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Keywords : Total productive maintenance, Preventive maintenance, Overall equipment efficiency, Boiler plant, Malt manufacturing industry.

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TOTAL PRODUCTIVE MAINTENANCE A CASE STUDY IN MANUFACTURING INDUSTRY

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Melesse Workneh Wakjira [α], Ajit Pal Singh [σ]

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I. Introduction

TPM is a unique Japanese philosophy, which has been developed based on the productive maintenance concepts and methodologies. This concept was first introduced by M/s Nippon Denso Co. Ltd. of Japan, a supplier of M/s Toyota Motor Company, Japan in the year 1971. Total productive maintenance is an innovative approach to maintenance that optimizes equipment effectiveness, eliminates breakdowns and promotes autonomous maintenance by operators through day-to-day activities involving total workforce (Bhadury, 2000).

The manufacturing industry has experienced an unprecedented degree of change in the last three decades, involving drastic changes in management approaches, product and process technologies, customer expectations, supplier attitudes as well as competitive behaviour (Ahuja et al., 2006). In today's fast - changing marketplace, slow, steady improvements in manufacturing operations do not guarantee sustained profitability or survival of an organization (Oke, 2005).Thus the organizations need to improve at a faster rate than their competitors, if they are to become or remain leaders in the industry.

A survey of manufacturers found that full-time maintenance personnel as a percentage of plant employees averaged 15.7 percent of overall staffing in a study involving manufacturing organizations (Dunn, 1988), whereas in refineries, the maintenance and operations departments are often the largest and each may comprise about 30 percent of total staffing (Dekker, 1996). It has been found that in the UK manufacturing industry, maintenance spending accounts for a significant 12 to 23 percent of the total factory operating costs (Cross, 1988). With sobering figures like these, manufacturers are beginning to realize that maintenance organization and management, and design for maintainability and reliability are strategic factors for success in 1990s (Yoshida et al., 1990). Thus the effectiveness of maintenance function significantly contributes towards the performance of equipment, production and products (Teresko, 1992).

Nakajima (1989), a major contributor of TPM, has defined TPM as an innovative approach to maintenance that optimizes equipment effectiveness, eliminates breakdowns, and promotes autonomous maintenance by operators through day-to-day activities involving the total workforce (Bhadury, 2000).

II. Contributions Of Tpm Towards Improving Manuafcturing Performance

Manufacturing is considered to be an important element in a firm's endeavour to improve firm performance (Skinner, 1982; Hayes & Wheelwright, 1984). Superior manufacturing performance leads to competitiveness (Leachman et al., 2005). TPM is a highly structured approach, which uses a number of tools and techniques to achieve highly effective plants and machinery. With competition in manufacturing industries rising relentlessly, TPM has proved to be the maintenance improvement philosophy preventing the failure of an organization (Eti et al., 2006). Today, an effective TPM strategy and programs are needed, which can cope with the dynamic needs and discover the hidden but unused or under utilized resources (human brainpower, man-hours, machine-hours). TPM methodology has the potential to meet the current

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demands. A well conceived TPM implementation program not only improve the equipment efficiency and effectiveness but also brings appreciable improvements in other areas of the manufacturing enterprise.

Kutucuoglu et al. (2001) have stated that equipment is the major contributor to the performance and profitability of manufacturing systems. Seth & Tripathi (2005) have investigated the strategic implications of TQM and TPM in an Indian manufacturing set-up. Thun (2006) has described the dynamic implications of TPM by working out interrelations between various pillars of TPM to analyze the fundamental structures and identifies the most appropriate strategy for the implementation of TPM considering the interplay of different pillars of this maintenance approach. Ahuja & Khamba (2008a) have investigated the significant contributions of TPM implementation success factors like top management leadership and involvement, traditional maintenance practices and holistic TPM implementation initiatives, towards affecting improvements in manufacturing performance in the Indian industry.

III. TPM Pillars

The basic practices of TPM are often called the pillars or elements of TPM. The entire edifice of TPM is built and stands, on eight pillars (Sangameshwran & Jagannathan, 2002). TPM paves way for excellent planning, organizing, monitoring and controlling practices through its unique eight-pillar methodology. TPM initiatives, as suggested and promoted by Japan Institute of Plant Maintenance (JIPM), involve an eight pillar implementation plan that results in substantial increase in labor productivity through controlled maintenance, reduction in maintenance costs, and reduced production stoppages and downtimes. The core TPM initiatives classified into eight TPM pillars or activities for accomplishing the manufacturing performance improvements include autonomous maintenance; focused maintenance; planned maintenance; quality maintenance; education and training; office TPM; development management; and safety, health and environment (Ireland & Dale, 2001; Shamsuddin et al., 2005; Rodrigues & Hatakeyama, 2006).

The detailed maintenance and organizational improvement initiatives and activities associated with the respective TPM pillars are as follows:

Pillar 1-5S:

TPM starts with 5S. It is a systematic process of housekeeping to achieve a serene environment in the work place involving the employees with a commitment to sincerely implement and practice house keeping. Problems cannot be clearly seen when the work place is unorganized. Cleaning and organizing the workplace helps the team to uncover problems. Making problems visible is the first step of improvement. 5S is a foundation program before the implementation of TPM. If this 5S is not taken up seriously, then it leads to 5D (delays, defects, dissatisfied customers, declining profits, and demoralized employees).

This 5S implementation has to be carried out in phased manner. First the current situation of the workplace has to be studied by conducting a 5S audit. This audit uses check sheets to evaluate the current situation. This check sheet consists of various parameters to be rated say on a 5-point basis for each 'S'. The ratings give the current situation. The each of the above-mentioned 5S is implemented and audit is conducted at regular intervals to monitor the progress and evaluate the success of implementation. After the completion of implementation of 5S random audits could be conducted using company check sheets to ensure that it is observed in true spirits by every one in the work place. Table 1 depicts the key activities to be holistically deployed for effective 5S implementation at the workplace.

Table 1 : Key activities for effective 5S implementation at the workplace

Japanese nomenclature (English 5S/5C):Features
Seiri (Sort/Clear): Sort out unnecessary items from the workplace and discard them
Seiton (Set in order/Configure): Arrange necessary items in good order so that they can be easily picked up for use
Seisio (Shine/Clean and check): Clean the workplace completely to make it free from dust, dirt and clutter
Seiketsu (Standardize/Conformity): Maintain high standard of house keeping and workplace organization
Shitsuke (Sustain/Custom and practice): Train and motivate people to follow good housekeeping disciplines autonomously

Pillar 2- Autonomous maintenance (AM):

This pillar is geared towards developing operators to be able to take care of small maintenance tasks, thus freeing up the skilled maintenance people to spend time on more value added activity and technical repairs. The operators are responsible for upkeep of their equipment to prevent it from deteriorating. By use of this pillar, the aim is to maintain the machine in new condition. The activities involved are very simple nature. This includes cleaning, lubricating, visual inspection, tightening of loosened bolts etc.

AM policy are-uninterrupted operation of equipments, flexible operators to operate and maintain other equipments, and eliminating the defects at source through active employee participation.

Steps in AM are preparation of employees, initial cleanup of machines, take counter measures, fix tentative AM (JISHU HOZEN) standards, general inspection, autonomous inspection, and standardization.

Pillar 3-Kaizen:

"Kai" means change, and "Zen" means good (for the better). Basically kaizen is for small improvements, but carried out on a continual basis and involve all people in the organization. Kaizen is opposite to big spectacular innovations. Kaizen requires no or little investment. The principle behind is that "a very large number of small improvements are move effective in an organizational environment than a few improvements of large value". This pillar is aimed at reducing losses in the workplace that affect our efficiencies. By using a detailed and thorough procedure we eliminate losses in a systematic method using various kaizen tools. These activities are not limited to production areas and can be implemented in administrative areas as well.

Kaizen policy are practice concepts of zero losses in every sphere of activity, relentless pursuit to achieve cost reduction targets in all resources, relentless pursuit to improve over all plant equipment effectiveness, extensive use of PM analysis as a tool for eliminating losses, and focus of easy handling of operators. Kaizen target are achieve and sustain zero loses with respect to minor stops, measurement and adjustments, defects and unavoidable downtimes. It also aims to achieve 30% manufacturing cost reduction.

Tools used in kaizen are Why-Why analysis, Poka-Yoke (Poka-Yoke is Japanese term, which in English means 'mistake proofing' or 'error prevention'), summary of losses, kaizen register, and kaizen summary sheet.

Six losses in the work place: The objective of TPM is maximization of equipment effectiveness. TPM aims at maximization of machine utilization and not merely machine availability maximization. As one of the pillars of TPM activities, kaizen pursues efficient equipment, operator and material and energy utilization that is extremes of productivity and aims at achieving substantial effects. Kaizen activities try to thoroughly eliminate losses. Six major losses that were identified are-equipment failure, set-up and adjustments, small stops, speed losses during production, and losses during warm-up (Nakajima, 1988).

Pillar 4-Planned maintenance (PM):

It is aimed to have trouble free machines and equipments producing defect free products for total customer satisfaction. This breaks maintenance down into four "families" or groups, viz., preventive maintenance, breakdown maintenance, corrective maintenance, and maintenance prevention.

With PM we evolve our efforts from a reactive to a proactive method and use trained maintenance staff to help train the operators to better maintain their equipment. In PM policy are achieve and sustain availability of machines, optimum maintenance cost, reduces spares inventory, and improve reliability and maintainability of machines.

PM targets are zero equipment failure and break down, improve reliability and maintainability by 50 percent, reduce maintenance cost by 20 percent, and ensure availability of spares all the time.

Six steps in planned maintenance are equipment evaluation and recoding present status; restore deterioration and improve weakness; building up information management system; prepare time based information system; select equipment, parts and members and map out plan; prepare predictive maintenance system by introducing equipment diagnostic techniques; and evaluation of planned maintenance.

Pillar 5-Quality maintenance (QM):

It is aimed towards customer delight through highest quality through defect free manufacturing. Focus is on eliminating non-conformances in a systematic manner, much like focused improvement. We gain understanding of what parts of the equipment affect product quality and begin to eliminate current quality concerns, and then move to potential quality concerns. Transition is from reactive to proactive (quality control to quality assurance).

QM activities are to set equipment conditions that preclude quality defects, based on the basic concept of maintaining perfect equipment to maintain perfect quality of products. The condition is checked and measure in time series to very that measure values are within standard values to prevent defects. The transition of measured values is watched to predict possibilities of defects occurring and to take counter measures before hand.

In QM policy are defect free conditions and control of equipments, quality maintenance activities to support quality assurance, focus of prevention of defects at source, focus on Poka-Yoke (fool proof system), in-line detection and segregation of defects, and effective implementation of operator quality assurance. QM targets are achieve and sustain customer complaints at zero, reduce in-process defects by 50 percent, and reduce cost of quality by 50 percent.

Pillar 6-Training:

It is aimed to have multi-skilled revitalized employees whose morale is high and who has eager to come to work and perform all required functions effectively and independently. Education is given to operators to upgrade their skill. It is not sufficient know only "Know-How" by they should also learn "Know-Why". By experience they gain, "Know-How" to overcome a problem what to be done. This they do train them on knowing "Know-why". The employees should be trained to achieve the four phases of skill. The goal is to create a factory full of experts. The different phase of skills is phase 1-do not know, phase 2-know the theory but cannot do, phase 3-can do but cannot teach, and phase 4-can do and also teach.

Training policy's are focus on improvement of knowledge, skills and techniques, creating a training environment for self-learning based on felt needs, training curriculum including tools/assessment etc. conductive to employee revitalization, and training to remove employee fatigue and make, work enjoyable.

Training target are achieve and sustain downtime due to want men at zero on critical machines, achieve and sustain zero losses due to lack of knowledge/skills/techniques, and aim for 100 percent participation in suggestion scheme.

Steps in educating and training activities are setting policies and priorities and checking present status of education and training, establish of training system for operation and maintenance skill up gradation, training the employees for upgrading the operation and maintenance skills, preparation of training calendar, kick-off of the system for training, and evaluation of activities and study of future approach.

Pillar 7-Office TPM:

Office TPM should be started after activating four other pillars of TPM (AM, Kaizen, PM, and QM). Office TPM must be followed to improve productivity, efficiency in the administrative functions and identify and eliminate losses. This includes analyzing processes and procedures towards increased office automation.

Office TPM addresses twelve major losses, they are processing loss; cost loss including in areas such as procurement, accounts, marketing, sales leading to high inventories; communication loss; idle loss; set-up loss; accuracy loss; office equipment breakdown; communication channel breakdown, telephone and fax lines; time spent on retrieval of information; non availability of correct on line stock status; customer complaints due to logistics; and expenses on emergency dispatches/purchases.

Office TPM and its benefits are involvement of all people in support functions for focusing on better plant performance, better utilized work area, reduce repetitive work, reduced administrative costs, reduced inventory carrying cost, reduction in number of files, productivity of people in support functions, reduction in breakdown of office equipment, reduction of customer complaints due to logistics, reduction in expenses due to emergency dispatches/purchases, reduced manpower, and clean and pleasant work environment.

Pillar 8-Safety, health and environment:

In this area focus is on to create a safe workplace and a surrounding area that is not damaged by our process or procedures. This pillar will play an active role in each of the other pillars on a regular basis. Safety, health and environment target are zero accident, zero health damage, and zero fires.

A committee is constituted for this pillar, which comprises representative of officers as well as workers. The committee is headed by senior vice president (technical). Utmost importance to safety is given in the plant. Manager (safety) looks after functions related to safety. To create awareness among employees various competitions like safety slogans, quiz, drama, posters, etc. related to safety can be organized at regular intervals.

IV. TPM Imlementation Stages

a) Stage A-Preparatory stage

Step 1-Announcement by management to all about TPM introduction in the organization: Proper understanding, commitment and active involvement of the top management in needed for this step. Senior management should have awareness programmes, after which announcement is made. Decision the implement TPM is published in the in house magazine, displayed on the notice boards and a letter informing the same is send to suppliers and customers.

Step 2-Initial education and propaganda for TPM: Training is to be done based on the need. Some need intensive training and some just awareness training based on the knowledge of employees in maintenance.

Step 3-Setting up TPM and departmental committees: TPM includes improvement, autonomous maintenance, quality maintenance etc., as part of it. When committees are set up it should take care of all those needs.

Step 4-Establishing the TPM working system and target: Each area/work station is benchmarked and target is fixed up for achievement.

Step 5-A master plan for institutionalizing: Next step is implementation leading to institutionalizing wherein TPM becomes an organizational culture. Achieving PM award is the proof of reaching a satisfactory level.

b) Stage B-Introduction stage

A small get-together, which includes our suppliers and customer's participation, is conducted. Suppliers as they should know that we want quality supply from them. People from related companies and affiliated companies who can be our customers, sisters concerns etc. are also invited. Some may learn from us and some can help us and customers will get the message from us that we care for quality output, cost and keeping to delivery schedules.

c) Stage C-TPM implementation

In this stage eight activities are carried which are called eight pillars in the development of TPM activity. Of these four activities are for establishing the system for production efficiency, one for initial control system of new products and equipment, one for improving the efficiency of administration and are for control of safety, sanitation as working environment.

d) Stage D-Institutionalizing stage

By now the TPM implementation activities would have reached maturity stage. Now is the time to apply for preventive maintenance award.

V. TPM Imlementation

The following is the brief description of each of the TPM implementation activities:

(i) Master plan: The TPM team, along with manufacturing and maintenance management, and union representatives determines the scope/focus of the TPM program. The selected equipments and their implementation sequence are determined at this point. Baseline performance data is collected and the program's goals are established.

(ii) Autonomous maintenance: The TPM team is trained in the methods and tools of TPM and visual controls. The equipment operators assume responsibility for cleaning and inspecting their equipment and performing basic maintenance tasks. The maintenance staff trains the operators on how to perform the routine maintenance, and all are involved in developing safety procedures. The equipment operators start collecting data to determine equipment performance.

(iii) Planned maintenance: The maintenance staff collects and analyzes data to determine usage/need based maintenance requirements. A system for tracking equipment performance metrics and maintenance activities is created (if one is not currently available). Also, the maintenance schedules are integrated into the production schedule to avoid schedule conflicts.

(iv) Maintenance reduction: The data that has collected and the lessons learned from TPM implementation are shared with equipment suppliers. This 'design for maintenance' knowledge is incorporated into the next generation of equipment designs. The maintenance staff also develops plans and schedules for performing periodic equipment analysis (burner pump, fuel filter, rotary cup atomizer, furnace tube and valve, etc.). This data from analysis is also fed into the maintenance database to develop accurate estimates of equipment performance and repair requirements. These estimates are used to develop spare parts inventory policies and proactive replacement schedules.

(v) Holding the gains: The new TPM practices are incorporated into the organization's standard operating procedures. These new methods and data collection activities should be integrated with the other elements of the production system to avoid redundant or conflicting requirements.

The new equipment management methods should also be continuously improved to simplify the tasks and minimize the effort required to sustain the TPM program.

VI. Overall Equipment Effectiveness

TPM initiatives in production help in streamlining the manufacturing and other business functions, and garnering sustained profits (Ahuja & Khamba, 2007). The strategic outcome of TPM implementations is the reduced occurrence of unexpected machine breakdowns that disrupt production and lead to losses, which can exceed millions of dollars annually (Gosavi, 2006). OEE methodology incorporates metrics from all equipment manufacturing states guidelines into a measurement system that helps manufacturing and operations teams improve equipment performance and, therefore, reduce equipment cost of ownership (COO).

TPM initiatives are focused upon addressing major losses, and wastes associated with the production systems by affecting continuous and systematic evaluations of production system, thereby affecting significant improvements in production facilities (Ravishankar et al., 1992; Gupta et al., 2001, Juric et al., 2006). TPM employs OEE as a quantitative metric for measuring the performance of a productive system. OEE is the core metric for measuring the success of TPM implementation program (Jeong & Phillips, 2001). The overall goal of TPM is to raise the overall equipment effectiveness (Shirose, 1989; Huang et al., 2002; Juric et al., 2006). OEE is calculated by obtaining the product of availability of the equipment, performance efficiency of the process and rate of quality products (Ljungberg, 1998; Dal et al., 2000):

OEE = Availability (A) × Performance efficiency (P) × Rate of quality (Q); where: Availability (A) = [(Loading time-Downtime) ÷ Loading time] × 100, Performance efficiency (P) = [Processed amount ÷ (Operating time ÷ Theoretical cycle time)] × 100, Rate of quality (Q) = [(Processed amount-Defect amount) ÷ Processed amount] × 100

This metric has become widely accepted as a quantitative tool essential for measurement of productivity in manufacturing operations (Samuel et al., 2002). The OEE measure is central to the formulation and execution of a TPM improvement strategy (Ljungberg, 1998). TPM has the standards of 90 per cent availability, 95 percent performance efficiency and 99 percent rate of quality (Levitt, 1996). An overall 85 percent benchmark OEE is considered as world-class performance (McKone et al., 1999). OEE measure provides a strong impetus for introducing a pilot and subsequently company wide TPM program.

A comparison between the expected and current OEE measures can provide the much-needed impetus for the manufacturing organizations to improve the maintenance policy and affect continuous improvements in the manufacturing systems. OEE offers a measurement tool to evaluate equipment corrective action methods and ensure permanent productivity improvement. OEE is a productivity improvement process that starts with management awareness of total productive manufacturing and their commitment to focus the factory work force on training in teamwork and cross-functional equipment problem solving.

VII. Case Study At Asella Malt Industry

This study is done in the manufacturing sector at Asella Malt Industry, Asella, Ethiopia, Africa and the values chosen are meant for justifying the research initiatives only. Finally, to evaluate the effectiveness of TPM implementation steps, OEE value in boiler plant was calculated and analyzed before and after implementation of TPM in industry. In the process industry it is very much essential to maximize the production effectiveness; the effectiveness of a plants production depends on the effectiveness with which it uses equipment materials people and methods. This is done by examining the inputs to the production process and identifying, eliminating the losses associated with each to maximize the production. Major industry losses were identified are shut down (planned maintenance), production adjustment, equipment failure (mainly boiler), process failures, normal production loss, abnormal production loss, quality defects, and reprocessing.

The bottle neck is boiler plant for malt manufacturing process due to which productivity is going down most of the time and this plant was selected as equipment for OEE calculation.

Calculations on OEE of the boiler plant for January, 2011(before TPM implementation):

Mechanical breakdown=43.43hrs

Electrical breakdown=11.25hrs

Electronics/safety device breakdown=2.03hrs

Total breakdown=57.11hrs

Setup and other conditions=7.30hrs

Total loss=64.41 hrs (Summation of all above losses)
Total good hours=720hrs

Net loss (Total good hours-Total loss)

=720 hrs - 64.41hrs =655.19hrs

(a) Availability rate=(Net loss ÷ Total good hours) × 100

=(655.12 ÷ 720) × 100=90.99%

Thus, availability rate is 90.99%.

(b) Percentage of quality=(Total steam produced-Defected steam) ÷ Total steam produced
Defected steam=Total breakdown × Steam produced per hour=(7200-571.1) ÷ 7200=92.07%
Thus, quality rate is 92%.

(c) Performance rate=[Net loss-(Management loss+Start up loss] ÷ Net loss=[655.19-(90+15)] ÷ 655.19=83.97%. (Consumption item furnace oil per batch=5550 litters and 210,316 litter's/month, Management loss=90 hrs, Startup loss=15hrs). Thus, performance rate is 83.97%.

OEE=(Availability rate) × (Performance rate) × (Quality rate)100=(0.9099) × (0.8397) × (0.9207)=70.35%

[Note: If OEE is less than 85% (world class manufacturing performance for continuous manufacturing process industry) it indicates improvements are required urgently]

Similarly, before implementation of TPM, the results of total loss (hours) and OEE value was calculated for the months of February and March, 2011 (Tables 4 and 5). At the same time data was collected from production section monthly report as shown in Table 2.

Table 2 : Production section report January, 2011

Works planned to	Plan	Actual
Malt production (Quintal)	20,700	21326
Production cost (Birr)	-	16197395.13
Productivity (Man/Hrs.)	1.5	1.9
Date of submission of monthly production plan and report (Days)	25/01/11 and 1/02/11	25/01/11 and 1/02/11
Malting loss (%)	15-17	15.9
Down time-machineries problem (Hrs.)	36	82

Calculations on OEE of the boiler plant for June, 2011(after TPM implementation):

Mechanical breakdown=13.35hrs

Electrical breakdown=2.50hrs

Electronics breakdown=0

Total breakdown=16.25hrs

Setup and other conditions=7.30hrs

Total loss=23.55hrs (Summation of all above losses)
Total good hours=720hrs

Net loss (Total good hours-Total loss)

=720 hrs.-23.55hrs. = 696.05hrs

(a) Availability rate=(Net loss ÷ Total good hours) × 100

=(696.05 ÷ 720) × 100=96.67%

Thus, availability rate is 96.67%.

(b) Percentage of quality=(Total steam produced-Defected steam) ÷ Total steam produced
Defected steam=Total breakdown × Steam produced per hour=(7200-162.5 ÷ 7200)=97.74% ≈ 98%
Thus, quality rate is 98%.

(c) Performance rate=[Net loss-(Management loss+Start up loss)] ÷ Net loss =[696.05-(90+15)] ÷ 696.05=84.91%.(Consumption item furnace oil per batch= 5550 litters and 210,316 litters per month, Management loss=90hrs, Startup loss=15hrs)
Thus, performance rate is 84.91%.

OEE=(Availability rate) × (Performance rate) × (Quality rate) × 100%=(0.9667) × (0.8491) × (0.9774)=80.23%.

Similarly, after implementation of TPM, the results of total loss (hours) and OEE value was calculated for the month of May, 2011 (Tables 4 and 5). At the same time data was collected from monthly production section report as shown in Table 3.

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Table 3 : Production section report June, 2011

Works planned to	Plan	Actual
Malt production (Quintal)	19550	21649
Production cost (Birr)	17,034,000	17,406,221.316
Productivity(Man/Hrs)	1.5	2.5
Date of submission of monthly production plan and report (Days)	25/06/11 and 1/07/11	25/06/11 and 2/07/11
Malting loss (%)	15-17	15.2
Down time-machineries problem (Hrs)	36	38.35

The results of total loss (hours) and OEE calculation for three months during TPM implementation (before and after) in boiler plant at malt manufacturing factory are shown in Tables 4 and 5.

Table 4 : Total loss for OEE value calculation

Before TPM implementation (2011)		**After TPM implementation (2011)**	
Month	Total loss	Month	Total loss
January	64.48hrs	May	41.40hrs
February	81.40hrs	June	23.55hrs
March	62.50hrs		

Table 4 : OEE value for three months

Before TPM implementation (2011)		**After TPM implementation (2011)**	
Month	OEE value	Month	OEE value
January	70.35%	May	75.60%
February	66.44%	June	80.23%
March	70.81%		

VIII. Conclusion

A manufacturing facility has been studied and analyzed to study TPM implementation issues, the roadmap followed and the key benefits achieved from OEE as a result of TPM implementation. It can be seen that OEE on boiler plant has shown a progressive growth (Table 4), which is an indication of increase in equipment availability, decrease in rework, rejection and increase in rate of performance. As a result overall productivity of industry also increased (Table 3). OEE value is encouraging and with the passage of time results will be quite good and may reach a world class OEE value of 85%-90%.

TPM has been widely known in manufacturing environment. This proactive maintenance strategy contributed to manufacturing performance improvements are highlighted by various researchers (Tsang and Chang, 2000; Eti et al., 2004; Ahmad et al., 2005; Ahuja and Khamba, 2008b). Through TPM process focus, the cost and quality were improved significantly by reducing and minimizing equipment deterioration and failures. Cost of rework and repairs reduced due to very limited products rejected due to equipment failure. Thus, the overall effectiveness of equipment also improved significantly. Additionally, equipment deterioration was eliminated as the equipment operated efficiently. Autonomous maintenance activities were carried out with total employee participation. The investment in training and education managed to boost operator's morale and the commitment towards company's goals.

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