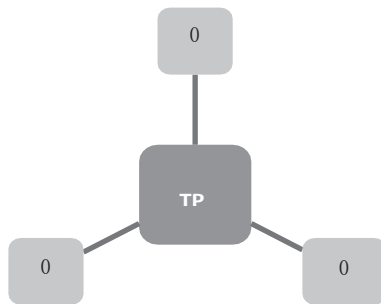


## Module-5

### Total Productive Maintenance (TPM)

Total productive maintenance is an innovative approach to equipment maintenance involving maintenance personnel and operators working in teams focusing on eliminating equipment breakdowns and equipment-related defects. It is a systematic approach to improving production and quality systems by including all employees through a moderate investment in maintenance. The full support of all employees and top management is necessary for TPM to be successful. TPM is also a key aspect in a quality management system. TPM strives to increase productivity by investing in appropriate maintenance to reduce losses.

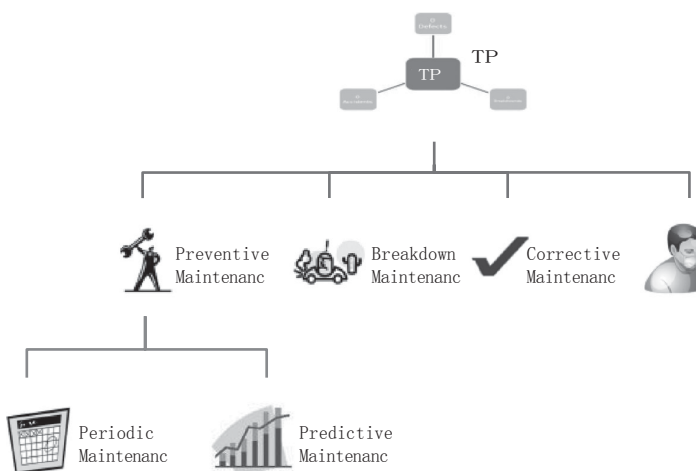
The TPM strategy includes zero defects, zero accidents, and zero break-downs, as shown in Figure 5.1



**FIGURE 5.1** TPM methodologies.

**Maintenance prevention:** Machine engineering and design that is based on preventing the need for maintenance or for ease of access to machine parts so that maintenance may be carried out easily, different than preventative maintenance in that maintenance is performed while a machine is still in working order to keep it from breaking down. Maintenance prevention indicates the design of new equipment. Any current machines operating inefficiently are studied and incorporated into the new design and commission of machinery.

Preventive maintenance includes lubricating, tightening, and replacing worn parts. Preventive maintenance is work that is done on a machine, often involving testing and the replacement of worn but still functioning parts, in order to prevent a failure (as against fixing something only when it breaks). Maintenance prevention means stopping maintenance from taking place. If used in a positive context, it is steps taken perhaps in the design of a device to make it require less maintenance. The types of maintenance are shown in Figure 5.2.



**FIGURE 5.2** Types of TPM maintenance.

## Types of Maintenance Involved with TPM

There are different types of maintenance involved with TPM, which will be described in detail below:

1. Breakdown maintenance
2. Preventive maintenance
  - a. Periodic maintenance
  - b. Predictive maintenance
3. Corrective maintenance
4. Maintenance prevention

**Breakdown maintenance:** You wait until the machine completely fails, and then you repair it to working order. Usually this type of maintenance is assigned to machines with backups in place, or machines that are of low importance to production.

**Preventive maintenance:** You maintain the machine, while still in operation, to prolong or prevent the machine's failure. This should be applied to machines of importance and high value when compared to production. This type of maintenance includes cleaning, oiling, retightening, and inspecting. Preventative maintenance is further divided into predictive maintenance and periodic maintenance.

**Predictive maintenance:** You predict when the machine may require maintenance based on analyzing past history, inspecting, and applying maintenance just before the machine has failed in the past, extending its service life. Predictive maintenance is condition-based maintenance. It manages trend values by measuring and analyzing data about deterioration and employs a surveillance system designed to monitor conditions through an online system. This concept often is applied in conjunction with preventative maintenance.

**Periodic maintenance:** A set schedule of maintenance routines assigned to prolong the life of the machine. This is a time-based maintenance consisting of periodically inspecting, servicing, and cleaning equipment while also replacing parts to prevent unexpected failures and process issues. This concept is often applied in conjunction with preventative maintenance.

**Corrective maintenance:** A form of system maintenance that is performed after a fault or problem emerges in a system, with the goal of restoring operability to the system. In some cases it can be impossible to predict or prevent a failure, making corrective maintenance the only option. Corrective maintenance improves the equipment and its components so that preventative maintenance can be carried out reliably. Any design weaknesses in the equipment must be redesigned in order to improve reliability and maintainability.

There are six preventable losses:

1. Breakdowns
2. Setup and adjustments
3. Idling
4. Minor stoppages
5. Quality
6. Rework

The first two losses, breakdowns and setup, affect the availability of equipment. Losses from idling and minor stoppages affect equipment efficiency. The last two losses, quality and rework, are a result of reduced output quality.

There are three main goals of TPM:

1. Reduce unplanned equipment downtime
2. Eliminate barriers between departments
3. Reduce equipment-related defects

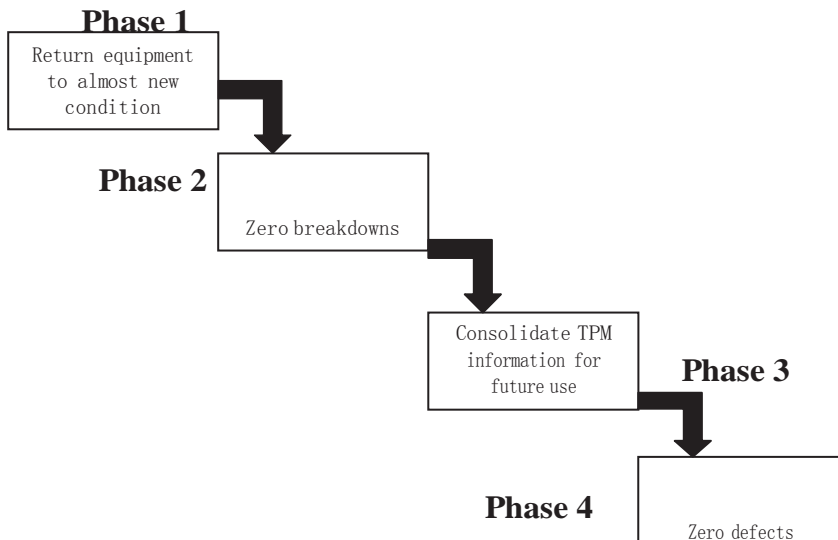
In addition, there are three main objectives:

1. Total employee involvement
2. Hands-on approach

### 3. Improve the organization's competitiveness

Just as with any other Lean technique, implementing TPM is not easy. It is important to have a clear strategy with metrics that are communicated and easy to understand.

The total productive maintenance methodology consists of four key phases, as outlined in Figure 5.3. The methodology starts by returning equipment to almost new condition. Next, the focus is on zero breakdowns through proper maintenance. The third phase focuses on consolidating information for future use. The final phase of TPM is zero defects.



**FIGURE 5.3** Total productive maintenance phases.

Preventive maintenance is a time- or usage-based method of maintaining equipment. Much like maintenance of oil changes in your automobile, maintenance activities are performed on equipment based on defined time or usage intervals to prevent equipment breakdowns from occurring.

Predictive maintenance is a situation-based method of maintaining equipment. Maintenance activities are performed on equipment based on visible signals or diagnostic techniques to prevent equipment breakdowns from occurring. Examples of predictive maintenance include vibration analysis, ultrasound, thermography, laser measuring, generator analysis, and oil analysis.

The TPM concept became an innovative Japanese concept in the 1950s. The preventive maintenance concept portion of TPM was taken from the United States. Autonomous maintenance was added and the maintenance crew improved equipment reliability by modifying equipment. These new modifications were made or incorporated into new equipment. This then led to maintenance prevention. Thus, preventive maintenance combined with maintenance prevention and maintainability improvement came to a new concept called productive maintenance. The goal of productive maintenance was to maximize plant and equipment effectiveness to achieve optimum life cycles of production equipment. The involvement of all employees helped make the program a well-established and sought-after system.

TPM had a few main targets:

#### **Production:**

Obtain minimum 80% overall production effectiveness (OPE).

Obtain minimum 90% overall equipment effectiveness (OEE).

Run the machines even during lunch (lunch is for operators and not for machines!).

**Quality:** Operate in a manner so that there are no customer complaints.

**Cost:** Reduce manufacturing costs by 30%.

**Delivery:** Achieve 100% success in delivering the goods as required by the customer.

**Safety:** Maintain an accident-free environment.

**Multi skilled labor:** Increase the suggestions by three times. Develop multi skilled and flexible workers.

The stages to roll out TPM in an organization consisted of the following steps:

**Stage A: Preparatory stage:**

**Step 1: Announcement by management to all about TPM introduction in the organization.**

Proper understanding, commitment, and active involvement of the top management are needed for this step. Senior management should have awareness programs, after which an announcement is made to all. Publicity of the pro-gram should be completed for this stage.

**Step 2: Initial education and propaganda for TPM.** Training is to be done based on the need. Some need the intensive training in the main concepts with addition to awareness training. Successful implementation roles will occur where maturity has already been developed in the areas.

**Step 3: Setting up TPM and departmental committees.** TPM includes improvement, autonomous maintenance, quality maintenance, etc., as part of its base core structures.

**Step 4: Establishing the TPM working system and target.** Each area is benchmarked and target key performance indicators (KPIs) are set up to monitor achievements.

**Step 5: A master plan for institutionalizing.** Implementation leading to institutionalizing wherein TPM becomes an organizational culture is desired.

**Stage B: Introduction stage.** This is a ceremony for celebration where many should be invited. Suppliers should be invited to gain their awareness and ensure they understand the need for needing quality support from them. Related companies and affiliated companies who can become partners or customers should also be invited. Learning will take place and customers will appreciate the communication efforts that take place.

**Stage C: Implementation.** In this stage eight activities are carried out, which are called the pillars of the TPM activities. Four activities takeplace for establishing the system:

- Production efficiency
- Initial control system of new products and equipment
- Improvements of efficiency
- Control of safety

**Stage D: Institutionalizing stage.** At this time the maturity of the system should be in place. Challenging levels of achievement should besought after at this point in time.

**Steps in Institution TPM in an organization:**

The high-level details for introducing and institutionalizing TPM based onthe outline above are as follows:

1. The purpose of TPM: To ensure that all equipment required for production is operating at 100% efficiency at all times. The goal of the TPM program is to increase production and at the same time increase employee morale and job satisfaction. It brings maintenance into focus as a necessary and vitally important part of any business or manufacturing operation.
  - a. Losses: Defect losses and performance losses.
    - Defect losses: Quality defects and reprocessing losses that affect production effectiveness.
    - Performance losses: Performance takes into account speed losses, which include all factors that cause the production assets to operate less than the maximum speed when the machine is running. The calculation for performance losses is  

$$(\text{Ideal cycle time} \times \text{Total pieces}) / \text{Operating time}.$$
  - b. Variation and the utilization of Lean Six Sigma: Inevitable change in the output or result of a process because all systems vary overtime. Two major types of variation are common, which is inherent in a system, and special, which is caused by changes in the circumstance or environment.  
 A process with little variation is said to be precise. When studying process variation it is important to make a clear distinction between process accuracy and process precision. A process that is accurate may not be precise, and a process that is precise may not be accurate.
  - c. Cost of poor quality: COPQ consists of those costs that are generated as a result of producing defective material.

- d. Overall equipment effectiveness (OEE): Overall equipment effectiveness (OEE) is an indicator of the overall health of equipment and is the most commonly used measure of equipment performance.

2. Equipment maintenance:

- a. Tolerances: It is important to understand what tolerance is. ASME Y14.5M defines it as “the total amount a specific dimension is permitted to vary. The tolerance is the difference between the maximum and minimum limits.” This can be shown as upper and lower limits (0.2500 over 0.2498) or an allowable amount above and below a nominal dimension (0.2500 + 0.0000 over -0.0002, 0.2499 ± 0.0001). Both of these methods define the same range of allowable dimensions. In this example, a finished part is acceptable when its dimension is anywhere between 0.2498 and 0.2500 inch; outside of this range, it is rejected. This range of allowable dimensions is the tolerance band. The larger the difference between the upper and lower limits, the larger the tolerance band, referred to as a looser tolerance. Conversely, a smaller tolerance band is considered a tighter tolerance.
- b. Lubricants/greasing:
- Ensure lubricant stores are always kept clean and well organized utilizing 5S principles.
  - Ensure proper stock controls are practiced for lubricants.
  - Ensure grease nipples and ports are clean.
  - Ensure the proper types of lubricants are used and labels are maintained accurately.
  - Ensure oil levels are clean and easy to see.
  - Ensure oil levels are clearly marked.
  - Ensure automated lubricants are dispersing the proper amount of lubricant.
  - Ensure no blockages or leaks occur from lubricants or grease.
  - Ensure rotating parts, sliding parts, and transmissions are always clean and well lubricated.
  - Ensure the surroundings are free of contamination.
  - Ensure there is no excess lubrication.
- c. Bearings:
- Check for loose nuts or bolts.
  - Check for missing bearings.
  - Check thread lengths.
  - Check washers for accuracy.
  - Check if bolts are inserted from below and nuts are visible from the outside.
  - Check to see if important bearings have the right number of bolts.
  - Check if wing nuts are on the right way.
- d. Vibrations and loose-fitting parts:
- Check for excessive vibration of equipment.
  - Check for any loose-fitting parts to ensure the parts do not come off.

Machine depreciation: Depreciation results from obsolescence and wear. Age is the predominant factor in establishing the market value of used farm machinery. Consequently, depreciation is usually considered a fixed annual cost that disregards amount of use, although the condition of the used machine does affect its market value.

- e. Corrosion: Corrosion costs companies billions of dollars each year. Much of this loss is due to the corrosion of iron and steel. When exposed to moisture and oxygen, iron and steel will react, forming an oxide. This oxide does not firmly adhere to the surface of the metal and will flake off, causing pitting. Extensive pitting eventually results in weakness and disintegration of the metal, leading to failure. It is important to take great care from



the design stage forward to quickly help spot and correct corroded materials and installation defects.

- f. Normal operating conditions that affect equipment: Continuous improvement to improve production effectiveness in process industries will need to take place in order to compensate with normal operating conditions that can affect equipment. Some of the things to look out for include large-scale equipment, continuous 24-hour operations, handling of many different materials, corruptions, spills, and leaks.
3. Operator involvement:
  - a. Operator ownership: Meaningful results can only occur when everyone participates and takes ownership. Each team member must be held responsible for taking on and carrying out individual assignments. They are accountable for sharing ideas and opinions, carrying out any special assignments, and learning techniques and methods to improve the organization day to day.
  - b. Equipment condition monitoring: Through operator ownership, operators should follow autonomous maintenance steps through cleaning up their equipment and eliminating excess deterioration. A vision of the type of maintenance system that is needed should be outlined. The maintenance should take place to maximize overall plant effectiveness while reducing costs and increasing efficiencies. As organizations tend to go toward an unattended operation, the amount of periodic maintenance and repair work that operators complete will be minimized.
  - c. Preventive maintenance: Preventive maintenance is a combination of time-based and condition-based methodologies to keep equipment functioning well by controlling its components, assemblies, subassemblies, accessories, attachments, etc. The maintenance of the structure takes place to prevent corrosion, fatigue, and other forms of deterioration.
4. Maintenance planning and scheduling: Planned maintenance is broken down into three main components, which are listed below.
  - Breakdown maintenance: You wait until the machine completely fails, then you repair it to working order. Usually this type of maintenance is assigned to machines with backups in place, or machines that are of low importance to production. TPM activities focus on improving the response time for sudden machine failures.
  - Preventive maintenance: You maintain the machine, while still in operation, to prolong or prevent the machine's failure. This should be applied to machines of importance and high value when compared to production. This type of maintenance includes cleaning, oiling, retightening, and inspecting, which is mainly performed by the operators (autonomous maintenance). Preventative maintenance is further divided into predictive maintenance and periodic maintenance.
  - Predictive maintenance: You predict when the machine may require maintenance based on analyzing past history, inspecting, and applying maintenance just before the machine has failed in the past, extending its service life. Predictive maintenance is condition-based maintenance. It manages trend values by measuring and analyzing data about deterioration and employs a surveillance system designed to monitor conditions through an online system.
5. Implementing TPM:
  - a. Change management: Change management relies on the understanding of why things are done and why people are comfortable. Managing others through change processes is needed to change the status quo. This type of change requires guidance, encouragement, empowerment, and support.
  - b. Visual management: Visual management and measures promote successful layouts. Visual management involves bins, cards, tags, signals, lights, alarms, and other signaling mechanisms. Visual systems include:
    - Indicators such as signs, maps, and displays convey passive information.
    - Signals such as alarms or lights are assertive devices.
    - Controls provide aggressive information by monitoring size, weight, width, or length.
    - Guarantees such as sensors, guides, and locators provide assured information.

- c. Decision making: Advising people of the data behind decision making makes them more confident in believing the goals and strategies. If opinions are given on why a topic is to be completed, it is important in letting others know the reasoning behind it. Giving past experiences to convince others is a methodology that should be used to show the transparency in the decision making. The end goal is to ensure the effectiveness of the communication is occurring. It is clear when communication is effective because fewer mistakes will occur and the end goal is achievable while innovative thinking occurs concurrently.
- d. Cross-functional teams: It is important to have a cross-functional team for the knowledge base to be broad and the proper subject matter experts to be present. The transparency of these teams should be as visible as possible. The team should know vast areas of the entire environment. The cross-functional teams working together with different skill sets drive successful change. The real change comes from the combination of these people.
- e. Train the trainer: Training is aimed to have multi skilled and energized employees who have high morale and are eager to come to work to perform all their required functions independently and effectively. Training from a skilled employee to another employee ensures the training is periodic and the entire organization is able to be trained.

The steps for training are as follows:

- Setting policies and priorities, and checking present status of education and training
- Establishment of a training system for operations and maintenance skill
- Training the employees for the operation and maintenance skills
- Preparation of a training calendar
- Kickoff the training
- Evaluation of activities and study of future approach
- f. Champion training: This training provides a business management approach that aims to prepare champions to meet the demands of their employees for setting up and running a business improvement program. The success of any business improvement strategy is founded on strong and dynamic leadership that needs to be present in champions. The techniques in this training should manage and develop teams in order to successfully roll out large programs such as TPM.

## TPM

Total productive maintenance (TPM) has become a well-known activity that has several names associated with it. Many people associate TPM with total predictive maintenance or total preventative maintenance. The association explained below will be total productive maintenance, but includes the above as well.

TPM originated in Japan in 1971 as a methodology to improve machine availability and throughput through the utilization of more efficient maintenance and production resources.

### Goals and Benefits of TPM

The goal of TPM is to increase job satisfaction through the following means

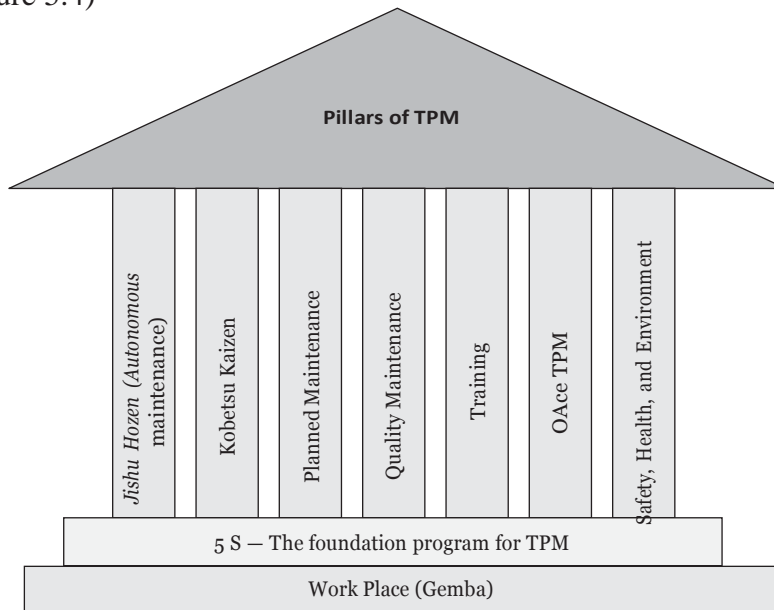
- Reduced breakdowns
- Reduced quality issues
- Reduced safety/environmental incidents
- Reduced costs
- Improved throughput
- Competitive advantage
- Emergency and unplanned maintenance at a minimum

There are four main objectives of TPM:

1. Avoid waste in quickly changing environments
2. Reduce costs of manufacturing
3. Produce a low batch quantity at the earliest possible time
4. Goods sent to customers must be non defective

### Pillars of TPM:

TPM is also known for having pillars inside of a house. The house and pillars consist of the following (Figure 5.4)



**FIGURE 5.4** Pillars of TPM.

#### **Pillar 1: 5S**

- TPM starts with 5S: Issues cannot be seen clearly in a un-organized place.
- Cleaning and organizing will uncover problems.
- Making problems visible is the first step of improvement.
  - Sort
  - Straighten
  - Shine/sweep
  - Standardize
  - Sustain

The summary of 5S can be seen in Figure 5.5.

The most basic concept when discussing waste reduction begins with kaizen. Kaizen is a Japanese concept defined as “taking apart and making better.” The concept takes a vast amount of project management techniques to facilitate the process going forward. 5S processes are the most predominant and commonly known for kaizen events. 5S principles are determined by finding a place for everything and every- thing being in its place.

The 5S levels are as follows.

**Sort:** Identify and eliminate unnecessary items and dispose of unneeded materials that do not belong in an area. This reduces waste, creates a safer work area, opens space, and helps visualize processes.

It is important to sort through the entire area. The removal of items should be discussed with all personnel involved. Items that cannot be removed immediately should be tagged for subsequent removal.

**Sweep:** Clean the area so that it looks like new and clean it continuously. Sweeping prevents an area from getting dirty in the first place and eliminates further cleaning. A clean workplace indicates high standards of quality and good process controls. Sweeping should eliminate dirt, build pride in work areas, and build value in equipment.

**Straighten:** Have a place for everything and everything in its place. Arranging all necessary items is the first step. It shows what items are required and what items are not in place. Straightening aids



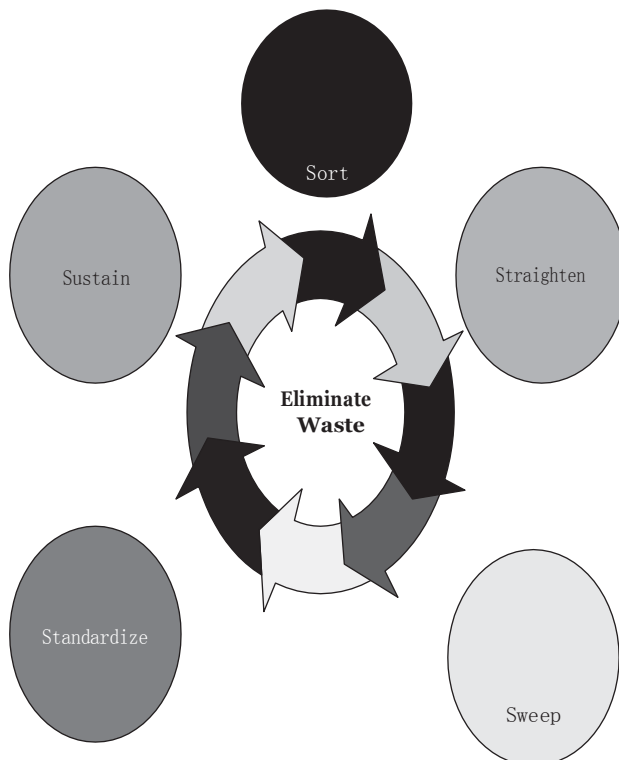
efficiency; items can be found more quickly and employees travel shorter distances. Items that are used together should be kept together. Labels, floor markings, signs, tape, and shadowed outlines can be used to identify materials. Shared items can be kept at a central location to eliminate purchasing more than needed.

**Schedule:** Assign responsibilities and due dates to actions. Scheduling guides sorting, sweeping, and straightening and prevents regressing to unclean or disorganized conditions. Items are returned where they belong, and routine cleaning eliminates the need for special cleaning projects. Scheduling requires checklists and schedules to maintain and improve neatness.

**Sustain:** Establish ways to ensure maintenance of manufacturing or process improvements. Sustaining maintains discipline. Utilizing proper processes will eventually become routine. Training is the key to sustaining the effort and involvement of all parties. Management must mandate the commitment to housekeeping for this process to be successful.

The benefits of 5S include:

1. A cleaner and safer workplace
2. Customer satisfaction through better organization
3. Increased quality, productivity, and effectiveness



**FIGURE 5.5 5S.**

### **Pillar 2: Autonomous Maintenance (Jishu Hozen)**

- Empowering and developing operators to be able to take care of small maintenance tasks.
- Frees up skilled maintenance people to spend time on more value-added activity and technical repairs.
- The operators are responsible for upkeep of their equipment to prevent it from deteriorating.

Targets for autonomous maintenance:

- Reduce process time by  $x\%$ .
- Increase autonomous maintenance (AMs) activities.
- Operations of equipment are uninterrupted. Operators are flexible and maintain other equipment.
- Defects are eliminated at the source through employee participation.

Steps:

1. Preparation of employees
2. Initial cleanup of machines
3. Take countermeasures
4. Fix tentative Jishu Hozen (JH) standards
5. General inspection
6. Autonomous inspection
7. Standardization
8. Autonomous management

Operators can detect and prevent 75% or more of machine breakdowns. Quick and simple autonomous maintenance activities such as inspection and lubrication can:

- Prevent overheating or wear on moving parts
- Remove contamination
- Detect early warning signs of deterioration

In autonomous maintenance the focus is on empowering the machine operators to detect early warning signs on machines, and contact maintenance to request repairs or work on the machine. The majority of autonomous maintenance tasks are cleaning, inspection, and lubrication activities that can be done quickly on a daily basis.

As a rule, the operator's domain is the exterior of the machine, or what can be accessed from the outside. The maintenance person's domain is the interior of the machine, or the working components that are inside the machine. By performing maintenance tasks, the operators free up the maintenance technicians to work more on training, preventive and planned maintenance, and equipment improvement.

Autonomous maintenance allows for rapid identification and problem resolution, establishes standards, stabilizes equipment conditions, and stops accelerated deterioration of plant and equipment. Autonomous maintenance is the principal way in which production workers are involved in TPM in order to:

1. Help operators learn more about their equipment
2. Prepare operators to be active partners with maintenance and engineering in improving equipment performance and reliability
3. Enable early detection of problems

Autonomous maintenance will detect abnormalities early to prevent failures and modify equipment so that operators can easily detect abnormalities, and train operators as a first line of defense to detect deterioration.



**FIGURE 5.6** Autonomous maintenance (Jishu Hozen).

### Pillar 3: Kobetsu Kaizen (Particular Case)

The kaizen symbol is shown in Figure 9.5.

- Japanese term.
- *Kai* means “change.”
- *Zen* means “for the better.”
- *Kaizen* means “continuous improvement.”

Concept:

- Small incremental improvements
- Improvements add up over time

*Kai* is defined as “to break apart or disassemble so that one can begin to understand.” *Zen* is defined as “to improve.” This process focuses on improvements objectively by breaking down the processes in a clearly defined and understood manner so that wastes are identified, improvement ideas are created, and wastes are both identified and eliminated. The philosophy includes reducing cycle times and lead times, in turn increasing productivity, reducing work-in-process (WIP), reducing defects, increasing capacity, increasing flexibility, and improving layouts through visual management techniques.

Kaizen



**FIGURE 5.7** Kaizen symbol.

Operator cycle times need to be understood in order to reduce the non-productive times. Operators should also be cross-functional so that they are able to perform different job functions and the workloads of each function are well balanced. Any work performed should not only be value-added work, but also work that is in demand through customers. WIP should be eliminated to reduce inventory. Inventory should be seen simply as money waiting in process and should be reduced as much as possible. WIP can be reduced by reducing setup times, transporting smaller quantities of batch outputs, and line balancing. Bottlenecks should be removed by finding non-value-added tasks and removing the excess time spent by both machinery and humans.

Targets:

- Zero losses sustained with minor stops, measurements, and adjustments
- Zero defects and unavoidable downtime
- Reduce manufacturing costs by  $x\%$

Steps:

1. Practice concepts of zero losses in every sphere of activity.
2. Relentless pursuit to achieve cost reduction targets in all sources.
3. Relentless pursuit to improve overall plant equipment effectiveness.
4. Extensive use of preventive maintenance (PM) analysis as a tool to eliminate losses.
5. Focus on easy handling of operators.

### Pillar 4: Planned Maintenance

- Aimed to have trouble-free machinery and equipment with zero defects for 100% customer satisfaction
- Become proactive versus reactive while utilizing trained maintenance staff to help train

operators to better maintain their equipment

Targets:

- Zero equipment failure and breakdown
- Improve reliability and maintainability by 50%
- Reduce maintenance costs by 20%
- Ensure availability of spares at all times

Steps:

1. Equipment evaluation and recording present status
2. Restore deterioration and improve weakness
3. Building up information management system
4. Prepare time-based information system, select equipment, parts, and members, and map out the plan
5. Prepare predictive maintenance system by introducing equipment diagnostic techniques
6. Evaluation of planned maintenance

Basic goals of planned maintenance:

1. Zero equipment failures and breakdowns
2. 20% reduction in maintenance cost
3. Spare parts available when needed

Planned maintenance consists of progress from reactive to proactive maintenance, professional maintenance staff performing more advanced tasks (once simpler daily tasks are done as part of AM) and developing capabilities of management staff.

Planned maintenance consists of scheduled maintenance activities for prevention, equipment restoration program, and predicting life span using equipment diagnostics. Planned maintenance also prevents forced deterioration by understanding the following:

- Deterioration is accelerated by neglect.
- Preventive maintenance involves maintenance in daily, weekly, and monthly checks.
- Picks up where autonomous maintenance ends (requires higher level of skill to check).
- Based on documented standards (such as one-point lessons).

Planned maintenance has three main steps:

Preventive maintenance (1 of 3):

1. Time-based maintenance:

- Timing parameter is set according to known rates of deterioration.
- Parts replacement and repairs performed at set time, regardless of actual condition.
- Economical to exchanging parts on a set time basis (cost of parts is low compared to cost of failure).

Preventive maintenance (2 of 3):

1. Condition-based (predictive) maintenance:

- Deterioration is measured periodically and analyzed.
- Parts replacement and repairs performed when measured deterioration is at set value.
- Economical to exchanging parts near end of the useful life (cost of parts is high compared to cost of failure).

Preventive maintenance (3 of 3):

2. Inspection and repair (overhaul):

- Equipment is periodically disassembled and inspected.
- Parts replacement and repairs performed when need is discovered during overhaul.
- Economical to exchanging parts based on actual condition but also within set timing (after X hours of operation).

## **Pillar 5: Quality Maintenance**

- Aimed toward customer delight by achieving improved levels of quality through defect-free manufacturing.

- Focus is on eliminating non conformances in a systematic manner.
- We gain an understanding of what parts of the equipment affect product quality and begin to eliminate current quality concerns, and then move to potential quality concerns.
- Transition is from reactive to proactive.

Targets:

- Zero customer complaints
- Reduce in-process defects by 50%
- Reduce cost of quality by 50%

Quality defects are classified as customer end defects and in-house defects. For customer end data, we have to get data on:

1. Customer end line rejection
2. Field complaints

In-house data include data related to products and data related to process. Any equipment components that affect a product's quality are considered quality components. These components will prevent defects from occurring by maintaining such components in their specified condition.

The main goal is to control quality components by understanding the problems and being able to improve components.

### Pillar 6: Training

A training demonstration is shown in Figure 5.5.

- Aimed to have multi skilled and energized employees who have high morale and are eager to come to work to perform all their required functions independently and effectively.
- Education is given to operators to upgrade their skills.
- Employees should be trained to achieve the following phase offorms:

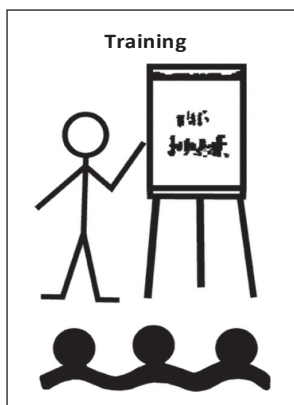
Phase 1: Do not know.

Phase 2: Know the theory but cannot do. Phase 3: Can do but cannot teach.

Phase 4: Can do and also teach.

Targets:

- Achieve and sustain downtime at zero on critical machines
- Achieve and sustain zero losses due to lack of knowledge/skills/techniques
- Aim for 100% participation in suggestion scheme



**FIGURE 5.8 Training demonstration.**

Steps:

1. Setting policies and priorities and checking present status of education and training
2. Establishment of training system for operations and maintenance skills
3. Training the employees for the operation and maintenance skills
4. Preparation of training calendar
5. Kick off the training

## 6. Evaluation of activities and study of future approach

The TPM education and training methods are listed below:

1. One-point lessons:
  - Basic equipment function
  - As needed to support AM activity
2. Practical problem solving:
  - Improvement teams
  - Quality Check (QC) circles
3. Skill development plan:
  - Equipment operation
  - Maintenance and problem solving

The TPM education and training goals consider the following:

- Operator skills:
  - Daily checking and lubricating
  - Capable of detecting abnormalities
  - Capable of making minor improvements
  - Define good operating conditions
  - Operate and maintain equipment
- External maintenance—responsibility of operator
- Maintenance skills:
  - Equipment restoration
  - Monitoring equipment
  - Improve and correct design flaws
  - Enhance technical skills
  - Training/instructing operators
  - Internal maintenance—responsibility of professional maintenance

The TPM education and training steps consist of:

1. Conduct introduction to TPM training: Should already be started by this point in the deployment.
2. Determine maintenance subjects, for example:
  - Drive systems
  - Lubrication
  - Hydraulics
  - Electrical system
  - Mechanical components
3. Develop training materials by subject.
4. Conduct maintenance training:
  - General inspection
  - Problem analysis
  - Technician course
5. Conduct one-point lessons for operators.
6. Audit TPM performance by area and provide coaching as part of leader standard work:
  - 5S
  - Performance boards
  - Overall equipment effectiveness



### Pillar 7: Office TPM

- Office TPM should be started after activating from other pillars of TPM (Jishu Hozen (JH), Kobetsu Kaizen (KK), Planned Maintenance (PM), and Quality Maintenance (QM)).
- Office TPM must improve productivity, efficiency, and flow in the administrative functions while identifying losses.
- Analysis of processes and procedures toward office automation is sought after.

Twelve major losses are covered:

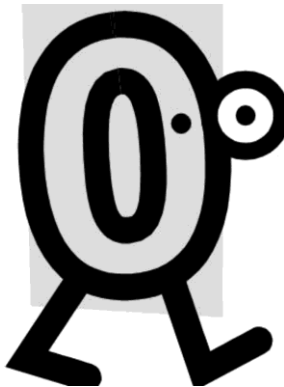
1. Processing loss
2. Cost loss, including in areas such as procurement, accounts market-ing leading to high inventories
3. Communication loss
4. Idle loss
5. Setup loss
6. Accuracy loss
7. Office equipment breakdown
8. Communication channel breakdown
9. Time spent on retrieval of information
10. Non availability of correct online stock status
11. Customer complaints due to logistics
12. Expense on emergency dispatches/purchases

### Pillar 8: Safety, Health, and Environment

- Focus to create a safe workplace and a surrounding area that is not damaged by process or procedures.
- This pillar will play an active role in each of the other pillars on a regular basis.

The zero mindset mentality shown in Figure 9.7 consists of the following:

- Zero accidents
- Zero health damages
- Zero fires



**FIGURE 5.9** Zero mindset mentality.

There are different types of maintenance involved with TPM, which are

1. Breakdown maintenance
2. Preventive maintenance
  - a. Periodic maintenance
  - b. Predictive maintenance
3. Corrective maintenance
4. Maintenance prevention

Introducing TPM at a production unit has four main steps:

Step 1: Preparatory stage

- Announcement by top management to all about TPM introduction in the organization
- Initial education and publicity for TPM
- Setting up TPM and departmental committees
- Establishing the TPM working systems and target
- A master plan for institutionalizing

Step 2: Introduction stage

Step 3: Implementation

Step 4: Institutionalizing stage

### PLANNED MAINTENANCE SYSTEM

It is well understood that well-planned, properly scheduled and effective communication can accomplish more work, more efficiently, and at a lower cost. Work properly prepared in this fashion disturbs operations less frequently, and is accomplished with higher quality, greater job satisfaction, and higher organizational morale than jobs performed without proper preparation. Planned maintenance refers to maintenance work that is performed with advance planning, foresight, control, and records. It is characterized by the following:

- The maintenance policy has been stated carefully
- The application of the policy is planned in advance
- The work is controlled to conform to the original plan
- Data are collected, analyzed, and used to provide direction for future maintenance policies.

A planned-maintenance system administers the company's maintenance policy by providing the means of technically and financially directing and controlling the maintenance operations with the objective of higher plant maintenance standards and greater cost effectiveness. The successful planned-maintenance systems are those, which are simple to administer and involve shop-floor personnel in the minimum amount of paper work.

The steps involved in evolving a successful planned maintenance system are as follows:

- i) The first step is to establish what is to be maintained. This involves setting up of a facility record with complete details of all the items in the plant.
- ii) Next step involves preparation of maintenance schedule for every item of plant or equipment, which requires application of planned preventive maintenance. In the first instance this may be done for critical units of the plant. After gaining experience this can be implemented for all the units in the plant.
- iii) Detailed job specifications communicating engineer's requirements to the tradesman are prepared. They are prepared separately for each trade and frequency of inspection.
- iv) In order to apply job specification and control their issue, a maintenance program is drawn up. It is convenient to plan preventive maintenance on a weekly basis. This is done in close collaboration with production department. The production planner and planned maintenance controller work very close together. A proper arrangement for plant release for planned maintenance work is an absolute essential requirement.
- v) Each week copies of agreed weekly planning program are distributed by the maintenance planning office to the shop-floor production staff and to the maintenance staff, together with the appropriate job specifications listed on the planning program for distribution to the tradesman selected to carryout preventive inspection. The responsibility to select the

tradesman to do this work must be that of maintenance supervisor, who knows which of his men are best suited for the job. Plant must be released according to the program and maintenance persons must be made available to carry out maintenance work.

- vi) A blank inspection report accompanies the job specification. The inspection report is completed by the tradesmen carrying the maintenance job in accordance with the accompanying job specification. Inspection reports are checked and signed by maintenance supervisor before passing it back to the planning office. He can add any pertinent information that might be required for the plant-history record. Any fault which is noticed during planned inspections and not attended because of any reasons is reflected on the inspection report. Planning department schedules these jobs depending on the urgency involved.
- vii) Any emergency work arising at the shop floor is passed on to the maintenance supervision directly by the production supervision in the form of work-order. Work-orders are completed by the tradesmen carrying out the maintenance job. Work-orders are checked and signed by the maintenance supervisor before passing them on to planning office.
- viii) Plant history records are compiled from the inspection reports and maintenance requests after completion of the jobs by the tradesmen. Proper analysis of maintenance reports and designing out maintenance as a result of such an analysis helps in raising the maintenance standards and improve the cost effectiveness. As a result of the analysis if emergency maintenance is found to persist, it will indicate one of the following:
  - Insufficient maintenance
  - Incorrect maintenance
  - Inadequate standards of maintenance work.

### **Planned versus Total Maintenance**

A useful measure of TPM implementation is the ratio of planned maintenance versus total maintenance. Total maintenance represents all of the recorded maintenance hours. Planned maintenance is calculated as the total maintenance minus the maintenance performed due to equipment breakdown.

$$\text{Planned vs. Total Maintenance} = \frac{\text{Planned Maintenance}}{\text{Total Maintenance}}$$

Organizations typically calculate this ratio on a monthly basis, as it provides an indicator of the TPM system health.

### **Quality Maintenance**

Quality Maintenance is the sixth pillar of TPM and aims to assure zero defect conditions. It does this by understanding and controlling the process interactions between manpower, material, machines and methods that could enable defects to occur. The key is to prevent defects from being produced in the first place, rather than installing rigorous inspection systems to detect the defect after it has been produced.

Quality Maintenance is launched later in the overall TPM deployment process because certain conditions must be in place for it to be successful. These conditions are delivered by full implementation of the first four pillars. Forced deterioration must be abolished, process problems must be eliminated and any variation in materials must be under control. Operators and maintenance must have the required capability to sustain equipment conditions. Quality Maintenance is implemented in two phases. The first phase aims to eliminate quality issues by analysing the defects, so that optimum

conditions can be defined that prevent defects occurring. Then, the current state is investigated and improvements are implemented. The second phase ensures that quality is sustained, by standardising the parameters and methods to achieve a zero defect system.