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A Survey of Multi-Document Summari Enhancing Plant Availability Through Maintenance Technology Tools for Dairy Industry: Case Studyzation

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Abstract

This research investigates some industrial maintenance and respective technologies, though, it seeks to address maintenance at a dairy product processing plant. Both qualitative and quantitative techniques for analyzing maintenance systems problems are pursued. Plant availability has been identified as a major contributor in benchmarking areas at the company. As unavailability breeds huge costs due to loss of production and efficiency which results in poor utilization of resources and possible losses in monetary terms. An exploration of the history of maintenance objectives in general which includes prolongation of equipment life span as far as possible to ensure optimum plant availability. The use of tools that aid maintenance is emphasized in particular use the ABC analysis to identify equipment that contributes most to generation of losses.

Keywords: maintenance, availability, performance indices, reliability, input consumption

Introduction

The function of all organised forms of human endeavour is to take a primary input, add value to it, and dispose of the output. In manufacturing, the primary inputs are raw materials; value is added by converting these materials into something else, and disposal entails selling them to customers.

Nearly all value chains, especially those associated with for-profit business, consist of three main organizational elements [1]. At one end, one finds the raw materials procurement function. In the middle is the operations department, which is responsible for operating the value-adding processes. At the other end is the marketing and sales function, which has to locate potential customers and persuade them to acquire the output of the value-adding process.

Justification

The secure certainties of equipment care, which tend to be based on fixed-interval overhauls and component replacements, have been found to be often actively counterproductive [2]. These needless overhauls cost a fortune in terms of both maintenance expenditure and equipment downtime and hence lost production, while contributing little in terms of improved equipment reliability.

Organisations have become aware of the invalidity of traditional maintenance procedures like fixed interval overhauls, and have reacted with a massive swing toward predictive or condition-based maintenance but unfortunately in some cases, some organisations go too far, and are in danger of reaching the point where predictive technologies are being employed either at the expense of more important tasks such as failure-finding, or where they are simply another expensive waste of time [3]. The problem lies in identifying the optimum point.

From research carried out on major industrial sectors, it is apparent that there is a great deal of uncertainty about the precise role of the maintenance function. There arise questions like, should it be centralized or decentralized? To what extent should maintenance be outsourced? What is the ideal maintenance strategy?

Underlying this uncertainty is a widespread feeling that the maintenance department as a whole lacks the organisational influence to do whatever needs to be done to achieve real world-class equipment performance [1]. To understand why this may be so, it is useful to analyse approaches to the management of physical assets. But first, we define asset management then take a look at maintenance history and find out how asset management/ maintenance has developed.

Maintenance Literature

Supervisors who are responsible for organising maintenance tasks on a day-to-day basis, and for ensuring that the work is done as planned to the required standard are responsible for the maintenance assets. The maintainers who make use of the spanners and the operators who push the buttons and pull the levers should report to these supervisors [4].

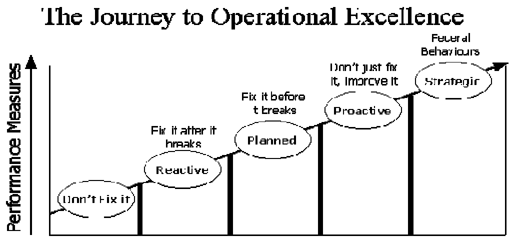

Figure 1: The journey to operational excellence [4]

At the extreme left hand of side of the chart, you could consider that maintenance is at a level of "innocence" and at the extreme right hand side, it is at "excellence" level.

The limitation of PM is that it is relatively still expensive as parts are replaced when their life span is still not exhausted and maintenance tends to introduce unnecessary downtimes, as equipment would still be in good working condition. The maintenance work also tends to introduce what are termed self-inflicted wounds due to re-assembly errors or damage to equipment during dismantling and reassembling [5].

The shortcomings of PM gave birth to condition based maintenance (CBM) making use of conditional monitoring (CM), which is essentially a type of preventive maintenance. This avoids breakdown maintenance and at the same time allows PM to be carried out when it's really required i.e. when the life span of parts is almost exhausted. However for on line CBM to be applied, there has to be a measurable parameter, so that alarm points can be set at limit values to inform that there is something wrong with the equipment and maintenance is therefore required.

The fact that none of the maintenance strategies i.e. BM, PM and CBM was able to adequately address maintenance shortcomings and objectives led to the development of reliability centered maintenance (RCM) which mainly targets improvement of equipment reliability so as to achieve high availability [6]. Still this failed to address all the shortcomings and objectives of the mentioned maintenance strategies hence Total Productive Maintenance (TPM) was born. This is a hybrid maintenance strategy that combines PM, training of workers, motivation and minimization of production losses.

1 Maintenance Management

The function of maintenance management team is to identify appropriate maintenance policies to control the condition of equipment to be in line with the objectives of the organization, which certainly include minimisation of maintenance costs [6]. Maintenance tries to lengthen the operating life of equipment as long as possible in order to maximize the returns on investment. The main problem maintenance attempts to address is to minimise plant failure as far as possible to ensure maximum reliability and availability of plant hence facilitate optimum productivity and profitability. Any money saved due to improved productivity of maintenance goes straight to profits.

It is not possible to run any plant without maintenance but too much maintenance leads to high maintenance costs and high unavailability hence lower output. There is therefore an amount of maintenance that is optimum for any particular plant needs and any deviation from the optimum by decreasing or increasing the maintenance effort leads to increases in running costs. The modern economic environment of high competition forces one to seek better maintenance decision support methods like quantitative methods that optimize frequencies of inspections, of replacements or of preventive maintenance as well as optimize workforce size in an attempt to minimize maintenance costs hence contribute to the profit making effort [7].

Proper maintenance should be able to handle complex and unexpected maintenance workloads. The maintenance control system should ensure that maintenance planning and organization are updated to meet challenges of the ever-changing maintenance environment. The effectiveness of the maintenance effort should be measured against target maintenance indices like availability.

To maximize availability ways should be found of carrying out load maintenance as far as possible, put in place maintenance support systems like diagnosis charts and communication systems so as to minimize waiting times, carry out opportune inspections during brief stoppages and put back plant to plan outage at opportune times like production windows, carry out training and work studies to minimize repair times, communication between production and maintenance is necessary to ensure harmonization of production and maintenance plans hence achieve effective and flexible maintenance schedules.

Tasks to be fulfilled by maintenance department [8]

- Complete cooperation and mutual understanding between maintenance and production department.
- Effective maintenance policy for planning, controlling and directing all maintenance activities

- Maintenance department must be well organized and adequately staffed with well trained personnel
- There must be progressive effort to reduce or eliminate breakdowns.

2.1 The need to predict equipment failures

The key thing to note from the maintenance history is the different focus of maintenance at each of the stages on the journey. When in the reactive mode, the motivator for improvement is the need to avoid failures. In terms of CM, this means that the primary use for CM is to predict unplanned equipment failures. The benefits of using CM in this way are significant, when you are predominantly operating in a reactive maintenance mode or even predominantly traditional "fixed-interval. Time-based" mode of preventive maintenance [6].

2.2 The need for greater accuracy in failure prediction [8]

There are still significant benefits to be had from integrating process control data with CM data. For example, it is known that certain electric motors will display higher vibration when operating under low loads, than when they are operating under high load. Yet in the traditional methods of using periodically collected data, the variations are not effectively taken into account, except perhaps in a qualitative manner. If we were able to collect relevant quantitative data regarding the "process conditions" existing at the time that the vibration data was collected, and correct the vibration data for these conditions, then our diagnostic capability would become far more accurate and sensitive. At present, this is not the case. Analysis experience becomes, therefore, more important in arriving at accurate fault detection and failure prediction.

3.3 The need for a holistic view of equipment condition

Opportunities exist to minimise total equipment downtime by taking a holistic view of plant condition, and combining planned maintenance tasks, wherever possible, into a single equipment shutdown. For example, if vibration analysis indicated that a bearing failure on a particular pump was imminent, it would be preferable to be able to assess the condition of all the other components of the pump (impeller, seals, back plate etc.) in order to determine whether any of these items should be replaced or refurbished at the same time as the bearings.

3.4 The need to improve equipment and component reliability

Once an effective planned and predictive mode of maintenance has been established within an organisation, the next opportunity for improvement is by progressively extending the Mean Time Between Failures for that equipment. While this can be achieved by modifying equipment or components, or replacing them with more reliable items, a major opportunity for improvement exists by improving the precision with which maintenance is performed.

Modern technology can assist here in a number of ways. Taking Vibration Analysis as an example, it should first be recognized that there is a strong negative correlation between the overall vibration level for a bearing, and the expected life of that bearing [7]. Put simply, the higher the overall vibration level to which the bearing is subjected, then the shorter the expected life of the bearing.

3.5 The need to optimize equipment performance

There have been several articles written about the use of performance monitoring on steam turbines, using measurements of temperature, pressure, power output and other techniques to determine turbine condition, and the specific faults that may require attention. It is likely that this type of monitoring will become more widespread on large equipment. Large Diesel engines, pumps and other sophisticated equipment may also be able to be monitored using similar principles. Expect to find work being done to increase the sophistication of techniques such as ultrasonic flow measurement to assist with the cost-effective application of performance monitoring techniques to a wider range of equipment [6].

3.4 Plant Maintenance Strategies

The purpose of plant maintenance is to ensure the availability of operational facilities at a minimal cost. In many cases, it also involves utility installations or disposal of materials. Plant maintenance comprises 'all measures for maintaining and restoring the target condition as well as determining and assessing the actual condition of the technical equipment in a system'. These measures are subdivided into

- Preventive maintenance
- Inspection
- Repairs

3.5 Condition-based plant maintenance

Of the three traditional plant maintenance methods, condition-based plant maintenance is the one that enables the service life to be leveraged optimally and economically. In condition-based maintenance, a maintenance task is required only if a specific level of wear and tear has been reached (for example, if and only if the value for the pump has actually reached 9900 litres).

To enable condition-based plant maintenance to be carried out, the actual condition of the system component must be measured precisely by means of regular inspections. For example, the pump can be fitted with a meter that measures the flow in litres and is read regularly [8].

CM is sometimes referred to as machine health monitoring, indicating regular check-ups or continuous monitoring. It is attractive in many ways to have an indication of the state of the machinery as work progresses. However, the mistake made by many companies is to install condition based monitoring systems in isolation. Condition monitoring systems are effective when they become part of an overall planned maintenance strategy. In this there is scheduling of the work, planned stock control, adequate documentation and allowance for emergency maintenance.

Not all plant failures can be predicted. The potential purchaser of the CM system must asses the unit that is required to be monitored. If the sources of failure of a unit falls into this category there is no profit in purchasing a CM package [4].

4.6 Modern plant maintenance management

4.6.1 System-oriented plant maintenance

System-oriented plant maintenance focuses on safeguarding the functioning of a production system as a whole. Plant maintenance in this sense belongs to system logistics, the primary goals of which are planning, creating and maintaining system availability.

Yield and expenditure are optimized when the maintenance costs, as well as costs incurred through loss of output, are reduced to a minimum.

Costs related to system logistics include:

- Procurement costs of the system
- Preventive maintenance costs
- Procurement costs for replacement equipment
- Costs incurred through loss of output

The goals of plant maintenance here are subordinate to those of system logistics. As a result, the aim of plant maintenance is, by means of corrective maintenance, to prevent loss of output and maximize system lifetime. Ideally, plant maintenance should also ensure that maintenance tasks are scheduled to coincide with normal breaks in production or system downtimes. In production, this requires close coordination between maintenance planning and production planning.

The basic dilemma in plant maintenance is that, while preventive maintenance initially increases plant maintenance costs, it can help to prevent even higher costs being incurred as a result of breakdowns in production. This means that every company has to determine a plant maintenance strategy located between the following positions:

- Risk-based plant maintenance with low maintenance costs, but with a high risk of system breakdown and high repair or replacement costs;
- Preventive maintenance with high regular plant maintenance costs, but with a low risk of system breakdown.

In recent years, plant maintenance has been freed from its original, purely production-based context. In addition to its traditional task of safeguarding system availability, plant maintenance has come to include disposal of basic materials in accordance with ecological considerations and environmental legislation. The following definition takes these recent trends into account.

4.6.2 Total productive maintenance (TPM)

The main characteristic of TPM is that the tasks formerly planned and carried out by central PM departments are transferred gradually to the machinist [7].

TPM means that operators are empowered to maintain continuous production on totally efficient lines. Within the scope of TPM, the actual PM department analyses the PM tasks carried out by the operating personnel. The PM department also carries out strategic planning, administration of maintenance task lists and maintenance plans, as well as cost control.

4.6.3 Reliability centered maintenance (RCM)

RCM, also known as Reliability Based Maintenance (RBM), is concerned specifically with system breakdowns, the associated follow-up costs, and how to avoid them. The aim of this method is to use a risk analysis and risk evaluation (as a separate method, Risk Based Maintenance) to decide whether preventive PM tasks could incur higher costs than a system breakdown and its consequences [5].

The question of whether preventive measures are operational arises especially where redundant systems are used. This is because the bypass is intended to take effect if the component breaks down. The most important prerequisites for RCM are calculation and evaluation of a system breakdown.

4.7 Trends for modernizing plant maintenance

4.7.1Automation

Over the years we have seen a leap in automation. The number of operators has shrunk by an order of magnitude as machines have taken over duties that used to be performed by humans. In the case of some systems, pumping stations for example, there are no operators on site. Computer programs drive these systems, with occasional additional guidance provided by people in distant control rooms [6].

4.7.2 Facility management

Building maintenance is a subarea of facility or building management. The greater the level of automation via building control systems, the more important it is to integrate the PM processes smoothly. If computers are used to support plant maintenance operations, an interface must exist between the maintenance planning and control system (MPC) and the building control system so that a malfunction report is generated automatically in the MPC as soon as the building control system detects a malfunction.

4.7.3 Graphical user interfaces for MPC

Traditional MPC systems can be made easier for PM planners or technicians to operate by means of intuitive user interfaces. Malfunctions in a system can be localized more easily if the MPC system is equipped with a user interface supporting CAD drawings, three-dimensional images, construction plans, or process and instrumentation diagrams.

Drawings or images of this kind can be made available throughout the company on the internet/intranet and accessed via a browser. This means that users do not require a technical key for the system component affected in order to enter data and trigger events in an MPC system for example, to initiate a malfunction report.

4.7.4 Solution databases

Analysis procedures, such as 'Safety through organizational learning' (SOL), are centered on the concept of learning from experience. Breakdowns, malfunctions, accidents and near-accidents are evaluated systematically to enable processes to be improved and similar malfunctions to be corrected more quickly.

Tried-and-tested solutions can be stored in solution/task databases. By means of Case- Based Reasoning systems (CBR), the system can link the description of a particular problem to descriptions of similar problems. These descriptions are connected, in turn, to a tried-and-tested solution that has already been used successfully and linked to the descriptions of problems via SOL, for example. This enables company-internal knowledge relating to plant maintenance processes to be stored in a knowledge base. Some system engineers or manufacturers of spare parts supply product-specific knowledge bases with their products. The PM technician can then call up the manufacturer's knowledge base directly or via the Internet should problems arise.

4.7.5 Simulation programs

Simulation programs can be used, for example, to show how the breakdown of a subsystem will affect the system as a whole. In the simulation system itself, the behaviour of the system is mapped via events, which are triggered at the appropriate times by means of the determined characteristics. These cause changes in the system condition, which trigger further events. This not only enables the behaviour of real systems/ system components to be described, but also allows supplementary levels of analysis to be integrated in the simulation model in parallel with the actual process flows [4].

When used as part of a preliminary economic evaluation of the simulated malfunction, this procedure enables the costs for PM personnel to be calculated directly according to the duration of the malfunction and the hourly rate.

4.8 Tools that aid maintenance

4.8.1 ABC Pareto analysis

This is a maintenance control tool used to graphically and analytically group plant equipments into three groups' w.r.t. a particular maintenance/production parameter or indices. The groups are critical items (group A), moderate (group B) and non critical (group C) [5]. The parameter can be non-availability (downtime), downtime loses, maintenance costs, number of breakdowns etc. the plant items are then arranged in descending order according to the magnitude of the parameter associated with each and every item. The cumulative contribution of the first major items in descending order that make say 75% of the total represent group A items and most of the maintenance effort should be directed as these items. The next group (group B) is those items in descending order that have a cumulative contribution of say 20% and the corresponding maintenance effort should be directed to these items. The last group is those that have a cumulative contribution of 5 % and the least maintenance effort is directed at these items.

4.8.2 Failure mode effect and criticality analysis (FMECA)

This is an analytical tool used in decision making, which associates each plant item and its parts to all possible failures, the modes of failure, their causes, the effect of each and every failure and how each failure can be prevented or eliminated. It has the following benefits:

1. It provides designers and maintenance engineers with an understanding of the structure of the system, and the factors, which influence reliability.
2. It helps to identify items that are reliability sensitive or high risk, and so gives a means of deciding priorities for corrective action.
3. It identifies where special effort is needed during manufacture, assembly or maintenance
4. It establishes if there are operational constraints resulting from the design.
5. It gives assurance to management and or customers that reliability is being or has been properly addressed
6. It can be used as a maintenance review tool after application of ABC analysis.

4.8.3 Maintenance decision trees

It is a diagrammatical analytical maintenance tool that is detailed used to analyse complex maintenance systems to complement FMECA. It is a top-down approach. It starts with system fault (top event) and then analyse the fault in terms of sub systems faults [6].

4.8.4 Maintenance performance indices/ Ratios

A ratio is a comparison of two quantities; many ratios can be constricted from quantities of interest in maintenance, but the ones of real value are those that enable [6]:

- Decisions today be taken
- One year today be compared with another
- The benefit of a maintenance policy today be tested
- A maintenance budget today be constructed

These are essentially standards used to measure the effectiveness of the maintenance effort through indices like O.E.E, availability, load factor; number of trips etc. mathematical expressions of maintenance performance and production indices are shown in appendix

4.8.5 Computer Maintenance information systems

An effective computerized maintenance management system (CMMS) must be able to efficiently manage all maintenance activities including planning, data processing, reporting and recording, it must be able to give quick access to information especially if there is a LAN hence reduce waiting and repair times. It must also be interfaced with other relevant support systems Maintaining equipment involves the collection or storage of large amounts of information like asset register, maintenance procedures, historical records of equipment performance, identify Spares, defect plant items, theory reference for complicated equipment, request plant item isolations, generations of work order cards, identity equipment due for PMs or inspections, identify periodicity of PMs, request spares from stores, generate spares or material purchase orders, identify supplies of spares, and generate maintenance performance reports [4].

Just about every maintenance organization that is likely, to need a CMMS already has one, so the need for and capabilities of such systems are already well established. The only question that sometimes remains is whether the systems should be under the control of a centralized physical asset management department or whether they should be under the control of field maintenance people [4].

The other two asset management functions tend to control the specification, installation, and operation of the computer systems used to manage their assets, so it makes sense that the physical asset management function should do likewise. The field people should simply have access to the systems to help them plan their work on a day-to-day basis and to feed back data as required.

4.8.6 PERT and Gantt charts

These are important planning tools used for outages to find the critical path for a maintenance outage hence identify the critical jobs and ensure these are completed in time to ensure the planned duration of the stoppage is not exceeded hence minimize [3].

4.8.7 Check sheets, maintenance audits and records

Check sheets are used as data-capturing tool during inspections. Maintenance audits are a maintenance performance control tool used to check resource usage like funds to see whether this conforms to company policy and objectives. It also tracks maintenance performance through performance indices.

4.8.8Maintenance, commissioning and operations procedures

Maintenance procedures ensure that maintenance work is up to standard and important issues are addressed during maintenance. They also act as a reference in case an artisan has forgotten certain aspects of the maintenance work. In short, they assist in ensuring quality work. Likewise, commissioning and operations procedures if strictly followed help ensure equipment is not put in service when its condition is unsatisfactory hence; this prevents mal-operations and improve reliability [2].

4.8.9 Group technology

Group technology is a philosophy that takes advantage of similarities in processes; failure characteristics, equipment construction and function to standardize e.g. repair procedures, manufacturing processes, maintenance policies, and fault diagnosis procedures for equipment that falls into the same category[2].

4.8.10 Cause and effect diagrams

This is a graphical method of listing causes of an event like equipment failure. The top event is shown at the end of a horizontal line on the right of the diagram and major categories of possible causes are arranged as branches slanting off above and below this line. It focuses on possible causes and attempts to eliminate. It addresses causes not symptoms and each cause is analysed by technical like FMECA.

4.8.11 Life Cycle Costing

Life cycle costing refers to the cost of ownership of given equipment. It is the users total cost burden during the lifetime of the equipment in question. These costs include maintenance costs, purchasing costs, training costs for operators, environmental costs, and energy consumption costs. The buyer wants to know which future costs he commits himself by buying a certain type of pump for example ahead of another type. The other type might have expensive spares or might need highly trained operators or might consume more electrical power.

The key feature of modern technology is the accumulation of data, which at the time of collection seems to have limited value. However, only when sufficient data is collected can normal condition and possible deviations be established and redunded data cease to be accumulated, keeping records is essential. Noting that one of the most common difficulties encountered by the decision maker is lack of data, where many machines are operated, consideration should be given to the advantages of computer data storage and presentation

Case Study: Dairy Company

5.1 Dairy Co. process overview

The core business of Dairy Co. is centered on production and sales. Other functions support these two activities.

Production planning is triggered by sales forecast. The sales forecast is based on customer requirements and anticipated market growth. Based on the production plans material requests are made to stores whose responsibility is to maintain stocks at stipulated levels and purchase non-stock items on request.

The engineering dept provides maintenance support for equipment and infrastructure for all units. The role of finance is to provide appropriate optimal financing and capital structure for the organization. The unit is responsible for provision of funds for operational work, purchases, remuneration and capital expenditure.

5.1 Dairy Co. maintenance

A maintenance planning plant is the organizational unit in which maintenance requirements are planned. Each maintenance affiliate will be created as a maintenance planning plant.

5.1 Maintenance strategy

A maintenance strategy defines the rules for when planned maintenance activities are to be performed. The maintenance strategy includes scheduling parameters plus the individual packages for when maintenance is to be performed.

5.2 Time based strategy plan

A time based strategy plan is used for technical objects that require different maintenance activities to be performed at different time intervals. Multiple maintenance items can be assigned to the plan but all for the same technical object.

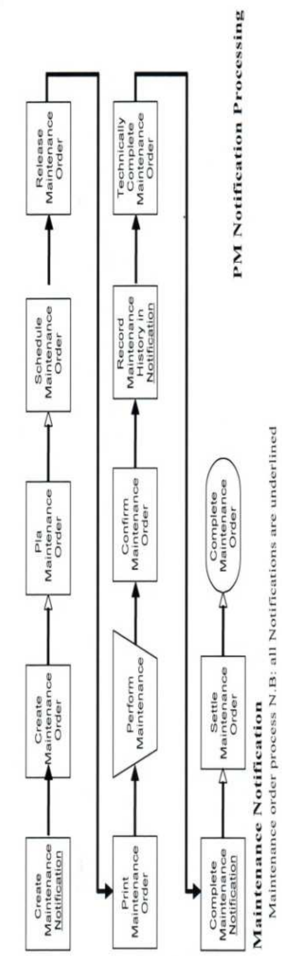

Figure 2: General maintenance order process

The maintenance notification is a document used to request work to be performed and record technical history after completion of the work. A notification serves the purposes of:

- Requesting the maintenance department to perform a maintenance task
- Document the damage, malfunction or exceptional condition of the technical object
- Document technical findings for maintenance already performed

5.3 Maintenance notification types

The 6 maintenance notification types that are used by DZPL are:

- M1 – Corrective (Planned)
- M2 – Breakdown report
- M3 – Activity report
- M4 – Preventive request
- M5 – Projects request
- M6 – Shutdown request

5.4 Corrective Notification / Notification type M1.

This notification is created to request maintenance assistance for corrective maintenance activities that will require planning. It is used to request the following types of maintenance:

General maintenance
- Inspections
- Improvements
- Upgrades of technical objects

It can be used to record maintenance history. Condition monitoring can initiate the automatic creation of a corrective notification.

5.5 Breakdown Report Notification / Notification type M2.

A breakdown report notification is created to rectify the problem after a breakdown of a technical object. It can be created prior to or after the problem has been rectified. It's also used to record:

- Breakdown dates and times
- Maintenance history
- System availability details

5.6 Activity Report Notification / Use notification type M3.

This notification is created after preventive maintenance activities have been performed to record technical history. It's only used if there is not an initial notification used to initiate the maintenance activities. Activity report notifications will never be turned into a maintenance order but they will be used in preventive maintenance to record technical history.

5.7 Preventive Request Notification / Notification type M4.

A preventive request notification is created by preventive maintenance plans; it will never be manually created. It is used to perform inspections by operations. Preventive Request Notification will never be turned into a maintenance order but they will be used in preventive maintenance to record technical history.

5.8 Project Request Notification / Notification type M5.

This notification is created to request maintenance activities to be performed within the following types of projects:

- Engineering
- Maintenance

The Project Engineer is responsible for the creation of project requests for Engineering Projects.

5.9 Shutdown Request Notification / Notification type M6.

A shutdown request notification is created to request maintenance activities to be performed during a plant shutdown. It can be used to record maintenance history.

5.10 Plant maintenance order processing

The maintenance processes include:

- Corrective Maintenance
- Breakdown Maintenance
- Preventive Maintenance
- Shutdown Maintenance
- Project Maintenance
- Refurbishment Maintenance
- Special Event Maintenance

Components

Any components required to complete a maintenance operation are planned against the operation in the order. There are three types of components:

- Stock: Material master record exists and quantity kept in warehouse
- Non stock: Material master record exists but not kept in warehouse and/or purchased each time there is a requirement
- Non stock, non catalogue: No material master record exists and/or purchased each time there is a requirement

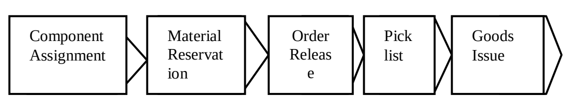

Figure 3: Stock material process flow

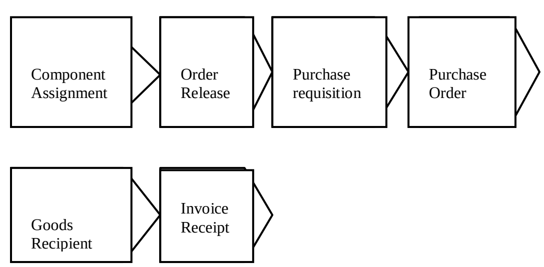

Figure 4: Non stock material processes

Table 1: Plant equipment /machinery

Classification	Equipment /Machinery
Refrigeration	J & E Halls Ammonia Compressor
System	Sabroe Ammonia Compressor
	Graham Enock Ammonia compressor
	Chilled water pumps
	Cooling Tower No.1
	Cooling Tower No.2
	Cooling Tower No.3 Coldrooms
Boilers	John Thompson Boiler 5610
	NEI Cochrane Afripac MK2 Boiler 5638
	2 x Boiler water feed pumps
	2 x Boiler hot well
Pneumatic	Ammonia Receiver
System	GA 30 Air Atlas COPCO Compressor
	GA 30 Air Atlas COPCO Compressor
	Air receiver
Processing	Alfa Laval Pasteuriser
Plant	Silo No.1
	Crate conveyor
	C.I.P. Tanks
	IS6 Machines 1 and 2
	IS6 Machines 3 and 4
	Pasilac High Speed Mixer
	Lacto Recombination Tank
	Juice mixing tank
	IS6 water circulation
	Crate washer
	West falia separator MM5004
Milk Reception	Deairator
Reception	Milk Cooler
	Diessel Flow Meter
	Silo No.2
	Silo No.3
	Silo No.4
	Silo No.5
	Intake milk pump
	Borehole Plant

Maintenance at the Plant

Current Ways of Working

Scheduled Maintenance

Scheduled maintenance is performed to ensure systematic inspection of all plant machinery and equipment at regular intervals. All plant machinery and equipment is serviced at predetermined intervals as per planned maintenance programme or preventive action requests form. Each machine is assigned a permanent and individual asset register number and a record of each machine is maintained. At the end of each month the regional engineer runs the date monitoring the programme and prints worked orders due the following month.

On servicing of machine the artisan uses the works order as a guideline for maintenance. Where spares are required, the artisan withdraws spares against the reservation and works orders number from stores.

After completion of service, quality of work is inspected by Regional Engineer before machine is handed over to user dept. Just after commissioning the machine, the artisan completely fills in the works order document detailing the nature of work done, and spares usage, before handing it over the engineer for approval.

After approval, the artisan completes the works order and the order is completed in the SAP system, which updates the machinery history.

For work to be carried out by outside contractors the regional engineer raises a purchase requisition within the window suggested by the SAP system. Stores will then raise a purchase order. Records of service carried out are captured in SAP system in Table 2.

Table 2: SAP system

Code Number	Process Name
PM-01	
PM-01-01	Preparation for new machine
PM-01-02	Installation
PM-01-03	Commissioning
PM-01-04	Opening a history card for new
PM-01-05	Opening a service contract with machine supplier
PM-01-06	Authorisation of service contract
PM-01-07	maintenance plan for a new machine
PM-01-08	Authorisation of stores requisition
PM-02	
PM-02-01	Global maintenance plan
PM-02-02	Generate job cards: Planned
PM-02-	Raising a Stores Requisition

03	
PM-02-04	Authorisation of stores requisition
PM-02-05	Check job card after completion
PM-02-06	Job costing and history card updating
PM-03	
PM-03-01	User dept. Raising a job requisition
PM-03-02	Job Assessment
PM-03-03	Generate job card repairs
PM-03-04	Check job after completion
PM-03-05	Job costing and history updating
PM-04	
PM-04-01	Raising purchase requisition
PM-04-02	Authorisation of a purchase requisition
PM-04-04	Check job report after completion
PM-04-05	Job costing and History Card updating (Planned)
PM-04-06	Job costing and History Card updating (B/downs)
PM-04-07	Authorisation for payment

THE PHASES IN DETAIL

PM – 01 – 01 Preparation for new machine

1.Objective: To prepare for the installation of a new machine in an existing plant.

2Scope starts:

When the Engineer receives notification of the arrival of a new machine.

Scope Ends: When a work order for the installation of services and machine issued out to an artisan.

Scope involves: Engineer.

Documentation: Technical specifications, Work order

3.**Policies and principles**

Dairy Co. engineering department should prepare for services prior to the arrival of a new machine

4Performance measures

- Elapsed time
- Accuracy of using the technical specifications to establish material requirements

Steps	Process Steps
1	Notification of arrival of machine is communicated to Engineer from chief engineer. Technical specification is by way of a fax detailing the aspects of the machine making it easy to plan for services and location.
2	The Engineer liaises with production on the best physical location of the new machine in an existing process plant. The Engineer together with his artisans plans for the services (utilities), human resources and materials.
3, 4, 5	The Engineer raises a work order and issues it out to the artisan carrying out the installation.

Analysis of Weaknesses and Inefficiencies:

Ratio of "touch time" to "dwell time"

Touch time = 4hrs. Dwell time = 8hrs

Touch time / dwell time = 1/2

The dwell time is longer due consultations made by PM to user departments for location of machine.

Analysis of "value add" steps

Value add steps: 3, 4, 5

These are the steps where the actual preparation for the new machine starts.

Overall Quality of the Process

The process is good although it can be improved if the dwell time can be reduced. The dwell time is dependent on the response of the other departments who participate in the preparation for new machine.

PM – 01 –02 Installation

1 **Objectives**: Installation of machine and termination of services.

2 **Scope starts**: When artisan receives work order from Engineer.

Scope ends: When the completed work order with details of work carried out is forwarded to the Engineer.

Scope involves: Artisan

Documentation: Work order.

3 **Policies and principles:** All installation work to be of manufacturer's standard.

4 **Performance measures and constraints:**

- Elapsed time

Steps	Process
1, 2, 3	The artisan receives the work order from the Engineer. Since the machine has been delivered and the materials are at hand, the machine is installed into position and all services (utilities) are terminated into the machine. The artisan cannot carry out test running of the machine, this is the responsibility of the Supplier Engineer.
4, 5	The artisan, after completion of the above job, will fill in the work order detailing all the work done. He will also include materials he has used and the man hours taken. The work order is then sent to the Engineer for approval. It will then be forwarded to the Clerk for completion in the SAP system.

Analysis of Weaknesses and Inefficiencies:

Ratio of "touch time" to "dwell time"

Touch time = 24hrs dwell time = 40hrs

Touch time / dwell time = 3/5

This process is done over some days and the dwell time is higher than the touch time since silent hours are also included.

Analysis of "value add" steps

Value add steps: 2, 3

The actual installation of the machine is done in steps 2 and 3, which is why they are the value adding steps to this process.

Overall Quality of the Process

Despite the "inflated" dwell time of this process, it is of good quality.

PM – 01 –03 Commissioning

1	**Objective:** To bring newly acquired machine into production line.
2	**Scope starts:** When the supplier Engineer inspects the installation of the new machine. **Scope ends:** When machine is handed over to production. **Scope involves:** Supplier Engineer, Operators, Service personnel, Regional Engineer **Documentation:** Operators and service manual
3	**Policies and principles** The supplier Engineer should ensure that machine is performing to specified standards. He should also train operators and service personnel.
4	**Performance measures** ▪ Quality of the work carried out and the training provided.

Steps	Process Steps
1, 2	The Supplier Engineer, before test-running the machine, inspects the condition of the machine and the way in which the services have been terminated. If he is not satisfied, he will specify the necessary corrections to the artisan.
3	Once the installation is to his satisfaction, the Supplier Engineer now test-runs the machine and checks for the following: a) Proper functioning of all machine components b) Machine throughput (capacity) c) Product quality He will make necessary adjustments to correct any anomalies.
4	The supplier Engineer then conducts several training sessions of the operators and service personnel. The training of service personnel, though, starts at the onset of machine test-runs.
5	When the Supplier Engineer is satisfied with the performance of the machine operators and service personnel, he will then hand over the machine to production department.

Analysis of Weaknesses and Inefficiencies:

Ratio of "touch time" to "dwell time"

Touch time = 28 hrs dwell time = 56 hrs

Touch time / dwell time = 1/2

Once again, the dwell time here is lengthened by the fact that this process is done over a couple of days and all the silent hours during this period are included in the dwell time.

Analysis of "value add" steps

Value add steps: 1, 2, 3, 4

Inspection of machine, test running of machine and training of personnel are the core activities of this process and as such, are the steps that add value to the process

Overall Quality of the Process

The process quality is good but there is need to put more resources into personnel training than what is currently in place. The training of personnel during commissioning does not really give enough exposure as would be ideal.

PM – 01 –04 Creating a new machine in the SAP system

1 **Objective**
Costing the details of a work order and creating the machine in the SAP system

2 **Scope starts:** When the clerk receives a work order from the Engineer.
Scope ends: When clerk updates the system.
Scope involves: Clerk
Documentation: Work order, Sap system

3 **Policies and principles**
All work orders must be valued for labour and material.
The Sap must capture all history for any machine.

4 **Performance measures and constraints**
- Elapsed time
- Accuracy of transferring information from work order onto sap system

Steps	Process
1, 2, 3	The machine has been installed and tested. The clerk now receives the work order with the work and material details. He then costs the labour and the materials.
4, 5	The clerk opens a history card for the new machine and then transfers the information on the work order into the Sap system
6,	The clerk then files the work order and the history card.

Analysis of Weaknesses and Inefficiencies:
Ratio of "touch time" to "dwell time"
Touch time = 1hr dwell time = 8hrs
Touch time / dwell time = 1/8

Analysis of "value add" steps
No value adding steps. All the steps in this process are administrative

Overall Quality of the Process
The process quality is good, as it requires only one person to carry out the whole process. The touch time is also reasonable for the process but there is need to cut down on the dwell time.

PM – 01 –05 Opening a service contract with machine supplier.

1 **Objective:** To put in place a contract with the supplier for back-up service and maintenance of a new machine.

2 **Scope starts:** When Regional Engineer receives contract/proposal from machine supplier.
Scope ends: When signed contract/proposal is sent to Chief Engineer for approval.
Scope involves: Supplier Engineer, Regional Engineer
Documentation: Proposal/contract

3 **Policies and principles**
For a new machine there may be need to enter into a service contract – this depends on the complexity of machinery and also warranty clauses.

4 **Performance measure and constraints**
- Elapsed time

Steps	Processes
1.	The Engineer receives from the Supplier Engineer a service contract proposal, specifying the costs involved, the frequency and the period of the contract. Note that it is not all new machines were contracts are entered into – it depends largely on the complexity of equipment as well as warranty clauses which may state that machine will be maintained by supplier for a period of, say, 1 year.
3, 4, 5	The Engineer then assesses the proposed terms and conditions. If he is not in agreement, he will renegotiate terms it with the supplier engineer.
4, 6	The Engineer signs the contract if he is satisfied with the proposal. He will then forward the signed contract to the Chief Engineer for approval.

Analysis of Weaknesses and Inefficiencies:
Ratio of "touch time" to "dwell time
Touch time = 2hrs dwell time = 336hrs
Touch time / dwell time = 1/168
The dwell time is so long because more often than not, the Engineer has to re-negotiate the terms of the contract and delays are bound to occur.

Analysis of "value add" steps
No value add steps. All the steps in this process are administrative

Overall Quality of the Process

The quality of this process is poor because of the dwell time that is too long, especially considering that the process involves only one person.

PM – 01 –06 Authorisation of service contract

1 **Objective:** To approve/disapprove the proposed service contract of a new machine.

2 **Scope starts:** When Chief Engineer receives contract/proposal
Scope Ends: When approved/disapproved contract is sent back to the Regional Engineer.
Scope involves: Chief Engineer
Documentation: Proposal/contract

3 **Policies and principles**
For a new machine, there is need for a service contract. The service contract has to be authorised by the Chief Engineer.

4 **Performance measures and constraints**

- Elapsed time.

Steps	Processes
1, 2	The Chief Engineer receives the contract proposal from the Engineer and, like the Engineer, assesses the terms. If it is acceptable, he approves it by signing other wise he endorses his rejection comments. The contract, whether approved or not is forwarded to the Engineer for actioning.

Analysis of Weaknesses and Inefficiencies:

Ratio of "touch time" to "dwell time"

Touch time = 2hrs dwell time = 336hrs

Touch time / dwell time = 1/168

The dwell time is so long mainly because of other commitments on the part of the Chief Engineer

Analysis of "value add" steps

No value add steps. All steps in this process are administrative.

Overall Quality of the Process

The quality of this process is poor because of the dwell time that is too high, considering that this is a one-man process

PM – 01 –07 Maintenance planning for new machine

1 **Objective:** To draw up a maintenance plan for a new machine.

2 **Scope starts**: When engineer receives service manual from supplier of machine.
Scope ends: When programme for new machine is entered into Microsoft Document.
Scope involves: Assistant Engineer / Regional Engineer
Documentation: Service manual, Task List, Maintenance Plan

3 **Policies and Principles**
There is need to have a planned maintenance programme for all machines including new ones.

4 **Performance measures and constraints.**

- Elapsed time.

Steps	Processes
1, 2, 3	The service manual is normally included in the shipment of the machine. The Engineer goes through the manual and draws up a frequency of maintenance as recommended in the manual. The Engineer will also draw up descriptions of all jobs to be carried out (task lists) per each maintenance schedule.
4, 5	The drawn up maintenance programme is then included in the existing Global maintenance plan, the blueprint of which is a Microsoft excel document. A printout is then made of the amended Global maintenance programme.

Analysis of Weaknesses and Inefficiencies:

Ratio of "touch time" to "dwell time"

Touch time = 2hr Dwell time = 8hrs

Touch time / dwell time = 1/4

The dwell time is higher than the touch time as the maintenance planning does not start immediately on receipt of service manual due to other commitments on the part of the Engineer

Analysis of "value add" steps

No value adding steps. All steps are administrative.

Overall Quality of the Process

The quality of the process is good considering that it involves only one person. The process can be improved though if the dwell time is shortened.

PM-01 – 08 Authorisation of stores requisition

1 **Objective:** To ensure ready availability of spares at stores

2 **Scope starts:** When spares list is compiled

Scope Ends: When spares list is submitted to Stores

Scope involves: Engineer

Documentation: Manual, Spares List, and Memo

3 **Policies and principles**

The spares list should be compiled using the service manual

4 **Performance measures and constraints**

- Accuracy

Steps	Processes
1	This is an event, which initiates the drawing up of a spare parts list.
2	The Engineer then compiles a spare parts list using the service manual. This list is for spares, which are fast moving (critical) and need to be kept in stock. The supplier engineer, with his experience usually assists in the compilation of the lists.
3, 4	The Engineer will then raise a memo to stores department and attaches the spare parts list. He then sends the memo to stores department for procurement.

Analysis of Weaknesses and Inefficiencies:

Ratio of "touch time" to "dwell time

Touch time = 1hr dwell time = 8hrs

Touch time / dwell time = 1/8

Analysis of "value add" steps

No value add steps. All steps in this process are administrative.

Overall Quality of the Process

The quality of this process is good as it only involves one person. However, the dwell time of this process is too long and needs to be reduced to improve the quality of the process.

PM-02 - 01 Global maintenance plan

1 **Objective:** To update existing Global Maintenance programme

2 **Scope starts:** When Engineer extracts old maintenance programme from computer/files

Scope Ends: When Engineer files new Global Maintenance programme

Scope involves: Engineer

Documentation: New maintenance programme

3 **Policies and principles**

There is need to have a maintenance programme for all machines.

4 **Performance measures and constraints**

- Elapsed time
- Accuracy of scheduling
- Lack of technical information from supplier

Steps	Process Steps
1	The Engineer retrieves the old global maintenance programme from a Microsoft Excel document.
2	The Engineer then deletes all obsolete machines from the blueprint. He then includes newly acquired machinery.
3	The new global maintenance schedule is then printed and filed.

Analysis of Weaknesses and Inefficiencies:

Ratio of "touch time" to "dwell time"

Touch time = 1.5hrs dwell time = 8hrs

Touch time / dwell time = 3/16

Analysis of "value add" steps

No value add steps. All the steps are administrative.

Overall Quality of the Process

The quality of the process is good as it involves only one person. The dwell time needs to be reduced so that the quality can be improved.

PM-02 - 02 Generate job cards: Planned

1 **Objective:** To issue out a work order on work to be carried out as per maintenance programme

2 **Scope starts:** When Engineer consults maintenance schedule for services due

Scope Ends: When Engineer issues out work order

Scope involves: Engineer

Documentation: Maintenance programme

3 **Policies and principles**

All maintenance work should be accompanied by a work order

4 **Performance measures and constraints**

- Punctuality, as in timeous issuing out of work order as per maintenance schedule

Steps	Processes
1	At the beginning of each week, the engineer will consult the global maintenance schedule for services that are due for that week.

2, 3 He will then generate work orders from the computer which include service instructions, spares required, consumables, estimated man hours and special tools if any. He will then issue the work order to the artisan.

Analysis of Weaknesses and Inefficiencies:

Ratio of "touch time" to "dwell time"

Touch time = 2hrs dwell time = 8hrs

Touch time / dwell time = 1/4

Touch time for the generation of work order due to that several job cards have to be raised at the same time for all the jobs that are due. The dwell time comes up to 8hrs due to other commitments on the part of the Engineer

Analysis of "value add" steps

No value add steps. All the steps in this process are administrative.

Overall Quality of the Process

The overall quality of this process is good as it involves only one person and the ratio of the touch time to the dwell time is relatively high.

PM-02 – 03 Raising a stores requisition.

1 **Objective:** To raise a stores requisition in order to obtain spares and materials from main stores.

Scope starts: When artisan receives job card

Scope Ends: When artisan sends stores requisition to Engineer for authorisation

Scope involves: Artisan

Documentation: Work order, Requisition

3 **Policies and principles**

Spares and materials are obtained from Stores only with the presentation of an authorised stores requisition.

4 **Performance measures and constraints**

- Elapsed time
- Prices have to be obtained from stores before requisition can be signed

Steps	**Processes**
1, 2	the artisan, on receiving the work order for spares or materials requirements. If there are no such requirements, he will proceed with the job.
3, 4	If there is need for spares and / or materials, he will then raise a stores requisition specifying the spares needed and prices thereof. He then forwards it to the engineer for authorisation.

Analysis of Weaknesses and Inefficiencies:

Ratio of "touch time" to "dwell time"

Touch time = 0.5hrs dwell time = 0.5hrs

Touch time / dwell time = 1/1

The touch time and the dwell time are the same as the stores requisition is almost every time authorised on receipt of the stores requisition as most stores requests are for breakdowns.

Analysis of "value add" steps

No value adding steps. All process steps are administrative.

Overall Quality of the Process

The quality of this process is very good as it only involves one person and the delay time is almost zero as the artisan has to 'hunt' for the Engineer to authorise the stores request at all costs.

PM-02 – 04 Authorisation of stores requisition

1 **Objective:** To approve of items that have been requested from stores

Scope starts: When Engineer receives stores requisition from artisan

Scope Ends: When Engineer sends signed stores request to stores

Scope involves: Engineer

Documentation: Stores requisition

3 **Policies and principles**

All stores requests have to be authorised by the Engineer

4 **Performance measures and constraints**

- Elapsed time

Steps	**Processes**
1, 2, 3	After receiving the requisition the engineer checks on the balance of the R&M expense heading budget for availability of funds. If the funds cannot accommodate the impending maintenance work, he will seek authority to overspend on that expense heading.
4, 5	If funds are adequate he will authorise the withdrawal and forward the requisition to stores.

Analysis of Weaknesses and Inefficiencies:

Ratio of "touch time" to "dwell time"

Touch time = 0.5hrs dwell time = 0.5hrs

Touch time / dwell time = 1/1

The touch time and the dwell time are the same as the stores requisition is almost every time authorised on receipt of the stores requisition as most stores requests are for breakdowns.

Analysis of "value add" steps

No value adding steps. All process steps are administrative.

Overall Quality of the Process

The quality of this process is very good as it only involves one person and the delay time is almost zero as the artisan has to 'hunt' for the Engineer to authorise the stores request at all costs.

PM- 02 - 05 Check job card after completion

1	**Objective:** To ascertain that the requested job has been executed.
2	**Scope starts:** When Engineer receives filled in work order from artisan **Scope Ends:** When Engineer hands over approved work order to clerk **Scope involves:** Engineer **Documentation:** Work order
3	**Policies and principles** All work orders have to be approved by the Engineer before they are priced
4	**Performance measures and constraints** ▪ Elapsed time

Steps	**Processes**
1, 2	the engineer receives a filled in work order after artisan has completed the service. He then goes on site to inspect the workmanship of the artisan.
3, 4, 5	He will then decide whether or not the job was done as specified. If not he instructs the artisan to redo the job; otherwise, he endorses his signature on the work order.
6	The signed job card is then sent to the clerk for costing and updating of the Sap system.

Analysis of Weaknesses and Inefficiencies:

Ratio of "touch time" to "dwell time"

Touch time = 0.5hrs dwell time = 2hrs

Touch time / dwell time = 1/4

The dwell time is 2 hours due to other commitments on the part of the Engineer

Analysis of "value add" steps

No value adding steps. All process steps are administrative

Overall Quality of the Process

The quality of the process is relatively good but the process can be improved if the dwell time is reduced. The process is also good as it involves only one person.

PM-02 - 06 Job costing and history card updating

1	**Objective:** To capture all the costs of the work done (labour and materials) and to record service information in Sap System
2	**Scope starts:** When Clerk receives work order from Engineer **Scope Ends:** When Sap system is updated **Scope involves**: Clerk **Documentation:** Work order, Sap system
3	**Policies and principles** All work orders must be priced for materials The Sap system must be updated for all work done on a machine
4	**Performance measures and constraints** ▪ Elapsed time Accuracy of recording work order information in to the system as well as calculations of labour costs Prices of materials are not readily available and at times, job card is not filled to completion.

Steps	**Processes**
1, 2, 3	The clerk receives the work order from the engineer. He then costs the materials used for the particular job.
4	He retrieves from the Sap system information for that machine and transfers the work order information onto it.
5, 6	He then files the work order and updates the Sap system

Analysis of Weaknesses and Inefficiencies:

Ratio of "touch time" to "dwell time"

Touch time = 2hrs dwell time = 8hrs

Touch time / dwell time = 1/4

Analysis of "value add" steps

No value adding steps. All steps in this process are administrative.

Overall quality of the process

The quality of this process is relatively good as it involves only one person. However, the dwell time needs to be reduced and the accuracy of transferring information from work order to Sap system needs to be guaranteed, as this information is very critical for future reference.

PM-03 - 01 User dept. raising a job requisition

1. **Objective:** To request PM to attend to breakdown on Plant Machinery
2. **Scope starts:** When job request is raised
   Scope Ends: When job notification is sent to PM
   Scope involves: Production Controller/Supervisor
   Documentation: Job Notification
3. **Policies and principles**
   A job request has to be raised for every breakdown
4. **Performance measures and constraints**
   - Elapsed time

See drg. in a appendix

Steps	Processes
1	This is the event that initiates the raising of a job notification.
2, 3	the production controller / supervisor raises a job notification and sends it to PM to inform them of the machine breakdown, requiring PM's attention.

Analysis of Weaknesses and Inefficiencies:

Ratio of "touch time" to "dwell time"

Touch time = 0.25 hrs dwell time = 0.25hrs

Touch time / dwell time = 1/1

The touch time and dwell time are equal as the job notification is raised as soon as a machine breaks down (there is no time delay)

Analysis of "value add" steps

No value add steps. All steps are administrative

Overall Quality of the Process

The quality of the process is very good as it involves only one person and also because it is executed timeously so as not to disrupt production.

PM- 03 - 02 Job Assessment

1. **Objective:** To assess nature of breakdown
2. Scope starts: When Engineer receives job notification from user dept.
   Scope Ends: When Engineer has assessed the nature of breakdown
   Scope involves: Engineer
   Documentation: Job Request
3. **Policies and principles**
   All job notifications have to pass through the Engineer for assessment
4. **Performance measures and constraints**
   - Elapsed time

Steps	Processes
1, 2	The engineer receives the job notification from production and assesses the scope of work involved.
3, 4	He then decides whether the job can be done using available human resources, or if it has to be sub-contracted.

Analysis of Weaknesses and Inefficiencies:

Ratio of "touch time" to "dwell time"

Touch time = 0.25hrs dwell time = 0.25hrs

Touch time / dwell time = 1/1

The ratio of the touch time to the dwell time is one, as the Engineer has to assess the job as soon as he gets the job notification so that repairs can be performed immediately.

Analysis of "value add" steps

Steps 2 and 3 are value adding

Overall Quality of the Process

The quality of this process is good as it involves only one person. The delay time is virtually zero, as the Engineer has to ensure that repairs are performed immediately.

PM-03 - 03 Generate job card repairs

1. **Objective:** To raise a work order in order for service personnel to carry out repairs
2. **Scope starts:** When Engineer raises work order
   Scope Ends: When Engineer issues out second and third copy of work order to artisan
   Scope involves: Engineer
   Documentation: Work order
3. **Policies and principles**
   Engineer has to keep a copy of the work order for follow – up purposes
4. **Performance measures and constraints**
   - Elapsed time

Steps	Processes
1	When he has assessed that the job can be done internally, the Engineer raises a work order in triplicate.
2, 3	He then files the original, and issues the to copies to the artisan.

Analysis of Weaknesses and Inefficiencies:

Ratio of "touch time" to "dwell time"

Touch time = 5 min dwell time = 5min

Touch time / dwell time = 1/1

The ratio of touch time to dwell time is 1 as this process is treated as top priority to facilitate the immediate repair of a broken down machine.

Analysis of "value add" steps

No value adding steps. All steps in this process are administrative.

Overall Quality of the Process

The process quality is very good as it involves only one person and the delay time is virtually zero to avoid disruption of production.

PM-03 - 04 Check job after completion

1. **Objective:** To check the standard of work carried out by the artisan
2. **Scope starts:** When the Engineer receives work order from the artisan
   Scope ends: When the Engineer sends work order to the clerk
   Scope involves: Engineer
   Documentation
   Work order
3. **Policies and principles**
   The Engineer should check the standard of workmanship performed by the artisan on completion of the job.
4. **Performance measures**
   - Elapsed time

Steps	Processes
1, 2	The engineer receives the filled in work order after the artisan has completed the repair work. He then goes on site to inspect the workmanship.
3, 4, 5	He will then decide whether or not the repairs are satisfactory. If not, the artisan is instructed to redo, otherwise, the engineer endorses his signature on the work order.
6	The signed work order is then sent to the clerk for costing and Sap system updating.

Analysis of Weaknesses and Inefficiencies:

Ratio of "touch time" to "dwell time"

Touch time = 0.25hrs dwell time = 1hr

Touch time / dwell time = 1/4

The dwell time is 1 hour, as the machine has to be test run before the Engineer can approve that the job was done satisfactorily.

Analysis of "value add" steps

The value adding steps are 2 and 3.

Overall Quality of the Process

The quality of the process is good as it only involves one person and the ratio of the touch time to the dwell time is acceptable.

PM-03 - 05 Job costing and history updating

1. **Objective:** To cost the labour and materials for a job that has been satisfactorily completed and to update the Sap system.
2. **Scope starts:** When the clerk receives the work order from the Engineer.
   Scope ends: When the updated work order and Sap have been filed.
   Scope involves: Clerk
   Documentation: Work order, Sap system
3. **Policies and principles**
   All jobs done must be priced using standard costs for labour and materials
4. **Performance measures and constraints**
   - Elapsed time

See drg. in a appendix

Steps	Processes
1, 2, 3	The clerk receives the Work order from the engineer. He then costs the materials used for that particular job.
4	He retrieves information from sap for that machine and transfers the work order information into the Sap system.
5, 6	He then files the work order and updates the Sap system.

Analysis of Weaknesses and Inefficiencies:

Ratio of "touch time" to "dwell time"

Touch time = 0.25hrs dwell time = 8hrs

Touch time / dwell time = 1/32

The dwell time is 8 hours because the clerk first accumulates the work orders while carrying out other duties and then updates sap system at the same time.

Analysis of "value add" steps

No value adding steps. All steps are administrative.

Overall Quality of the Process

The process quality is relatively good since it involves only one person. However, the quality can be improved if the dwell time is reduced.

PM-04 - 01 Raising purchase requisition

1. **Objective:** To raise a purchase requisition for services to be done by external suppliers
2. Scope starts: When the clerk receives instructions from Engineer
Scope Ends: When purchase requisition is sent to Engineer for authorisation
Scope involves: Clerk
Documentation: Purchase requisition
3. **Policies and principles**
A purchase requisition has to be raised for all sub-contracting work
4. **Performance measures and constraints**
   - Elapsed time

See drg

Steps	**Processes**
1	When the engineer has assessed that the job needs to be sub-contracted, he instructs the clerk to raise a purchase requisition, detailing the nature of work to be carried out.
2, 3	The clerk then raises the purchase requisition, which he sends to the engineer for authorisation.

Analysis of Weaknesses and Inefficiencies:

Ratio of "touch time" to "dwell time"

Touch time = 10min dwell time = 10min

Touch time / dwell time = 1/1

The ratio of the touch time is 1 as there is no delay in this process.

Analysis of "value add" steps

No value adds steps. All steps are administrative.

Overall Quality of the Process

The process quality because the dwell time is equal to touch time implying that the delay is zero. The quality is also good because it involves only one person.

PM-04 - 02 Authorisation of a purchase requisition

1. **Objective:** To authorize a purchase request for work that has to be sub-contracted
2. **Scope starts:** When Engineer receives purchase request from Clerk
Scope Ends: When purchase request is sent to Stores
Scope involves: Engineer
Documentation
Purchase request
3. **Policies and principles**
All purchase requests have to be authorized by the Engineer
4. **Performance measures and constraints**
   - Elapsed time

Steps	**Processes**
1, 2	The engineer receives the completed purchase requisition from the clerk which he approves / endorses for it to be actioned by stores.
3	The endorsed purchase requisition is then sent to stores for the sourcing of quotations from at least three suppliers of the required service.

Analysis of Weaknesses and Inefficiencies:

Ratio of "touch time" to "dwell time"

Touch time = 10min dwell time = 10 min

Touch time / dwell time = 1

The touch time is equal to the dwell time as the clerk just brings the requisition to the Engineer for signing and immediately takes it to stores.

Analysis of "value add" steps

No value adding steps. All steps are administrative.

Overall Quality of the Process

The overall quality of this process is good as it involves only one person and the ratio of the touch time to the dwell time is one, implying there is no time delay.

PM04 - 04 Check job report after completion

1. **Objective:** To check if the sub - contracted job has been done to standard
2. **Scope starts:** When Engineer receives job report from contractor
Scope Ends: When job report is sent to the clerk
Scope involves: Engineer
Documentation
Job notification
3. **Policies and principles**
The Engineer should approve the standard of workmanship of every contracted job
4. **Performance measures and constraints**
   - Elapsed time

Steps	**Processes**
1	When a contractor completes a planned maintenance job, he

	submits a report of the work carried out, the time taken and the materials used to the engineer.
2, 3, 4	The Engineer then assesses if the job has been done as specified. If not, then the contractor has to redo the job; otherwise, the Engineer approves the job report.
5	The Engineer then sends the job report to the clerk for costing and updating of the sap system.

Analysis of Weaknesses and Inefficiencies:

Ratio of "touch time" to "dwell time"

Touch time = 2hr dwell time =8hr

Touch time / dwell time = 1/4

The dwell time is eight hours since the Engineer may have to schedule the inspection into his daily routine.

Analysis of "value add" steps

Step 2 is value adding as it involves physically inspecting the completed job for approval purposes, while the rest of the steps are mainly administrative.

Overall Quality of the Process

The quality of the process is good as the Engineer manages to carry out the inspection within 24hrs of receiving the job report.

PM-04 - 05 Job costing and History Card updating (Planned)

1. **Objective:** To capture all costs and record the work carried out by the contractor
2. **Scope starts:** When clerk receives job report from Engineer
   Scope Ends: When Sap system is updated
   Scope involves: Clerk
   Documentation: Job notification, Invoice, Sap system
3. **Policies and principles**
   All work carried out on plant machinery has to be recorded
4. **Performance measures and constraints**
   - Elapsed time

   Accuracy of labour calculations and correct recording of work order information into the Sap system.

Steps	**Processes**
1, 2, 3	The clerk receives the job report and invoice from the Engineer and proceeds to cost the job and update the history card using the two supplied documents.
4, 5, 6	He then sends the invoice to stores to facilitate payment and the report back to the Engineer for filing. He then updates the sap system.

Analysis of Weaknesses and Inefficiencies:

Ratio of "touch time" to "dwell time"

Touch time = 0.25hr dwell time = 8hr

Touch time / dwell time = 1/32

The dwell time is eight hours since the clerk accumulates incoming job cards while attending to other jobs. He then does the costing and up dates the sap system at the end of the day.

Analysis of "value add" steps

This process involves no value adding steps

Overall Quality of the Process

The quality of this process is good since the clerk manages to carry out this process in eight working hours.

PM- 04 – 06 Job costing and History Card updating (B/downs)

1. **Objective:** To capture all costs and record the work carried out by the contractor
2. Scope starts: When clerk receives invoice from stores
   Scope Ends: When Sap system is updated
   Scope involves: Clerk
   Documentation: Invoice
3. **Policies and principles**
   All costs incurred in repairs done on plant machinery has to be recorded
4. **Performance measures and constraints**
   - Elapsed time
   - Accuracy of transferring work order information into the Sap system.

Steps	**Processes**
1, 2, 3	The clerk receives the invoice from stores and proceeds to cost the job and update the Sap system using the information from the invoice.
4, 5	The clerk then sends the invoice back to stores.

Analysis of Weaknesses and Inefficiencies:

Ratio of "touch time" to "dwell time"

Touch time = 0.25hrs dwell time = 8hrs

Touch time / dwell time = 1/32

The dwell time is too long as the process involves too many signatories and distance between offices involved.

Analysis of "value add" steps

There are no value adding steps in this process.

Overall Quality of the Process

The quality of this process is good since the clerk manages to carry out this process in eight working hours.

PM-04 – 12 Authorisation for payment

1. **Objective:** To authorise the payment for work carried out on plant machinery
2. **Scope starts:** When Engineer receives invoice from stores
   Scope Ends: When approved invoice is sent to stores
   Scope involves: Engineer

   Documentation: Invoice
3. **Policies and principles**
   All invoices can only be paid out if the Engineer approves them
4. **Performance measures and constraints**
   - Elapsed time

Steps	Processes
1	Engineer receives invoice (prior to payment) from stores to verify the accuracy of the invoice (work done, time taken, and costs.)
2	He checks the invoice against the quotation.
3, 4, 5	If incorrect, the invoice is sent back to the contractor, if correct then, the Engineer approves it and sends it to stores for payment.

Analysis of Weaknesses and Inefficiencies:

Ratio of "touch time" to "dwell time"

Touch time = 10min dwell time = 10min

Touch time / dwell time = 1.

The Engineer on receiving the invoice immediately compares it with the quotation and passes it on for payment.

Analysis of "value add" steps

This process involves no value adding steps.

Overall Quality of the Process

Process quality is good since it is promptly executed.

Engineering Objectives and targets

Department aims to avail plant and equipment in order to manufacture quality products at minimum costs in order to satisfy customers' needs in terms of quality, quantity and other requirements. In order to achieve the above the following are specific key result areas

1) To maintain plant availability of 98% by December 2012
2) To ensure achievement of the following targets by December 2012:
   Coal - (To maintain 0,048 kg/ltr of milk)
   Water (To maintain 4,5 ltr/ltr of milk)
   Electricity –(To maintain 0.22 Kwhr/ltr of milk)
   MD (To maintain 184 KVA)
3) To ensure that at least 95% of measurement equipment is within specifications at time of calibration up to December 2012.
4) To aim at zero accidents per year by December 20012

6._2010 – 2012 Indices and plant availability

2010 - ENGINEERING PERFORMANCES

Table 3: Coal consumption indices for Jan to Dec 2010

	MILK UTILISATION IN LITRES	CONSUMPTION IN KG	MONTH	ACTUAL INDICE	TARGET INDICE
	185624	9032	JAN	0.049	0.052
	252602	12000	FEB	0.048	0.052
	272594	14000	MAR	0.051	0.052
	348813	16000	APRIL	0.046	0.052
	321285	16500	MAY	0.051	0.052
	318060	16200	JUNE	0.051	0.052
	300942	14100	JULY	0.047	0.052
	258063	10500	AUG	0.041	0.052
	190205	8000	SEPT	0.042	0.052
	210588	8313	OCT	0.039	0.052
	191206	10238	NOV	0.054	0.052
	158873	8697	DEC	0.055	0.052
Total	3008855	143580	Average	0.048	0.052

Table 4: Water consumption indices Jan to Dec 2010

	MILK UTILISATION IN LITRES	CONSUMPTION IN LTRS	MONTH	ACTUAL INDICE	TARGET INDICE
	185624	1496000	JAN	8.06	4.5
	252602	880000	FEB	3.48	4.5
	272594	1039000	MAR	3.81	4.5
	348813	1084000	APRIL	3.11	4.5
	321285	1194000	MAY	3.72	4.5
	318060	1116000	JUNE	3.51	4.5
	300942	1098000	JULY	3.65	4.5
	258063	1045000	AUG	4.05	4.5
	190205	790000	SEPT	4.15	4.5
	210588	790000	OCT	3.75	4.5
	191206	790000	NOV	4.13	4.5
	158873	790000	DEC	4.97	4.5
Total	3008855	1129571		4.2	4.5

Table 5: Electricity consumption indices Jan to Dec 2010

	MILK UTILISATION IN LITRES	CONSUMPTION IN KWH	MONTH	ACTUAL INDICE	TARGET INDICE
	185624	61516	JAN	0.33	0.24
	252602	54404	FEB	0.22	0.24
	272594	58153	MAR	0.21	0.24
	348813	55962	APRIL	0.16	0.24
	321285	56123	MAY	0.17	0.24
	318060	58310	JUNE	0.18	0.24
	300942	56410	JULY	0.19	0.24
	258063	53619	AUG	0.21	0.24
	190205	51366	SEPT	0.27	0.24
	210588	56266	OCT	0.27	0.24
	191206	55921	NOV	0.29	0.24
	158873	54890	DEC	0.35	0.24
Total	3008855	57268		0.24	0.24

Table 6: Maximum demand consumption indices Jan to Dec 2010

	MILK UTILISATION IN LITRES		MONTH	ACTUAL INDICE	TARGET INDICE
	185624		JAN	200	165
	252602		FEB	195	165
	272594		MAR	184	165
	348813		APRIL	183	165
	321285		MAY	181	165
	318060		JUNE	182	165
	300942		JULY	173	184
	258063		AUG	172	184
	190205		SEPT	181	184
	210588		OCT	191	184
	191206		NOV	184	184
	158873		DEC	180	184
Total	3008855			184	175

Table 7 : Plant availability from Jan to Dec

	MILK UTILISATION IN LITRES	%	MONTH	Plant Availability Actual %	Plant Availability Target %
	185624	97	JAN	97	98
	252602	98	FEB	98	98
	272594	96	MAR	96	98
	348813	95	APRIL	95	98
	321285	95	MAY	95	98
	318060	97	JUNE	97	98
	300942	98	JULY	98	98
	258063	98	AUG	98	98
	190205	98	SEPT	98	98
	210588	96	OCT	96	98
	191206	96	NOV	96	98
	158873	95	DEC	95	98
Total	3008855	97		97	98

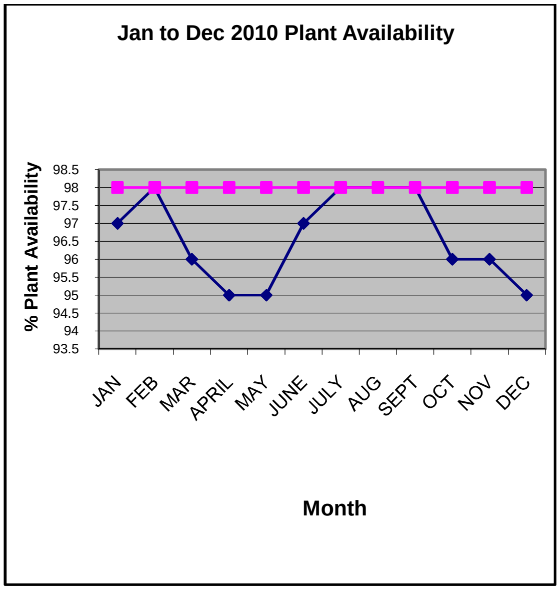

Figure 5: 2010 – Plant availability

2011 - ENGINEERING PERFORMANCES

Table 8: Water consumption indices Jan to Dec 2011

Month	Utilisation In Litres	Water in Litres	MONTH	WATER (Ltr/ltr of milk)	Target % (Ltr/ltr of milk)
JAN	147534	790	JAN	5.35	4.5
FEB	173415	790	FEB	4.56	4.5
MAR	177065	790	MAR	4.46	4.5
APRIL	119127	790	APRIL	6.63	4.5
MAY	129013	790	MAY	6.12	4.5
JUNE	157503	790	JUNE	5.02	4.5
JULY	188447	790	JULY	4.19	4.5
AUG	183119	790	AUG	4.31	4.5
SEPT	186143	790	SEPT	4.24	4.5
OCT	258727	790	OCT	3.05	4.5
NOV	263189	790	NOV	3	4.5
DEC	321756	790	DEC	2.46	4.5
Average	192087	790		**4.45**	**4.5**

Table 9: Coal consumption indices for Jan to Dec 2011

MONTH	Utilisation In Litres	COAL (Kg)	MONTH	COAL (Kg/ltr of milk)	Target % (Kg/ltr of milk)
JAN	147534	7274	JAN	0.049	0.048
EB	173415	7644	FEB	0.044	0.048
MAR	177065	8000	MAR	0.045	0.048
APRIL	119127	6265	APRIL	0.053	0.048
MAY	129013	8541	MAY	0.066	0.048
JUNE	157503	7860	JUNE	0.05	0.048
JULY	188447	5998	JULY	0.032	0.048
AUG	183119	9430	AUG	0.051	0.048
SEPT	186143	11153	SEPT	0.06	0.048
OCT	258727	14421	OCT	0.056	0.048
NOV	263189	12350	NOV	0.05	0.048
DEC	321756	12000	DEC	0.037	0.048
Average	192087	9244.7		**0.05**	**0.05**

Table 10: Electricity consumption indices Jan to Dec 2011

Month	Utilisation In Litres	Electricity in Kwh	MONTH	Electricity (Kwh/ltr of milk)	Target % (Kwh/ltr of milk)
JAN	147534	52500	JAN	0.36	0.22
FEB	173415	48779	FEB	0.28	0.22
MAR	177065	50315	MAR	0.28	0.22
APRIL	119127	44425	APRIL	0.37	0.22
MAY	129013	43668	MAY	0.34	0.22
JUNE	157503	40653	JUNE	0.26	0.22
JULY	188447	43530	JULY	0.23	0.22
AUG	183119	45795	AUG	0.25	0.22
SEPT	186143	49320	SEPT	0.26	0.22
OCT	258727	58313	OCT	0.23	0.22
NOV	263189	54272	NOV	0.21	0.22
DEC	321756	55697	DEC	0.17	0.22
Average	192087	48939		**0.27**	**0.22**

Table 11: Maximum demand consumption indices for Jan to Dec 2011

Month	Utilisation in Litres	MD In KVA	MONTH	MD KVA Actual
JAN	147534	179	JAN	179
FEB	173415	156	FEB	156
MAR	177065	149	MAR	149
APRIL	119127	148	APRIL	148
MAY	129013	150	MAY	150
JUNE	157503	137	JUNE	137
JULY	188447	141	JULY	141
AUG	183119	150	AUG	150
SEPT	186143	163	SEPT	163
OCT	258727	181	OCT	181
NOV	263189	165	NOV	165
DEC	321756	162	DEC	162
Average	192087	157		**157**

Table 12: Plant availability Jan to Dec 2011

Month	Utilisation In Litres	Plant Availability Actual %	MONTH	Plant Availability Actual %	Plant Availability Target %
JAN	147534	95	JAN	95	98
FEB	173415	96	FEB	96	98
MAR	177065	95	MAR	95	98
APRIL	119127	95	APRIL	95	98
MAY	129013	96	MAY	96	98
JUNE	157503	95	JUNE	95	98
JULY	188447	92	JULY	92	98
AUG	183119	93	AUG	93	98
SEPT	186143	97	SEPT	97	98
OCT	258727	94	OCT	94	98
NOV	263189	94	NOV	94	98
DEC	321756	92	DEC	92	98
Average	192087	95		95	98

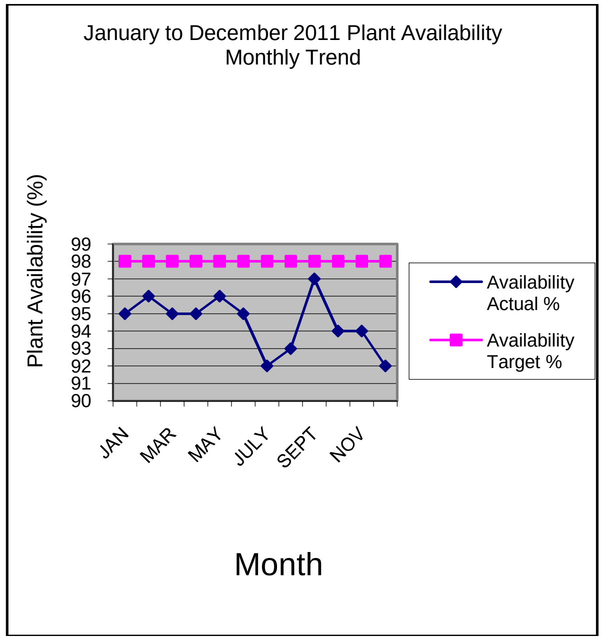

Figure 6: 2011 – Plant availability

2012-ENGINEERING PERFORMANCES

Table 12: Coal consumption indices for Jan to Dec 2012

	MILK UTILISATION IN LITRES	CONSUMPTION IN KG	MONTH	ACTUAL INDICE	TARGET INDICE
	132559	8610	**JAN**	0.065	0.048
	167969	8588	**FEB**	0.051	0.048
	87481	8520	**MAR**	0.097	0.048
	66237	5377	**APRIL**	0.081	0.048
	85874	7543	**MAY**	0.088	0.048
	136214	13300	**JUNE**	0.098	0.048
Average	**676334**	**51938**		**0.08**	**0.05**

Table 13: Water consumption indices for Jan to Dec 2012

	MILK UTILISATION IN LITRES	CONSUMPTION IN LTRS	MONTH	ACTUAL INDICE	TARGET INDICE
	132559	790000	JAN	5.96	4.5
	167969	790000	FEB	4.7	4.5
	87481	790000	MAR	9.03	4.5
	66237	790000	APRIL	11.93	4.5
	85874	790000	MAY	9.2	4.5
	136214	790000	JUNE	5.8	4.5
Average	676334	677143		7.77	4.5

Table 14: Electricity consumption indices for Jan to Dec 2012

	MILK UTILISATION IN LITRES	CONSUMPTION IN KWH	MONTH	ACTUAL INDICE	TARGET INDICE
	132559	47203	JAN	0.356	0.24
	167969	51574	FEB	0.307	0.24
	87481	50940	MAR	0.582	0.24
	66237	44756	APRIL	0.676	0.24
	85874	45135	MAY	0.526	0.24
	136214	46412	JUNE	0.341	0.24
Average	676334	40860		0.46	0.24

Table 15: Maximum demand consumption indices for Jan to Dec 2012

	MILK UTILISATION IN LITRES		MONTH	ACTUAL INDICE	TARGET INDICE
	132559		JAN	232	184
	167969		FEB	230	184
	87481		MAR	165	184
	66237		APRIL	144	184
	85874		MAY	176	184
	136214		JUNE	178	184
Average	676334			188	184

Table 16: Plant availability from Jan to Dec 2012

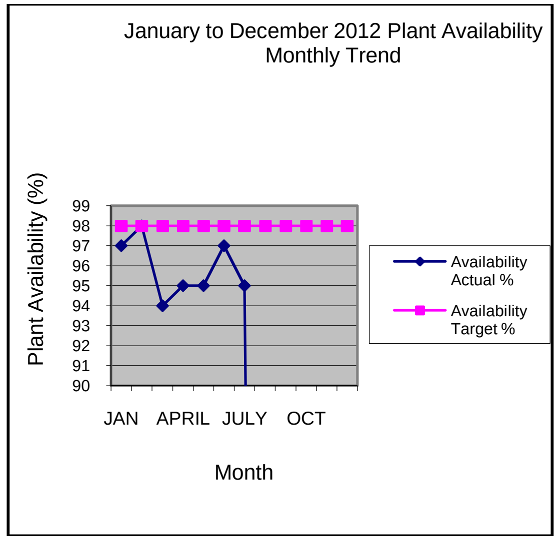

Figure 7: 2012 – Plant availability

Maintenance managers at the dairy should use tools that aid maintenance whenever possible. This would go a long way in improving maintenance management and maintenance performance, leading to greater productivity and profits.

Recommendations

Systematic inspection of all plant machinery and equipment at regular intervals ensures that the plant availability is guaranteed. All plant machinery and equipment is serviced at predetermined intervals as per planned maintenance program or preventive action requests instruction. Each machine is assigned a permanent and individual asset register number and a record of each machine is maintained. At the end of each month the engineer runs the date monitoring the program and prints worked orders due the following period.

After completion of service, quality of work is inspected by the Engineer before machine is handed over to user dept. Just after commissioning the machine, the artisan completely fills in the works order document detailing the nature of work done, and spares usage, before handing it over the engineer for approval.

After approval, the artisan completes the works order and the order is completed in the SAP system, which updates the machinery history.

Conclusion

The need to have improved plant availability has seen reliability systems put in place as well as intelligent condition monitoring to assist the operations of the Dairy Company. Systems and procedures have been revisited with the view to expose the components which require urgent attention in terms of replacement and repairs with minimum interruption of the required production targets. In the dairy industry over the years plant availability is critical as the perishable fresh milk has to be timely processed before it gets bad as well as on time delivery to the customer to survive the competitive milk market in the country.

Further Research

In as much as the good scheduling of maintenance work is good work practice, studies have shown that basic maintenance has to be transferred to machine operators to mind their own machine through doing basic maintenance work as well as trained to be multi-skilled to positive results. Therefore further investigation can be done in terms of human resource leverage to excel in plant availability.

References

[1] Nakajima, S, TPM Development Program

[2] Berzun, J and Graff, F.H, The Modern Researcher, Harcourt Brace Jovanivich, 1985

[3] Porter, Michael E, Competitive advantage: creating and sustaining superior performance: with a new introduction; New York: Free Press, 1985

[4] Anthony, K, Maintenance planning and control,

[5] Jardine, S, K, A, Maintenance, Replacement and Reliability

[6] Tom Copeland, Tim koler, Jack Murrin, 3RD Edition, Valuation measuring and managing the value of companies, John Wiley and sons, inc, 2000 www.plantmaintenance.com/

[7] www.Rom-reliability.com/ reameth.htm

[8] www.maint2k.com/

Authors' profiles

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Kumbi Mugwindiri, did Bsc Mechanical Engineering Honours at the University of Zimbabwe, and Masters in Manufacturing Systems at Cranfield University, England. Currently, lecturing Engineering Management at the University of Zimbabwe. Worked as Workshops Engineer for Zimbabwe Phosphates Industries responsible for heavy maintenance of process plant equipment . In 1993 carried out a project with the Ford Motor Company to determine ways of improving working patterns and practices, this was a European Union wide project. In 2000, he undertook collaborative research in Clean Technologies at Tulane University in New Orleans. Has worked with many organizations researching/and or consulting in Maintenance Engineering and Cleaner Production.