TOTAL PRODUCTIVE MAINTENANCE
PLANNED MAINTENANCE
STEP 1
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1. Introduction

Planned maintenance (PM) is the third pillar of Total Productive Maintenance (TPM). Its purpose is to improve the effectiveness of operational equipment, in terms of increasing its reliability, maintainability and performance and 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. The benefits of introducing a planned maintenance system are described in the section following, as an incentive to working together as a team in its implementation.

A series of steps make up the planned maintenance pillar, with this module focusing on step one – evaluating equipment failures and assessing the current situation. Each step contributes to the reduction and prevention of unforeseen equipment failures and breakdowns.

This module is aimed at describing the activities required for implementing step one of planned maintenance.
2. Planned maintenance benefits

The benefits of planned maintenance are depicted below:

<table>
<thead>
<tr>
<th>BENEFITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) The quality of the part is maintained,</td>
</tr>
<tr>
<td>b) Increase in production up-time,</td>
</tr>
<tr>
<td>c) Reduced cost of operations,</td>
</tr>
<tr>
<td>d) Reduction in the number of machinery required,</td>
</tr>
<tr>
<td>e) Improving equipment capability and reliability – increasing the mean-time-between-failures (MTBF),</td>
</tr>
<tr>
<td>f) Improving equipment maintainability by reducing sporadic maintenance time – reduction in the mean-time-to repair (MTTR),</td>
</tr>
<tr>
<td>g) Establishing/improving predictive maintenance,</td>
</tr>
<tr>
<td>h) Reduced maintenance costs.</td>
</tr>
</tbody>
</table>
Consequently, poor maintenance activities have a negative effect on operational activities and are listed in figure 1 below:

![Figure 1: The effect of poor maintenance activities](image)

3. Planned maintenance responsibilities

The implementation of planned maintenance activities requires the commitment and support of both Production and Maintenance. Each play a role in ensuring the planned maintenance activities are followed through, thereby improving the reliability, maintainability and availability of equipment, as well as reducing costs as a result of these improvements.

The crucial roles played by each of these parties, is described in the sections following and summarised in the tables shown in figure 2 and 3.
3.1 The role of the production department

The role of production entails the support for steps 0 to 3 of autonomous maintenance (this is known as planned maintenance step 0, as explained in the PM step 0 module), segregated into three categories: preventing deterioration, measuring deterioration and rectifying deterioration.

**Preventing deterioration** requires the up-keep of equipment through cleaning, oiling, tightening and routine inspections of equipment conditions, to avoid forced deterioration.

**Measuring deterioration** involves periodic inspection of the equipment, to ensure its reliability and avoid unforeseen failures.

**Rectifying deterioration** includes minor maintenance on equipment to ensure its uptime, as well as countermeasures for causes of forced deterioration on the equipment.
Summary – Roles of the production department tabled in figure 2:

<table>
<thead>
<tr>
<th>Maintenance Classification</th>
<th>Preventing Deterioration</th>
<th>Measuring Deterioration</th>
<th>Rectifying Deterioration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Operation</td>
<td>Correct operation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Setup and adjustment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Routine Maintenance</td>
<td>Cleaning and Countermeasures of defects</td>
<td></td>
<td>Minor maintenance</td>
</tr>
<tr>
<td></td>
<td>Oiling</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tightening</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Routine inspection of conditions of use and deterioration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Periodic Maintenance</td>
<td>Periodic inspection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breakdown Maintenance</td>
<td></td>
<td>Early Detection of situation and speedy countermeasures</td>
<td></td>
</tr>
<tr>
<td>Corrective Maintenance (Reliability)</td>
<td>Enhancement of material strength</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrective Maintenance (Maintainability)</td>
<td>Reduction of load</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Enhancement of accuracy</td>
<td>Development of condition monitoring</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2: The roles of the production department

3.2 The role of the maintenance department

As is required of production, the role of maintenance includes the support for steps 0 to 3 of autonomous maintenance (AM), as well as support of planned maintenance activities. The maintenance activities to be performed are segregated into three categories: preventing deterioration, measuring deterioration and rectifying deterioration.

Preventing deterioration by improving the service life of the equipment, reducing its load or enhancing the material strength of the equipment, improves its reliability.
Measuring deterioration involves periodic inspection and examination of the equipment, to monitor equipment conditions, as well as develop trends in downtime or failures. Maintenance is also involved in improving the methods for inspecting equipment.

Rectifying deterioration includes maintenance or repair on equipment that production is unable to do. To ensure equipment up-time, periodic shut-downs and the early detection of failures are required, to avoid unscheduled downtime and sporadic repair. This requires an improvement in maintenance work (time, method, quality, etc).

Summary – Roles of the maintenance department tabled in figure 3:
Once the roles between production and maintenance have been established and support for AM steps 0 to 3 are in place (i.e. step 0 of planned maintenance), step 1 of planned maintenance can commence.

4. PM Step 1: Evaluate equipment failures and assess the current situation

Step 1 involves the evaluation of equipment failure/breakdown status and understanding the current situation. This depicts the current state of the equipment and provides a baseline for further information and future improvements.

A team for the planned maintenance pillar is required, as per the autonomous maintenance and focused improvement (FI) pillars. The pillar head may be the same for both the AM and PM pillars, while the supporting team should consist of maintenance personnel who are willing to collect and record information on equipment failures.

Although an entire plant or section of a plant may be used for the collection of data, the model area chosen for TPM should receive focus in terms of goal planning and equipment improvements, in order to pass the PM audits.

Figure 4 describes the process to be followed for PM step 1. These steps will be explained in further detail in the sections following.
Process for planned maintenance step 1:

4.1 Data collection

Collect data on all the machine failures/breakdowns that have caused production losses and analyse the data. The data should be recorded by maintenance personnel on equipment logs and breakdown sheets, to keep a history of the equipment failures for further analyses. Below are examples of sheets used to record equipment breakdown data.

Example 1: Past history of equipment
The data sheet shown in figure 5 is used to record data on a grinding machine for a period of one year. The failure type has been documented, as well as the parts changed/adjusted to correct the failure. The number of occurrences provides information on whether the problem occurs frequently, possibly showing an underlying issue, while the breakdown minutes records the time lost due to the failure.

Recording the failure dates, allows the mean time between failures to be calculated and later used for time-based maintenance planning. Any Kaizens developed for a failure are also linked to the breakdown history data, to show improvements made to the failures.

The second example shown in figure 6 collects data on machine breakdowns and includes the date of the failure, duration of the time lost and the reason for each failure. This can be used to find the possible causes of the problem.

Example 2: Past breakdown history record

![Past breakdown history record](image)

4.2 Create an equipment ledger and negative map

An equipment ledger is updated by maintenance personnel and is used to retain the information collected on the machine failures/breakdowns. This is used to evaluate the equipment and should show its operating and maintenance history for equipment analyses.
An example of an equipment ledger is shown in figure 7 below:

![Equipment Management Record](image)

Figure 7: Equipment ledger template

The equipment ledger consists of machine specific information, such as the asset number, equipment name/description, machine model and drawing reference number. It includes the manufacturer’s information for ease of reference in the case of major faults or requirements for original replacement parts. This information includes the designer, manufacturer, purchased price and purchased date.

Data is then collected on failures/breakdowns specific to the machine, as well as the repair details associated with the breakdown and the costs associated with the planned and unplanned maintenance of the equipment.

A negative map should be created for a section of the plant or for the model area alone, to graphically display the breakdowns that have occurred in the area. This shows where most breakdowns occur, in a picture format for greater impact. An example of a negative map is shown in figure 8 below:
A negative map is prepared in the following way:

**Process for developing a negative map:**

1) Obtain a layout of the area to be observed, eg: a section of the plant or the model area. This should include drawings of the machines in the area/cell,

2) As failures or breakdowns occur in the area, a red pin or dot is placed on the layout, on the machine where the failure occurred,

3) This becomes the negative map and should be maintained for a period of time,

4) The layout will demonstrate groups of red dots, indicating problem areas or machines that have the highest number of breakdowns in a given period,

5) The negative map is then used to help prioritise the areas/machines to be focused on, for improvements in reducing the number of machine failures.
4.3 Evaluate and rank equipment

To determine which equipment receives planned maintenance, criteria for evaluating and ranking equipment is required. Each machine should be evaluated according to its effect on safety, quality, operability and maintainability, as well as any other critical aspects determined by the pillar committee.

The equipment can then be ranked from high to low, based on specific evaluation criteria or the summation of points allocated per evaluation criterion. This is explained in further detail, using the examples below:

Example 1: Equipment ranked using evaluation criteria

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Evaluation Criterion</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety: Effect of failure on people and environment</td>
<td>Equipment failure poses explosion risk or other hazards; equipment failure causes serious pollution</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Equipment failure might adversely affect the environment</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>Other equipment</td>
<td>C</td>
</tr>
<tr>
<td>Quality: Effect of failure on product quality</td>
<td>Equipment failure has a major effect on quality (could lead to product contamination or abnormal reactions and produce out-of-spec product)</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Equipment failure produces quality variations that can be put right by the operator comparatively quickly</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>Other equipment</td>
<td>C</td>
</tr>
<tr>
<td>Operation: Effect of failure on production</td>
<td>Equipment with major effect on production, without standby provision, whose failure causes previous and subsequent processes to shut down completely</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Equipment failure causes only partial shutdown</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>Equipment failure has little effect or no effect on production</td>
<td>C</td>
</tr>
<tr>
<td>Maintenance: Time and cost of repair</td>
<td>Equipment takes 4+ hours or costs $2,400+ to repair, or fails three or more times per month</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Equipment can be repaired in under 4 hours at a cost of between $240 and $2,400 or fails less than three times/month</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>Equipment costs less than $240 to repair or can be left unrepaired until a convenient opportunity arises</td>
<td>C</td>
</tr>
</tbody>
</table>

Figure 9: Evaluation criteria for ranking equipment (example)

In figure 9 above, equipment is ranked as A, B or C, based on the severity of the failure and its effect on safety, quality, production and maintenance. An “A” machine is most critical, causing safety risks or quality defects during a failure, while a “C” machine will cause no major issues in the event of a breakdown.
Example 2: Equipment ranked using evaluation points

In figure 10 above, equipment is assessed using points assigned to each evaluation criterion. Once the points have been totalled, the equipment is ranked as S, A, B or C, based on the number of points accumulated. An example of an equipment classification is shown in figure 11 below:

![Equipment Ranking Chart](image)

**Figure 10: Equipment ranking template (example)**

An “S” machine is most critical, while a “C” machine will cause no major issues in the event of a breakdown.
Note: The tables above serve as examples of equipment classification and ranking. Equipment should be classified based on the manufacturer’s recommendations and maintenance’s experience in the criticality of certain parts/machinery.

4.4 Select equipment for planned maintenance

The equipment selected for planned maintenance, should be based on the following criteria listed in figure 12 below:

- EQUIPMENT RANKING
- FREQUENCY AND INTENSITY RATE OF FAILURES
- MEAN TIME BEFORE FAILURES (MTBF)
- MEAN TIME TO REPAIR (MTTR)
- MAINTENANCE COSTS

Figure 12: PM equipment selection criteria

The equipment logs, breakdown sheets, equipment ledgers, negative map and equipment ranking sheets mentioned earlier, are all used in determining the equipment requiring planned maintenance.

A breakdown occurrence list can be used to collect data on the failure numbers, frequencies, MTBFs and MTTRs. An example of a breakdown occurrence list is shown in figure 13 below:
4.4.1 Mean time between failures and Mean time to repair

The mean time between failures measures the reliability of the equipment, by determining how long a machine runs for, before a breakdown or failure occurs. The longer the period between failures, the longer the machine is running for. This provides higher machine reliability and availability.

The formula for calculating MTBF is shown in figure 14:

\[
\text{MTBF} = \frac{\text{Total Operating Time}}{\text{Total Failures}}
\]

MTBF is calculated by adding the total operating time for a period and dividing it by the total number of failures within that period. This provides the average time a machine runs for, before a failure occurs.

The mean time to repair measures the average time taken to repair a machine/component failure and is an indicator of the maintainability of the equipment. The shorter the repair time, the smaller the machine down-time, thereby providing higher machine availability.

The formula for calculating MTTR is shown in figure 15:
MTTR is calculated by adding the total repair time for a period and dividing it by the total number of failures within that period. This provides the average time taken to repair a machine/component failure.

An example of a MTBF and MTTR calculation is shown in figure 16.

Example of MTBF and MTTR:

\[
\text{MTBF} = \frac{\text{Total Operating Time}}{\text{Total Number of Failures}}
\]

\[
\text{MTTR} = \frac{\text{Total Repair Time}}{\text{Total Number of Failures}}
\]

Therefore: 

**MTBF = 270/3 = 90min of operating time before a failure occurs (average)**

**MTTR = 45/3 = 15min to repair a failure when it occurs (average)**

Ideally, the MTBF should be as long as possible and the MTTR as short as possible, to maintain the up-time of the machine. Evaluating equipment failures, ranking equipment and prioritising the equipment for planned maintenance, forms part of improving the reliability and availability of the machinery.

Figure 17 is used to distinguish between failure metrics:
4.5 Set goals for reducing breakdowns

Once the equipment for planned maintenance has been selected, prepare baseline figures and set goals for reducing unpredicted or unscheduled breakdowns using planned maintenance. Goals can be based on improving the frequency of failures, reducing the severity of failures or achieving the planned maintenance schedule on time, etc.

Examples of these are shown in figure 18 below, with Equipment Failure Severity explained in further detail as an illustration of one of the goals.

The goal of Equipment Failure Severity depicts that the total failure downtimes for the month, divided by the operating time for the month, should equal 0.15 or less, in order to be within target.
Figure 18: Example of PM goals

It is important that goals are realistic and achievable; to avoid discouraging the team who are working towards accomplishing these targets.

4.6 Activity plan for eliminating breakdowns

Prepare a plan for reducing and eventually eliminating unscheduled breakdowns. The plan should coincide with the targets/goals set, to provide maintenance activities for accomplishing each goal.
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