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Sustainment of Plant Assets through TPM: An Implementation Strategy

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Abstract:
Total Productive Maintenance (TPM) first took root in the automobile industry and rapidly became part of the corporate culture in companies such as Toyota, Nissan, and Mazda and their supplies and affiliates. Later it was also introduced by other industries such as consumer appliances, microelectronics, machine tools, plastics and many others. The TPM activities are not only limited to departments directly involved with production, but the departments like product development, sales, administrative and support departments, can also apply this to enhance their effectiveness.
It is imperative for any target oriented organization to implement world class techniques to derive maximum results from the existing resources. It is felt that many of the specific methods/techniques required in implementing TPM are not new. For instance, the concept of maintenance prevention (MP) through the introduction of reliability, maintainability and supportability characteristics in equipment design has been applied for the many defence systems (going back to mid-1950s). However, these methods/techniques have not been very well understood or properly integrated, nor have they been effectively applied. Thus, there is an educational issue that must be addressed if the concept of TPM is to be accepted in the long term to achieve desired optimum results.
All organizations are in the throes of restructuring, delayering and re-engineering. The purpose is to make them more light and effective. The resulting resource crunch has made it imperative to apply world class techniques to derive optimum benefits out of existing ones. An effort has been made through this paper to convince the readers about applicability of TPM in sustainment of plant assets for optimum results.

1. Introduction

Total Productive Maintenance (TPM) first took root in the automobile industry and rapidly became part of the corporate culture in companies such as Toyota, Nissan, and Mazda and their supplies and affiliates. Later it was also introduced by other industries such as consumer appliances, microelectronics, machine tools, plastics and many others. The TPM activities are not only limited to departments directly involved with production, but the departments like product development, sales, administrative and support departments, can also apply this to enhance their effectiveness.
All organizations are in the throes of restructuring, de-layering and re-engineering. The purpose is to make them more light and effective. The resulting resource crunch has made it imperative to apply world class techniques to derive optimum benefits out of existing ones. An effort has been made through this paper to convince the readers about applicability of TPM in sustainment of plant assets for optimum results.

2. TPM Methodology

TPM is normally implemented in four phases (preparation, introduction, implementation, and consolidation), which can be broken down into twelve steps as explained in succeeding paras.

2.1. Preparation Phase (Steps 1-5)

The preparation phase starts with top management's announcement of its decision to introduce TPM and is completed when the TPM development master plan has been formulated.

- **Step 1: Top Management Announces its Decision to Introduce TPM.** Top Management informs all employees and interested outside parties that management understands the long-term value of TPM and will provide the physical and organizational support needed to solve the various problems that are likely to surface during implementation.

- **Step 2: TPM Introductory Education.** Before a TPM programme can be implemented, it must be understood. To achieve this, some people must attend outside seminars, and an in-house training programme should be planned and implemented.
- **Step 3: Create a TPM Promotion Organization.** TPM is promoted through a structure of overlapping small groups. Top management itself also constitutes a small group. Establish a TPM promotion office responsible for developing and promoting effective TPM promotion strategies. Its functions include preparing the TPM master plan and coordinating its promotion.
- **Step 4: Establish Basic TPM Policy and Goals.** The goals should be expressed numerically as far as possible. To set goals, start by establishing clear baselines. These should provide a snapshot of the existing situation and be expressed partly quantitatively and partly qualitatively. Goals should be very challenging, but also achievable.
- **Step 5: Draft a TPM Master Plan.** To formulate a master plan for implementation, first decide what activities must be pursued to achieve the TPM goals. This is an important step, because it makes people think about the most efficient ways of bridging the gaps between baselines and goals.

2.2. Introduction Phase- Step 6: Kick Off TPM Initiatives

Once the master plan has been approved, the TPM kick –Off can take place. The kick-off should be designed to cultivate an atmosphere that raises morale and inspires dedication.

2.3. Implementation Phase (Steps 7-11)

During the implementation phase, selected activities designed to achieve the targets shown in the master plan are carried out. The fundamental TPM activities are summarized below.

- **Step 7-1: Focused Improvement.** Focused improvement is an improvement activity performed by cross-functional project teams composed of people such as production personnel, maintenance personnel, and operators. These activities are designed to minimize targeted losses that have been carefully measured and evaluated. Focused improvement activity can be directed at a specific object such as a process, a flow system, an item of equipment, an operating procedure, ideas for stabilizing processes and eliminating equipment breakdowns, idling, and minor stops.
- **Step7-2: Autonomous Maintenance.** Operators become involved in routine maintenance and improvement activities that halt accelerated deterioration, control contamination, and help prevent equipment problems.
- **Step7-3: Planned Maintenance.** Planned or scheduled maintenance embraces three forms of maintenance, i.e. breakdown, preventive, and predictive. The purpose of performing predictive and preventive maintenance is to eliminate breakdowns, but even when systematic maintenance practices are carried out, unexpected failures still occur. Such failures reveal inadequacies in the timing and content of maintenance plans and highlight ineffective recurrence-prevention measures. In TPM, planned maintenance activities emphasize monitoring mean times between failures (MTBF) and using that analysis to specify the intervals for tasks in annual, monthly, and weekly maintenance calendars.
- **Step 7-4: Training.** Training must be tailored to serve the individual's needs. Assess each person to measure his grasp of the required knowledge and skills and pinpoint weaknesses, then use the results to make the general training more effective. Workers and their supervisors should discuss the results of this assessment annually and use them to set the next year's targets and plan the next phase.
- **Step 8: Early Management**. Early management includes both early product management and early equipment management. The purpose of these activities is to achieve-quickly and economically-products that are easy to make and equipment that is easy to use.
- **Step 9: Quality Maintenance.** Quality maintenance (QM) is a method for building in quality and preventing quality defects through the process and through the equipment. In quality maintenance, controlling the condition of equipment components that affect it controls variability in a product quality characteristic. Quality characteristics are mainly influenced by the four production inputs: equipment, materials, people's actions (skills), and methods used. The first step in quality maintenance is to clarify the relationships between these factors and a product's quality characteristics by analyzing quality defects.
- **Step 10: TPM in Administrative and Support Departments.** Administrative and support departments play an important role in backing up production activities. The quality and timeliness of the information supplied by administrative and support departments have a major impact on these activities. TPM activities performed by administrative and support departments must not only support TPM in the workplace; they should also strengthen the functions of the departments themselves by improving their own organization and culture.
- **Step 11: Safety and Environmental Management.** Safety prevention and adverse environmental impacts are promoted systematically as part of TPM activities. It is particularly important to incorporate fail-safe mechanisms-that is, to design equipment that will remain safe even when people do not take the proper precautions.

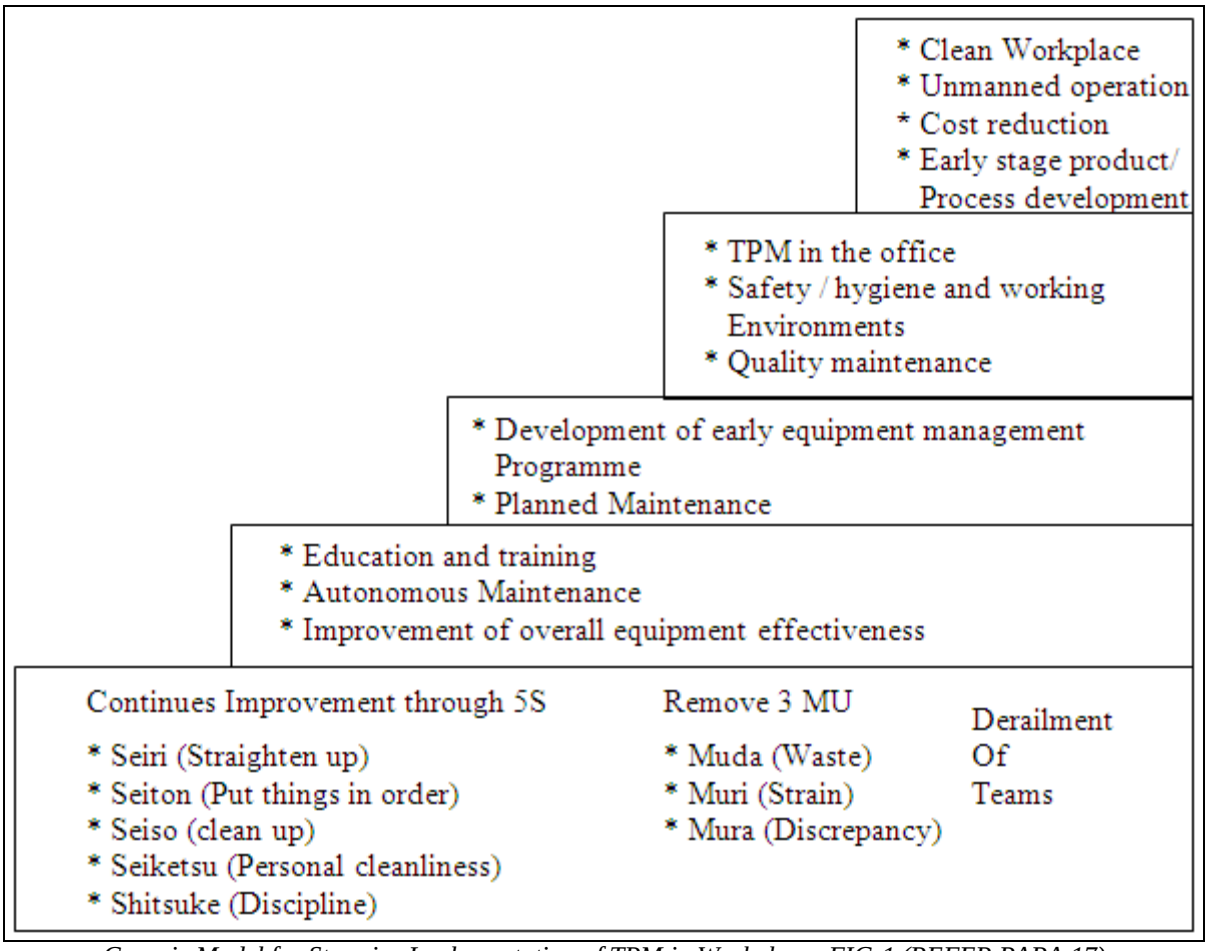
2.4. Consolidation Phase Step 12: Sustaining TPM Implementation and Raising Levels

Emphasizing a continuous-improvement approach, continually revising goals upward, and setting new challenges are also helpful. None of these approaches will be effective without the support of careful, continuous, and concrete measurement. Start with clear baselines and document improvement regularly and in detail.

3. Proposed System

3.1. Generic Model for Proposed System

Based on TPM philosophy, Generic Model as shown in Fig1 is proposed. The model depicts the stepwise implementation and growth of TPM in workplace in five phases. The various phases and proposed system therein are explained in the succeeding paras.

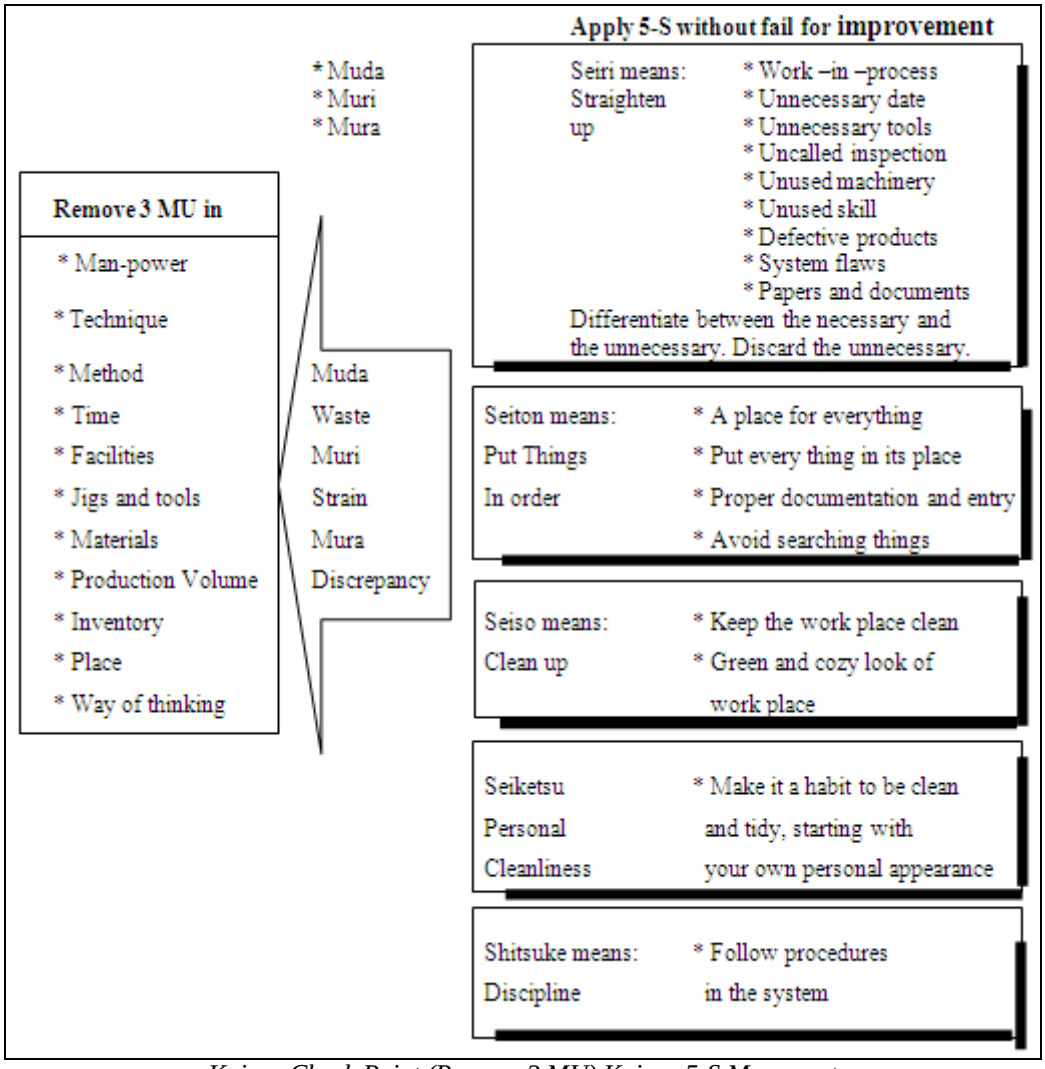


Generic Model for Stepwise Implementation of TPM in Workplace -FIG-1 (REFER PARA 17)

3.2. Phase 1: Implementation of 5 S's and 3 M U's

Kaizen a Japanese word means ongoing improvement involving everyone i.e. top management, managers and workers. It is a Japanese way of life. The most important difference between Japanese and Western Management-concepts is that Japanese Kaizen and its process-oriented way of thinking verses the West's innovation and result-oriented thinking. Kaizen involves removal of 3 MUs at different checkpoints. These Japanese-MUs are: Muda (means, waste), Muri (means, strain) and Mura (means, discrepancy). These MUs should gradually be removed at different levels of manpower, technique, method, time, facilities, jigs and tools, material, production volume, inventory, place and way of thinking.

Kaizen also involves the application of 5-S for improvement. These are: Seri (means, Straighten-up), Seiton (means, put things in order), Seiso (means, clean up), Seiketsu (means, personal cleanliness) and Shitsuke (mean, discipline) Seiri is applicable for tools, unused machines, defective products, etc. Seiton and Seiso are for place of work. Sieketsu is for personal habits, and Shitsute is for cultural discipline. Pictorial depiction of the anatomy of 3 MUs and 5 Ss is shown in Fig 2.



Kaizen Check Point (Remove 3 MU) Kaizen 5-S Movement
Figure 2: (REFER PARA 17 (a))

3.2.1. Derailment of Teams

In this phase the management should decide to implement TPM and it should be production driven. For prompt and accurate information, the management should introduce Computerized Maintenance Management System (CMMS). Dedicated teams should be detailed for promotion of TPM. Basically there should be two teams i.e.; Implementation teams (ITs) and Training Teams (TTs). The main tasks of each individual in the TPM implementation can be summarized as follows:-

3.2.1.1. Implementation teams (ITs)

- (aa) **Production associates.** The main task includes the inspection routines, cleaning routines, simple maintenance tasks and assists tradesmen as required.
- (ab**) Maintenance technicians.** The main tasks include the assistance in the process of identifying problems and solving them, train production associates, and carryout checking's and complete recommended adjustments and preventive replacement actions.

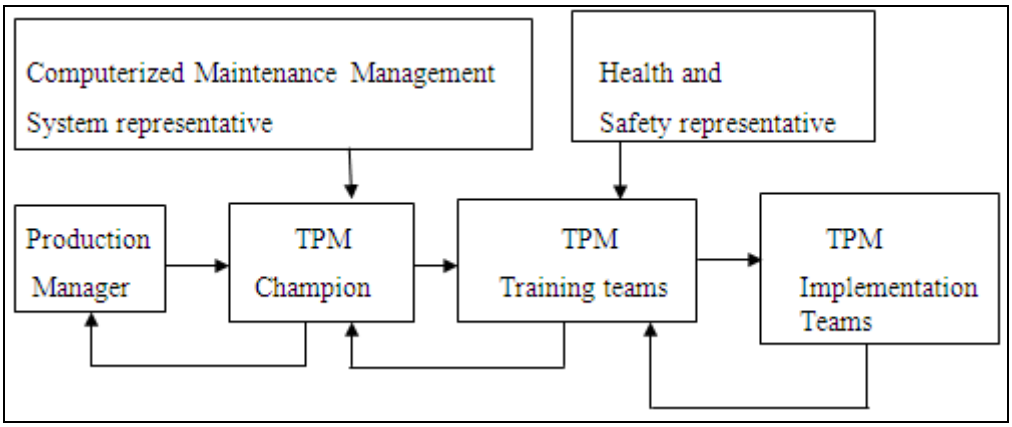
3.2.1.2. Training Teams (TTs)

- (aa) **Production Manager (PM).** The main task is to initiate TPM implementation.
- (ab) **Maintenance technicians, union, health and safety representatives.** The main tasks include the education to the implementation teams (ITs), and finalize TPM instructions and action taken.
- (ac) **TPM Champion (CH).** The main tasks include to co- ordinate activities and assess and evaluate the process of TPM and specify new targets.

3.3. Phase 2: Overall Equipment Effectiveness, Autonomous Maintenance Education and Training

The improvement of overall equipment effectiveness, autonomous maintenance, education and training have been integrated and suggested methods for their stepwise implementation have been explained in succeeding paras.

- **Step 1: Goals of TPM Implementation.** In this step TPM goals are set. For the short to medium term, availability and meantime between failures (MTBF) targets are specified. These two measurements can be calculated automatically by the CMMS. For the longer term, overall equipment effectiveness (OEE) figures are set to eliminate the six big losses i.e. downtime losses (breakdowns due to equipment failures, set-up and adjustment), speed losses (idling, minor stoppages and reduced speed), defect losses (defects in process, rework and reduced yield).
- **Step 2: Selection of TPM Machines.** Here we use combination of three main criteria for the selection of TPM machines. These are process bottlenecks, one offs (machine unique in plant), and low availability or low MTBF.
- **Step 3**: **Training of Individuals**. The TPM champion is trained on the CMMS by the CMMS representative. Subsequently, the TPM champion provides education and awareness programs to the TTs. Finally, the TTs trains the ITs on the machine selected for TPM. The trainers in these training programs have to include targets of the TPM implementation, necessary procedure in order to meet these targets, and training on CMMS. The structure of TPM promotion is shown in Fig 3.



Structure of TPM Promotion -Fig-3 (Refer Para 17(C) Step 3)

- **Step 4: TPM Schedule**. Implementation team works out the schedule and it consists of:-
  (i) **Instruction list**. It contains instructions for machine checks. These instructions are the combined result of the production associates and maintenance technician's experience, the recommendations found in the machine manuals, and, more critically, the most common failure patterns experienced over the years. The later is another input provided by the CMMS and consists of the Pareto analysis of the machine's failure mode together with the detailed records that the technicians have raised after every corrective and preventive action.
  (ii) **Required Time or TPM window.** The correct amount of time required machine check up is absolutely crucial since if it is set too high production planning might suffer; and if too low the quality of maintenance activities might suffer. For example initially the TPM selected can be four to five hours.
  (iii) **TPM Frequency**. The frequency for overall check up may vary from 10 to 12 weeks.
- **Step 5: Release of Machine**. The relevant section in charge can decide about the most convenient day to release the machine. In the meantime, the particular section can built up adequate stock .
- **Step 6: Initial Cleaning**. Each TPM machine goes through the initial cleaning up. Cleaning lengthens each component's lifetime and maintains the equipments precision and quality requirements.
- **Step 7: Overall Check Up of Machine**. During this all necessary corrective actions are identified. At the end of the TPM window the implementation team updates the CMMS on the corrective actions completed.
- **Step 8: Expansion of TPM**. For each TPM machine, the overall equipment effectiveness is recorded, monitored and continuously analysed by the CMMS. The purpose of this procedure is the reduction and, if possible, the elimination of six big losses, and therefore the continuous improvement of the TPM machines effectiveness.

3.4. Phase-3 Planned Maintenance

Here the relevant instructions do not limit themselves to checking and corrective actions to the machines, but they are extended to adjustments and preventive replacements too, including the requirements for the necessary spare parts. The maintenance engineers are handed sets of detailed instructions which include CMMS outputs, detailing machine and specific failure modes, the numerical codes of the spares to be used, current spare parts availability in the stores (EQ), the minimum acceptable stock quantity (MQ), the reorder quantity (RQ) if that is necessary, and the quantity required for the TPM (QR). The quantity to be ordered (OQ) by the technical services is calculated from the formula.

OQ = RQ if EQ - QR < MQ.

3.4.1. Development of early equipment management programme
The concept is already explained in TPM methodology

3.5. Phase 4 & Phase 5
The steps shown in generic model in phase 4 & phase 5 have been explained conceptually in the TPM methodology and they need no further elaboration.

4. Devising TPM Performance Measures
TPM is highly regarded because its benefits are both tangible and sustainable. TPM effectiveness indicators can be classified into seven types. These have been described briefly in the succeeding paras.

4.1. Management Indicators
The indicators that are relevant are as follows**: -**

(a) Labor productivity = No of products manufactured in a year
No of workers (or total working hours)

(b) Average through put time in manufacturing products in a month.

4.2. Plant Effectiveness Indicators
The macro indicator of plant effectiveness is overall plant effectiveness (OPE). This is made up of three sup-indicators i.e., availability, performance rate, and quality rate.

4.2.1. Availability
It is the operating time expressed as a percentage of the calendar time. To calculate availability, subtract from calendar time the time lost during shutdown (for planned maintenance and production adjustments) and the time lost in major stoppages (equipment and process). Then divide the result by calendar time and multiply by100

Availability = Calendar time – (shut down loss + major stoppage loss) x 100%
Calendar time (in a month in hrs)

Shut down losses (in hrs) = Shutdown maintenance loss + production adjustment loss.
Major stoppage loss (in hrs) = Equipment failure loss + process failure loss.

4.2.2. Performance Rate
A plant performance rate expresses the actual production rate as a percentage of the standard production rate.
Performance Rate = Average actual products manufactured in a month (in No) x 100%
Standard products manufactured in a month (in No)

4.2.3. Quality Rate
It expresses the amount of acceptable product as a percentage of total production.
Quality Rate = Total products manufactured in a month - Rejections
Total products manufactured in a month

The overall plant effectiveness is the product of the availability, performance rate and the quality rate.
Overall plant effectiveness = Availability X Performance Rate X Quality Rate

4.3. Quality Indicators
The quality indicators relevant are as follows: -

- Number of rejections at the final inspection stage.
- Demerit rating calculated from, the defects noticed by Quality Team.
- Calculation of Quality score or index from the observations obtained through Demerit Rating.
- Number of premature failures reported by the users.
- Vendor Rating.

4.4. Energy Saving Indicators
It may include the consumption of fuel (diesel), lubricants (oil) and electricity consumption trend in a month.

4.5. Maintenance Indicators
It may include the following: -
(a) Mean time between failures of machines on monthly basis

$$\textbf{MTBF} = \frac{\textbf{Total operating time}}{\textbf{No of stops}}$$

(b) Mean time taken to repair the machines on monthly basis

$$\textbf{MTTR} = \frac{\textbf{Total stoppage time}}{\textbf{No of stops}}$$

(c) Preventive Maintenance achievement rate

$$= \frac{\textbf{PM tasks completed X 100}}{\textbf{PM tasks planned}}$$

4.6. Health, Safety and Environment Indicators
It may include the following:

- (a) Actual number of accidents occurred in a month in three categories i.e., fatal, major, & trivial.
- (b) Actual number of cleanliness drives organized in a month.

4.7. Training and Morale Indicators
It includes the following: -

- Actual number of meetings or time spent on small group activities in a month.
- Number of improvement suggestions reported by workers.
- Actual time spent on training the workers in a month.

4.8. Advantage of Proposed System
The advantages of proposed system are elaborated in the succeeding paras.

4.9. Development of Human Resources
The proposed system aims at developing the human resources. Since, without the involvement of workforce, no development is possible, the improvement through 5 S's, 3 MUs, and education/training would ensure the pleasant workplace and hence belongingness of workforce towards the workplace will also increase.

4.10. Increased Co-ordination among various departments.
Although the TPM implementation will be production driven, but other departments will also be involved directly in implementation programme. This will enforce the atmosphere of close coordination among various departments.

4.11. Improved Equipment Effectiveness
Through the programme suggested, equipment effectiveness will definitely improve and the belongingness of operators towards the equipment/machines through autonomous maintenance will help in increased productivity too.

4.12. Role of Quality Assurance Department
The proposed system has given wider role to quality assurance department by indulging in quality maintenance (QM) approach. Project teams from quality assurance should tackle the analysis/evaluation of processes requiring advanced technology with assistance from production, works and other departments. After teams establish the condition for zero defects, operators will maintain and control most of the conditions as part of autonomous maintenance.

4.13. Role of Top Management
The proposed system defines the wider role to the top management. In this the project team headed by top management personnel would ensure that aspects of maintenance management like maintenance-prevention (MP) design are not neglected.

4.14. Tangible Results

The proposed performance measures ensure the tangible result, which can be seen and analyzed by anyone at all levels. These results would indicate the immediate improvement and hence increased motivation of all involved in the programme.

5. Conclusion

It is imperative for any target oriented organization to implement world class techniques to derive maximum results from the existing resources. It is felt that many of the specific methods/techniques required in implementing TPM are not new. For instance, the concept of maintenance prevention (MP) through the introduction of reliability, maintainability and supportability characteristics in equipment design has been applied for the many defense systems (going back to mid-1950s). However, these methods/techniques have not been very well understood or properly integrated, nor have they been effectively applied. Thus, there is an educational issue that must be addressed if the concept of TPM is to be accepted in the long term to achieve desired optimum results.

6. References

1. Armand V Feigenbaum" Total Quality Control" McGraw Hills, USA.
2. Bill Creech" The Five Pillars of TQM-How to make total quality Management works for you" Penguin Group, USA.
3. Hartman EH "Successfully Installing TPM in a Non- Japanese Plant" TPM Press Inc' New York.
4. J M Juran and Frank M Grynea "Quality Planning and analysis" TATA Mc Graw Hill, India.
5. Tokutaro Suzuki "TPM in Process Industries" Productivity Press USA.