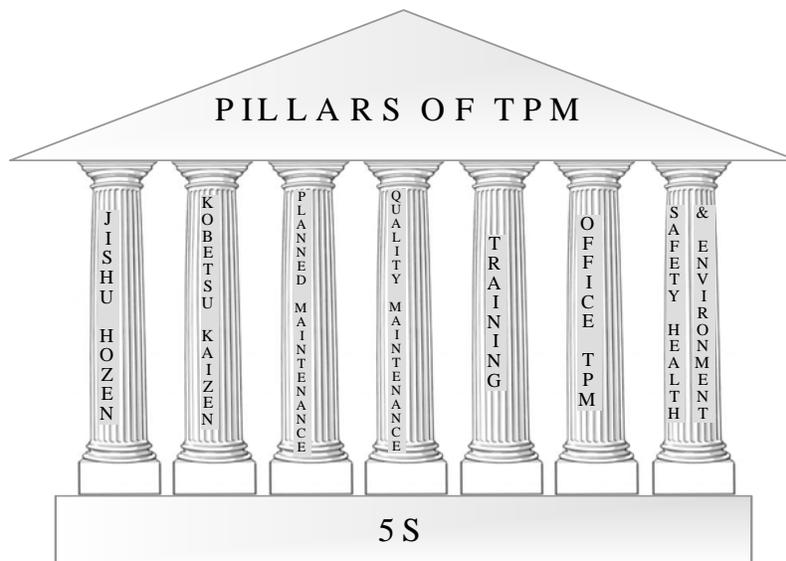


DENSO

INTRODUCTION TO TOTAL PRODUCTIVE MAINTENANCE

Student Study Guide

TPM100



Revision 0

MODULE 1

INTRODUCTION TO TOTAL PRODUCTIVE MAINTENANCE

Objectives:

- 1.1 LIST Goals of the TPM Program.
- 1.2 STATE five benefits of the TPM Program.
- 1.3 DESCRIBE briefly the major production losses that affect overall equipment efficiency.
- 1.4 Given a verbal or written description, IDENTIFY the major types of Maintenance.
- 1.5 DESCRIBE the general roles of Production, Maintenance, and Engineering Groups, etc., in a TPM Program.
- 1.6 DESCRIBE the specific responsibilities of Production Operators in a TPM Program.
- 1.7 STATE the activities that are the foundation of a TPM Program.
- 1.8 DESCRIBE how the Operator's senses can be used to inspect equipment.
- 1.9 DESCRIBE the general requirements for lubricating equipment.
- 1.10 DESCRIBE briefly the purposes of the "pillars" of TPM.

1-1-0 What is TPM?

Total Productive Maintenance (TPM) is a well-defined and time-tested concept for maintaining plants and equipment. TPM can be considered the science of machinery health.

TPM was introduced to achieve the following objectives:

- Avoid waste in a quickly changing economic environment.
- Produce goods without reducing product quality.
- Reduce costs.
- Produce a low batch quantity at the earliest possible time.
- Send only non-defective parts to the customers.

TPM involves all Denso Associates. The major difference between TPM and other concepts is that the Production Operators are directly involved in the process of maintaining their equipment.

The old notion of "*I operate the equipment, You Maintain it*" is NOT followed.

1-1-1 Denso's History with TPM

Total Productive Maintenance is an innovative Japanese concept, the origin of which can be traced back to the early 1950s when preventive maintenance was introduced in Japan. The concept of preventive maintenance originated in the USA. Preventive maintenance is the concept of daily maintenance designed to maintain equipment in good condition and prevent failure through the prevention of deterioration and periodic inspections. **Nippondenso** was the first company to introduce plant-wide preventive maintenance in 1960.

Nippondenso operators used machines to produce products and the maintenance group maintained the machines; however, with the introduction of more and more factory automation, maintenance became a problem because more maintenance personnel were required. Management decided that the production operators could perform the routine maintenance on their equipment (*Autonomous Maintenance*, one of the features of TPM). The maintenance group could then focus on essential maintenance projects.

Thus, **Nippondenso**, which already practiced preventive maintenance, also added Autonomous Maintenance performed by production operators. The maintenance group began identifying modifications to improve overall equipment reliability. The modifications were made or incorporated in new equipment. This led to *Maintenance Prevention*. *Preventive maintenance* along with *Maintenance Prevention* and *Maintainability Improvement* gave birth to *Productive Maintenance*. The goal of productive maintenance was to maximize plant and equipment effectiveness to achieve optimum life cycle cost of production equipment.

1-1-1 Denso's History with TPM (Cont.)

By then **Nippondenso** had made quality circles, involving the employees' participation in implementing Productive Maintenance. Based on these developments **Nippondenso** was awarded by the *Japanese Institute of Plant Engineers* (JIPE) the distinguished plant prize for developing and implementing TPM. **Nippondenso** of the Toyota group became the first company to obtain the TPM certification.

Denso Vision 2015

To meet our Goals, we must surpass customer expectations of quality, cost, and delivery, which create a new level of value for everyone.

TPM supports Denso Vision 2015.

1-1-2 TPM Goals and Benefits

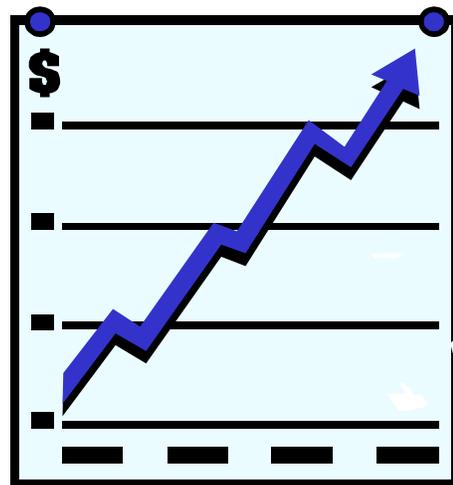
The goal of the TPM program is to markedly increase production while, at the same time, increase associate morale and job satisfaction.

TPM brings maintenance into focus as a necessary and vitally important part of the business. It is no longer regarded as a non-profit activity. Downtime for maintenance is scheduled as a part of the manufacturing day and, in some cases, as an integral part of the manufacturing process.

The goal is to hold emergency and unscheduled maintenance to a minimum.

The benefits of TPM are:

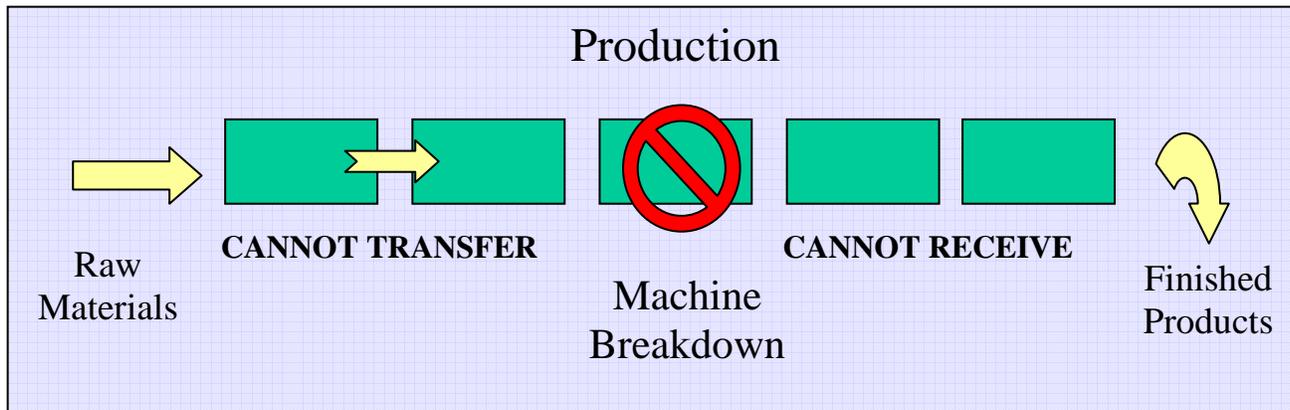
- A Safer Workplace
- Associate Empowerment
- An Easier Workload
- Increased Production
- Fewer Defects
- Fewer Breakdowns
- Fewer Short Stoppages (Chokotei)
- Decreased Costs
- Decreased Waste (Muda)



1-2 Equipment Efficiency

Equipment that does not operate well or is always breaking down causes more work for everyone and can cause customer dissatisfaction.

If equipment breaks down during production, many other processes can be affected. Refer to the figure.



Production equipment not being able to produce products with normal equipment performance is due to 6 major losses:

- Startup Loss
- Setup/Adjustment Loss
- Cycle Time Loss
- Chokotei Loss
- Breakdown Loss
- Defect Loss

If the equipment operates without breakdowns and is consistently working well, everyone's work is easier, the company is more profitable, and working conditions are improved.

The inverted stair step diagram on the following page shows graphically how the losses in availability, performance, and quality work together to reduce the overall effectiveness of a machine.

1-2 Equipment Efficiency (Cont.)

The top bar, total operating time, shows the total time a machine is available to make a product. This is usually considered to be 480 minutes per 8-hour shift.

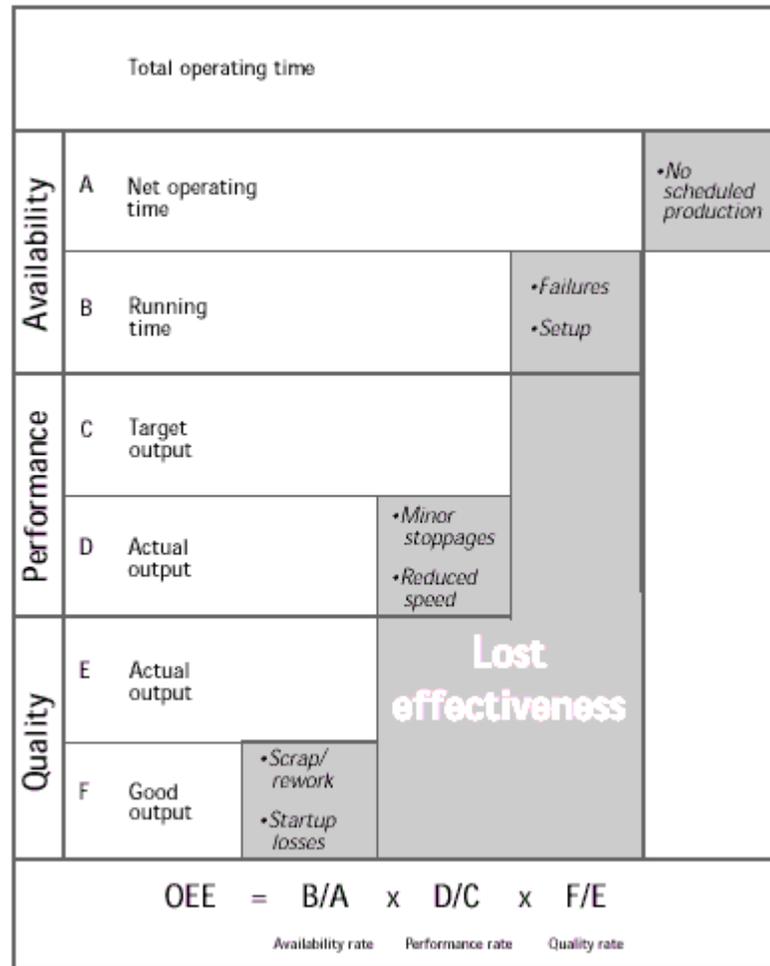
Bars A and B show availability. Bar A represents the net operating time, which is the time available for production after subtracting planned downtime (no scheduled production) such as a holiday, no orders, or no personnel.

Bar B shows the actual running time after subtracting downtime losses such as equipment failures and setup and adjustments.

Bars C and D show performance. Bar C represents the Target Output of the machine during the running time, calculated at the designed speed of the machine. Below it, bar D represents the actual output, reflecting speed losses such as minor stoppages and reduced operating speed.

Bars E and F show quality. As you can see, the actual output (E) is reduced by defect losses such as scrap and startup losses, shown as the shaded portion of bar F.

As this diagram shows, the bottom-line good output is only a fraction of what it could be if losses in availability, performance, and quality were reduced. The diagram also suggests that to maximize effectiveness—to grow the good output on the bottom line—you must reduce not only quality losses, but also availability and performance losses. The three factors work together, and the lowest percentage is usually the constraint that most needs addressing.



1-3 Maintenance

Maintenance is defined as “activities that retain machine performance”.

The number, frequency, and severity of equipment breakdowns can be decreased with proper maintenance. Maintenance includes servicing current conditions and taking action to prevent future problems.

1-3-1 Types of Maintenance

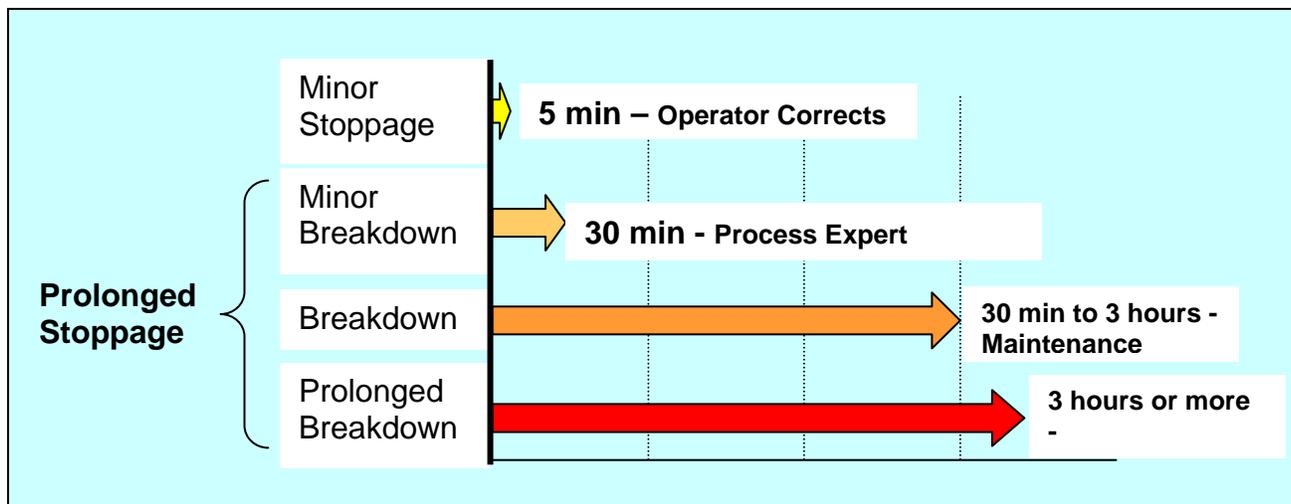
The major categories of Maintenance include:

- Breakdown Maintenance
- Preventive Maintenance
- Predictive Maintenance
- Corrective Maintenance
- Maintenance Prevention



Breakdown Maintenance (BM) is when we wait for equipment to fail and then repair it. For example, some electronic equipment is simply replaced when it fails.

Equipment breakdown is classified according to the duration of the stop. Refer to the diagram.



Preventive Maintenance is periodic maintenance that retains the condition of equipment and prevents failure through the prevention of deterioration, periodic inspection, and equipment condition diagnosis. PM includes daily cleaning, inspection, lubrication and tightening.

Autonomous Maintenance is daily preventive maintenance (cleaning, inspection, lubrication and re-tightening) performed by the equipment operator.

1-3-1 Types of Maintenance (Cont.)

Preventive Maintenance is further divided into *Periodic Maintenance* and *Predictive Maintenance*. Periodic Maintenance is time-based, which involves periodically inspecting, servicing, and cleaning equipment and replacing parts to prevent problems. Predictive Maintenance is condition-based, which involves predicting the service life of important parts based upon inspection or diagnosis, to use the parts to the limit of their service life.

Corrective Maintenance improves equipment and its components so that preventive maintenance can be performed reliably. Equipment with a design weakness is redesigned with corrective maintenance to improve reliability or maintainability.

Maintenance Prevention deals with improving the design of new equipment. Current machine data (information leading to failure prevention, easier maintenance, prevention of defects, safety, and ease of manufacturing) are studied and designs are incorporated in new equipment.

1-4 TPM Activities

“TPM Activities” involve everyone working together to make effective use of the equipment and maintain good production conditions. Refer to the Example TPM Activities Chart, which shows how everyone works together to maintain equipment.

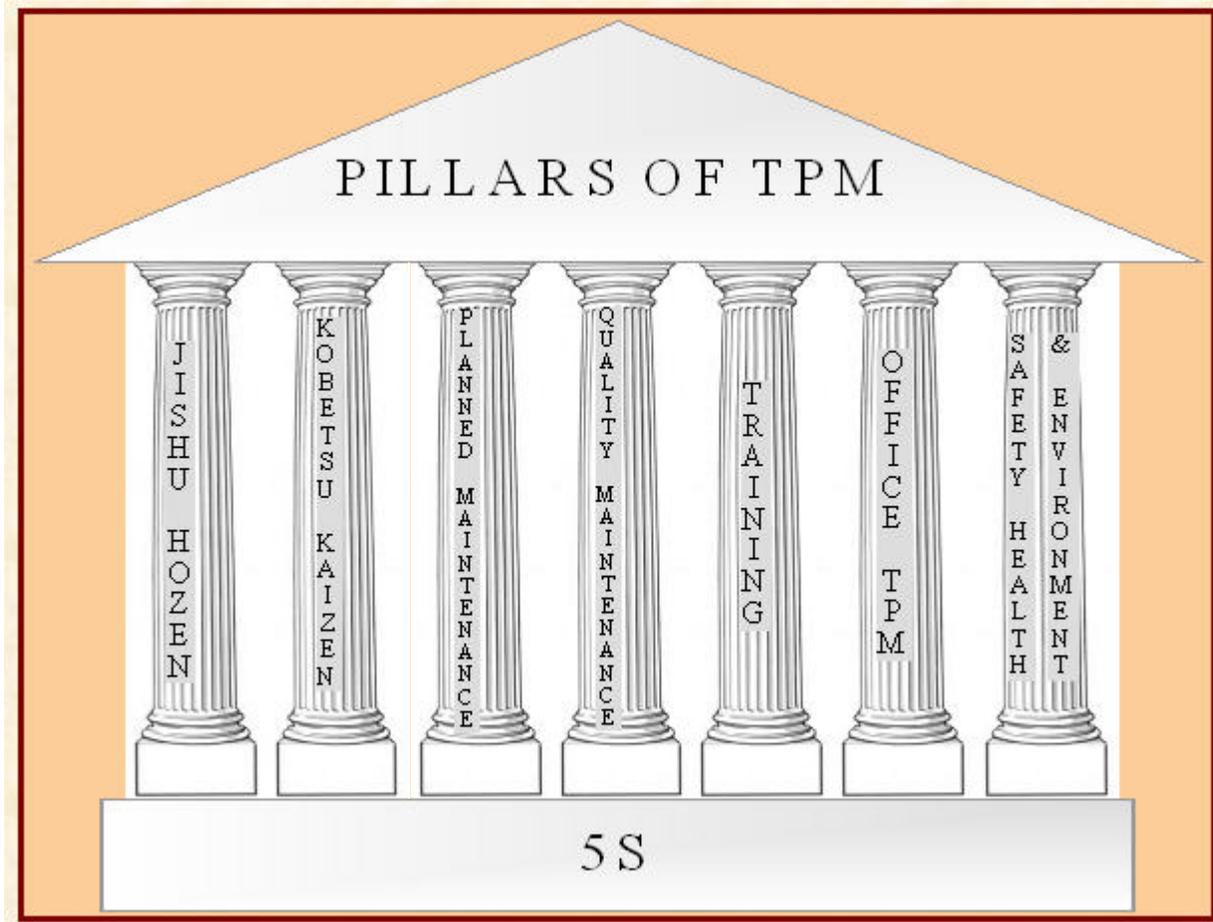
EXAMPLE TPM ACTIVITIES					Production						
Objectives	Classification of Methods	ACTIVITIES			Production Operator	Intermediate Process Expert	Advanced Process Expert	Maintenance	Production Engineering	Machine Improvement	
		Prevent Deterioration	Measure Deterioration	Restore Deterioration							
Effective use of Equipment	Maintenance Activities	Normal Operation	Correct Operation		○	○	○				
			Setup/Adjustment		○	○	○				
			Cleaning (Detection and disposal of defects)		○	○	○	△			
		Daily Maintenance	Lubrication		○	○	○	△			
			Tightening		○	○	○				
			Daily Inspection		○	○	○				
		Periodic Maintenance	Periodic Inspection	Minor mechanical service ※1			○	○	△		
				Periodic Mechanical Service			△※2	△	○		
			Trend Analysis	Irregular Mechanical Service			△※2	△※2	○		
		Predictive Maintenance	Assessments	Countermeasure			○	○	○	△	
							○※3	○※4	○		
		Corrective Activities	Corrective Maintenance (Reliability)	Improve strength					△	○	
				Reduce the load					△	○	△
				Improve precision					△	○	△
			Corrective Maintenance (Maintainability)	Development of condition-monitoring						○	△
Improvement of Inspection work								○	△		
		Improvement of Maintenance work					○	△			

※1 Replacement and adjustment of consumable parts
 ※2 Range of the work transferred to Process Expert, considering the hardware and software of equipment.
 ※3 Troubleshooting less than 30 minutes
 ※4 Troubleshooting exceeding 30 minutes

Work Classification (○ : Normal work)
 (△ : Support work)

1-4-1 Pillars of TPM

Because TPM involves everyone, the concept of TPM can be illustrated as being supported by seven TPM Activities “Pillars”, all of which are supported by 5S. Refer to the figure.



1-5 5S – The Foundation of TPM

TPM starts with 5S. Problems cannot be clearly seen when the work place is unorganized. Cleaning and organizing the workplace helps the team to uncover problems. Making problems visible is the first step of improvement.

1-5 5S – The Foundation of TPM

Refer to the table for the 5Ss and their meanings.

Japanese Term	English Translation	Equivalent 'S' term
<i>Seiri</i>	Organization	Sort
<i>Seiton</i>	Tidiness	Organize
<i>Seiso</i>	Cleaning	Sweep
<i>Seiketsu</i>	Standardization	Standardize
<i>Shitsuke</i>	Discipline	Self - Discipline

SEIRI - Sort:

Seiri means sorting and organizing the items as critical, important, frequently used items, or items that are not currently needed. Unwanted items can be salvaged. Critical items should be kept for use nearby and items that are not needed in near future should be stored some place else.

For this step, the priority of the item should be decided based upon utility and not cost. As a result of this step, the search time is reduced.

Priority	Frequency of Use	How to use
<i>Low</i>	Less than once per year, Once per year<	Throw away, Store away from the workplace
<i>Average</i>	At least 2/6 months, Once per month, Once per week	Store together but in an appropriate location away from the immediate work area
<i>High</i>	Once Per Day	Locate at the workplace

1-5 5S – The Foundation of TPM

SEITON - Organize:

The concept here is that "A place for everything, and everything in its place". After usage items should be stored in their designated storage location. To identify items easily, name plates and colored tags can be used. Vertical racks can be used for organization.

SEISO - Shine:

Seiso involves cleaning the workplace and ensuring equipment is free of burrs, loose wires, grease, oil, waste, scrap, etc.

SEIKETSU - Standardization:

Associates decide together on standards for keeping the workplace, machines, and pathways neat and clean. These standards are implemented for whole organization and are regularly checked.

SHITSUKE - Self Discipline:

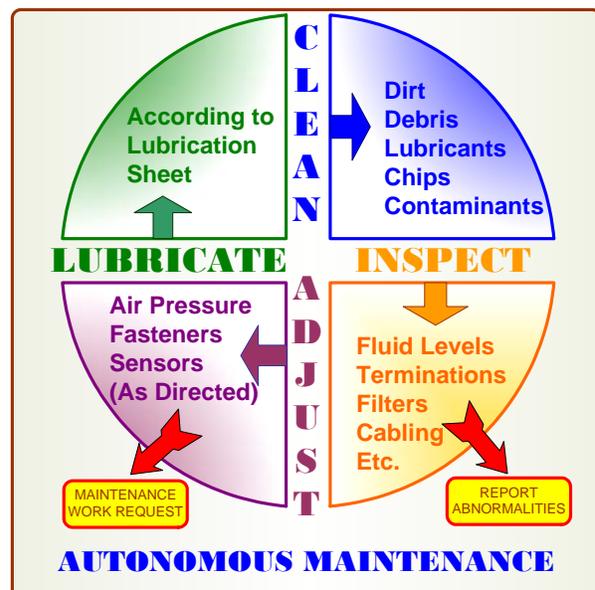
Accepting 5S as a way of life forms self-discipline among the associates. This includes wearing badges, following work procedures, punctuality, dedication to the organization, etc.

1-6 JISHU HOZEN PILLAR (Autonomous Maintenance)

Jishu Hozen, which means autonomous or self-maintenance, promotes development of production operators to be able to take care of small maintenance tasks, such as cleaning, inspecting, and lubricating their equipment, thus freeing the maintenance associates to spend time on more value-added activities and technical repairs. The operators are responsible for upkeep of their equipment to prevent it from deteriorating. Jishu Hozen (JH) has been shown to reduce oil consumption by 50% and process time by 50%.

Goals of Jishu Hozen:

- Uninterrupted operation of equipment
- Flexible operators who can operate and maintain other equipment
- Elimination of defects at the source through active employee participation
- Stepwise implementation of JH activities



1-6 JISHU HOZEN PILLAR (Autonomous Maintenance) (Cont.)

The effects of Autonomous Maintenance include:

- Equipment condition is known at all times.
- Unexpected breakdowns are minimized.
- Corrosion is prevented, wear is delayed, and machine life is extended.
- Judgment of machine capability is improved.
- Parts costs are reduced.
- Machine operation ratio is improved.

Production Operators are expected to perform the TPM Activities of Cleaning, Lubrication, and Inspection on a Daily Basis. Make sure you follow the instructions given by your G/L, T/L, or Supervisor.

1-6-1 Cleaning

Clean machines are easier to operate, inspect, and maintain. When the machine is dirty and corroded problems cannot be seen.

Sixty percent of factory automation maintenance troubleshooting involves problems that could have been addressed with general preventive maintenance. Examples of causes of problems include debris, contaminants, bad connections, loose terminations, intermittent wire, dirty contacts, clogged filters, bad gaskets, low fluid levels, etc.

The following steps outline the initial cleanup of machines:

1. Arrange all items needed for cleaning.
2. Clean equipment completely (with help from Maintenance, if necessary).
3. Remove dirt, dust, stains, oils, and grease.
4. Take care of any oil leaks, loose wires, loose nuts or bolts and worn parts.

After the initial cleanup of machines:

1. Note inaccessible machine areas and sources of contamination.
2. Categorize and tag problem areas. (Use white tags to note problems that operators can solve; red tags note the maintenance department is needed.)
3. Transfer tag contents to a database for a record.

1-6-2 Inspection

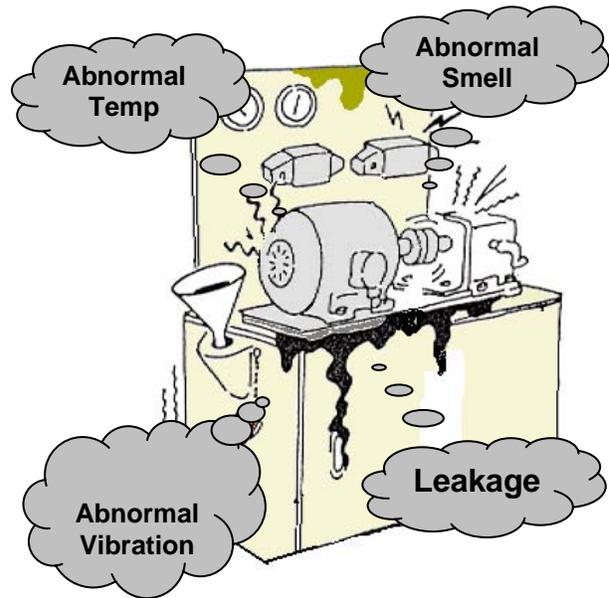
Inspect the conditions of each part of equipment using the human senses of sight, hearing, smell, and touch to detect signs of equipment failure.

Symptoms of potential problems can include unusual vibrations, noises, abnormal smells, abnormal component heating, or unusual sights, such as smoke, metal chips, or fluid leakage.

By identifying potential problems with inspections, we can plan and implement repair or replacement before a breakdown or defect occurs.

Inspection can be aided through the use of stickers affixed to the equipment to show which sense is to be used at which location.

Refer to the figure below.



TPM - INSPECTION



Abnormal hydraulic pump sound/temp can mean cavitation, pump failure, etc.

Inspection Stickers

 <p style="font-size: small;">See something wrong?</p>	 <p style="font-size: small;">Something smell?</p>
 <p style="font-size: small;">Feel something wrong?</p>	 <p style="font-size: small;">Hear something wrong?</p>

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1-6-2 Inspection (Cont.)

Inspection Findings

Address any problems found during inspections with countermeasures. Example countermeasures:

- If many screws must be unscrewed to open a cover plate door, use a hinged door instead.
- Instead of opening a machine inspection door, use a see-through acrylic sheet.
- Modify machine parts to prevent buildup of chips, dirt, and dust.

1-6-3 Lubrication

Prime movers transfer power so the equipment can do work. This involves a number of moving components, e.g., bearings, gears, shafts, spindles, sprockets, chains, levers, and slides. Without proper lubrication, ALL of these components WILL FAIL.

Machinery must be properly lubricated to reduce surface wear, prevent corrosion, cool moving parts, dampen shock, and seal out contaminants. Proper lubrication involves using the proper type of lubricant in the proper amount at the proper time. Too much lubricant can cause problems including overheating the components; collecting dust, dirt, and debris; and causing slip hazards, etc.

The Lubrication Instruction found in each Denso Machine Operation Manual lists the equipment component to be lubricated, the proper type of lubricant, the interval (how often to lubricate), and the proper amount of lubricant to use.

Lubrication Instruction Sheet

The Lubrication Instruction is displayed in a schematic drawing form to indicate:

- 1) Which areas are oiled
- 2) When it is oiled
- 3) Which type of oil,
- 4) Who is to oil it, and
- 5) How much oil is used.

Follow the lubrication instruction when lubricating equipment.

Equipment Sketch

1-6-3 Lubrication (Cont.)

Each machine lubrication location is color coded to match the container used to dispense the lubricant.

The storage container is color coded to match the dispenser.

Equipment may also have color-coded lubrication labels. Always follow the lubrication instruction sheet. If you have any question about the instructions, ask your supervisor.



Color-Coded Lubrication Container Station

1-6-4 Minor Repairs

Production Operators should perform minor repairs and adjustments as training and approval by supervision allows. Minor repairs and adjustments may include:

- Tightening loose fasteners
- Replacing consumable parts
- Tightening loose connections
- Performing precision checks
- Adjusting sensors, etc.

As Production Operators upgrade their skills, they will be better able to maintain their own machines, understand why failures occur, and suggest ways of avoiding failures.

1-6-5 Production Data

Part of the Production Operator's job is to record production information such as:

- Daily Run Sheets
- In-Progress Rejects Chart
- Machine Operation Ratio (MOR) Chart
- Chokotei Charts, etc.

Performance tracking is a very important tool for the management of manufacturing equipment. Denso uses performance tracking data to identify problems and track them. Performance data can indicate where improvements are needed and helps to prioritize improvement work. We also need to be able to measure the effects of changes or modifications; therefore, performance tracking gives us a baseline to judge the effects of machine improvements and good machine operation.

1-6-5 Production Data (Cont.)

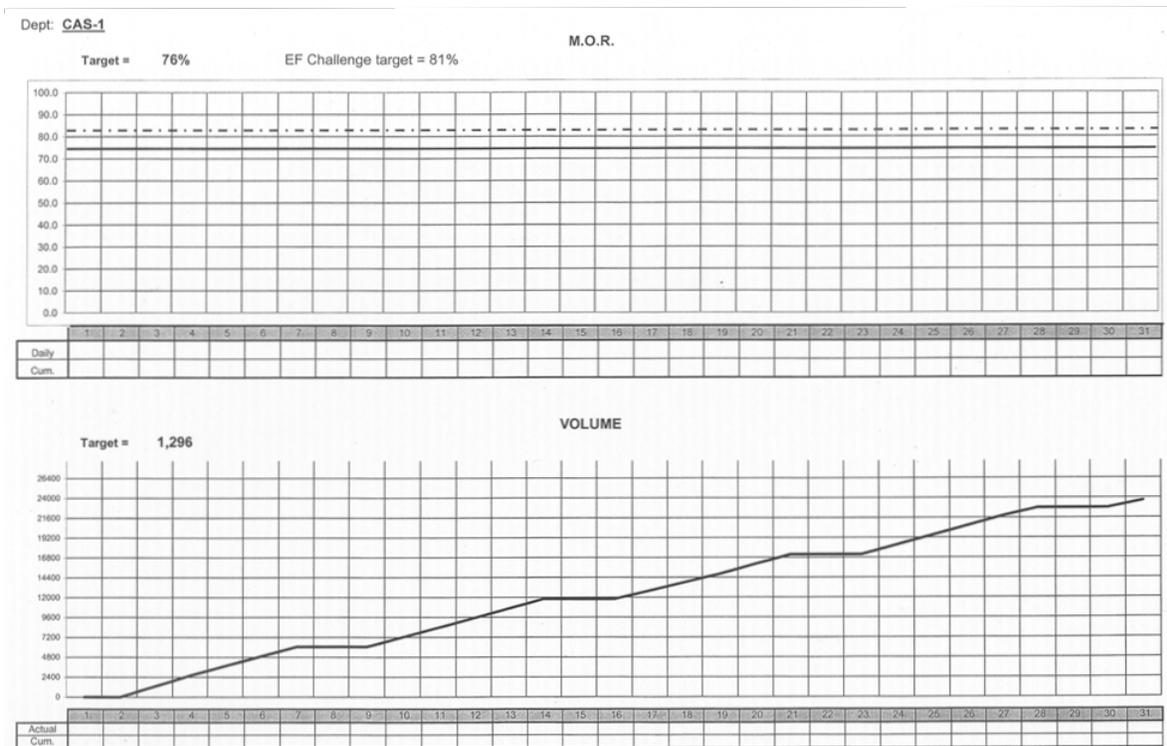
Performance tracking considers production volume, product quality, operation efficiency, and time usage.

Performance tracking data is collected on a daily run sheet at each machine. The production operator manually records the following items:

1. Quantity of Good Parts (hourly)
2. Quantity of Scrap Parts (hourly)
3. Quantity of Defect Parts (Hourly)
4. Machine Stop/Downtime, Time Down (Per event)
5. Machine Stop/Downtime, Description (Per event)
6. Scrap Material (Per Shift)

A description of any downtime is also recorded on the daily run sheet.

Below are examples of an MOR Chart and a Volume Chart.



1-7 Kobetsu Kaizen Pillar

"Kai" means change, and "Zen" means good (for the better). Kaizen is the opposite of big spectacular innovations. Kaizen is small improvements carried out on a continual basis and involves all people in the organization. Kaizen requires no or little investment. The principle behind Kaizen is that a large number of small improvements are more effective in an organizational environment than a few large-scale improvements. Systematically using various Kaizen tools in a detailed and thorough method eliminates losses. The goal is to achieve and sustain zero losses with respect to minor stops, measurement and adjustments, defects, and unavoidable downtimes.

Kobetsu Kaizen uses a special event approach that focuses on improvements associated with machines and is linked to the application of TPM. Kobetsu Kaizen begins with an up-front planning activity that focuses its application where it will have the greatest effect within a business and defines a project that analyses machine operations information, uncovers waste, uses a form of root cause analysis (e.g., the 5 Why approach) to discover the causes of waste, applies tools to remove waste, and measures results.

The objective of TPM is maximization of equipment effectiveness. TPM maximizes machine utilization, not merely machine availability. As one of the pillars of TPM activities, Kaizen activities promote efficient equipment and proper utilization of manpower, materials, and energy by eliminating 16 major losses.

Examples of Kobetsu Kaizen to make machines easier to maintain include:

- Relocating gauges and grease fittings for easier access.
- Making shields that minimize contamination.
- Centralizing lubrication points.
- Making debris collection accessible.

1-8 Planned Maintenance Pillar

The goal of planned maintenance is to have trouble-free machines and equipment that produce defect-free products for total customer satisfaction. Planned Maintenance achieves and sustains availability of machines at an optimum maintenance cost, reduces spares inventory, and improves reliability and maintainability of machines.

With Planned Maintenance the associates' efforts evolve from a reactive approach to a proactive method and trained maintenance staff helps train the operators to better maintain their equipment.

1-8 Planned Maintenance Pillar (Cont.)

Steps in Planned Maintenance include:

1. Evaluate and record present equipment status.
2. Restore deterioration and improve weaknesses.
3. Build information management system.
4. Prepare time-based data system, select equipment, parts, and team, and make plan.
5. Prepare predictive maintenance system by introducing equipment diagnostic techniques.
6. Evaluate planned maintenance.

1-9 Quality Maintenance Pillar

Quality Maintenance (QM) targets customer satisfaction through defect free manufacturing of the highest quality products. The focus is on eliminating non-conformances in a systematic manner. Through QM we gain an understanding of what parts of the equipment affect product quality, eliminate quality concerns, and then move to potential quality concerns. The transition is from reactive to proactive (From Quality Control to Quality Assurance).

QM activities control equipment conditions to prevent quality defects, based on the concept of maintaining perfect equipment to maintain perfect quality of products. These conditions are checked and measured in time series to verify that measured values are within standard values to prevent defects. The transition of measured values is trended to predict possibilities of defects occurring and to take countermeasures before defects occur.

QM activities to support Quality Assurance through defect free conditions and control of equipment. The focus is on effective implementation of operator quality assurance and detection and segregation of defects at the source. Opportunities for designing Poka-Yoke (foolproof system) are investigated and implemented as practicable.

1-10 Training Pillar

The goal of training is to have multi-skilled revitalized employees whose morale is high and who are eager to come to work and perform all required functions effectively and independently. The focus is on achieving and sustaining zero losses due to lack of knowledge / skills / techniques. Ideally, we would create a factory full of experts.

Operators must upgrade their skills through education and training. It is not sufficient for operators to learn how to do something; they should also learn why they are doing it and when it should be done. Through experience operators gain “know-how” to address a specific problem, but they do so without knowing the root cause of the problem and when and why they should be doing it. Hence it becomes necessary to train operators on knowing why. This will enable the operators to maintain their own machines, understand why failures occur, and suggest ways of avoiding the failures occurring again.

1-11 Office TPM Pillar

Office TPM should be started after activating four other pillars of TPM (Jishu Hozen, Kobetsu Kaizen, Quality Maintenance, and Planned Maintenance). Office TPM must be followed to improve productivity, efficiency in the administrative functions, and identify and eliminate losses. This includes analyzing processes and procedures towards increased office automation.

Office TPM addresses twelve major losses:

1. Processing loss
2. Cost loss including in areas such as procurement, accounts, marketing, sales leading to high inventories
3. Communication loss
4. Idle loss
5. Set-up loss
6. Accuracy loss
7. Office equipment breakdown
8. Communication channel breakdown, telephone and fax lines
9. Time spent on retrieval of information
10. Unavailability of correct on-line stock status
11. Customer complaints due to logistics
12. Expenses on emergency dispatches/purchases

Improving the office efficiency by eliminating the above-listed losses helps in achieving Total Productive Maintenance.

1-12 Safety, Health and Environment Pillar

The target of the Safety, Health & Environment pillar is:

- Zero accidents,
- Zero health damage, and
- Zero fires.

The focus is on creating a safe workplace and surrounding areas that are not damaged by our process or procedures. This pillar plays an active role in each of the other pillars on a regular basis.

SUMMARY

Today, with competition in industry at an all time high, TPM may be the only thing that stands between success and total failure for some companies. It has been proven to be a program that works. Employees must be educated and convinced that TPM is not just another "program of the month" and that management is totally committed to the program and the extended time frame necessary for full implementation. If everyone involved in a TPM program does his or her part, an unusually high rate of return compared to resources invested may be expected.

