or reduce the effect of a failure. If a predictive or fault finding task cannot be identified to address the failure mode, then the logic diagram asks for a time based maintenance task.

From its evolutionary nature, RCM 2 was developed and applied since 1990, particularly to address environmental industrial concerns. The need for reformulating the RCM methodology related to the distinction that had to be made between environmental hazards and safety hazards.

Per definition, RCM 2 can be described as "a process used to determine the maintenance requirements of any physical asset in its operating context".

The RCM 2 technique recognises six failure patterns and then applies a standard decision diagram to establish the maintenance requirements for each machine. Applying the RCM process is done in a teamwork context, preferably under the leadership of an in-house facilitator.

Moubray (1997:292) argues at length that RCM 2 achieves three tangible outcomes:

- Maintenance schedules to be carried out by the maintenance department.
- Revised operating procedures for operators of the assets.
- A list of areas where once-off changes must be made to the design of the asset.

In conclusion, the RCM 2 technique provides a scientific approach to do a Failure Mode and Effect Analysis (FMEA) at different levels of a production system and then make informed decisions to implement a maintenance strategy associated with an acceptable risk level as formulated by the end user.

3.5.3 COMPARISON BETWEEN TOTAL PRODUCTIVE MAINTENANCE (TPM) AND RELIABILITY CENTERED MAINTENANCE (RCM).

Von Wielligh (1994:23) analysed the basic differences between the approaches followed with TPM and RCM. The findings can be summarised as described in table 3.2. It must be emphasised that TPM and RCM both rely upon group techniques to create commitment. In order to facilitate the RCM process with-in the group context, special computerised software flow charts have been developed to simplify the process.

The summary in table 3.2 only highlights three major comparison areas:

- Availability
- Preventive maintenance
- Costs involved

Table 3.2: A basic comparison between TPM and RCM.

<table>
<tr><th>TPM</th><th>RCM</th></tr>
<tr><td>Machine Availability performance
Can always be improved through a “total knowledge” approach of all employees.</td><td>Machine Availability performance
A function of the inherent reliability of the original design.</td></tr>
<tr><td colspan="2">Preventive Maintenance (PM) and Condition monitoring
This is an essential part of both maintenance strategies. Condition monitoring is an important tool to achieve maximum results. Preventive maintenance follows as the result of condition monitoring.</td></tr>
<tr><td>Cost of improvement
Any failure is regarded as unacceptable, therefore cost is of less importance.</td><td>Cost of improvement
If the intervention cost exceed the failure cost, then no action is taken.</td></tr>
</table>

3.6 COMPUTERISED MAINTENANCE MANAGEMENT SYSTEMS

The maintenance system can be viewed as a transformation system that takes inputs and converts them into useful outputs. In order to assist the maintenance team, computerised systems are employed in large modern manufacturing systems.

A company should formulate its maintenance strategy before introducing a CMMS. Variations of the two main strategies (RCM and TPM) are used to formulate company specific maintenance strategies. The aim of this maintenance management system is to allow the maintenance manager to keep track of who is doing which maintenance task, on what equipment, what spare parts are used and eventually what the costs were (Visser, 1998:17). This is achieved by operating the CMMS on a basis for enhanced effectiveness of planning, organising and controlling.

The average live of a CMMS is five years (Weiss, 1998:133). Since it is such a vital instrument for ensuring optimal plant availability, the process of establishing a computerised maintenance management system (CMMS) comprises a number of discrete steps. This includes requirement analysis, definition of alternatives, selection of the best alternative, testing and implementation. (Visser, 1998:17)

Although the computerised maintenance management system industry has now developed into the matured stage, Wireman (1998:41) established ten items that may still hinder the successful implementation of a CMMS if not properly addressed:

- Expectations
- Requirements
- Adjustments
- Implementation plan
- Implementation skills
- Support
- Training
- Utilisation
- Optimisation
- Benefits

Some companies have become so involved in the implementation process that they have omitted to plan for and focus on the benefits that they would eventually derive from the process. They therefore fail to realise a large part of the potential return on the investment.

The latest development in the area of fully integrated maintenance management systems has been the incorporation of a graphics interface to rapidly display engineering drawings, saving time and maximising the benefits available from the CMMS to take full advantage of its functionality.

The CMMS must be optimised to fit the company's philosophy of maintenance management. Alternative suggestions must therefore be included in the approach for identifying the best CMMS. Optimisation is an essential part of engineering and can only be achieved if the system allows a number of degrees of freedom.

All systems have multiple attributes that define the nature of the system. The maintenance department must therefore define those attributes that are most important for achieving greater maintenance effectiveness. The trade-off sought is to obtain a balance between the effectiveness and the life-cycle profit of the CMMS. Ultimately, the system has to generate income.

The use of a CMMS as part of an integrated information system allows the business to focus on the maintenance function as one of the critical key performance areas. It also emphasises the maintenance manager's responsibility to motivate his personnel to work closer together with various other departments.

In conclusion, the CMMS should serve as an effective communication link between the maintenance department, procurement and the production department.

3.7 SUMMARY AND CONCLUSION

The significant role of the maintenance department as part of the value chain of the organisation was highlighted to show the valuable contribution it has on business performance. One of the main objectives of the maintenance department was identified as increasing the plant availability through effective maintenance. This implies balancing the total cost required for maintenance with the benefit obtained from the increased plant availability for production.

The literature study focused on three interdependent dimensions of the availability improvement drive within the maintenance department of a modern mini-mill. These are:

- Total Productive Maintenance (TPM)
- Reliability Centred Maintenance (RCM)
- The Computerised Maintenance Management System (CMMS)

TPM can be seen as the high level philosophy that helps to develop the climate and culture within the maintenance department. The TPM objective is to create aligned commitment amongst all the employees. Within the maintenance department, "World-best" practices are adopted and benchmark evaluations are regularly done to identify opportunities for improvement.

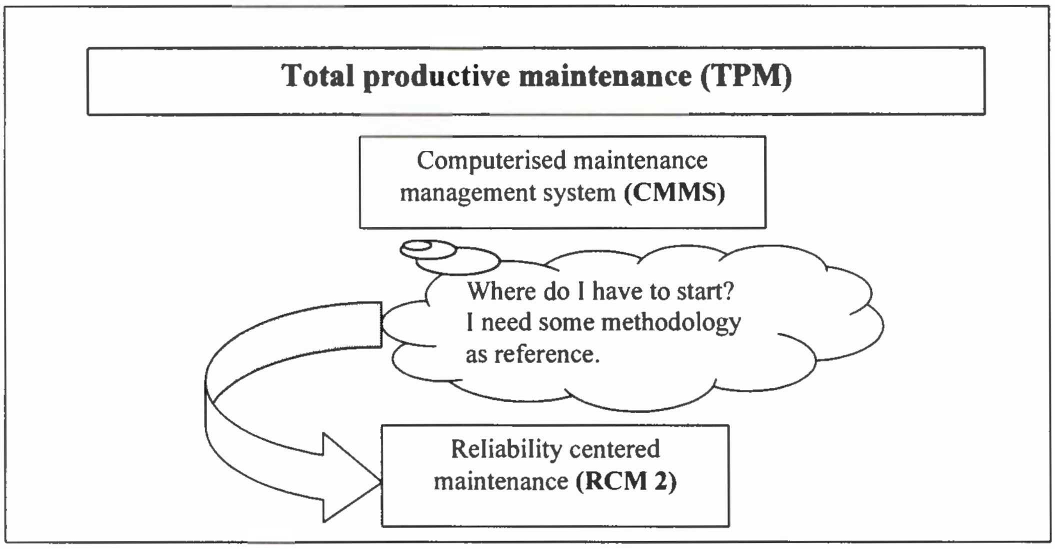
The effectiveness of this environment is measured by the results achieved in terms of plant availability. The CMMS supports the maintenance control system's effective operation. It also documents equipment downtime in a database for later analysis and corrective action.

The calculation of plant availability was investigated and two basic approaches were identified. The first approach is simply expressed as the percentage of time that a unit could run if called upon to do so. The second was a more scientific way to express availability as a function of reliability and maintainability of equipment. Applying the second approach would necessitate the implementation of a CMMS with accurate feedback from ground-floor level.

Finally, RCM provides a tool for accurate failure mode and effect analysis (FMEA). RCM has been redefined and presented in the form of RCM 2 to develop reliable and environmentally safe systems by formulating and implementing purpose made solutions.

When the relationship between the above aspects of maintenance management is carefully reviewed, there seems to be a need for applying a methodology to systematically identify areas that would significantly improve plant availability. The aim would be to create a better link between the CMMS and RCM 2. An illustration of the relationship is presented in figure 3.6.

Figure 3.6: Relationship of maintenance management tools.



Although benchmarking is also seen as an effective way of identifying areas for improvement, it is sometimes difficult to obtain comparable benchmarking information. The need therefore exists to initiate the improvement drive from within the organisation based on the available information.

Having identified our need, it was decided to use a consultancy group (Mc Kinsey), specialising in maintenance improvement to "lift the maintenance game" at Iscor Seamless Tubes.

The rest of this dissertation focuses on the results achieved with the "Scuba" methodology applied at a Seamless Tube mini-mill to identify and focus on problem areas.

CHAPTER 4

RESEARCH

4.1 INTRODUCTION

In this chapter it is the objective to identify the systematically developed driving initiatives employed in the maintenance department at IST and show what the outcomes were in terms of their objectives.

Data from the 96/97 and 97/98 financial years are compared to illustrate the results achieved. The company's financial year starts on July, 1st and ends on June, 30th each year.

4.2 DEVELOPMENT OF THE MAINTENANCE STRATEGY

The evolutionary development of the maintenance strategy started in October 1997, three months into the new financial year. The first objective was to obtain everybody's commitment and focus on obvious problem areas that could make a visible improvement. Areas were identified based upon experience and perceptions of the maintenance team.

Outcome of the first round:

- Over-all Availability Target: 85% (year to date was at 81.7%)
- Concentrate on **Mechanical** stoppages at:
  - i) Multi-stand Pipe Mill (MPM)
    - Mandrel Crane
    - Capsules
  - ii) Cone Type Piercer (CTP)
    - Thrust-block lubrication
    - Thrust-block belt
    - Calibration

iii) Tube Saws
    - Billet weighing system.
    - Inlet rollers.

iv) Rotary Hearth Furnace (RHF)
    - Floor.
    - Charger and Discharger.

- Concentrate on **Electrical** stoppages at:
    i) Multi-stand Pipe Mill (MPM)
        - Mandrel Crane control.
        - Rollerway to Mandrel cooling motors.
        - Mandrel rotation motors.
        - Mandrel and Shell support encoders.
    ii) Cone Type Piercer (CTP)
        - Rolling / Clamping position detection.
        - Inlet pusher slowdown.
    iii) Stretch Reducing Mill (SRM)
        - Induction heaters
        - Stretch control – new program.

- Improve spares availability through better communication and co-operation with the materials management department.
    i) Large Gearboxes
    ii) Geared Motor units
    iii) Electrical Motors

- Re-engineering of weak designs. Assist the drawing office with practical input and review of the designs before implementation.

- Help Production personnel where possible.

At the end of November 1997, another workshop session was held with a professional team of Mc Kinsey's maintenance management consultants. The workshop addressed the performance gaps in IST's maintenance organisation and potential key success factors to bridge these gaps. Participants to this workshop functioned on a higher level within the maintenance hierarchy of the organisation, allowing for a more generic approach to the specific problems experienced at IST.

Outcomes of the second round:

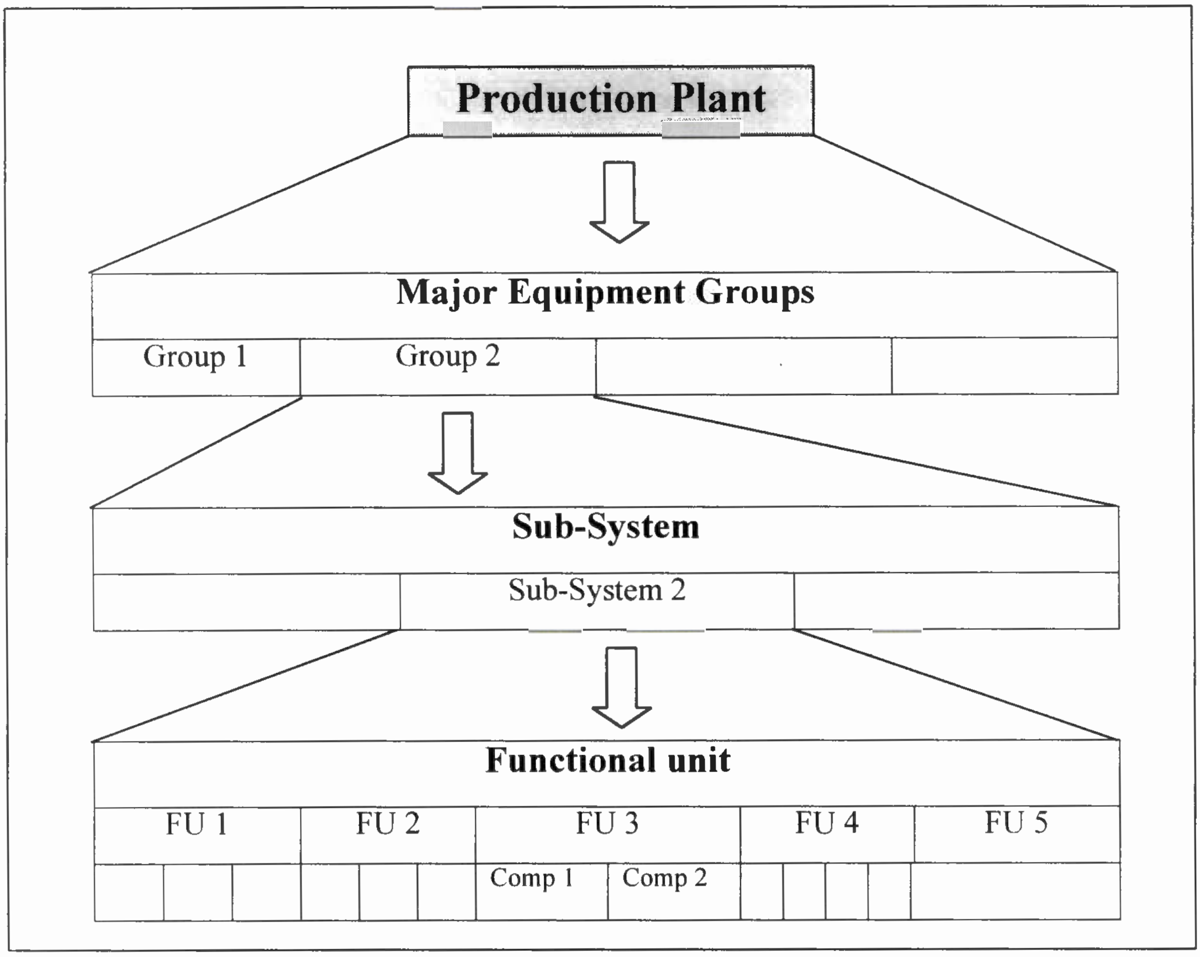
- The immediate goal should be to move away from the current mindset of "fixing failures" to one of "preventing failures".
- To move towards its goal, it is necessary to put in place sound maintenance practices, tools and systems like thorough inspection schedules, job cards and functional information loops.
- The success of the effort hinges solely on the commitment of the participants to implement these initiatives and nurture the new philosophy, not merely putting in place the right tools.

Having obtained new insights and aligned commitment to the challenge of improving the performance of the maintenance team, focus was set on "how" to bring this about. Different approaches were evaluated until a methodology was adopted and refined to satisfy the need for identifying delay causes to be urgently addressed. It is based on the Mc Kinsey group's general approach to "lifting the performance of the maintenance game". This methodology is described in the next section.

4.3 METHODOLOGY FOR IDENTIFYING DOWNTIME CAUSES

Participants chose to refer to the methodology as the "Scuba" process. This is a symbolic reflection on the active approach to get into your diving gear, "dive" into the problem and go down as deep as possible until you found a workable solution to the underlying cause.

Figure 4.1: Schematic diagram illustrating the logic behind the "Scuba" methodology.



The methodology can be described in the following ten steps:

i) Identify all the major equipment groups in the production line.

ii) Establish each equipment group's total time based downtime contribution. The data to be evaluated should be as comprehensive and recent as possible.

iii) Determine the equipment group with the largest contribution. If two groups' contributions are within 5 % of each other, then it is of equal importance.

iv) Rank the equipment groups in terms of criticality.

v) Identify the most critical equipment group (that has the largest time based downtime contribution).

vi) Identify all the sub-systems within the identified major equipment group.

vii) Establish each sub-system's total time based downtime contribution.

viii) Rank the sub-systems in terms of criticality.

ix) Rework the functional unit's downtime causes of the most critical sub-system.

x) Evaluate the downtime causes of the functional unit in a holistic way, taking into consideration the purpose of each component.

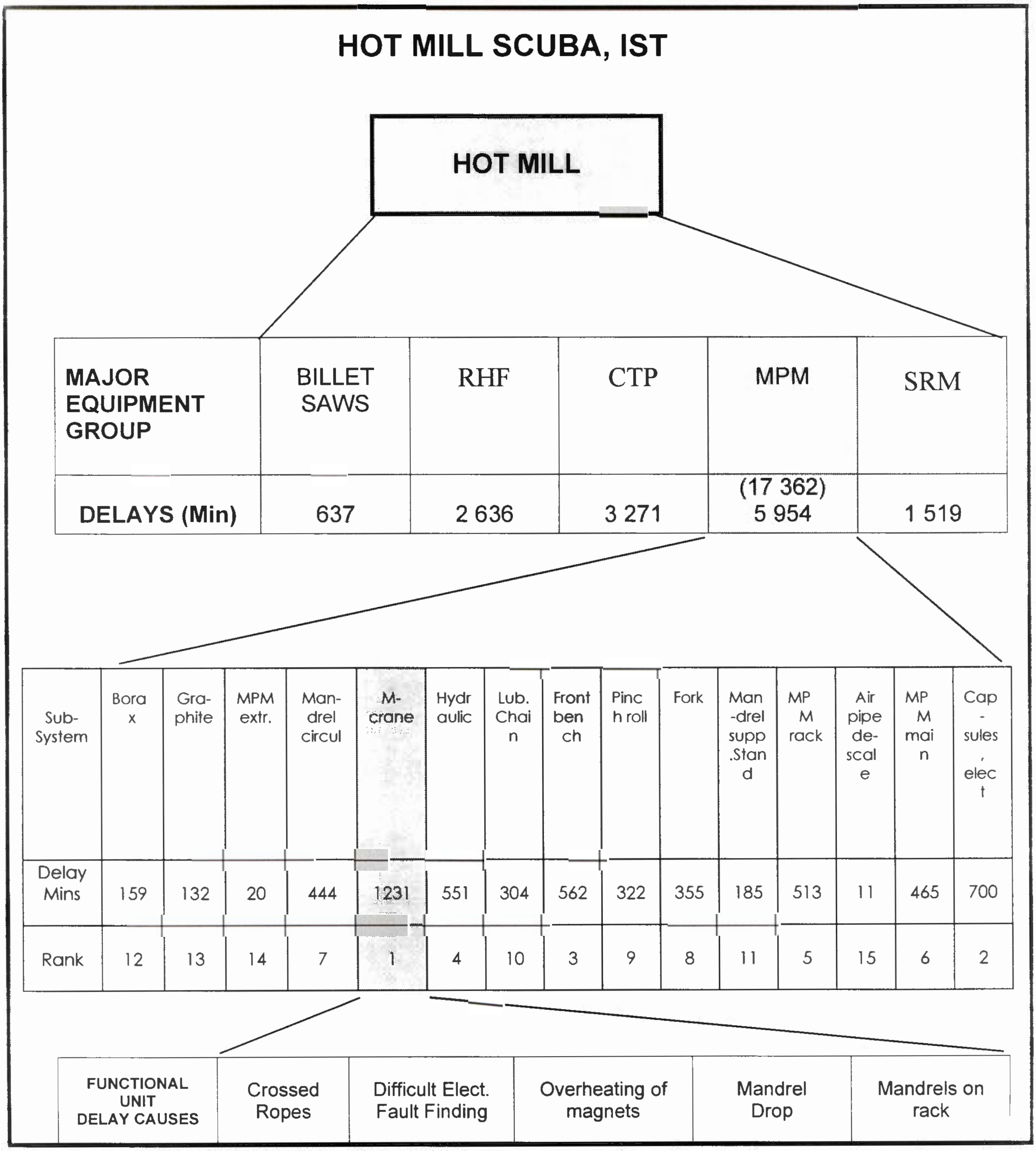
One of the key characteristics of downtime causes that are eliminated by applying this methodology, is their tendency for repetitive occurrence. This implies the assumption that plant availability is hampered by the multiple reoccurrence of preventable downtime causes. It is further assumed that the downtime cost of the plant exceeds the repair cost of the equipment by a comfortable margin. Even the implementation of a new engineering solution is seen as a viable option to get rid of poorly designed and under-performing critical equipment.

This process can be continued up to component level if accurate time based information is available. In practice, it was however found that the stoppage reports normally only indicate the sub-system that could be identified for the cause of the delay. This is the result of the reporting system being administrated by the production supervisors.

Figure 4.1 illustrates how the process was implemented at the hot-mill section of the Iscor Seamless Tube Plant, Vereeniging South Africa.

The data that were analysed for the implementation of the "Scuba" process is enclosed in Appendix C. It was downloaded from the plant's database of the CMMS implemented for reporting on the over-all plant utilisation.

Figure 4.2 Graphic illustration of "Scuba" methodology applied at IST for a three month period: January to March 1998.



HOT MILL SCUBA, IST

HOT MILL

MAJOR EQUIPMENT GROUP	BILLET SAWS	RHF	CTP	MPM	SRM
DELAYS (Min)	637	2 636	3 271	(17 362) 5 954	1 519

Sub-System	Borax	Graphite	MPM extr.	Mandrel circul	M-crane	Hydraulic	Lub. Chain	Front bench	Pinch roll	Fork	Man-drel supp .Stand	MPM rack	Air pipe de-scale	MPM main	Cap-sules, elect
Delay Mins	159	132	20	444	1231	551	304	562	322	355	185	513	11	465	700
Rank	12	13	14	7	1	4	10	3	9	8	11	5	15	6	2

FUNCTIONAL UNIT DELAY CAUSES	Crossed Ropes	Difficult Elect. Fault Finding	Overheating of magnets	Mandrel Drop	Mandrels on rack

4.4 DISCUSSION OF HOT MILL "SCUBA" PROCESS

Inspection of the downtime statistics available for the major equipment groups as recorded for the 97/98 financial year (up to the end of March 1998) revealed that the multi-stand pipe mill (MPM) was by far the most critical major equipment group.

Delays caused by the MPM as a major equipment group, amounted to almost double the time based contribution of the cone type piercer (CTP). Further, the MPM contribution is equal to the sum of the four other Major equipment groups of the hot-mill. Applying the "Theory of Constraints" principle, it can be concluded that due to the in-line nature of the manufacturing process, the MPM is a meaningful bottleneck that needs to be investigated. This confirmed the outcome of the first round's strategic planning exercise, highlighting the perception based need for focus on the MPM.

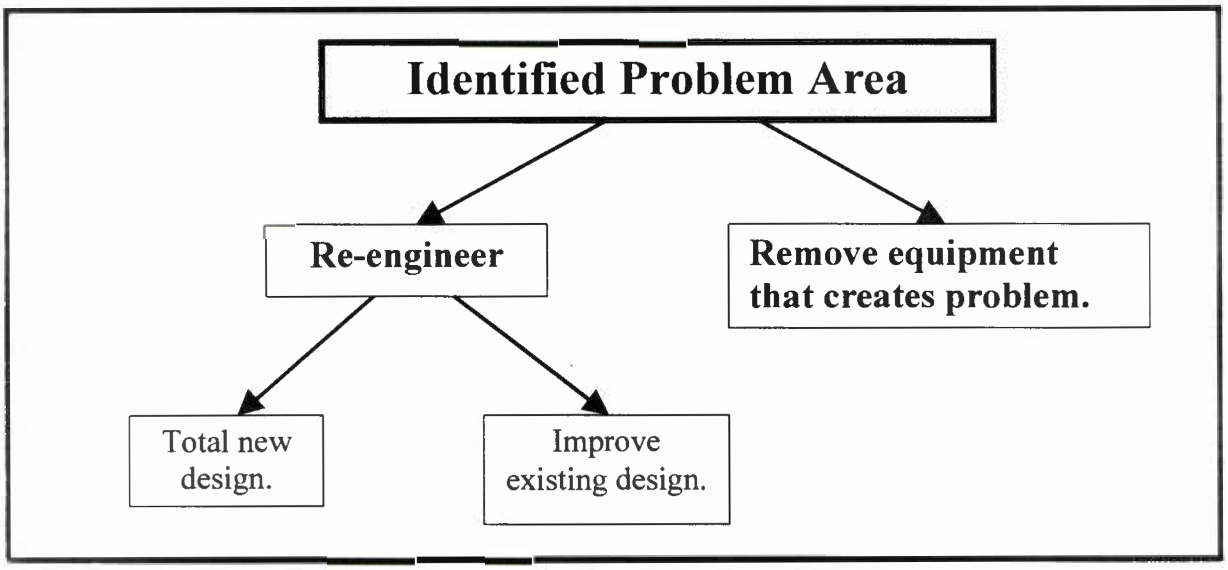
Within the MPM, an array of fifteen sub-systems were identified to contribute to the criticality of the MPM. Again the most recent time based downtime contribution of each sub-system was tabled and ranked in order of criticality. The result was the identification of the mandrel crane as the most important origin for downtime caused by the MPM as a major equipment group. Again, the mandrel crane was responsible for almost double the amount of downtime compared to the electrical problems that were experienced with the MPM-capsules.

"Diving" deeper into the MPM-reasons for such poor performance revealed five major causes at a functional unit level. Each of these difficulties was traditionally seen to be inherent problems of the mandrel crane without considering the important effect it had on plant availability. At this level, all these contributing factors were viewed to be of equal importance to address the mandrel crane's position in terms of plant availability.

Identifying the critical areas did not yet address the availability dilemma, but at least pointed a finger into the right direction for taking action.

A basic algorithm was introduced to decide in each case what the most effective approach would be to eliminate the downtime cause. Figure 4.3 illustrates this algorithm. It was found that the ultimate solution sometimes was a combination of all the possible approaches.

Figure 4.3: Decision algorithm for addressing identified problem areas.



The next step was to approach the MPM capsules, ranked second, in the same way.

Having gained this new insight into the advantages of systematically identifying the root causes that negatively affect plant availability, it was easier to implement the maintenance improvement drive towards the objective of 85% availability.

4.5 CONCLUSION

This chapter illustrated how the "Scuba" methodology was systematically implemented by the IST maintenance department. It started with the formulation of the basic maintenance management strategy. An international consultancy group was then used to act as a catalyst for the refinement of the adopted strategy. The result of these two interventions was the development and adoption of the department's own methodology for making informed decisions based on available data that was updated on a day to day basis.

The essence of the proposed methodology is then described in ten steps to illustrate the "drill-down" process to set focus on the core problems that negatively affect optimum plant availability. A basic decision algorithm is then used to decide what the most elegant approach would be to improve the situation. The implementation outcomes could be described in one of the following categories:

- Remove the equipment that creates the problem.
- Improve the existing design.
- Implement a total new design.

Finally, the situation for the three month period, January to March 1998 was analysed and presented to illustrate how this powerful methodology was applied at IST. To conclude the research, a discussion of the implementation process was included to give the reader some perspective on the situation.

With reference to the conclusion made in chapter 3 that the maintenance manager needs a standard methodology to effectively identify critical areas for improvement, it can further be concluded that this "Scuba" methodology addresses this need. It can be used in preparation for detailed RCM 2 analysis provided that enough useful data is available from a CMMS. However, on its own, the "Scuba" methodology proved to have the desired impact.

CHAPTER 5

RESULTS AND CONCLUSIONS

5.1 INTRODUCTION

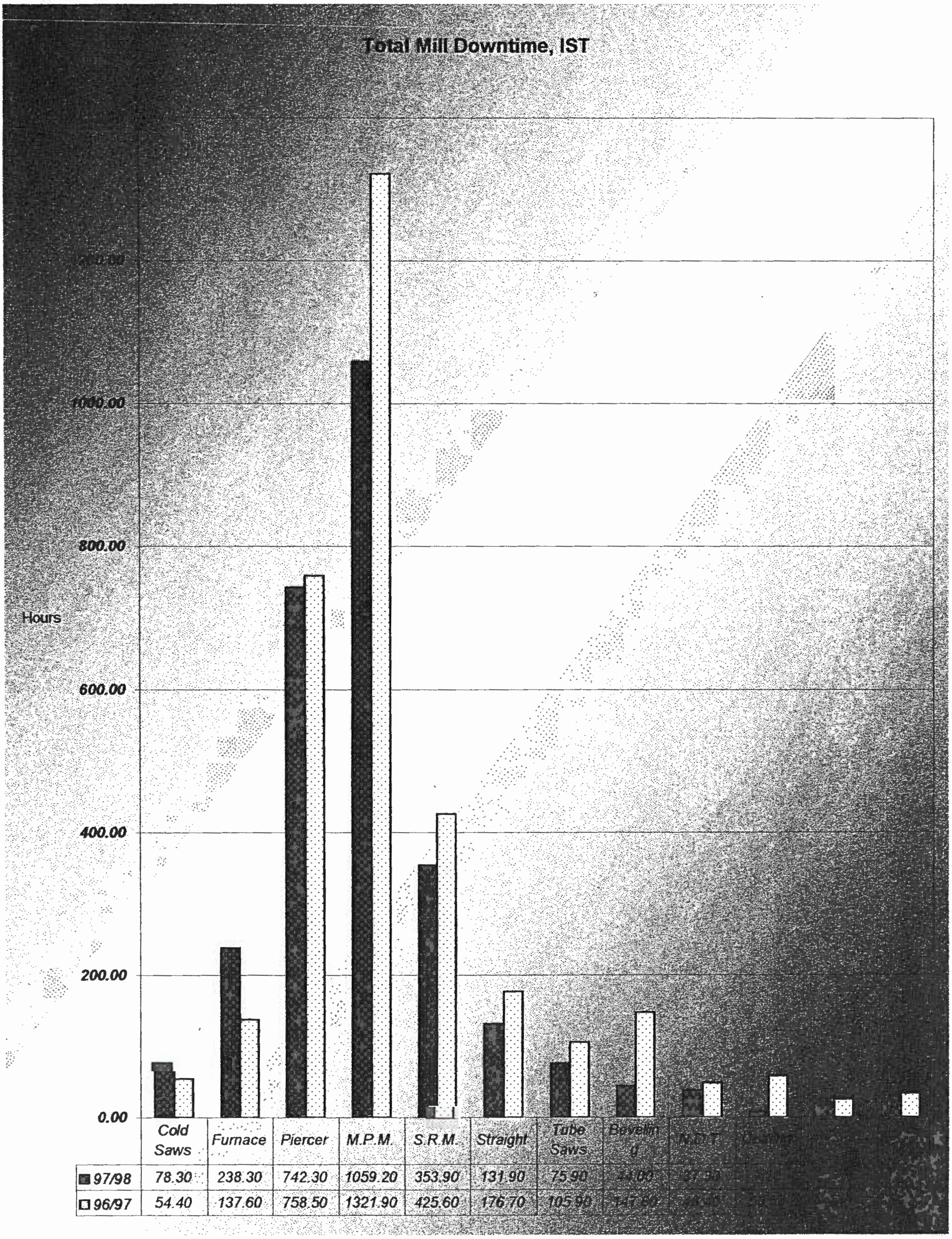
In chapter 1 of this dissertation, the complex dilemmas of the modern maintenance manager was presented, identifying "plant availability" as the prime objective for the maintenance department. An organisational overview of the Seamless Tube mini-mill in chapter 2, sketched the background where the improvement drive was to be launched. The next step was to investigate "world best" practices in chapter 3. The result was the identification of 3 prominent themes: TPM, RCM and thirdly, the importance of a reliable CMMS. With this background, chapter 4 presented an evolutionary methodology developed to fulfil the need for focus during the implementation of an availability improvement strategy for the maintenance department. The success of this methodology that has been applied to the mini-mill environment in the steel industry will now be evaluated.

5.2 AVAILABILITY IMPROVEMENT RESULTS

The results achieved by the IST maintenance department are presented in Figure 5.1 in a graphical format, comparing the total mill downtime figures for the 96/97 and 97/98 financial years.

The final impact of the "Scuba"-process on the MPM-availability shows a decline in mill downtime from 1321.9 hours p.a. to 1059.2 hours p.a. This represents an improvement of almost 20% better availability for this major equipment group.

Although only the MPM "scuba" lay-out was presented in chapter 4, the process was applied to every major equipment group on both the hot-mill and the downstream sections of the plant. It is clear that the hot-mill's downtime contribution is by far the most important area that had to be addressed.



	Cold Saws	Furnace	Piercer	M.P.M.	S.R.M.	Straight	Tube Saws	Bevelling	N.D.T.	[illegible]
■ 97/98	78.30	238.30	742.30	1059.20	353.90	131.90	75.90	44.00	37.30	[illegible]
□ 96/97	54.40	137.60	758.50	1321.90	425.60	176.70	105.90	147.60	[illegible]	[illegible]

Figure 5.1: Comparison of total mill downtime for two consecutive years.

Despite the success achieved at the MPM, SRM and CTP, an unfortunate deterioration was experienced at the Cold Saws and Furnace. The cause for the 73% increase in furnace related downtime could be attributed to the poor condition of the furnace floor, resulting in material handling problems. This situation could not be rectified during the production year but only at the end of the year when the major shutdown allowed for cooling and replacing the floor. Similarly, the cold saws area experienced process induced problems.

Figure 5.1 only presents the overall picture and the true value of the "scuba" process would not be identified unless the downtime is categorised to show the contribution of the mechanical, electrical and production related downtime. These graphs are presented in Appendix B.

On the MPM, mechanical downtime was drastically reduced by 65% while electrical downtime increased by 26.7%. In balance, the maintenance department experienced a down time based reduction of 35% on the MPM. This can be compared with the production department's increase of 26% more downtime on the MPM. The production department did not approach their problems in the same manner by developing a methodology for identifying priority areas for improvement.

A similar situation is observed at the CTP. The production department experienced an increase of almost 8% in downtime while the maintenance department showed positive results in both the mechanical and electrical disciplines.

Since the MPM is technologically the most advanced major equipment group at the hot-mill, electrical and electronic control equipment play an important role in the plant operation. The fact that this control equipment has virtually been in continuous operation, 24 hours per day for more than 10 years, was identified as one of the reasons for the poorer electrical maintenance performance on the MPM.

Despite this overall electrical availability result on the MPM, the practical outcome on the mandrel crane's availability and reliability was overwhelming. Downtime that could be attributed to the mandrel crane, was virtually eliminated.

5.3 CONCLUSIONS

The methodology had a greater impact on the mechanical side of the maintenance department than on the electrical side. This is the result of the redesign approach followed by the mechanical maintenance team.

The maintenance department definitely achieved positive results by implementing the "scuba" process, compared to the production department's deterioration for failing to develop and apply a similar methodology.

The absence of an integrated computerised maintenance management system (CMMS) hampered the acquisition of data for evaluation. The value of an effective CMMS with build-in analysis capability, would be of major assistance to the maintenance manager, opting to implement the "scuba" process. In future, the maintenance manager at IST would have this facility after the full implementation of the SAP R/3 integrated business management system which includes a plant maintenance module with management reporting facilities.

The results achieved at IST, should not be seen as an exclusive achievement due to the implementation of the "Scuba" process. Other strategic objectives of the maintenance strategy surely also contributed to the success, but the "scuba" process did act as a catalyst for realising those contributing factors.

Finally, the importance of this dissertation can be seen as the formulation of a practical methodology that can be applied to situations in the maintenance management field in order to systematically identify areas that prevent optimum plant availability. Further, the methodology that was applied helps to create aligned commitment in the maintenance department to focus on the problems that were identified. After all, maintenance work would always be a team effort and can only be achieved through the full co-operation of everybody involved in the manufacturing process.

5.4 RECOMMENDATIONS FOR FURTHER STUDY

The first recommendation that should be made is to implement the methodology presented in this document to other manufacturing plants for verification of the results.

From the literature study, the subject of availability measurement was identified as an area that needs to be investigated. The mere expression of this important indicator as an percentage of available production time does not help to improve the effectiveness of plant maintenance.

Developers of CMMS software can incorporate this methodology into their information system to directly generate the “Scuba”-diagram as a valuable output report to the end user. This would save time in preparing for strategic maintenance sessions to focus the team effort on critical aspects.

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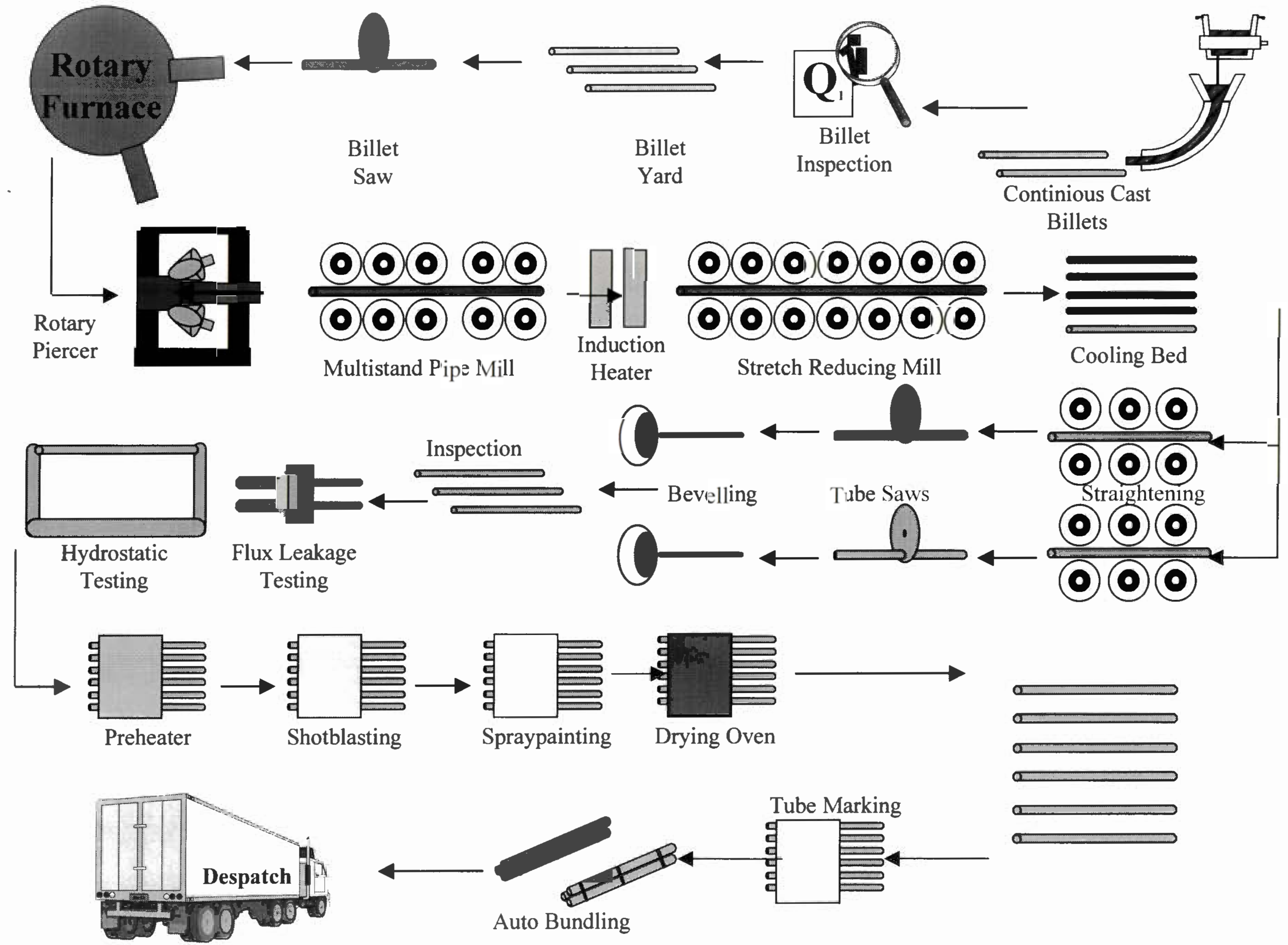
APPENDIX A

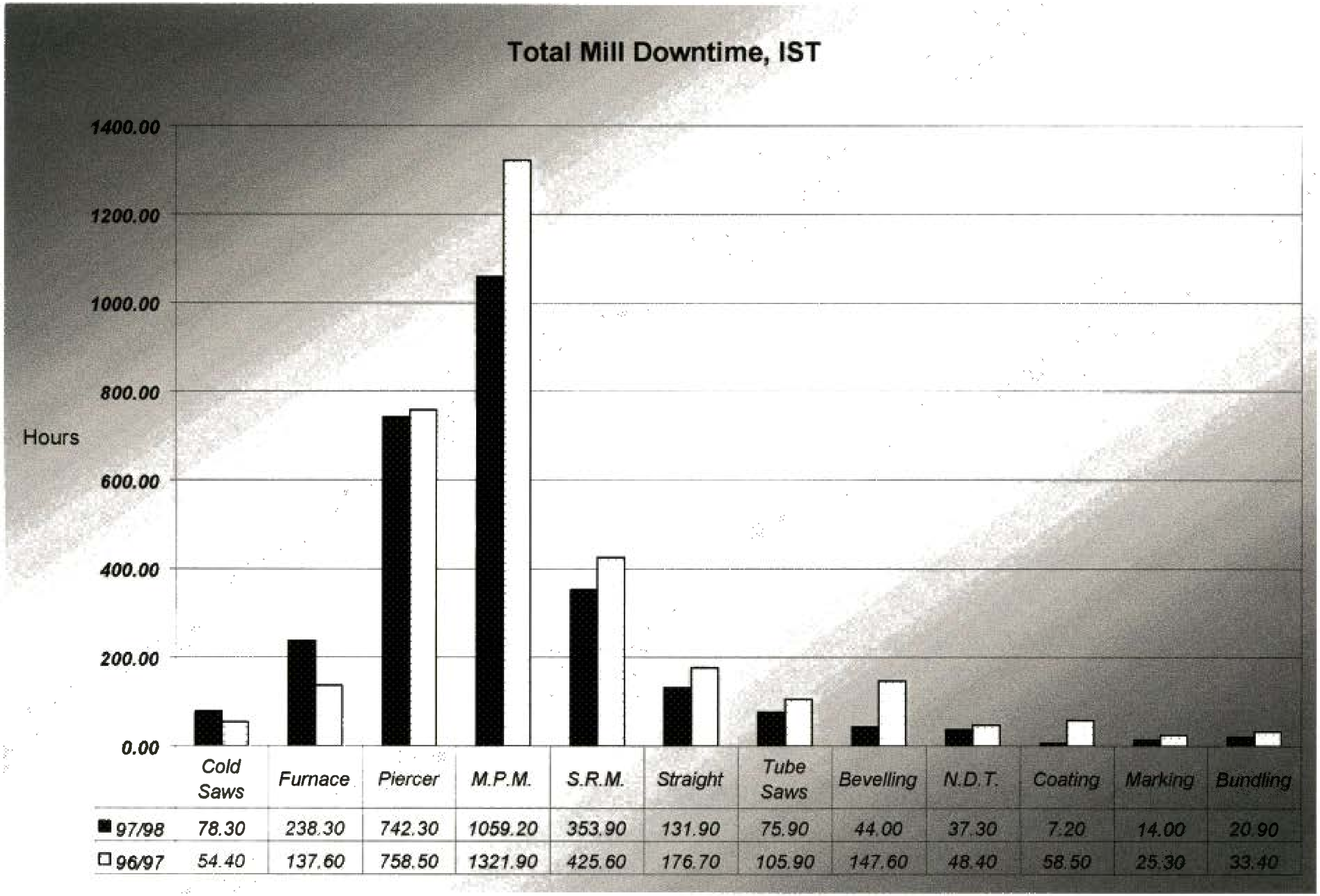
PROCESS FLOW PICTOGRAM, IST.

Iscor Seamless Tubes Process Flow Diagram



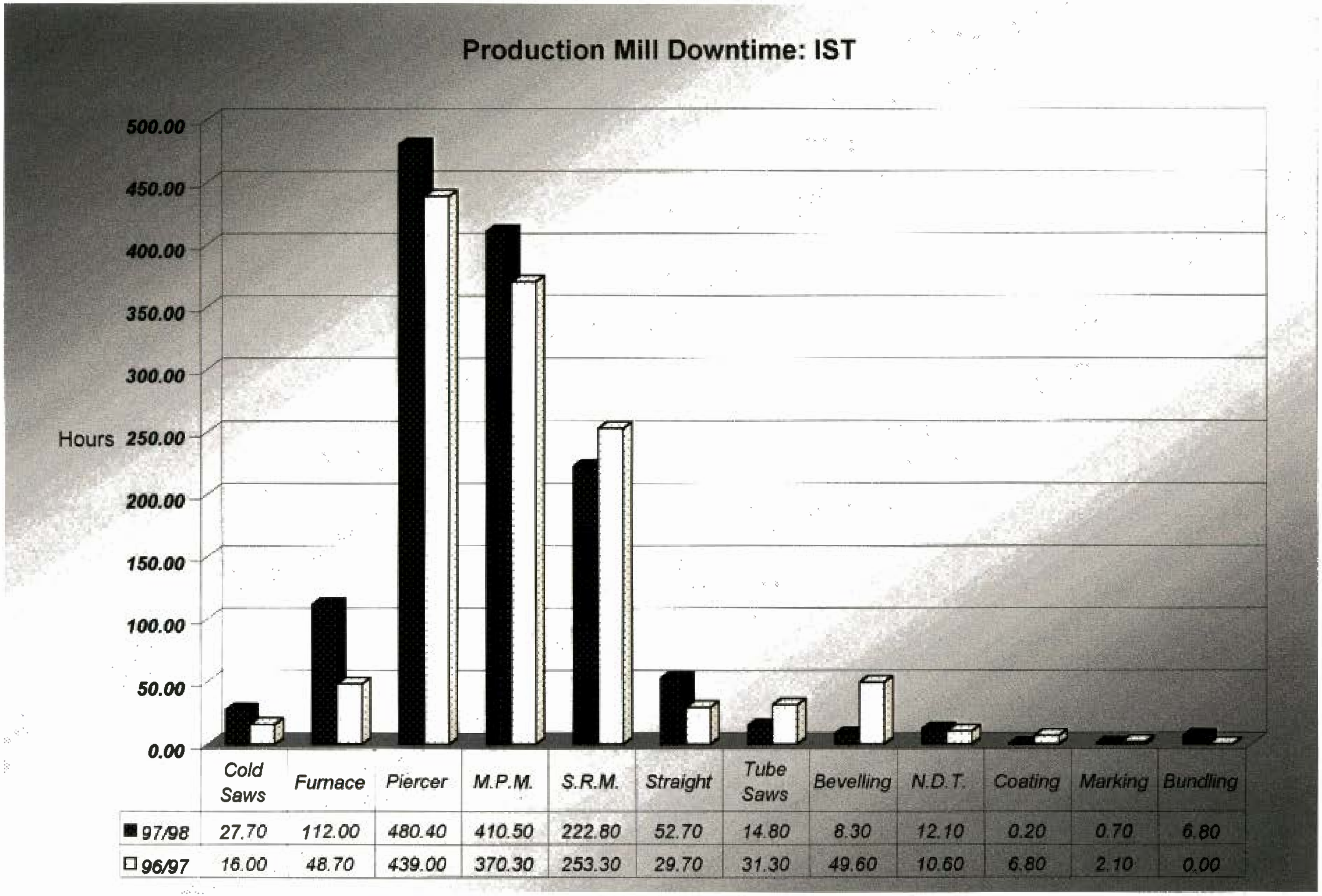
APPENDIX B

DOWNTIME GRAPHS, IST.



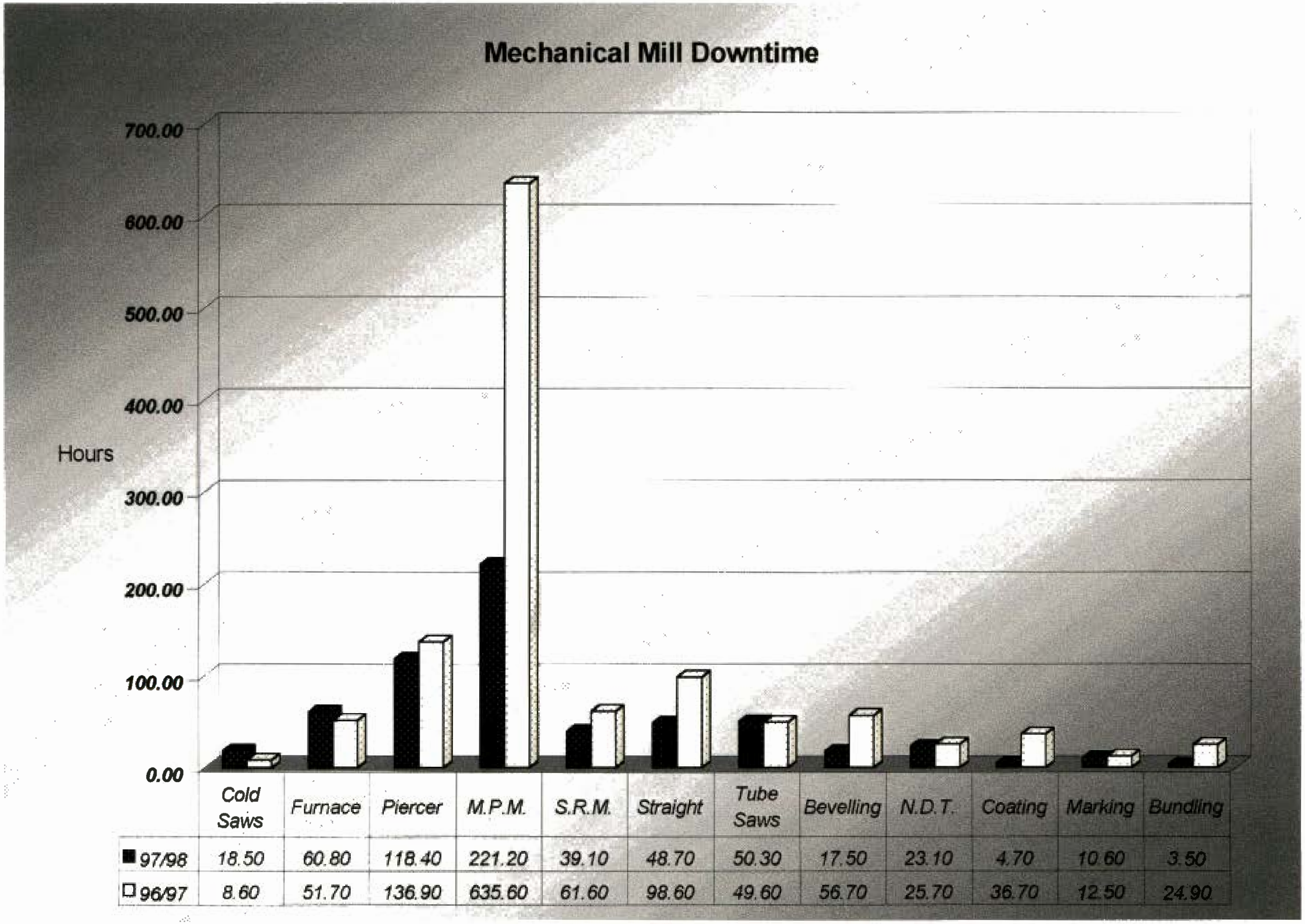
Total Mill Downtime, IST

	Cold Saws	Furnace	Piercer	M.P.M.	S.R.M.	Straight	Tube Saws	Bevelling	N.D.T.	Coating	Marking	Bundling
■ 97/98	78.30	238.30	742.30	1059.20	353.90	131.90	75.90	44.00	37.30	7.20	14.00	20.90
□ 96/97	54.40	137.60	758.50	1321.90	425.60	176.70	105.90	147.60	48.40	58.50	25.30	33.40



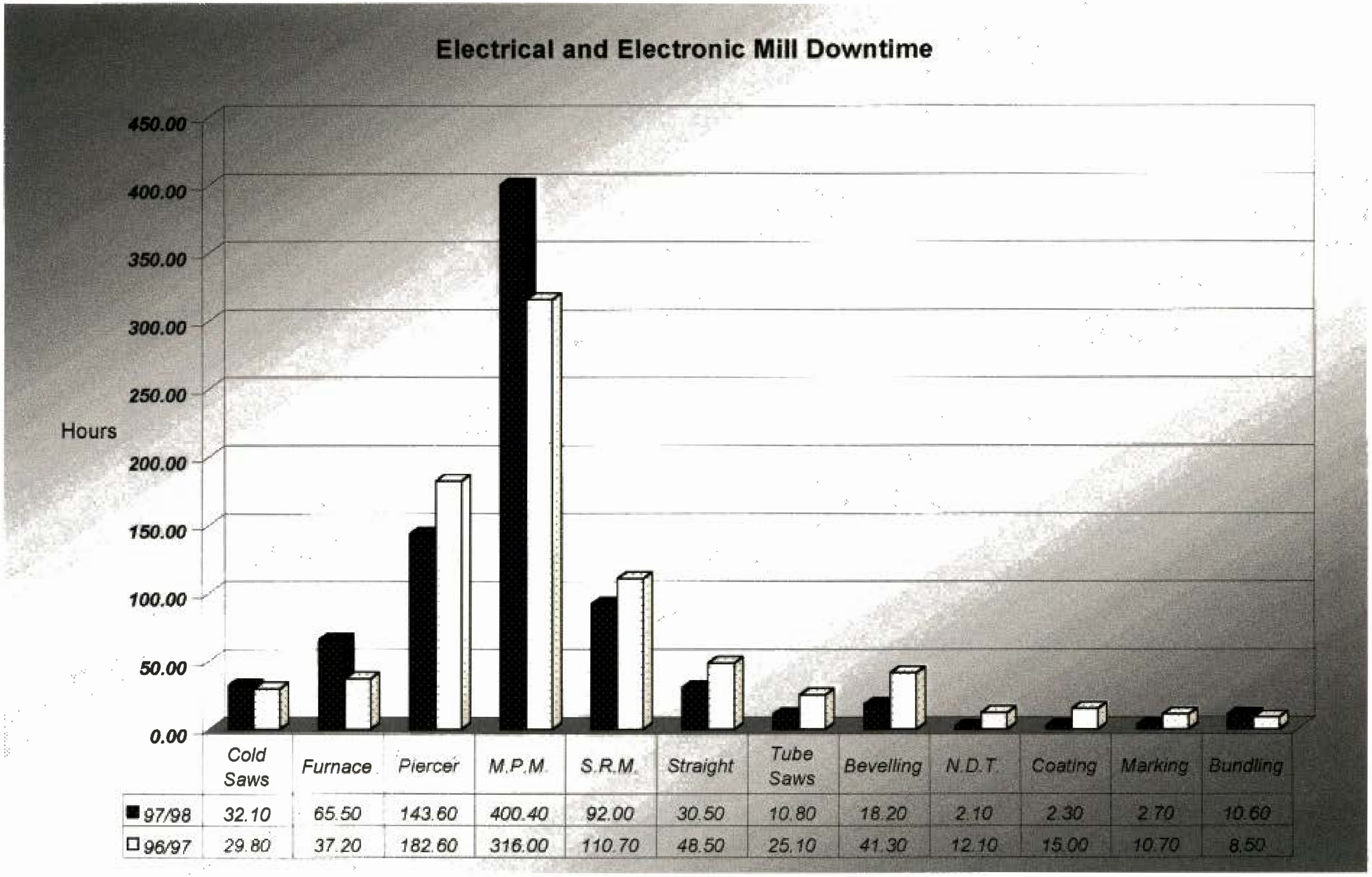
Production Mill Downtime: IST

	Cold Saws	Furnace	Piercer	M.P.M.	S.R.M.	Straight	Tube Saws	Bevelling	N.D.T.	Coating	Marking	Bundling
■ 97/98	27.70	112.00	480.40	410.50	222.80	52.70	14.80	8.30	12.10	0.20	0.70	6.80
☐ 96/97	16.00	48.70	439.00	370.30	253.30	29.70	31.30	49.60	10.60	6.80	2.10	0.00



Mechanical Mill Downtime

	Cold Saws	Furnace	Piercer	M.P.M.	S.R.M.	Straight	Tube Saws	Bevelling	N.D.T.	Coating	Marking	Bundling
■ 97/98	18.50	60.80	118.40	221.20	39.10	48.70	50.30	17.50	23.10	4.70	10.60	3.50
□ 96/97	8.60	51.70	136.90	635.60	61.60	98.60	49.60	56.70	25.70	36.70	12.50	24.90



	Cold Saws	Furnace	Piercer	M.P.M.	S.R.M.	Straight	Tube Saws	Bevelling	N.D.T.	Coating	Marking	Bundling
■ 97/98	32.10	65.50	143.60	400.40	92.00	30.50	10.80	18.20	2.10	2.30	2.70	10.60
□ 96/97	29.80	37.20	182.60	316.00	110.70	48.50	25.10	41.30	12.10	15.00	10.70	8.50

APPENDIX C

DOWNTIME DATA ANALYSED.

Maintenance Downtime, IST

AreaName Cold Saws

Description	Duration	Code
Arm to buffer conveyor not working	12	Mechanical
Billet stuck at charger	20	Electrical
Buffer table o.o.o	79	Electrical
Changed cylinder	5	Mechanical
Chip conveyor o.o.o	29	Mechanical
Magnet crane o.o.o	49	Electrical
Problems with sensor	71	Electrical
Rain water problem	25	Electrical
Rollers to buffer conveyor not working	5	Electrical
Saw no 2 o.o.o	30	Electrical
Storage conveyor o.o.o	122	Electrical
Swing table o.o.o	103	Mechanical
Swing table o.o.o	7	Electrical
Swing table o.o.o	5	Electrical
Swing table o.o.o	45	Mechanical
Tip conveyor o.o.o	30	Electrical
Total (min):	637	

AreaName CTP

Description	Duration	Code
3 Roll steady no 5 clevis broken	45	Mechanical
3 Roller guides not clamping	18	Electrical
3 Roller guides not clamping	40	Electrical
3 Roller guides not clamping	5	Electrical
All conveyors tripped	6	Electrical
Base bolts loose	3	Mechanical
Bent plug bar (settings due to stand 1 motor)	41	Electrical
Billet fell off rollerway	14	Electrical
Billet stuck on rollerway	14	Electrical
Billet stuck on rollerway	19	Electrical
Billet stuck on rollerway	4	Mechanical
Billet stuck on rollerway	7	Electrical
Billet stuck under kick out	6	Electrical
Bogie wheel fell off	20	Mechanical
Callibrate guide shoes (left g/shoe 10 mm out)	20	Electrical

Clamping not ready	20	Electrical
Clamping on thustblock hydraulic leak	21	Mechanical
Crane o.o.o	180	Electrical
First 3 Roller guide proxy	32	Electrical
First 3 Roller guide proxy	12	Electrical
Fitter adjust belt tension	15	Mechanical
Ghrease and colling pipe carrier broke	86	Mechanical
Hydraulic leak	35	Mechanical
Hydraulic leak on 3 roller guide	10	Mechanical
Hydraulic leak on 3 roller guide	20	Mechanical
Hydraulics on CTP	16	Mechanical
Hydraulics tripped	11	Electrical
Hydraulics tripped	11	Electrical
Hydraulics tripped low level	40	Mechanical
Hydraulics tripped low level	21	Mechanical
Hydraulics tripped low level	37	Mechanical
Hydraulics tripped low level	16	Mechanical
Kickover not working in auto	8	Electrical
Lost group 3	10	Electrical
Lost group 3	20	Electrical
Lost group 3	20	Electrical
Lower roll o.o.o	12	Electrical
Lower roll tripped	22	Electrical
No clamping signal	3	Mechanical
No oil, replace pipe	72	Mechanical
No power in pulpit	5	Electrical
No ready group 2	5	Mechanical
No ready on group 2	22	Electrical
No ready on group 2	7	Electrical
No ready on group 2	15	Electrical
No ready on group 2	82	Electrical
No ready on group 2	37	Electrical
No ready on piercer	12	Electrical
No rolling position	63	Electrical
No rolling position	25	Electrical
No rolling position	6	Electrical
No rolling position	108	Electrical
No rolling position	24	Electrical
No slow down on pusher bar	9	Electrical
No slow down on pusher bar	17	Electrical
No stripper position	24	Electrical

No water on CTP	37	Electrical
Plug bar carrier rope broke	90	Mechanical
Plug bar carrier rope broke	150	Mechanical
Plug bar water cooling pipe broke	24	Mechanical
Plug bar water cooling pipe broke	20	Mechanical
Plug bar water cooling pipe broke	7	Mechanical
Proxy at kick in to piercer	3	Electrical
Pusher not working on automatic	9	Electrical
Pusher not working on automatic	3	Electrical
Pusher o.o.o	12	Electrical
Pusher pushed billet into rolls before plug bar was clamped	42	Electrical
Pusher pushed billet into rolls before plug bar was clamped	100	Electrical
Reading on piercer motors	5	Electrical
Reject levers not throwing billet over	8	Mechanical
Repair plug bar carrier	46	Mechanical
Repair thrust block belt	203	Mechanical
Rollerway to piercer o.o.o	18	Electrical
Rollerway to piercer o.o.o	35	Electrical
Rollerway to piercer o.o.o	10	Electrical
Rollerway to piercer o.o.o	29	Electrical
Run in and out conveyor o.o.o	90	Electrical
Run in and out conveyor o.o.o	25	Electrical
Run in and out conveyor o.o.o	36	Electrical
Run in and out conveyor o.o.o	25	Electrical
Run in and out conveyor o.o.o	18	Electrical
Run out conveyor o.o.o	25	Electrical
Second rollerway rolls not turning	4	Electrical
Shearing pins of thrust block broke	19	Mechanical
Shearing pins of thrust block broke	25	Mechanical
Shearing pins of thrust block broke	15	Mechanical
Shell kick out cylinder	40	Mechanical
Shell kick out o.o.o	18	Electrical
Spindle support not in position	50	Mechanical
Sticker due to pusher bar	40	Electrical
Tail end stickers due to adjustment of CTP due to MPM rollers bad align	16	Mechanical
Thrust block cylinder oil leak	22	Mechanical
Thrust block did not return	5	Electrical
Thrust block drifting	14	Electrical
Thrust block hit crane hook	24	Mechanical
Thrust block keep on tripping	7	Electrical
Thrust block not in rolling position	13	Electrical

Thrust block not ready	29	Electrical
Thrust block not ready	18	Electrical
Thrust block not ready	46	Electrical
Thrust block proxy	35	Electrical
Thrust block proxy	19	Electrical
Thrust block proxy	5	Electrical
Thrust block shearing broke	30	Mechanical
Thrust block tripping	10	Electrical
Thrustblock not going into rolling position	21	Electrical
Thrustblock not going into rolling position	30	Electrical
Thrustblock not going into rolling position	4	Electrical
Thrustblock not going into rolling position	7	Electrical
Thrustblock not going into rolling position	40	Electrical
Thrustblock not going into rolling position	8	Electrical
Thrustblock not going into rolling position	14	Electrical
Thrustblock not going into rolling position	9	Electrical
Two billets in front of piercer	5	Electrical
Upper roll trip	10	Electrical
Upper roll trip	8	Electrical
Upper roll trip	39	Electrical
Upper roll trip	18	Electrical
Upper roll trip	11	Electrical
Total (min):	3271	

AreaName MPM

Description	**Duration**	**Code**
Adjust mandrel support rolls	53	Mechanical
Adjust mandrel support rolls	6	Mechanical
Adjust mandrel support rolls	43	Mechanical
Adjust shell support rolls	19	Mechanical
Adjust shell support rolls	18	Mechanical
Adjust shell support rolls	14	Mechanical
Air descaler tripped	4	Mechanical
Align mandrel crane	37	Mechanical
Align mandrel crane	19	Mechanical
Bar stuck on lubrication chain	5	Electrical
Borax blocked	10	Mechanical
Brakes of mandrel crane	73	Electrical
Calibrate rack drives	5	Electrical
Capsules stand 1 not zeroing	36	Electrical
Capsules stand 1 not zeroing	58	Electrical

Capsules tripped	192	Electrical
Cellar flooded	103	Electrical
Change limit	22	Electrical
Change shell support roller cylinder	37	Mechanical
Change valve stand 1	42	Mechanical
Clamping dirty, air cleaner o.o.o	13	Mechanical
Cleaned rack	4	Mechanical
Convertor fault on mandrel crane	6	Electrical
Cross transfer chain not in base	7	Electrical
Cross transfer chain not in base	5	Electrical
Cross transfer chain not in base	12	Electrical
Cross transfer chain not in base	4	Electrical
Cross transfer chain not in base	5	Electrical
Cross transfer chain not in base	5	Electrical
Cross transfer chain o.o.o	45	Electrical
Cross transfer chain o.o.o	10	Electrical
Cross transfer chain o.o.o	8	Electrical
Cross transfer chain o.o.o	10	Electrical
Cross transfer chain o.o.o	25	Mechanical
Cross transfer o.o.o	60	Electrical
Cross transfer tripped	13	Electrical
Cross transfer tripped	4	Electrical
Cross transfer tripped	16	Electrical
Cross transfer tripped	6	Electrical
Cross transfer tripped	5	Electrical
Cross transfer tripped	4	Electrical
Cross transfer tripped	8	Electrical
Descaler o.o.o	53	Electrical
Drive of stand 4 tripped	3	Electrical
Drives tripped	48	Electrical
Encoder on rack drive	71	Electrical
Extractor rollerway tripped	8	Electrical
Extractor tripped	25	Electrical
Fitters weld kick out	21	Mechanical
Graphite nozzles blocked	26	Electrical
Graphite nozzles blocked	29	Electrical
Graphite nozzles blocked	51	Electrical
Graphite pump not working	14	Mechanical
Graphite pump not working	10	Mechanical
Graphite pump not working	7	Mechanical
H1 tripped	9	Electrical

H1 tripped low level	23	Mechanical
H2 oil temperature too high	10	Mechanical
Heat up Mandrel bar with shell	22	Electrical
Hydraulic leak	66	Mechanical
Hydraulic leak	27	Mechanical
Hydraulic leak shell support roll 3	24	Mechanical
Hydraulics tripped	70	Mechanical
Kick out to cooling o.o.o	4	Electrical
Kick out to cooling o.o.o	17	Electrical
Kick transfers not working	56	Electrical
Kick transfers not working	3	Electrical
L1 tripped	40	Electrical
L1 tripped low level	41	Mechanical
L1 tripped low level	8	Mechanical
L1 tripped low level	8	Mechanical
Limit bracket faulty	7	Electrical
Limit on magnets striker stuck	3	Mechanical
Load furnace due to stand 3 motor	120	Electrical
Low oil level on MPM drives	15	Mechanical
Lubrication chain broke	11	Mechanical
Lubrication chain broke	16	Mechanical
Lubrication chain tripped	79	Electrical
Lubrication chain tripped	20	Electrical
Lubrication chain tripped	24	Electrical
Lubrication chain tripped	20	Electrical
Lubrication chain tripped	6	Mechanical
Lubrication chain tripped	84	Mechanical
Lubrication chain tripped	7	Electrical
Lubrication chain tripped	13	Electrical
Lubrication chain tripped	10	Electrical
Mandrel bar hit shell	14	Electrical
Mandrel bar hit shell, rolls out of line	61	Mechanical
Mandrel bar hit shell, rolls out of line	85	Mechanical
Mandrel bar kick out not in base	8	Electrical
Mandrel bar transfer to cooling	7	Mechanical
Mandrel bar trolley slow speed	85	Electrical
Mandrel circulation o.o.o	7	Electrical
Mandrel crane brakes	18	Mechanical
Mandrel crane did not pick bar up	3	Electrical
Mandrel crane drop bar	5	Mechanical
Mandrel crane drop bar	3	Electrical

Mandrel crane drop bar	64	Electrical
Mandrel crane drop bar	32	Mechanical
Mandrel crane drop bar	20	Electrical
Mandrel crane drop bar	10	Electrical
Mandrel crane drop bar	13	Electrical
Mandrel crane drop bar	5	Electrical
Mandrel crane drop bar	89	Electrical
Mandrel crane drop bar	10	Electrical
Mandrel crane jumped one tooth	55	Mechanical
Mandrel crane not ready	59	Electrical
Mandrel crane not ready	73	Electrical
Mandrel crane not ready	10	Mechanical
Mandrel crane not ready	6	Electrical
Mandrel crane not ready	8	Electrical
Mandrel crane not ready	17	Electrical
Mandrel crane not ready	5	Mechanical
Mandrel crane not running in auto	13	Electrical
Mandrel crane not running in auto	5	Electrical
Mandrel crane o.o.o	24	Electrical
Mandrel crane o.o.o	7	Electrical
Mandrel crane o.o.o	6	Electrical
Mandrel crane o.o.o	9	Electrical
Mandrel crane o.o.o	9	Mechanical
Mandrel crane o.o.o	7	Electrical
Mandrel crane o.o.o	28	Mechanical
Mandrel crane o.o.o	10	Electrical
Mandrel crane o.o.o	7	Electrical
Mandrel crane o.o.o	16	Electrical
Mandrel crane o.o.o	10	Electrical
Mandrel crane o.o.o	3	Electrical
Mandrel crane o.o.o	5	Electrical
Mandrel crane o.o.o	4	Electrical
Mandrel crane o.o.o	5	Electrical
Mandrel crane o.o.o	9	Electrical
Mandrel crane o.o.o	9	Electrical
Mandrel crane o.o.o	5	Mechanical
Mandrel crane o.o.o	8	Electrical
Mandrel crane o.o.o	3	Electrical
Mandrel crane o.o.o	6	Mechanical
Mandrel crane reflector o.o.o	3	Electrical
Mandrel crane rope	24	Mechanical

Mandrel crane rope	70	Mechanical
Mandrel crane rope tensioner stuck	8	Mechanical
Mandrel crane ropes cross on drum	4	Mechanical
Mandrel crane work in slow motion	45	Electrical
Mandrel induction heater o.o.o	10	Electrical
Mandrel kick out o.o.o	19	Electrical
Mandrel kick out o.o.o	9	Mechanical
Mandrel kick out o.o.o	3	Electrical
Mandrel rotation o.o.o	19	Electrical
Mandrel rotation o.o.o	78	Electrical
Mandrel rotation o.o.o	6	Electrical
Mandrel stuck at kick out	10	Mechanical
Mandrel support roll loose	20	Mechanical
Mandrel support roll o.o.o	89	Mechanical
Mandrel support stand 3 tripped	7	Electrical
Mandrel support stand 3 tripped	120	Electrical
Mill stopped	5	Electrical
Mill stopped	8	Electrical
Mill stopped	6	Electrical
Mill stopped	31	Electrical
Mill stopped	5	Electrical
Mill stopped	5	Electrical
Mill stopped	13	Electrical
Mill stopped	5	Electrical
Mill stopped	3	Electrical
Mill stopped	7	Electrical
Mill stopped	3	Electrical
Motor for stand 1 o.o.o	210	Electrical
Motor for stand 1 o.o.o	1194	Electrical
Motor for stand 1 o.o.o	1440	Electrical
Motor for stand 1 o.o.o	1440	Electrical
Motor for stand 1 o.o.o	960	Electrical
MPM shut off	9	Electrical
MPM shut off	6	Electrical
MPM shut off	5	Electrical
MPM shut off	10	Electrical
MPM shut off	9	Electrical
No air on graphite system	8	Mechanical
No ready on mill	279	Mechanical
No ready on MPM	17	Electrical
No ready on MPM	27	Electrical

No ready on rack	9	Mechanical
No signal on stand 1 spindle locking	36	Electrical
One bay centre crane o.o.o	25	Electrical
P/Block broke on mandrel crane	5	Mechanical
Pinch roll slipped	8	Mechanical
Pinch roll slipped	23	Mechanical
Pinch roll slipped	3	Mechanical
Pinch roll tripped	24	Electrical
Pinch roll tripped	4	Electrical
Pinch roll tripped	5	Electrical
Pinch roll tripped	21	Mechanical
Pinch roll tripped	28	Electrical
Pinch roll tripped	6	Electrical
Pinch roll tripped	10	Electrical
Pinch roll tripped	7	Electrical
Pinch roll tripped	10	Mechanical
Pinch roll tripped	11	Electrical
Pinch roll tripped	5	Electrical
Pinch roll tripped	5	Electrical
Pinch roll tripped	21	Mechanical
Pinch roll tripped	6	Electrical
Pinch roll tripped	11	Electrical
Pinch roll tripped	4	Electrical
Pinch roll tripped	16	Electrical
Power dip	103	Electrical
Power off on panels	60	Electrical
Problems with borax tanks	10	Mechanical
Problems with graphite system	12	Mechanical
Problems with L1	10	Mechanical
Proxy for pinch roll	34	Electrical
Rack controller o.o.o	8	Electrical
Rack controller o.o.o	196	Electrical
Rack drive cooling motor	87	Electrical
Rack drive cooling motor	130	Electrical
Rack drives tripped	9	Electrical
Rack not in home position	11	Electrical
Rack not in home position	49	Electrical
Rack not in home position	6	Electrical
Rack not in home position	47	Electrical
Rack not in home position	12	Electrical
Rack not in home position	8	Electrical

Rack not ready	26	Electrical
Rack returned too soon	9	Electrical
Rack returned too soon	156	Electrical
Rack returned too soon	12	Electrical
Rack sequence o.o.o	5	Electrical
Rack shearing pins	30	Mechanical
Rack shearing pins	37	Mechanical
Rack shearing pins	3	Mechanical
Rack switched off	3	Electrical
Rack went foreward after rolling	20	Electrical
Rack went foreward after rolling	12	Electrical
Re-align mandrel crane	26	Mechanical
Reflector at rack o.o.o	5	Electrical
Reflector bracket broke off	7	Mechanical
Remove scrap	3	Electrical
Repair cross transfer chain	37	Mechanical
Repair cross transfer chain	701	Mechanical
Repair cross transfer chain	30	Mechanical
Repair cross transfer chain	18	Mechanical
Repair cross transfer chain	10	Mechanical
Repair lubrication chain	105	Mechanical
Rollerway to cooling trip	5	Electrical
Rollerway to cooling trip	8	Electrical
Rollerway to cooling trip	84	Electrical
Rollerway to cooling trip	14	Electrical
Rollerway to cooling trip	7	Electrical
Rollerway to cooling trip	13	Electrical
Rollerway to cooling trip	3	Electrical
Rollerway to lubrication tripped	7	Electrical
Sensor at M/bar stopper o.o.o	24	Electrical
Sensor dirty	4	Electrical
Sensor dirty	3	Electrical
Sensor dirty	12	Electrical
Sensor dirty	7	Electrical
Sensor dirty	3	Electrical
Sensor dirty	13	Electrical
Set pinch roll	10	Mechanical
Shearing pins broke	19	Mechanical
Shell stopping fork proxy loose	31	Electrical
Shell stopping fork proxy loose	36	Electrical
Shell stopping fork stuck	3	Mechanical

Shell stopping fork stuck	38	Mechanical
Shell stopping fork stuck	17	Mechanical
Shell stopping fork stuck	5	Mechanical
Shell stopping fork stuck	10	Mechanical
Shell stopping fork stuck	19	Mechanical
Shell stuck	8	Mechanical
Shell support roll no 3 stay in down position	11	Mechanical
Shell support rolls in down position	28	Mechanical
Shell support rolls in down position	10	Mechanical
Shell transfer o.o.o	5	Mechanical
Shell transfer o.o.o	8	Mechanical
Shell transfer tripped	5	Electrical
Slow production due to ext. cross transfer and rack not in home pos.	87	Electrical
Stand 1 capsules not going under control	5	Electrical
Stand 1 capsules o.o.o	90	Mechanical
Stand 1 spindle stuck	25	Mechanical
Stand 1 tripped	150	Electrical
Stand 1 tripped	18	Electrical
Stand 1 tripped	7	Electrical
Stand 1 tripped	10	Electrical
Stand 2 balancing o.o.	20	Electrical
Stand 2 does not accept 480 mm roll dia	130	Electrical
Stand 2 gearbox o.o.o	750	Mechanical
Stand 2 gearbox o.o.o	360	Mechanical
Stand 2 shearing pins	14	Mechanical
Stand 3 motor o.o.o	1440	Electrical
Stand 3 motor o.o.o	375	Electrical
Stand 3 shearing pins	93	Mechanical
Stand 3 shearing pins	14	Mechanical
Stand 3 trip	230	Electrical
Stand 3 trip	15	Electrical
Stand 4 capsules not going to zero	5	Electrical
Stand 4 capsules tripped	10	Electrical
Sticker due to rack	900	Electrical
Stickers (stand 1 motor)	131	Electrical
Tongs of mandrel crane o.o.o	17	Mechanical
Top limit of mandrel crane	10	Electrical
Two mandrels in rack	20	Electrical
Two mandrels on lubr. chain	4	Electrical
Wear strips for mandrel kick out worn	34	Mechanical
Weld base for stand 3 motor	29	Electrical

Weld shaft on run out conveyor	20	Mechanical
Total (min):	17362	

AreaName RHF

Description	Duration	Code
A.C. drive tripped	4	Electrical
A.C. drive tripped	13	Electrical
A.C. drive tripped	4	Electrical
Adjust discharger height	3	Mechanical
Adjust valve at discharger	8	Mechanical
Billet stuck at charger	25	Electrical
Billet stuck on rollerway	10	Mechanical
Cables burnt due to oil catching fire	422	Mechanical
Cast no change	21	Electrical
Cast no change	19	Electrical
Cast no change	26	Electrical
Cast no change	4	Electrical
Cast no change	7	Electrical
Cast no change	15	Electrical
Cast no change	3	Electrical
Cast no change	37	Electrical
Cast no change	12	Electrical
Cast no change	17	Electrical
Cast no change	18	Electrical
Cast no change	20	Electrical
cast no change	15	Electrical
Cast no change	9	Electrical
Cast no change	12	Electrical
cast no change	24	Electrical
Cast no change	18	Electrical
Cast no change	22	Electrical
Cast no change	17	Electrical
Cast no change	15	Electrical
Cast no change	30	Electrical
Cast no change	12	Electrical
Cast no change	6	Electrical
Cast no change	24	Electrical
Change valve on discharger	10	Mechanical
Changed hydraulic valve	57	Mechanical
Charger door stuck	10	Mechanical
Charger door stuck	15	Mechanical

Charger drop billet	5	Mechanical
Charger not in back position	8	Electrical
Charger not ready	10	Electrical
Charger not ready	8	Electrical
Charger not running in auto	103	Electrical
Charger o.o.o	14	Mechanical
Charger o.o.o	19	Mechanical
Charger o.o.o	11	Electrical
Charger o.o.o	11	Mechanical
Charger o.o.o	5	Mechanical
Charger o.o.o	30	Electrical
Charger o.o.o	19	Electrical
Charger o.o.o	16	Electrical
Charger roller o.o.o	14	Electrical
Charger stay down	73	Mechanical
Charger stayed in down position	15	Electrical
Charger tripped	7	Electrical
Charger tripped	23	Electrical
Charger tripped	25	Electrical
Discharger clamp very slowly	6	Mechanical
Discharger clamping cylinder	18	Mechanical
Discharger did not return to stop position	6	Electrical
Discharger door proxy	3	Electrical
Discharger door stuck	6	Electrical
Discharger drop billet	4	Mechanical
Discharger not moving far enough	6	Electrical
Discharger not running in auto	7	Electrical
Discharger o.o.o	13	Electrical
Discharger o.o.o	155	Mechanical
Discharger o.o.o	34	Electrical
Discharger o.o.o	20	Electrical
Discharger o.o.o	17	Mechanical
Discharger o.o.o	25	Electrical
Discharger run through limit	13	Electrical
Discharger slewing	17	Mechanical
Discharger stay in top position	8	Mechanical
Discharger too low, bump billets	20	Mechanical
Discharger tripped	11	Electrical
Discharger tripped	3	Electrical
Hearth tripped	5	Electrical
Hearth tripped	7	Electrical

Hearth tripped	12	Electrical
Hearth tripped	7	Electrical
Hearth tripped	4	Electrical
Hearth tripped	6	Electrical
Hearth tripped	7	Electrical
Hydraulic leak charger	15	Mechanical
Hydraulic leak discharger	7	Mechanical
Hydraulic leak discharger	28	Mechanical
Hydraulic leak discharger	21	Mechanical
Hydraulic leak discharger	5	Mechanical
Hydraulic leak discharger	14	Mechanical
Hydraulic leak discharger	5	Mechanical
Hydraulic leak discharger	9	Mechanical
Hydraulic leak discharger	24	Mechanical
Hydraulic leak discharger	14	Mechanical
Hydraulic leak discharger	4	Mechanical
Hydraulic leak discharger	15	Mechanical
Hydraulic leak discharger	41	Mechanical
Hydraulic leak discharger	30	Mechanical
Motors missing	25	Electrical
No 24V supply on discharger controls	197	Electrical
No backstop on discharger	72	Mechanical
Replace cylinder	34	Mechanical
Replace cylinder	20	Mechanical
RHF does not increment	23	Electrical
RHF does not increment	9	Electrical
RHF does not increment	4	Electrical
RHF does not increment	3	Electrical
Rollers to charger stop before billet is at stopper	10	Electrical
Set charger upper limit	2	Electrical
Temp. 150 below setpoint	51	Electrical
Temperature too low	11	Electrical
Temperature too low	4	Electrical
Temperature too low	30	Electrical
Temperature too low	14	Electrical
Temperature too low	10	Electrical
Temperature too low	20	Electrical
Temperature too low	7	Electrical
Temperature too low	11	Electrical
Two billets sim. at swing table	7	Mechanical
Total (min):	2636	

AreaName SRM

Description	Duration	Code
Adjust kick out	12	Mechanical
Adjust kick out	9	Mechanical
Adjust kick out	6	Mechanical
Cables burnt	5	Electrical
Conveyor to saw 3 does not start in auto	10	Electrical
Cooling bed tripped	37	Electrical
Cooling bed tripped	21	Electrical
Crane broke, Bin fell	26	Electrical
Crop end stopper stuck at saw 3	15	Electrical
Cut and remove bent tubes due to sequence problems	7	Electrical
Cut saw 3 safety guard	16	Mechanical
Disapearing fork o.o.o	14	Mechanical
HMD o.o.o	28	Electrical
HMD o.o.o	15	Electrical
Induction heater o.o.o	180	Electrical
Induction heater o.o.o	17	Electrical
Inlet rollerway motors o.o.o	28	Electrical
Inlet rolls tripped	9	Electrical
Kick out not in base	19	Mechanical
Kick out not in base	12	Mechanical
Kick out to cooling bed o.o.o	61	Mechanical
Kick out to cooling bed o.o.o	10	Mechanical
Kick out to cooling bed o.o.o	16	Mechanical
Kick out to cooling bed o.o.o	6	Mechanical
Kick out work slow	16	Mechanical
Kick over to middle saw o.o.o	9	Mechanical
Lifters o.o.o	6	Electrical
Lifters o.o.o	8	Electrical
Lifters too weak (Air problem)	20	Mechanical
Main drive tripped, water very hot	169	Mechanical
Main drives o.o.o	47	Electrical
MPM Stand 4 water does not switch off	12	Electrical
Outlet table not calibrated	59	Electrical
Pipe throw out to soon	35	Electrical
Power dip	47	Electrical
Power dip	39	Electrical
Pusher type kick over not in base	16	Electrical
Reset SRM drives program	11	Electrical

Roll conveyor group 2 o.o.o	11	Electrical
Rollerways tripped	6	Electrical
Saw 1 cable burned	18	Electrical
Saw 1 proxy o.o.o	11	Electrical
Saw 1 proxy o.o.o	20	Electrical
Saw 1 proxy o.o.o	15	Electrical
Saw 1 stopper bolts broke	13	Mechanical
Saw 3 safety guard broke	11	Mechanical
Saw 3 stay in down position	10	Electrical
Saw 3 stopper bolts broke	9	Electrical
Saw 3 stopper stuck	9	Mechanical
Sequence problems	4	Electrical
Sequence problems	13	Electrical
Set timer for inlet conveyor	3	Electrical
SRM tripped	9	Electrical
Super imposed drive 1 trip	30	Electrical
Super imposed drive 1 trip	35	Electrical
Super imposed drive 2 trip	22	Electrical
Super imposed drive 2 trip	18	Electrical
Super imposed drive tripped	30	Electrical
Tilting table pin out	10	Mechanical
Transportation tripped	13	Electrical
Travel length stopper do not slew in	10	Electrical
Travel length stopper o.o.o	33	Electrical
Travel stopper & Induction heaters o.o.o	20	Electrical
Tube hook on saw 3 guard	19	Mechanical
Tube under kick out to cooling bed	10	Electrical
V belt broke saw 3	14	Mechanical
V belt broke saw 3	20	Mechanical
Total (min):	1519	

APPENDIX D

DAILY MANAGEMENT REPORT.

Stoppage analysis

Date: 29-Mar-99

Hotmill

FROM	TO	TIME	AREA	Notice No	CODE	DESCRIPTION	COBBLES		
Chris Barnard							ctp	mpm	srm
0:22	0:42	20	MPM	0	01	Sticker no borax	0	1	0
0:42	0:58	16	MPM	0	05	Size change to 88.9mm	0	0	0
2:42	2:47	5	Cold Saws	0	01	Problems at coldsaws	0	0	0
3:29	3:33	4	MPM	0	01	Change mandrel bars	0	0	0
5:20	5:23	3	MPM	0	01	Change mandrel bars	0	0	0
21:30	22:20	50	Bevelling	0	01	Adjust heads and allign clamps	0	0	0
22:30	22:32	2	MPM	0	01	Transfer Borax	0	1	0
22:41	22:56	15	Bevelling	0	01	Align clamps and rebevel tubes	0	0	0
23:50	0:00	10	CTP	0	05	Change to 160 (plug & pusher bar)	0	0	0
Neels vd Wath							ctp	mpm	srm
5:50	6:07	17	CTP	0	05	Change pusher bar and man/bars	0	0	0
6:30	6:50	20	CTP	0	05	Change pusher bar and man/bars	0	0	0
6:50	7:57	67	SRM	0	05	Check Sample on 14.02 w/t	0	0	0
8:32	8:37	5	Cold Saws	0	01	Gap due to swinging table	0	0	0
8:39	8:44	5	Cold Saws	0	01	Problem with shorts at cold saws	0	0	0
9:55	10:07	12	CTP	0	01	Change guide shoes	0	0	0
10:11	10:13	2	RHF	0	05	Gap between orders	0	0	0
10:28	11:01	33	SRM	0	05	Check Sample	0	0	0
11:02	11:06	4	Cold Saws	0	01	Long off cuts	0	0	0
11:35	11:45	10	Cold Saws	0	01	Long off cuts	0	0	0
12:10	12:36	26	CTP	0	05	change plug , m/bars, pusherbar	0	0	0
12:48	13:10	22	CTP	0	01	Front end sticker	4	0	0
13:17	13:21	4	Cold Saws	0	01	cold saw gap	0	0	0
Wim Smith							ctp	mpm	srm
14:04	14:09	5	MPM	0	01	Change mandrel bars	0	0	0
15:10	15:25	15	CTP	0	05	Change pusher bar and plug	0	0	0
17:20	17:36	16	MPM	0	05	Change over	0	0	0
18:00	18:04	4	SRM	0	01	Inlet lifters doesn't lower	0	0	0
19:33	19:45	12	CTP	0	01	Change guide shoes	0	0	0
20:18	20:27	9	MPM	0	01	Change mandrel bars	0	0	0
20:44	20:52	8	CTP	0	01	Changed plug	0	0	0
21:15	21:30	15	SRM	0	01	check samples	0	0	0

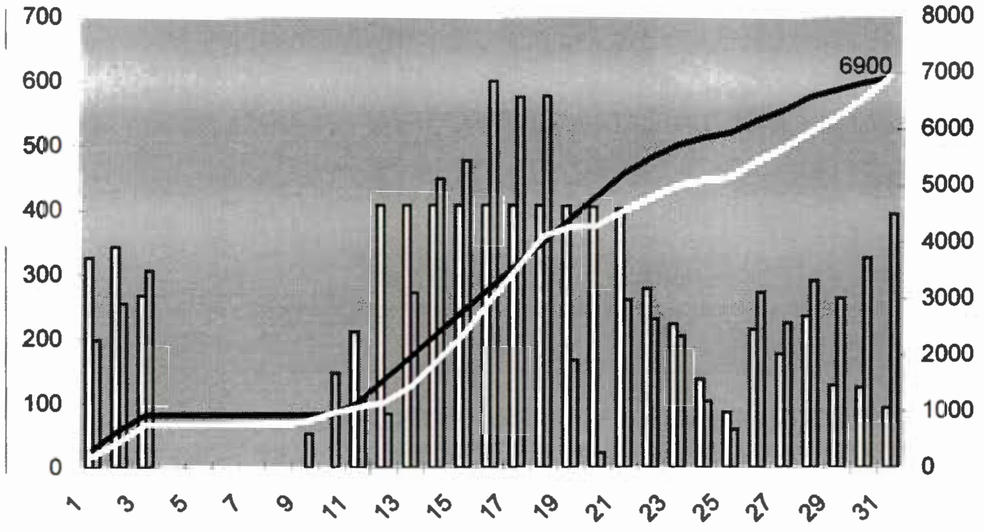
Stoppage analysis Date: 29-Mar-99

Downstream

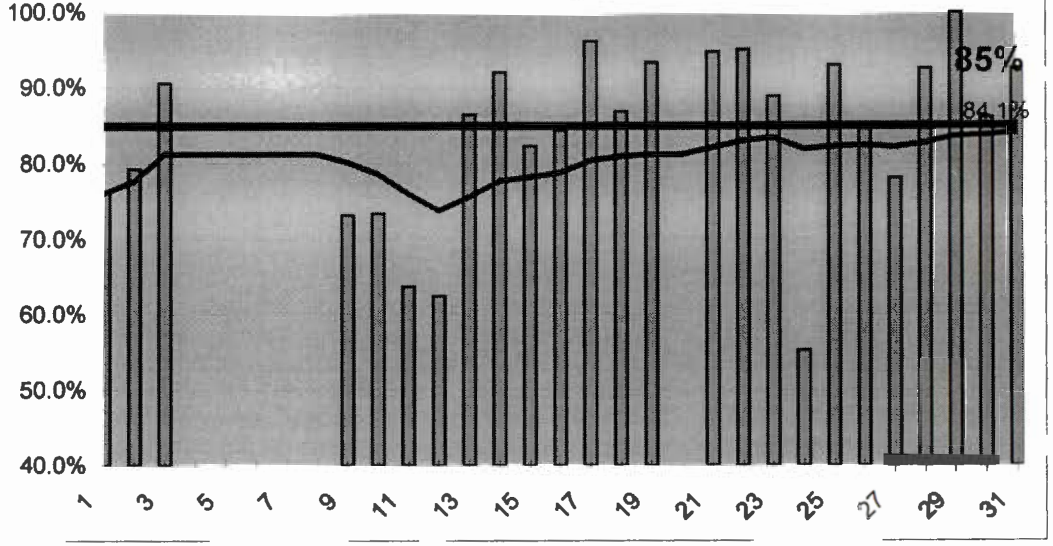
FROM	TO	TIME	AREA	Notice No	CODE	DESCRIPTION
Chris Barnard						
0:00	0:20	20	Bevelling	0	05	Change of schedule
3:45	4:30	45	Bevelling	0	05	Change size to 88.9mm
4:20	5:00	40	NDT	0	05	Changed to 88.9 mm
22:00	22:05	5	Tube saw 2	0	01	Change blade
22:15	22:50	35	Bevelling	0	01	Adjust heads and allign clamps
Neels vd Wath						
8:00	8:15	15	Bevelling	0	05	changed machine from bevell to face
8:35	8:38	3	Tube saw 2	0	05	changed length
9:55	9:58	3	Tube saw 2	0	05	changed length
10:55	11:00	5	Tube saw 2	0	05	changed length
Wim Smith						
14:05	14:15	10	Straight	0	05	CHANGE OVER
14:30	14:33	3	Tube saw 2	0	05	Changed orders
14:30	15:15	45	Tube saw 1	0	05	CHANGE OVER
16:20	17:00	40	Bevelling	0	05	Change size
16:45	16:50	5	Tube saw 1	0	05	Changed orders
16:45	16:50	5	Tube saw 2	0	05	Changed orders
17:15	19:30	135	NDT	0	05	Change over to 101.6
18:30	18:35	5	Tube saw 1	0	05	Changed orders

PERFORMANCE FOR MARCH 99

PRODUCTION OUTPUT



AVAILABILITY



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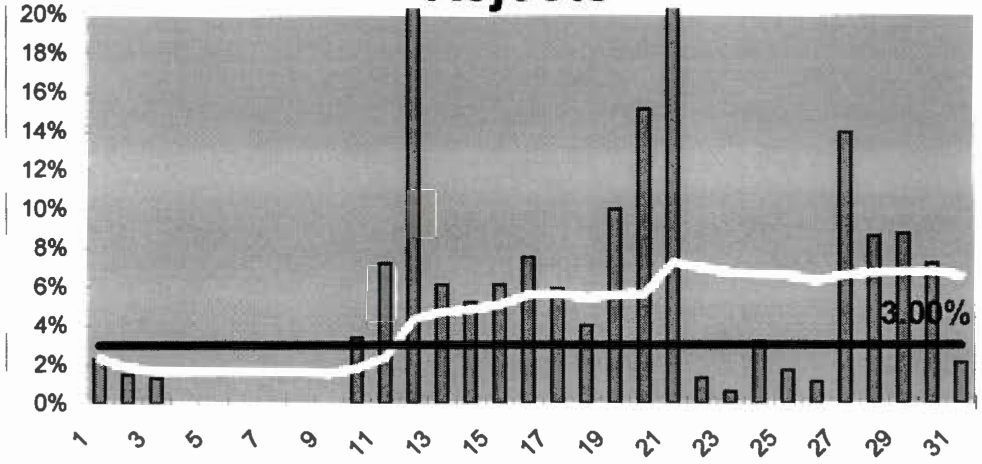

PRODUCTION STOPPAGE