Maintenance Technology Tools to Improve Plant Availability for Dairy Industry: Case Study

Ignatio Madanhire and Charles Mbohwa

Abstract— **This research study investigates some industrial maintenance, and respective technologies that can be employed at a dairy products processing plant. Qualitative as well as quantitative techniques are considered. Plant availability has been identified as a major contributor in benchmarking areas at the company to avoid possible huge costs associated with loss of production and efficiency resulting from poor utilization of resources. The use of tools that aid maintenance is emphasized in particular to identify critical plant equipment that requires greater attention**.

Index Terms—**maintenance, availability, performance indices, reliability, input consumption**

I. Introduction

The function of all organized forms of human endeavor 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.

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. 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.

II. Justification

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 organizational influence to do whatever needs to be done to achieve real world-class equipment performance. To understand why this may be so, it is useful to analyze approaches to the management of physical assets.

Manuscript received February 27 2015

Ignatio Madanhire is with the University of Johannesburg**,** School of Engineering Management, Faculty of Engineering and The Built Environment, Auckland Park 2006, South Africa

OR

University of Zimbabwe, Department of Mechanical Engineering, P O Box MP167, Mount Pleasant, Harare, Zimbabwe (phone: +263 712 453 451; e-mail: imadanhire@ eng.uz.ac.zw).

Charles Mbohwa is with the University of Johannesburg, School of Engineering Management, Faculty of Engineering and The Built Environment, Auckland Park 2006, South Africa (email: cmbohwa@uj.ac.za)

III. Maintenance Management

A. Traditional maintenance

The function of maintenance management team is to identify appropriate maintenance policies to control the condition of equipment in line with the objectives of the organization, which certainly include minimization of maintenance costs. 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 minimize 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.

B. 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. 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.

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.

C. 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. 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.

D. Tools that aid maintenance

i. ABC Pareto analysis

This is a maintenance control tool used to graphically and analytically group plant equipment into three groups' with respect to a particular maintenance/production parameter or indices. The groups are critical items (group A), moderate

(group B) and non-critical (group C). 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.

ii. 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:

- 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 overall equipment efficiency(O.E.E), availability, load factor; number of trips etc.

The key feature of modern maintenance 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 redundant data cease to be accumulated. 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.

IV. Case Study: Dairy Company

A. Dairy Co. process overview

In a dairy products processing the key operations were production and sales. 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 department provides maintenance support for equipment and infrastructure for all units.

B. 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.

C. 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.

D. 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.

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

E. Maintenance notification types

The are 6 maintenance notification types that are used by Dairy Co are:

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

F. Plant maintenance order processing

The maintenance processes given by order processing given in Fig 2 include:

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

G. 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, referred to by Fig 1 process
- ***Non stock:*** Material master record exists but not kept in warehouse and/or purchased each time there is a requirement, referred to by Fig 2

- ***Non stock, non catalogue***: No material master record exists and/or purchased each time there is a requirement

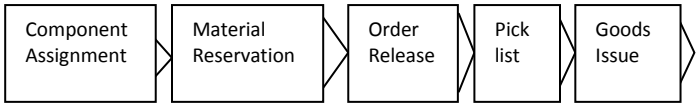

Fig 1 Stock material process flow

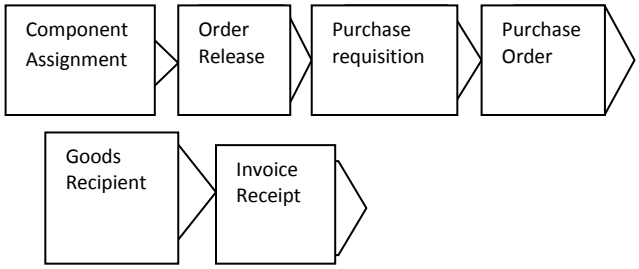

Fig 2. Non stock material processes

V. Study Findings

Scheduled maintenance is performed to ensure systematic inspection of all plant machinery and equipment (listed in Table I) at regular intervals. All plant machinery and equipment is serviced at predetermined intervals as per planned maintenance program 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 program 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 to 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 II.

TABLE I

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 Cold rooms
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 Pasteurizer
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	De-airator
Reception	Milk Cooler
	Diesel Flow Meter
	Silo No.2
	Silo No.3
	Silo No.4
	Silo No.5
	Intake milk pump
	Borehole Plant

TABLE II

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	Authorization of service contract
PM-01-07	maintenance plan for a new machine
PM-01-08	Authorization of stores requisition
PM-02	
PM-02-01	Global maintenance plan
PM-02-02	Generate job cards: Planned
PM-02-03	Raising a Stores Requisition
PM-02-04	Authorization 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	Authorization 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	Authorization for payment

A. The phases in detail

PM – 01 – 01 Preparation for new machine
Objective: To prepare for the installation of a new machine in an existing plant.
PM – 01 –02 Installation
Objectives: Installation of machine and termination of services.
PM – 01 –03 Commissioning
Objective: To bring newly acquired machine into

PM – 01 –04 Creating a new machine in the SAP system
Objective: Costing the details of a work order and creating the machine in the SAP system
PM – 01 –05 Opening a service contract with machine supplier.
Objective: To put in place a contract with the supplier for back-up service and maintenance of a new machine.
PM – 01 –06 Authorization of service contract
Objective: To approve/disapprove the proposed service contract of a new machine.

PM – 01 –07 Maintenance planning for new machine
Objective: To draw up a maintenance plan for a new machine.
PM-01 – 08 Authorization of stores requisition
Objective: To ensure ready availability of spares at stores

PM-02 – 03 Raising a stores requisition.
Objective: To raise a stores requisition in order to obtain spares and materials from main stores.
PM-02 – 04 Authorization of stores requisition
Objective: To approve of items that have been requested from stores
PM- 02 - 05 Check job card after completion
Objective: To ascertain that the requested job has been executed.
PM-02 - 06 Job costing and history card updating
Objective: To capture all the costs of the work done (labor and materials) and to record service information in Sap System
PM-03 - 01 User dept. raising a job requisition
Objective: To request PM to attend to breakdown on Plant Machinery
PM- 03 - 02 Job Assessment
Objective: To assess nature of breakdown
PM-03 - 03 Generate job card repairs
Objective: To raise a work order in order for service personnel to carry out repairs
PM-03 - 04 Check job after completion
Objective: To check the standard of work carried out by the artisan
PM-03 - 05 Job costing and history updating
Objective: To cost the labor and materials for a job that has been satisfactorily completed and to update the Sap system.
PM-04 - 01 Raising purchase requisition
Objective: To raise a purchase requisition for services to be done by external suppliers
PM-04 - 02 Authorization of a purchase requisition
Objective: To authorize a purchase request for work that has to be sub-contracted
PM04 - 04 Check job report after completion
Objective: To check if the sub -contracted job has been done to standard
PM-04 - 05 Job costing and History Card updating (Planned)
*Objective***:** To capture all costs and record the work carried out by the contractor
PM- 04 – 06 Job costing and History Card updating (B/downs)
Objective: To capture all costs and record the work carried out by the contractor
PM-04 – 12 Authorization for payment
Objective: To authorize the payment for work carried out on plant machinery

B .Engineering Objectives and targets

Maintenance 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 2014
2) To aim at zero maintenance related accidents per year by December 2014

VI. Study Results

TABLE III

PLANT AVAILABILITY FROM JAN TO DEC 2012

	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

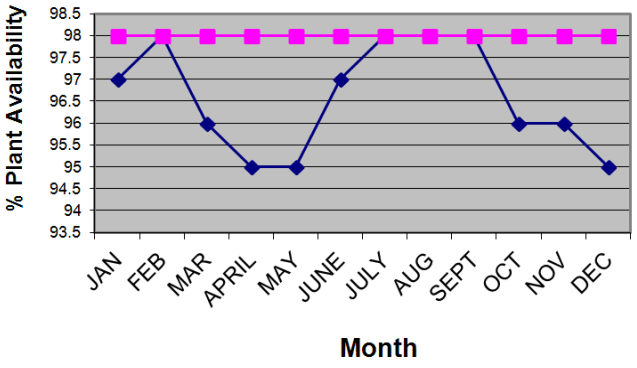

Fig 3. 2012 – Plant availability

TABLE IV

PLANT AVAILABILITY JAN TO DEC 2013

Month	Utilization 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

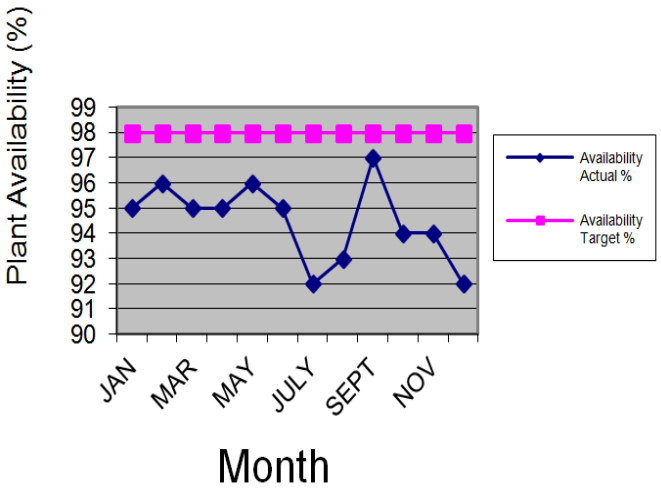

Fig 4. 2013 – Plant availability

TABLE V

PLANT AVAILABILITY FROM JAN TO JUN 2014

	MILK UTILISATION IN LITRES		MONTH	Plant Availability Actual (%)	Plant Availability Target (%)
	132559		JAN	97	98
	167969		FEB	98	98
	87481		MAR	94	98
	66237		APRIL	95	98
	85874		MAY	95	98
	136214		JUNE	97	98
Average	676334			96	98

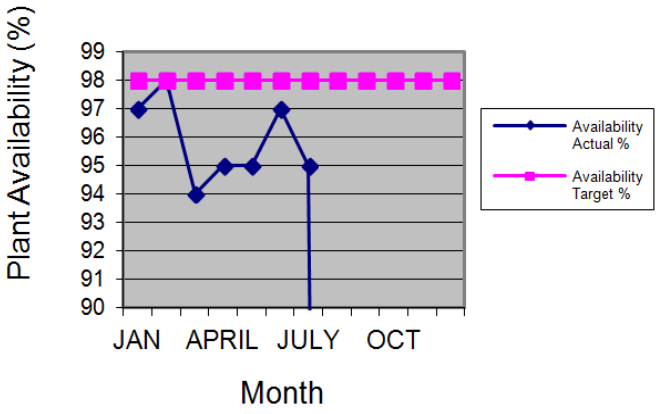

Fig 5. 2014 – Plant availability

Plant Availability (A) – is the total percentage of time for which a specific machine will be available/scheduled for production purposes

$$A = \frac{\text{Loading time} - \text{downtime}}{\text{Loading time}}$$

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.

VII. 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.

VIII. 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.

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, Timkoler, Jack Murrin, 3rd Edition, Valuation measuring and managing the value of companies, John Wiley and sons, inc, 2000