Effective Implementation of Planned Maintenance in a Gas Producing Plant: A Case Study at JSPL, Raigarh

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Abstract - *TPM is a Japanese concept for optimizing the efficiency of equipment. TPM methodology is performed by all employees from top management to bottom line of an organization. Planned Maintenance (Keikaku Hozen), one of the pillars of TPM is implemented for systematic maintenance planning of the equipment, to achieve the maximum availability of equipment, minimize maintenance cost, etc. Equipment availability is ensured by reducing failures and various losses. In this study, planned maintenance methodology of TPM is used to ensure maximum availability of machines by analyzing and implementation of effective planned maintenance system on the basis of past data of equipment failures. Systematic maintenance plan is basic requirement for smooth running of the plant and make a hazel free work environment within the organization.*

The main intention of this work is to pronounce the positive effect of Planned Maintenance Pillar of TPM on increasing equipment reliability, maintainability, performance, reducing maintenance costs, equipment failures, etc.

***Key Words*: Total Productive Maintenance (TPM), Gas Producing Plant, Planned Maintenance, Availability, Kaizen, Why-Why Analysis**

1. INTRODUCTION

TPM aims to maximize overall equipment efficiency, develop and establish a planned maintenance system for the entire life of equipment, ensure involvement of every single employee from all the departments in TPM activity, and encourage small group activities [1].

Planned maintenance (PM) is one of the most important pillars of TPM and very strong linkage with other pillars of TPM (Table 1). Its aims to improve the effectiveness of operational equipment, in terms of increasing its reliability, maintainability, performance, reducing maintenance costs and equipment failures, through scheduled maintenance tasks. These tasks are based on predicted and/or measured failure rates. In order to implement planned maintenance successfully, support is required from both Maintenance and Production personnel, in the execution of the planned maintenance pillar.

Table – 1: Linkage of PM with other TPM pillar activities

PM-JH	▪ PM team train JH team about basic mechanical, electrical function of equipment. ▪ Teach JH member to develop OPLs (One Point Lessons) ▪ Teach how to find Fuguais / abnormalities during initial cleaning.
PM-QM	▪ Finding and listing out the equipment parts which are responsible for quality of product and maintain these to its ideal operating state.
PM-DM	▪ Finding and Listing out of inherent design weaknesses present in the equipment. ▪ Kaizens done to eliminate weaknesses. Those weaknesses designs must be deployed horizontally to new procured machines.
PM-KK	▪ Done kaizens to reduce losses e.g., breakdown energy, etc. ▪ Reduce MTTR, increase MTBF, improve availability.
PM-E&T	▪ Relay teaching methodology ▪ OPLs /on the job training ▪ Cut out section models.
PM-SHE	▪ Inspection of the condition of pressure vessels, lifting tackles, dust collectors and general electrical inspection on regular basis. ▪ Monitoring and controlling the environment parameters e.g., quality of ambient air inside and out the factory premises, water, noise pollutions, stack emissions, etc.
PM-OTPM	▪ Controlling and management of maintenance spares parts inventory. ▪ CMMS for recording various maintenance activities. ▪ To avoid management losses, JIT methodology to procure spare parts, consumables, etc. ▪ Transport arrangements in time.

The purpose of PM is to schedule maintenance tasks and thereby avoid unscheduled down time. This requires measured failure rates, in order to predict breakdowns in the future and prevent identical or similar major breakdowns from reoccurring.

Improvements in the reliability and maintainability of equipment, increases the availability of the machine and thereby reduces losses.

The major losses which affects the availability of the machine adversely are:

1. Shutdown loss
2. Equipment failure loss
3. Setup and Adjustment loss
4. Startup loss

The availability of the machine can be calculated as follows:

Availability = (MTBF - MTTR)/ MTBF

Where,
MTBF = (Scheduled time - Down time)/ No. of failures
MTTR = Down Time / No. of failures

2. Literature Review

S. Nakajima [1], a pioneer in the field of TPM, mentioned that even if machines are fully automated still maintenance required. In his work he clearly defined preventive maintenance, productive maintenance and Total productive maintenance. Involvement of all people from shop floor to top management in TPM makes this maintenance methodology different from others. For the effective implementation of TPM, Nakajima suggested 12 essential steps consist of four stages. He emphasized that without the involvement of top management and creating work environment which supports autonomous maintenance activity TPM cannot be successful.

Kinjiro Nakano [2] cited that for proper maintenance system, autonomous maintenance (AM) and PM personnel should work with coordination to eliminate the failures and breakdowns. Further he emphasized that only by preventive maintenance system zero failure/breakdown cannot be achieved.

The factor of breakdowns was subsequently broken into five factors. Obviously, the elimination of these five factors would result in zero breakdowns. He also suggested five countermeasures for concrete actions against zero failure / breakdown.

Manoj Kumar Kar [3] explains, in his case study, major steps to implement a systematic planned maintenance system. Activities which should be done in each step for the effective implementation of planned maintenance are mentioned. In his work he tried to find out correlation between Mean Time to repair (MTTR) and availability to forecast availability.

Dr. Manish Raj et al.[4] recited the different Kobetsu Kaizen losses were identified which affect the different parameter of OEE (Overall equipment efficiency) i.e., Availability, Performance rate and Quality rate. Kaizen are done for major losses and the same cycle of step was followed to reduce other losses as well.

T. Suzuki [5] quoted that equipment management in process industry like steel industry is influenced by type of equipment, the nature of its process & equipment failures, the skill levels and roles of maintenance personnel, etc. Different type of equipment need different equipment maintenance practice like static equipment need corrosion, leaks, degradation checks whereas rotating components need vibration, loose or fallen-off parts checks.

In Planned Maintenance Manual [6], it is narrated that various activities which are performed under autonomous maintenance and planned maintenance, and how planned maintenance personnel help autonomous maintenance team are elaborated in the manual. How other pillars of TPM are interlinked with PM pillar is also elaborated.

3. Methodology

The objective of PM is to “establish and maintain optimal equipment and process conditions”. (Suzuki 1994). As defined by JIPM, “Devising a planned maintenance system means raising output (no failures, no defects) and improving the quality of maintenance technicians by increasing plant availability (machine availability). Implementing these activities efficiently can reduce input to maintenance activities and build a fluid integrated system, which includes

- Regular preventive maintenance to stop failures (Periodic maintenance, predictive maintenance).
- Corrective maintenance and daily MP [maintenance prevention] to lower the risk of failure.
- Breakdown maintenance to restore machines to working order as soon as possible after failure.
- Guidance and assistance in ‘Jishu-Hozen’ (AM).”

Like Focused Improvement, PM supports the concept of zero failures. “Planned maintenance activities put a priority on the realization of zero failures. The aim of TPM activities is to reinforce corporate structures by eliminating all losses through the attainment of zero defects, zero failures, and zero accidents. Of these, the attainment of zero failures is of the greatest significance, because failures directly lead to defective products and a lower equipment operation ratio, which in turn becomes a major factor for accidents.” (Shirose 1996). Maintenance activity can be viewed as a continuum of regimes as depicted in Fig. 1.

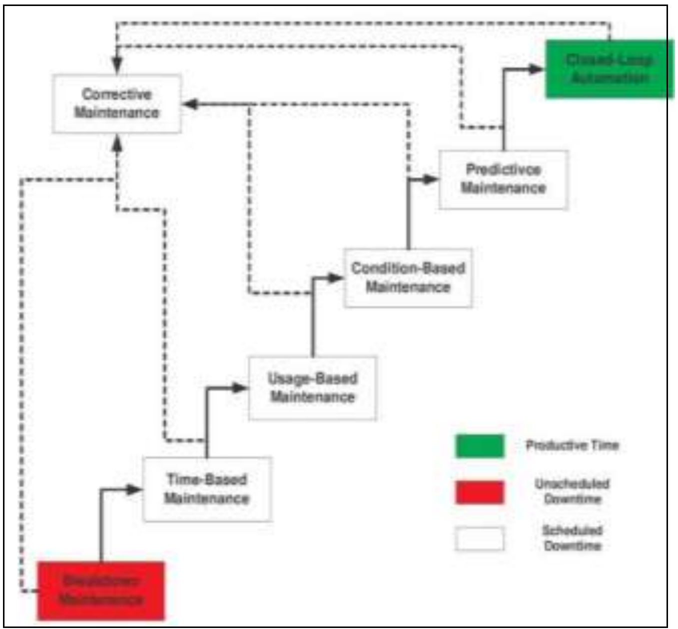

Fig - 1: Maintenance Regimes

Main Objective of implementing planned maintenance are

1. Achieve and sustain availability of machines
2. Maintenance planning and scheduling
3. Minimizing equipment failure and breakdown

To achieve the above objectives of the plant, the following steps under PM is adopted for the study:

S-1: Equipment criticality evaluation criteria and ranking

S-2: Reversing deterioration and rectify defects

S-3: Development of an information management system

S-4: Development of a robust periodic maintenance system

S-5: Development of a predictive maintenance system

S-6: Measurement of effectiveness of the implemented Planned Maintenance system

4. Steps involved in PM

S-1: Equipment criticality evaluation criteria and ranking

Master equipment list should be prepared. Every equipment should be evaluated against the set criteria (as shown in Fig. 2) for its ranking. Ranking is done to prioritize the equipment to take in PM. On the basis of rank all 'A'-ranked equipment may be selected for PM system first.

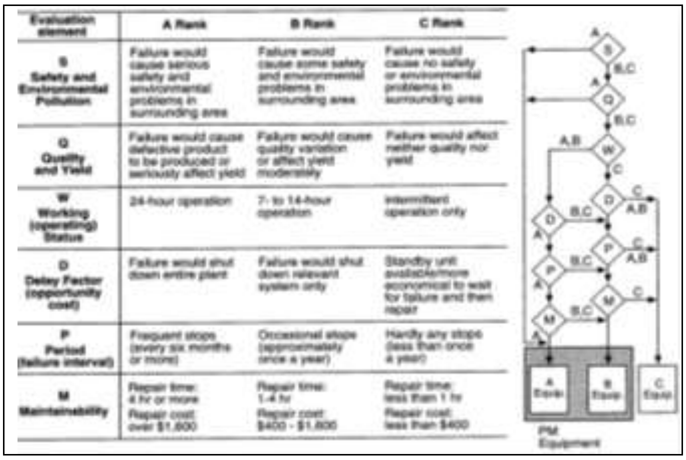

Fig – 2 : Equipment criticality evaluation criteria for ranking

S-2: Reversing deterioration and rectify defects

The primary step of PM personnel is to support AM activities for reversing deterioration, rectify design weaknesses / defects and restore equipment to its best / original operating condition.
Following activities are performed to help operators or to support AM activities:-

- Prepare One-Point Lessons (OPLs) sheets
- Prepare visual control standards and help operators to implement them.
- Prepare General Inspection Manual (GIM) and provide guidance to operators for understanding the current working system.
- Educate operators about different types of lubricants being used for different purposes.

To correct inherent weaknesses generated during design making, fabrication and installation PM team may use techniques like Failure mode and effect analysis (FMEA), P-M analysis, etc. to stop all the unexpected failures / breakdowns.

S-3: Development of an information management system

An effective equipment failure data management system is developed which include information like date, time, duration of failure, severity (major, intermediate, minor), nature of failure (like overheating, corrosion, vibration, etc.), action taken, hours and number of person required for restoration.

A system needs to be build up for controlling spare parts and materials to track stocks available, issues and receipts. System must include the information about equipment and component models, specification, order number, order month and also build a system for collecting technical information and drawings like flow diagrams, wiring drawings, equipment logs and so on.

S-4: Development of a robust periodic maintenance system

In periodic maintenance or Time-based maintenance of equipment spare parts, inspection equipment, lubricants are required in advance to carry out the schedule maintenance work. To prepare a systematic maintenance interval (like yearly, monthly, weekly and daily) the failure history of equipment, machine manufacturer manual, operators experience and average life of equipment details are essentially required.

S-5: Development of a predictive maintenance system

Predictive maintenance is also known as condition based maintenance and uses equipment diagnostics technique. Diagnostic techniques include the measurement of vibration, temperature, pressure, flow rate, lubricant contamination, wall thickness decrement, metallurgical defect growth, corrosion rate, electrical resistance etc. Trained maintenance team is required for equipment diagnosis and proper handling of diagnostic equipment. Equipment are identified on which suitable diagnostic technique can be performed (like vibration diagnosis done for rotating machines like feed pumps or gas compressors). This depends on equipment condition whether it is in static state or is in operation.

S-6: Measurement of effectiveness of the implemented PM system

By following above mentioned steps reduction in major breakdowns of 'A' equipment can be achieved. For observing the maintenance improvement indicators like major breakdown number, MTTR, MTBF, availability of equipment, etc. are considered.

5. CASE STUDY

5.1 Introduction of the Plant

The gas producing plant (capacity = 2000 NM^3/Hr/Gasifier) of Jindal Steel & Power Plant, India manufacture and provide useful combustible gas to some of its major departments section like Steel melting shop, Medium and Light structure mill. This gas is the mixture of mainly carbon monoxide and Hydrogen ($CO + H_2$). This combustible gas is produced by burning carbonaceous fuels (coal) in the presence of air. It is primarily a substitute for the furnace oil which is used as a fuel in the re-heating furnaces of mills and for other heating purposes e.g. ladles heating, tundish heating, etc. in steel melting shops.

The plant doesn't had a robust systematic plan of maintenance based on failure history due to which gas plant faced more number of equipment failures / breakdown. These losses ultimately affected the availability of machines adversely. Hence, to reduce the number of equipment failures / breakdown and ensure maximum availability of machines, the PM methodology of TPM was reinforced in gas plant.

5.2 Data Collection

For the study purpose, failure/breakdown record taken from January 2016 to December 2017. The data was collected for all failures/breakdown occurred during that period and MTTR, MTBF and availability are calculated. Data collected for all equipment and criteria of ranking was analyzed against all parameters and based on evaluation criteria, equipment's were ranked as per their score. The equipment's with more than 25 points are classified as 'A'-rank equipment, equipment's more than 20 are classified as 'B'-rank equipment and rest are 'C'-rank equipment. Table 3 shows the classification of equipment's based on score.

6. Data Analysis and Discussion

After collecting the data (Jan '16 to Dec. '17), it was found that the most critical equipment's ('A'-rank equipment) Gasifier, Booster fan and Electrostatic tar precipitator whose non-availability will lead to plant shut down or major quality issue. The cost of repairing, periodicity of failures and time to repair were very high for mentioned equipment.

As mentioned earlier, under PM S-1, equipment criticality evaluation criteria and ranking was done, for this, a master equipment list was prepared. Every equipment was evaluated against the set criteria (as shown in Fig - 2) for its ranking. Ranking is done to prioritize the equipment to take in PM. On the basis of rank all 'A'-ranked equipment were selected for PM system first.

As shown in Table-2 it was found that gasifier, booster fan and ETP are critical equipment for gas producing plant where as Chart – 1 shows the % distribution of equipment ranking.

Table – 2 : Ranking of equipment

Equipment	S (Max. score 5)	Q (Max. score 5)	W (Max. score 5)	D (Max. score 5)	P (Max. score 5)	M (Max. score 5)	Total Score	Rank
Gasifier	5	5	5	5	3	5	28	A
Booster Fan	5	5	5	5	3	5	28	A
Electrostatic Tar Precipitator	5	5	5	5	3	5	28	A
Boiler	5	3	5	3	3	5	24	B
Combustion Air Blower	3	5	5	5	3	3	24	B
Soft Water Pump	3	5	5	5	3	3	24	B
Re-Circulation Water Pump	3	3	5	3	3	5	22	B
Raw Material Handling System	5	0	5	3	3	5	21	B
Ash Conveyor	5	0	5	3	3	5	21	B
Poke Hole Air Blower	3	3	5	0	3	3	17	C
Waste Water Disposal Pump	3	0	5	0	3	3	14	C

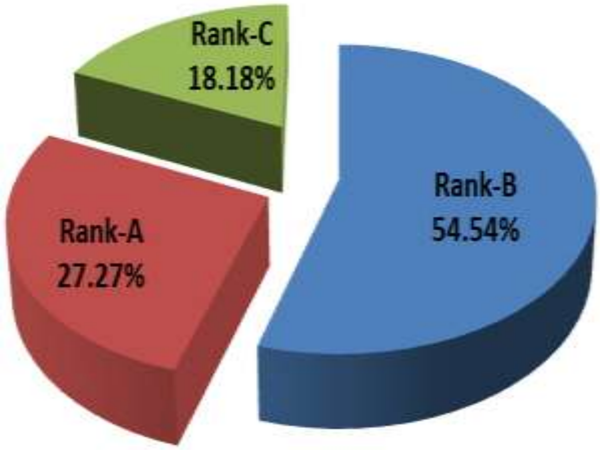

Chart – 1 : % distribution of equipment ranking

Data were collected for past failures/breakdown of these 'A' rank equipment. The details of failure number, downtime time and reasons for failures are listed in Tables 3, 4 and 5.

Table – 3 : Failure history of A-rank equipment during 2016

Month	Failure Type	Time (minutes)
Jan-16	Support roller bearing of ash bowl in gasifier changed	270
	Leakage of nitrogen line of ETP	60
Feb-16	Bush change / cleaning of coal charging system	60
	Support roller bearing of ash bowl in gasifier changed	225
	Inner core puncture of ash bowl in gasifier	180
	Skid welding done in ash bowl	90
Mar-16	Support roller bearing of ash bowl in gasifier changed	230
	Pneumatic cylinder change	90
Apr-16	Choking due to coal tar in ETP	120
	Support roller bearing of ash bowl in gasifier changed	240
	Pulley change	60
May-16	Support roller bearing of ash bowl in gasifier changed	190
	Pneumatic cylinder seal change	45
Jun-16	Terminal burning of wall bush in ETP	480
	Support roller bearing of ash bowl in gasifier changed	200
Jul-16	Fail of gas vent valve of ETP	120
	Support roller bearing of ash bowl in gasifier changed	245
	V-belt change / replace of booster fan	20
	Mechanical seal change of booster fan	300
Aug-16	Bearing change of air blower	300
	Support roller bearing of ash bowl in gasifier changed	210
	Bellcone cleaning of coal charging system	210
	V-belt change / replace of booster fan	25
Sep-16	Electrode misalignment of ETP	480
	Support roller bearing of ash bowl in gasifier changed	240
	Pulley change	80
Oct-16	Impeller cleaning of booster fan	240
	Support roller bearing of ash bowl in gasifier changed	205
	Skid welding done in ash bowl	110
	Leakage of nitrogen line of ETP	80
	Bellcone cleaning of coal charging system	105
Nov-16	Nozzle choking due coal tar in ETP steam purging nozzle	180
	Support roller bearing of ash bowl in gasifier changed	220
	Pneumatic cylinder seal change	40
	Fail of gas vent valve of ETP	105
Dec-16	Skid change of ash bowl	720
	Bellcone cleaning of coal charging system	110
	Support roller bearing of ash bowl in gasifier changed,	255

Table – 4 : Failure history of A-rank equipment during 2017

Month	Failure Type	Time (minutes)
Jan-17	Impeller change of air blower	300
	Support roller bearing of ash bowl in gasifier changed	260
	Bush change / cleaning of coal charging system	80
	Bellcone cleaning of coal charging system	90
Feb-17	Pulley change	80
	Support roller bearing of ash bowl in gasifier changed	210
Mar-17	Pneumatic cylinder change	30
	Support roller bearing of ash bowl in gasifier changed	205
	Fail of gas vent valve of ETP	130
Apr-17	Mechanical seal change of booster fan	300
	Support roller bearing of ash bowl in gasifier changed	240
	Hose change of coal charging system	10
	V-belt change / replace of booster fan	15
	Pneumatic cylinder change	30
	Bush change / cleaning of coal charging system	90
May-17	Burning of terminal in heater of ETP	120
	Support roller bearing of ash bowl in gasifier changed	240
	Skid welding done in ash bowl	120
Jun-17	Terminal burning of wall bush in ETP	440
	Support roller bearing of ash bowl in gasifier changed	210
	Choking due to coal tar in ETP	150
	Hydraulic cylinder change of ash bowl	30
Jul-17	Electrode misalignment of ETP	450
	Support roller bearing of ash bowl in gasifier changed	330
Aug-17	Bellcone cleaning of coal charging system	120
	Support roller bearing of ash bowl in gasifier changed	200
	Bush cracking of wall bush in ETP	480
	Skid welding done in ash bowl	60
Sep-17	Hydraulic cylinder change of ash bowl , 30 min	30
	Support roller bearing of ash bowl in	250

	gasifier changed	
	Fail of gas vent valve of ETP	130
Oct-17	Inner core puncture of ash bowl in gasifier	190
	Support roller bearing of ash bowl in gasifier changed	220
	Fail of gas vent valve of ETP	105
Nov-17	Shaft change of booster fan	480
	Impeller change of air blower	30
	Support roller bearing of ash bowl in gasifier changed	240
	Choking due to coal tar in ETP	120
Dec-17	Impeller change of air blower	300
	Bellcone cleaning of coal charging system	100
	Support roller bearing of ash bowl in gasifier changed	210
	Bush change / cleaning of coal charging system	90
	Pulley change	30

Table – 5 : Summary of failure and downtime of A-rank machine

Month	Failures(Nos.)		Downtime(Minutes)	
	2016	2017	2016	2017
January	2	4	330	730
February	5	2	555	290
March	2	3	320	340
April	3	6	420	560
May	2	3	235	480
June	2	4	680	830
July	3	2	665	680
August	4	4	625	860
September	2	3	800	410
October	4	3	740	515
November	4	4	505	870
December	3	5	1085	760

In PM S-2, the restoration of forced deterioration and rectification of weakness were done. To restore deterioration of Equipment's daily cleaning checklists were prepared, General Inspection Manual (GIMs) were made and provided to the operators so that they could understand the standard operating condition of equipment. Several fuguais (abnormality) like leakages, vibration, inaccessible places, unsafe places are identified and corrective actions were done by taking kaizens to eliminate these abnormalities.

Major breakdown in gas producing plant was the monthly failure of support roller bearing in ash bowl which was basically a design weakness. Every time, approx. 3-5 hours was required to change these roller bearing. Hence, to correct this design weakness, a kaizen project was taken and roller bearing setup was changed with thrust bearing. The monthly breakdown of roller bearing problem was permanently eliminated.

Under PM S-3, an information Management system was developed. New formats were prepared to capture more information about failure/breakdown e.g., date and time, equipment model, nature of failure (overheating, high noise, corrosion, etc.), cause for failure, action taken, time and number of persons required for repair work. This database of failure history was very helpful in making decisions like preparation of preventive maintenance schedule, spare parts inventory, making of predictive maintenance system and procurement process of spare parts, lubricants, etc. This information is still useful for future improvement in such areas.

For developing a robust periodic maintenance system, under PM S-4, first of all, all equipment and components were selected which required periodic maintenance and predictive maintenance.

For making a systematic periodic maintenance system (time interval of maintenance for different equipment), available failure/breakdown data for past two years were thoroughly examined. To analyze frequent failures and to determine the root cause, why-why analysis was done. Considering the failure frequency of critical equipment, Manufacturer Guidelines and operator experience, a tentative periodic maintenance schedule was developed (Table – 6).

Table – 6 : Tentative periodic maintenance schedule for A-rank machines

'A'-rank machine and its main components		Frequency of Periodic Maintenance
Gasifier		
1	Bearing check of air blower	6 Month
2	Air blower coupling checking	6 Month
3	Air blower impeller checking	1 Year
4	Coal charging system bush cleaning	15 Days
5	Bellcone cleaning of coal charging system	15 Days
6	Coal charging system pneumatic cylinder checking	15 Days
7	Hose change	2 Month
8	Thrust bearing lubrication checking	1 Month
9	Ash bowl skid checking	1 Month
10	Ash bowl hydraulic cylinder checking	15 Days
Booster fan		
1	Impeller checking	45 Days
2	Mechanical seal checking	45 Days
3	Shaft checking	2 Years
4	Pulley / coupling checking	45 Days
Electrostatic tar precipitator		
1	Checking of Wall Bush	6 Month
2	Support insulator checking	1 Years
3	Discharge electrodes alignment	6 Month
4	ETP tar discharge seal choking check	3 Month
5	Gas Vent Valve of ETP Failure Checking	8 Month
6	Nitrogen line of ETP leakage checking	1 Year
7	ETP steam purging nozzle choking	2 Month
8	Heater of ETP Coil Damage Checking	5 Month

Similarly, a predictive maintenance system was developed under PM S-5. The Predictive maintenance system (CBM-condition based maintenance) used for checking of vibration, alignment of all rotating parts including pumps & booster, leakages of gas network, noise level, heat, corrosion etc. A systematic schedule was made for predictive maintenance (Table – 7).

Table – 7 : Tentative predictive maintenance schedule

Equipment & Testing	Frequency
Alignment of shaft	Monthly/as when required
Vibration Checking of rotating component	Monthly/as when required
Static & Dynamic balancing of Impeller	Monthly/as when required
Bearing Clearance	Monthly/as when required
Belt pulley alignment	2 Month/as when required
Hydraulic oil testing (NAS level) in Hydraulic Power pack	15 Days/as when required
CO gas leakage identification and rectification in gasifier and gas network	Monthly/as when required

Under PM S-6, the measurement of effectiveness of the implemented PM system was carried out.

For the evaluation of implemented PM system, the data for failure (in nos.) and downtime (in min) were collected for the period of Jan – Aug. 2018. MTTR, MTBF, availability and number of major breakdown were taken as key performance indicators for the evaluation for implemented PM system.

Table - 8 depicts failure and downtime of A-rank machines whereas Chart – 2 shows the trend of the same.

MTBF, MTTR and availability, for the years 2016, 2017 & 2018, have been tabulated in Tables – 9, 10 and 11 respectively whereas Chart – 3 shows the trend of % availability.

Charts – 4, 5, and 6 shows the comparison of the data related to MTTR, MTBF and Availability for different years.

Table – 8 : Failure and downtime of A-rank machines

Month	Failures (nos.)			Downtime(minutes)		
	2016	2017	2018	2016	2017	2018
January	2	4	2	330	730	90
February	5	2	1	555	290	120
March	2	3	2	320	340	135
April	3	6	2	420	560	150
May	2	3	1	235	480	120
June	2	4	1	680	830	45
July	3	2	2	665	680	200
August	4	4	1	625	860	130
September	2	3		800	410	
October	4	3		740	515	
November	4	4		505	870	
December	3	5		1085	760	
Avg.	**3**	**3.58**	**1.5**	**580**	**610**	**124**

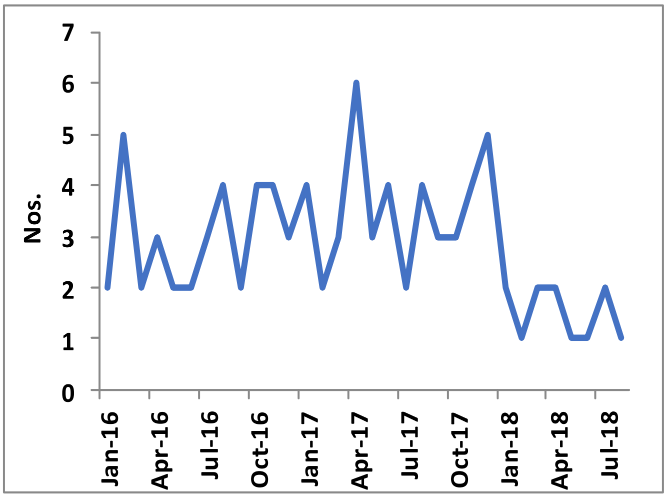

Chart – 2 : Trend of nos. of failure

Table – 9 : MTBF data for A-rank equipment during 2016-2018

Schedule time, hrs.	Month	MTBF		
		2016	2017	2018
580	JAN	287.25	141.96	289.25
580	FEB	114.15	287.58	578.00
580	MAR	287.33	191.44	288.88
580	APR	191.00	95.11	288.75
580	MAY	288.04	190.67	578.00
580	JUN	284.33	141.54	579.25
580	JUL	189.64	284.33	288.33
580	AUG	142.40	141.42	577.83
580	SEP	283.33	191.06	
580	OCT	141.92	190.47	
580	NOV	142.90	141.38	
580	DEC	187.31	113.47	
Avg.		**211.63**	**175.87**	**433.54**

Table – 10 : MTTR data for A-rank equipment during 2016-2018

Schedule time, hrs.	Month	MTTR		
		2016	2017	2018
580	JAN	2.75	3.04	0.75
580	FEB	1.85	2.42	2.00
580	MAR	2.67	1.89	1.13
580	APR	2.33	1.56	1.25
580	MAY	1.96	2.67	2.00
580	JUN	5.67	3.46	0.75
580	JUL	3.69	5.67	1.67
580	AUG	2.60	3.58	2.17
580	SEP	6.67	2.28	
580	OCT	3.08	2.86	
580	NOV	2.10	3.63	
580	DEC	6.03	2.53	
Avg.		**3.45**	**2.96**	**1.46**

Table – 11 : Availability data for A-rank equipment during 2016-2018

Schedule time, hrs.	Month	Availability		
		2016	2017	2018
580	JAN	0.990	0.979	0.997

580	FEB	0.984	0.992	0.997
580	MAR	0.991	0.990	0.996
580	APR	0.988	0.984	0.996
580	MAY	0.993	0.986	0.997
580	JUN	0.980	0.976	0.999
580	JUL	0.981	0.980	0.994
580	AUG	0.982	0.975	0.996
580	SEP	0.976	0.988	
580	OCT	0.978	0.985	
580	NOV	0.985	0.974	
580	DEC	0.968	0.978	
Avg.		0.9830	0.9821	0.9964

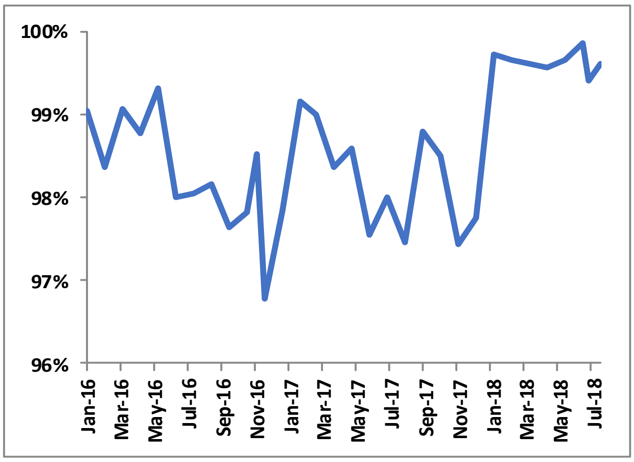

Chart – 3 : Trend of % Availability

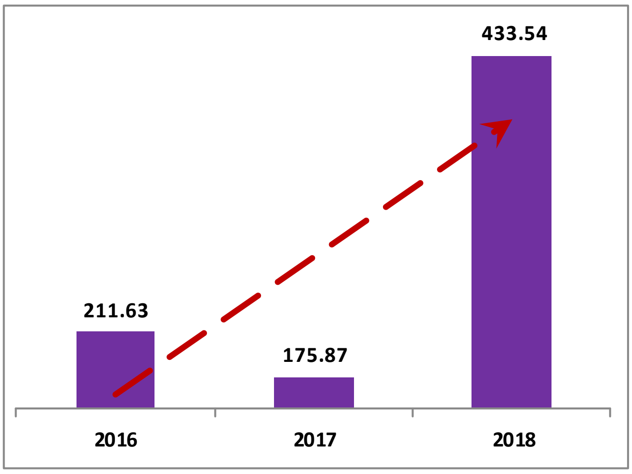

Chart – 4 : Trend of MTBF, in hrs.

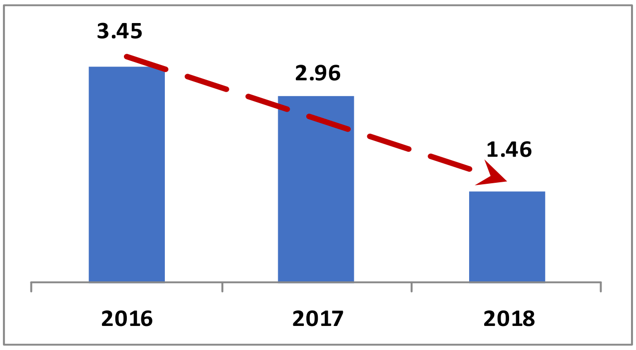

Chart – 5 : Trend of MTTR, in hrs.

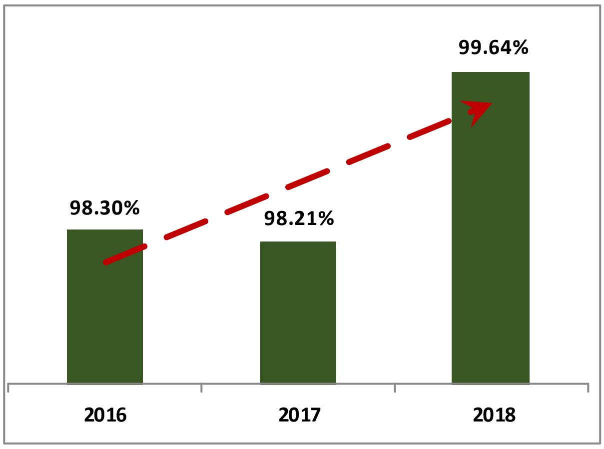

Chart – 6 : Trend of Availability

7. Conclusions

It can be observed from above mentioned tables and charts that

- ✓ The major breakdown was the monthly failure of support roller bearing was permanently eliminated since Jan. 2018.
- ✓ Avg. no. of failures has been reduced from 3.58 to aprrox. 1.5.
- ✓ MTBF has been increased from 175.8 hours to 433.5 hours.
- ✓ MTTR has decreased from 3.45 hours to 1.46 hours
- ✓ Equipment availability has been of increased from 98.2% to 99.64%.

Although, only few data after implementation of PM available, but all the parameters of equipment availability, MTBF, MTTR, etc. shows improvement. Hence, an effective and robust PM system ensures a systematic approach through which the goal of zero failures / breakdowns can be achieved.

7. Future scope of work :

Failure/breakdown can be minimized further with the shifting of periodic maintenance to predictive maintenance (condition based maintenance) and by using more advance information management system like computer maintenance management system (CMMS) for proper control on spare parts and maintenance activities. To get most out of CMMS, it should be implemented once plant became stabilized. For improving design weaknesses or to reduce losses which contribute to availability, more kaizen projects should be taken on regular intervals.

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