Measurement of Overall Equipment Effectiveness for Water Discharge System: A Case Study

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***Abstract*-Overall equipment effectiveness (OEE) is one of the performance evaluation methods that are most common and popular in the production plants. OEE is formulated of three components, which are availability, performance, and quality; it is used to determine various types of productivity losses. OEE method is implemented for performance evaluation of pumping station for water discharge. Six Big Losses such as Breakdowns, Setup and adjustments, Small Stops, Slow Running, Startup Losses and production Losses; these losses are important to identify for calculation of OEE. This paper presents the measurement of OEE for water discharge system in Narmada Water Supply Plant (NWSP) and using contains assumption through application of OEE. NWSP having five pumping station and it has design capacity of total water supply 180 Million Liter per Day (MLD), but actual daily Average water supply is low. NWSP are not able to fulfill of the total demand in their service areas. Data has been collected for three months for all pumping station for the same period. This study shows that there are three main losses during water discharge process mainly Downtime Losses (DL), Speed Losses (SL) and Quality Losses (QL). In this paper it has been investigated that during water discharge process DL, SL, QL reduce then World class level can be achievable.**

Keywords-Water discharge process; Overall equipment effectiveness; Key performance indicator; performance Measurement.

I. INTRODUCTION

OEE is an effective tool to benchmark, analyze, and improve your production process. The OEE tool gives you the ability to measure your machines for productivity improvements. OEE not only measures these inefficiencies but groups them into three categories to help you analyze the machine and have a better understanding of the production process. S. Nakajima et al. (1989) [1] Father of Total Productive Maintenance (TPM), has defined OEE is a comprehensive tool for Measuring performance of machine. Nakajima introduced this tool for assessing the success of TPM philosophy. According to Nakajima, OEE is applied to measure machine performance in term of availability, efficiency, and quality issue. These three elements concern with different losses as 1.Availability Rate-Equipment failure/breakdown losses and Set-up and adjustment losses. 2. Performance rate-Idling and minor stoppage losses and Reduced speed losses.3.Quality Rate- Defect rework losses and Start-up losses. Soniya Parihar, Sanjay Jain, Dr. Lokesh Bajpai et al. (2012) [2] are said OEE is a TPM tool; it is also commonly used as a Key Performance Indicator (KPI) in conjunction with lean manufacturing efforts to provide an indicator of success. It quantifies how well a manufacturing unit performs relative to its designed capacity, during the periods when it is scheduled to run. It is a well known concept in maintenance and is a way of measuring the effectiveness of a machine which evaluates and indicates how effectively a manufacturing operation is utilized. Disha M Nayak, et al.(2013) [3] this paper tries to evaluate the OEE index on insulation unit in a cable organization and identifies the main loss elements of the process. OEE data on machine performance is an initial key point to understand the equipment losses and establish improvement to eliminate them. The results are compared with world class level and result of the research demonstrates that although the OEE of assembly process is not meeting the world class level, however with the continuous improvement, performance of the machine can be acceptable. Binoy Boban1, Jenson Joseph et al. (2013) [4] the company has to low plant availability, increased rejection are a great threat to increase operating cost and lower productivity. The objective of the work is to enhance the OEE at a manufacturing company through the implementation of TPM. The company has to suffer due to lower availability of machines as a result of breakdowns. Comparison of OEE between before and after implementation of TPM can provide the much needed force to improve the maintenance policy. Islam H. Afefy et al. (2013) [5] have found the losses of Emisal company. The company produces anhydrous Sodium Sulphate and Sodium Chloride refined salt), Magnesium sulphate Heptahydrate (Epsom salt), Sodium chloride Pure. In anhydrous Sodium Sulphate plant most failure probably occurred. Osama Taisir R.Almeanazel et al. (2010) [6] TPM is also focusing on calculating the OEE benefits steel company and it also discuss what called the big six losses in any industry (the availability, speed and quality). Hemantsingh Rajput (2012) [7] TPM is a Maintenance program which involves a newly defined concept for maintaining production plants and equipment. The goal of the TPM program is to markedly increase production while, at the same time, increasing employee morale and job satisfaction.

Objectives

The objective of this case study,

- To identify the effectiveness of water discharge system in Narmada Water supply Plant (NWSP) through OEE.
- To compare OEE of NWSP with ideal/world class OEE.
- To identify and categorize major losses or reasons for poor performance.
- To suggest the ways to implement Total Productive Maintenance for maximizing water discharge plant effectiveness.

II. OVERALL EQUIPMENT EFFECTIVENESS

OEE was firstly proposed by Nakajima in 1988 [1].He proposed the OEE as a tool for assessing the success of TPM philosophy.OEE is a way to monitor and improve the efficiency of the production process. OEE has become an accepted management tool to measure and evaluate pumping machine productivity (water discharge). OEE is a tool for analyzing equipment performance based on three OEE factor measurable are directly related with six big equipment losses that interference with the effective operation of the equipment. Overall Equipment Effectiveness Model is shown in figure 1. OEE is broken down into three measuring metrics of **Availability, Performance** and **Quality.** These metrics help to gauge the machine efficiency and effectiveness and categorize these key productivity losses that occur within the production process. In practice, however, OEE is calculated as the product of its three contributing factors can be expressed as soniya parihar, July-Dec. 2012 [2]:

OEE = Availability x Performance x Quality.

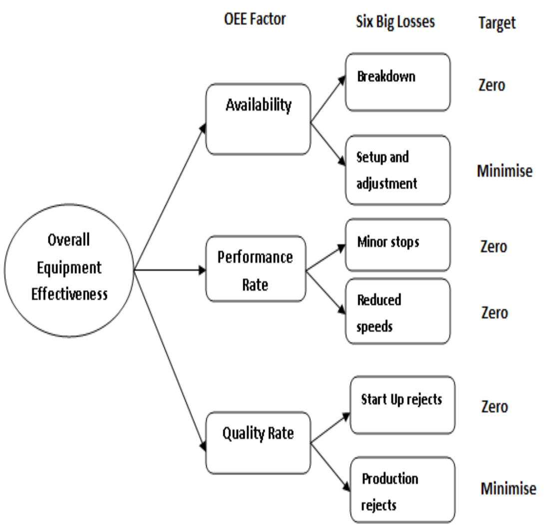

Fig. 1: Overall equipment effectiveness Model [2]

III. COMPONENT OF OEE

Three main factors make up the OEE calculation: They are

- Availability (A)
- Performance (P)
- Quality (Q)

A. Availability Availability represents the percentage of scheduled time that the equipment is available to operate. 100% Availability means the process has been running without any stops machine. The availability formula can be expressed as Islam H. Afefy, 2013 [5]:

Availability =

$$\frac{(\text{Total time} - \text{Total down time}) \times 100}{\text{Total time}}$$

- Availability takes into account **"Downtime Losses"** from
  - Pumps failures **(**Pump is breakdown>10 min.)
  - Setup and adjustments (Pump is breakdown>10 min.)

B. Performance Performance represents the Percentage of total actual amount of water produced on the pump machine to the production rate of machine (actual vs. designed capacity). 100% Performance means the process has been consistently running at its theoretical maximum speed. The formula to calculate the performance rate can be expressed as Disha M Nayak, 2013 and Soniya parihar July-Dec. 2012, [3]:

Performance rate =

<u>(Actual amt. of produced/Total operating time) X 100</u>

Design capacity of produced

- Performance takes into account **“Speed Losses”** from
  - Idling and Minor stoppages (Pump is stop< 10 min.)
  - Reduced speed operation (Actual vs. design cycle time)

C. Quality: Quality represents the Percentage of Good amounts produced out of the proposed amounts produced on the pumping machine. 100% *Quality* means there has been no defect amount The quality rate can be expressed in a formula as Chana et al.,2005 and H. Afefy 2013[5]:

Quality rate =

$$\frac{(\text{Proposed amount} - \text{Defect amount}) \times 100}{\text{Proposed amount}}$$

Where, **Defect amount** = Proposed amount – Actual amount of water supply.

- Quality takes into account **“Defect Losses”** from
  - Startup losses (pump required warm up time)
  - Production losses (Not production according to specification) .

IV. WORLD CLASS OEE

Islam H. Afefy et al. (2013) [5] has defined World class OEE is a standard which is used to compare the OEE of the plant. The percentage of World Class level OEE is given in Table I.

TABLE I

The percentage of world class OEE

OEE Factors	**OEE World Class**
Availability	90.0%
Performance	95.0%
Quality	99.9%
OEE	85.0%

V. PROBLEM DEFINITION

Narmada Water supply Plant (NWSP) has design capacity of total water supply / requirement 180 Million Liter per Day (MLD), but actual Average water supply is low. NWSP are not able to fulfil of the total demand in their service areas. In this case study is proposed TPM method will be used to find various types of productivity losses (Six Big Losses) and measurement of OEE in different pumping station PS-2, PS-3, PS-4, and PS-5 as shown in figure 2. Since OEE helps in indicating the process, performance and as well as equipment problem. OEE was used as a measurement tool to evaluate the plant productivity. Thus this metric help gauge the pumping machine efficiency, effectiveness and categorize these key productivity losses that occur within the water discharge process.

VI. THE WATER DISCHARGE PROCESS

Water discharge plant is situated at Mandleshwar and 70 km away from Indore. It is only one of the biggest plants of India for drinking water supply according to the height. This plant is major drinking water supply station for nearest cities. The main water source is at Village Jalud. In the first stage, with the help of five pumping station at various points along the pipeline, the water is pumped a distance of 22.10 Km and up to height of 680 meter at Vachoo Point(B.P. Tank) From there the water travels at distance of 47.9 Km. to Indore on gravitational force. The water discharge process is shown in fig.2.

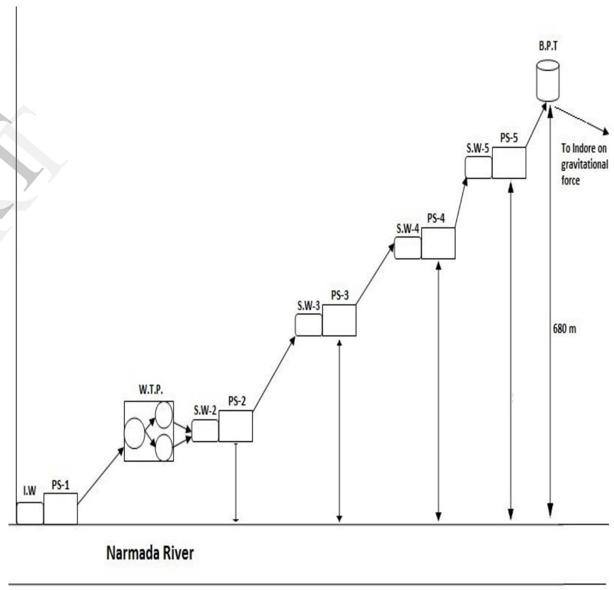

Fig. 2: Flow Chart of Water Discharge Process from Intake well (I.W.) to Back Pressure Tank (B.P.T.)

VII. IDENTIFICATION OF SIX BIG LOSSES IN WATER DISCHARGING PROCESS

One of the major goals of OEE programs is to reduce and/or eliminate what are called the Six Big Losses the most common causes of efficiency loss in water discharge process. The following table lists the Six Big Losses, and shows how they relate to the OEE Loss categories [3].

TABLE II
Six big losses in water discharging process

Six big losses category	**OEE loss category**	**Event examples**
Breakdowns	Downtime losses	• Fault in current • Tripped • Pipe line leakages • Water shortages in sump well • Incorrect assembly of pump (improper alignment to pump & motor
Setup and adjustments	Downtime losses	• Suction & Delivery valve Open / close • Warm-up time • Tripped
Small stops	Speed losses	• Under design capacity • Suction & Delivery valve Open / close • Warm-up time • Tripped
Reduced speed	Speed losses	• Low water level in sump well • Frequency & Voltage fluctuation. • Oldest Pump/motor life reduce due to continue running • Pump assembly parts life reduce and also gate valve at suction & delivery side. • Operator inefficient
Startup rejects	Quality losses	• Pipe line leakage • Leakage from suction/delivery valve • Sump well leakage • Friction losses in entrance/exit vortices • Separation disc friction losses • Friction losses in pipe line
Production rejects	Quality losses	• Pipe line leakage • Leakage from suction/delivery valve • Sump well leakage • Friction losses in entrance/exit vortices • Separation disc friction losses • Friction losses in pipe line

VIII. DATA COLLECTION & ANALYSIS

There are five pumping station in this plant. The first pumping station is raw water and next four pumping station is purified water. All the pumps installed in parallel combination in each pumping station and all the flow meters are fitted with individual pumps. Data has been collected for all the days of 3 months from Aug. 2013 to Oct. 2013 for the same period for all purified pumping station PS-2, PS-3, PS-4 and last PS-5. The data is pump wise flow rate is evaluated on daily basis and also combined water discharge is measure and analyzed pumping station wise. The operation is 24hrs.The daily average final water discharges in last pumping station PS-5, avg. data shown in table III.

TABLE III

Data collection of average water discharge from last pumping station (PS-5)

Parameters	Month			
	Avg. of Aug. 2013	Avg. of Sep. 2013	Avg. of Oct. 2013	Avg. of 3 Months
Shift Length/Total Time 24 hr.(sec.)	86400	86400	86400	86400
Total Down time of Pumps (sec.)	377	14670	10452	8500
Total available / Operating time (sec.)	86023	71730	75948	77900
Design capacity of pumps Configuration (l/s)	1622	1898	2073	1864
Target / proposed amt. of water supply (MLD)	142.99	164.05	179.13	162.06
Actual amount of water Supplied (MLD)	118.11	107.96	148.05	124.71
Defect amount rate (MLD)	24.88	56.09	31.00	37.32

The main losses during water discharge process which are as shown in figure 3and 4.

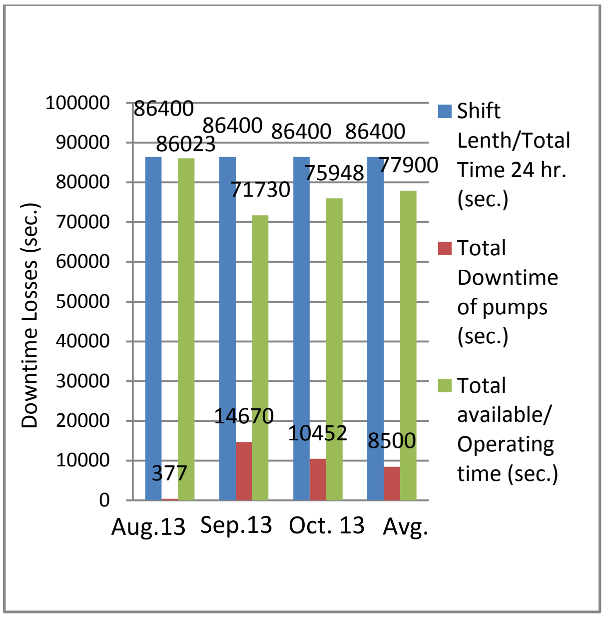

Fig. 3: Graphical representation of downtime losses avg. month wise & Avg. 3 months

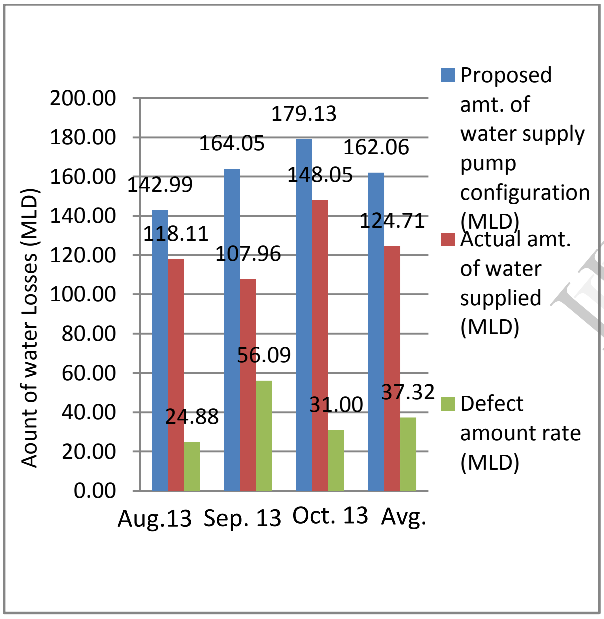

Fig. 4: Graphical representation of amt. of water discharge losses avg. month wise & Avg.3 months

IX. CALCULATION OF OEE

A. Availability
Availability takes into account Downtime Loss, and is calculated as:

Availability

= (Total time – Total down time) X 100
Total time

= (86400 –8500) x 100/ 86400

= 90.16 %

B. Performance
Performance takes into account **Speed Loss**, and is calculated as:

Performance rate =

(Actual amt. of produced/Total operating time) X 100
Design capacity of produced

= (124.71 x 1000000 / 77900) x 100 /1864
= 85.88 %

C. Quality
Quality takes into account **Quality Loss**, and is calculated as:

Quality rate =

(Proposed amount – Defect amount) X 100
Proposed amount

= (162.06 –37.32) x 100 / 162.06

= 76.97 %

D. Overall Equipment Effectiveness (OEE) *OEE* takes into account all three **OEE Factors**, and is calculated as:

OEE = Availability X Performance rate X Quality rate

= 0.9016 x 0.8588 x 0.7697

= 59.59 %

Graphical represent of Avg.OEE and its Components is show figure 5.

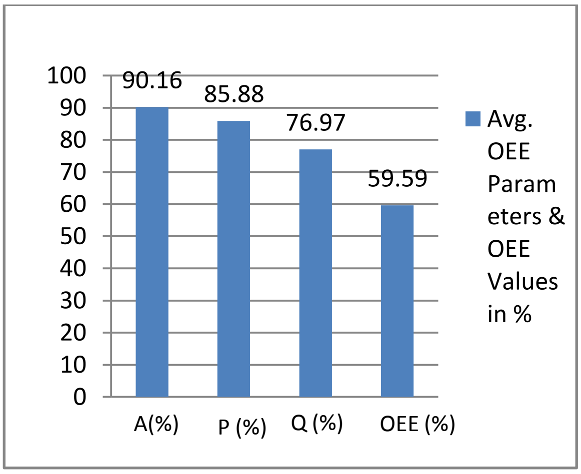

Fig. 5: Graphical represent of Avg.OEE and its Components

Comparison between World-Class OEE and pumping station water discharge process OEE rates are shown in table IV.

TABLE IV

Comparison of World Class OEE Factor and pumping water discharge process factor

OEE Factors	World Class	Water Discharge Process
Availability (A)	90.00%	90.16%
Performance (P)	95.00%	85.88%
Quality (Q)	99.90%	76.97%
O.E.E.	85.00%	59.59%

X. RESULTS

OEE factors of water discharge system in NWSP, the Availability is 90.16%, Performance is 85.88%, and Quality is 76.97%, OEE of NWSP water discharge process is 59.59 %.
There are three main losses during water discharge process which are downtime loss, speed loss, quality loss. These losses are important to identify for calculation of OEE and also to suggest improvement in existing process.

XI. CONCLUSION

Recent studies indicate that the average OEE rate of water discharge process in NWSP is 59.59 percent. As shown above a world-class OEE is considered to be 85 percent or better. Our water discharge process has 25.41% losses. These losses mainly are downtime losses, speed losses, quality losses which affect OEE. To minimize these losses and to achieve world class OEE there should be reduction in events which are discussed in six big losses section. The main events which are responsible for losses in water discharge process are shown in table II like as

- Fault in current
- Tripped
- Pipe line leakages
- Water shortages in sump well
- Incorrect assembly of pump (improper alignment to pump & motor)
- Operator inefficient
- Under design capacity due to continue running

It is important to reduce these non productive events which affect efficiency of the process. They can be reduce by implementing new techniques and tools, standardized speed for running the line, skilled labors, special purpose machinery which wont affects the environment of the shop floor etc.

A. RECOMMENDATION

This study selected the area of OEE and conducted an appropriate study on the subject. On the basis of the theory studied and analyzed, a set of recommendations were suggested in order to improve the OEE thereby increasing the water discharge of the pumping station.

- Control of extraneous leakages
- To remove number of joints in pipe line
- Proper alignment to pump and motor by Laser Alignment.
- To maintain sump well level (water level)
- Pump refurbishment work time to time according to maintenance schedule for maintaining pump life.
- Preventive maintenance time to time.
- Pumps and its driver's time to time checks according maintenance schedule.
- To remove fraction losses at pump casing inside area & made smooth surface by Belzona coating for improving water discharge.
- To repair suction & delivery gate valve for smooth running in operation & in future to be made Automation system
- To remove number of problem at pipe line leakages, during plant shutdown.
- OEE approaches can be applied in supporting technologies.
- We can experience changes in implementing OEE and can Identify, overcome barriers.

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REFERENCES

1. S. Nakajima, "Introduction to TPM", Productivity Press, Cambridge, MA, 1988.
2. Soniya Parihar, "Calculation of OEE an Assembly Process" IJRMET Vol.2, issue2, Jully-Dec 2012, pp. 25-29
3. Disha M Nayak, "Evaluation of OEE in a continuous process Industry on an insulation line in a cable manufacturing unit" IJERSET , Vol.2,Issue 5, May 2013, pp.1629-1634
4. Binoy Boban, "Enhancing Overall Equipment Effectiveness for a Manufacturing Firm through Total Productive Maintenance" ijetae, Vol.3, Issue8.August2013, pp. 425-429
5. Islam H. Afefy, "Implementation of Total Productive Maintenance and Overall Equipment Effectiveness Evaluation" IJMME-IJENS Vol:13 No:01, @ February 2013, pp.69-75
6. Osama Taisir R.Almeanazel, " Total Productive Maintenance Review and Overall Equipment Effectiveness Measurement" JJMIE *Volume 4, Number 4, September 2010 , pp. 517-522*
7. Hemantsingh Rajput, "A Total Productive Maintenance Approach to Improve Overall Equipment Efficiency" IJMER Vol.2,Issue.6, Nov – Dec. 2012 ,pp.4383-4386.

8. Laura Swanson, "Linking Maintenance Strategies to performance" International Journal of Production Economics, 70 (2001), pp. 237-144
9. Aaditya choubey, "Study The Initiation Steps Of Total Productivity Maintenance In An Organization And Its Effect In Improvement Of Overall Equipment Efficiency" (IJERA) ISSN:2248-9622, Vol.2,issue4, July-August 2012, pp.1709-1713
10. G.Chand, "Implementation of TPM in cellular Manufacture" Journal of Materials Processing Technology 103 (2000), pp. 149-154 .
11. M.M. Ravikumar, "Improving Equipment Effectiveness Through TPM" Medwell Journals, International Business Management 2(3), 2008, ISSN: 1993-5250, pp.91-96,
12. Ratapol Wudhikarn, "Implementation of Overall Equipment Effectiveness in Wire Mesh Manufacturing" IEEE International Conference on Industrial Engg. And Engg. Managemant (IEEM2011), 6-9 Dec.2011,Singapore, pp.819-823.
13. S. Fore, "Improvement of Overall Equipment Effectiveness through Total Productive Maintenance" World Academy of Science, Engineering and Technology 37 2010, pp. 402-410.
14. Ratapol Wudhikarn, "A Framework for Integrating Overall Equipment Effectiveness with Analytic Network Process Method" *International Journal of Innovation, Management and Technology, Vol. 4, No. 3, June 2013, pp. 351-355.*
15. R. Wudhikarn, "Overall Weighting Equipment Effectiveness" Proceedings of the 2010 IEEE IEEM, 978-1-4244-8503-1/10©2010 IEEE, pp. 23-27.
16. Ratapol Wudhikarn, "2010 2nd International Conference on Information and Multimedia Technology (ICIMT 2010), pp. V2-235-239.
17. Abdul Talib Bon et al., "Evaluating total productive maintenance using overall equipment effectiveness :fundamental study", Elixir Prod. Mgmt. 36 (2011),pp. 3293-3295.
18. V. Palanisamy and Jose Ananth Vino, "Implementing Overall Equipment Effectiveness in a Process Industry", Indian Journal of Science and Technology | Print ISSN: 0974-6846 | Online ISSN: 0974-5645, www.indjst.org | Vol 6 (6S) | June 2013, pp.4789-4793.