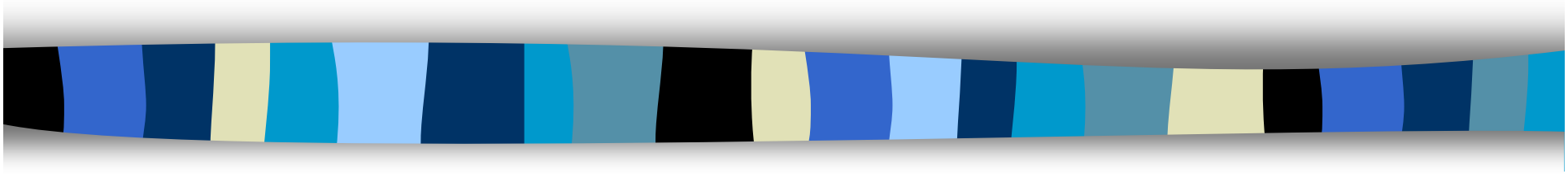
Total Productive Maintenance (TPM)



SMN 4842 Project Management & Maintenance Engrg.

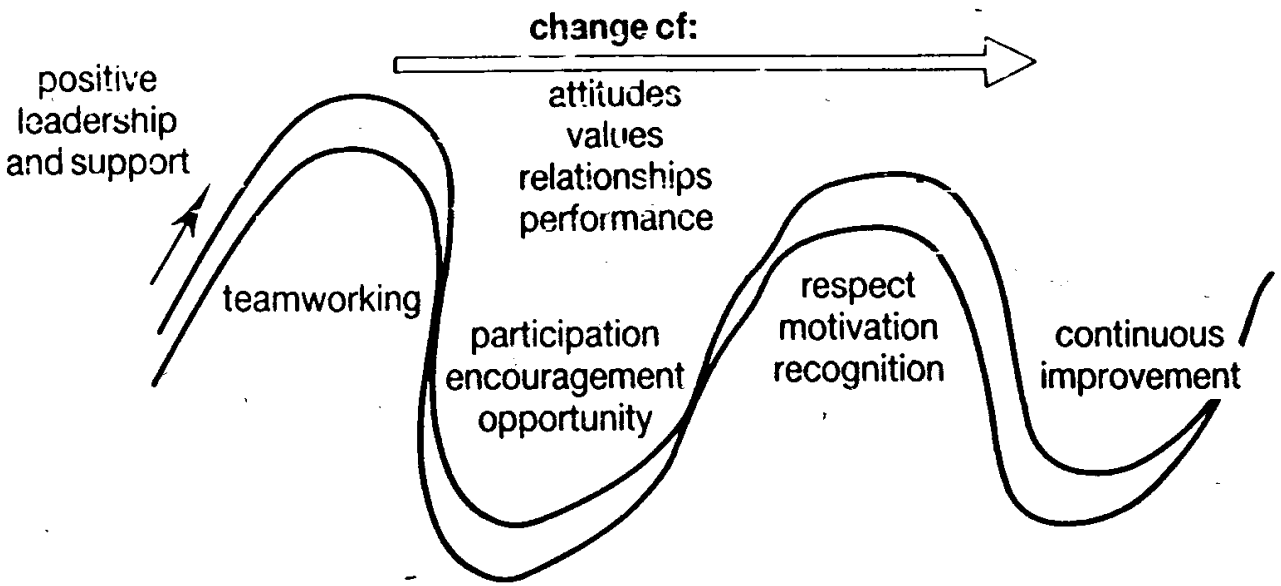
Semester 2 2010/2011

Introduction to TPM

What is TPM ?

- Total Productive Maintenance (TPM) is both
  - a philosophy to permeate throughout an operating company touching people of all levels
  - a collection of techniques and practices

    aimed at maximizing the effectiveness (best possible return) of business facilities and processes



The TPM philosophy

It is a Japanese approach for

- Creating company culture for maximum efficiency
- Striving to prevent losses with minimum cost
  - Zero breakdowns and failures, Zero accident, and Zero defects etc
- The essence of team work (small group activity) focused on condition and performance of facilities to achieve zero loss for improvement
- Involvement of all people from top management to operator

History/Origin

- TPM first introduced in Japan 20 years ago and rigorously been applied in past 10 years
- TPM planning & implementation in Japanese factories supported by JIPM (Japan Institute of Plant Maintenance)
- Awarded yearly prizes to various industries:
  - ✓ Automotive
  - ✓ Metals
  - ✓ Chemicals
  - ✓ Rubber
  - ✓ Food
  - ✓ Glass etc.

History/Origin

- Initially implemented in high-to-medium volume production areas

- Later successfully applied in:
  - ✓ Low-volume production
  - ✓ High-to-low volume assembly
  - ✓ Development areas
  - ✓ Warehouse
  - ✓ Whole range of industry

Role of TPM

Answers of the following questions are able to tell what role TPM can play within a company:

- Does TPM replace traditional maintenance techniques ?
- Why is it so popular and important ?
- What are its policies and objectives ?
- How does it fit in with TQM ?
- What are its steps, activities and components?
- What are its benefits and results ?

TPM and Traditional Maintenance

- Reactive maintenance inherently wasteful and ineffective with following disadvantages:

  - No warning of failure
  - Possible safety risk
  - Unscheduled downtime of machinery
  - Production loss or delay
  - Possible secondary damage

Need for:

- Stand-by machinery
- A stand-by maintenance team
- A stock of spare parts

Costs include:

- Post production
- Disrupted schedule
- Repair cost
- Stand-by machinery
- Spare parts

- Real cost of reactive maintenance is more than the cost of maintenance resources and spare parts

- Pro-active maintenance (planned, preventive and predictive) more desirable than reactive maintenance

- TPM enables or provides:

  - The traditional maintenance practices to change from reactive to pro-active
  - A number of mechanisms whereby
    - ✓ Breakdowns are analyzed
    - ✓ Causes investigated
    - ✓ Actions taken to prevent further breakdowns
  - Preventive maintenance schedule to be made more meaningful

- To ‘free up’ maintenance professionals to:
  - ✓ Carry out scheduled and preventive maintenance
  - ✓ Gather relevant information as important input to the maintenance system
  - ✓ Keep the system up to date
  - ✓ To review cost effectiveness
- To develop and operate a very effective maintenance system an integral part of manufacturing

Why is TPM so popular and important ?

Three main reasons:

1. It guarantees dramatic results (Significant tangible results)
   - Reduce equipment breakdowns
   - Minimize idle time and minor stops
   - Less quality defects and claims
   - Increase productivity
   - Reduce manpower and cost
   - Lower inventory
   - Reduce accidents

2. Visibly transform the workplace

(plant environment)

- Through TPM, a filthy, rusty plant covered in oil and grease, leaking fluids and spilt powders can be reborn as a pleasant and safe working environment
- Customers and other visitors are impressed by the change
- Confidence on plant's product increases

3. Raises the level of workers knowledge and skills

As TPM activities begin to yield above concrete results, it helps:

- The workers to become motivated
- Involvement increases
- Improvement suggestions proliferate
- People begin to think of TPM as part of the job

TPM Policy and Objectives

Policy and objectives:

- To maximize overall equipment effectiveness (Zero breakdowns and failures, Zero accident, and Zero defects etc) through total employee involvement

- To improve equipment reliability and maintainability as contributors to quality and to raise productivity

TPM Basic policy and objectives (Contd.)

- To aim for maximum economy in equipment for its entire life
- To cultivate equipment-related expertise and skills among operators
- To create a vigorous and enthusiastic work environment

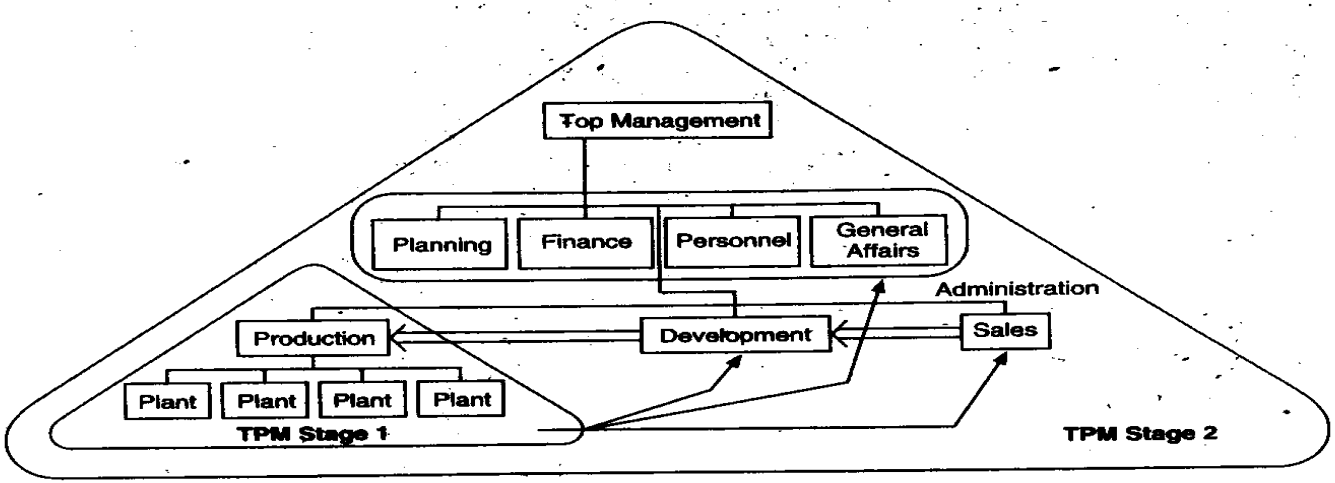
TPM Corporate policy for the following purposes:

- To aim for world-class maintenance, manufacturing performance and quality
- To plan for corporate growth through business leadership

TPM Corporate policy_(Contd.):

- To promote greater efficiency through greater flexibility
- Revitalize the workshop and make the most of employee talents

Production dept.TPM to Companywide TPM



TPM Stage 1: Production-department TPM
TPM Stage 2: Companywide TPM embracing production, development, sales, and administration

Figure 1-1. From Production-Department TPM to Companywide TPM

12 TPM Development Program Steps

Preparation

1. **Formally announce the decision to introduce TPM**

2. **Conduct TPM introductory education and publicity campaign**

3. **Create TPM promotion organization**

Preparation (Contd.)

4. Establish basic TPM policy and goals

5. Draft a master plan for implementing TPM

Introduction

6. Kick off TPM initiatives

   (to cultivate the atmosphere to raise morale, inspiration and dedication)

Implementation

7. Build a corporate constitution designed to maximize the effectiveness of facilities
   i. Conduct focused improvement activities
   ii. Establish and deploy autonomous maintenance program
   iii. Implement planned maintenance program
   iv. Conduct operation and maintenance skills training

8. Build an early management system for new products and equipment

Implementation (Contd.)

9. Build a quality maintenance system

10. Build an effective administration and support system
11. Develop a system for managing health, safety, and the environment

Consolidation

12. Sustain a full TPM implementation and raise levels (Prize)

Five fundamental TPM activities

1. Autonomous maintenance
2. Equipment improvement
3. Quality maintenance
4. MP(Maintenance Prevention) system-building
5. Education and training

Table **Five Fundamental TPM Development Activities**

Five TPM Activities	Goals	Division	Level
Autonomous Maintenance	• Eliminate six major losses and raise overall equipment effectiveness through small group activities • Educate workers in equipment-related knowledge and skills • Improve equipment, change workers' approaches, and revitalize the workshop	Production	Operators
Equipment Improvement	• Eliminate six major losses and maximize overall equipment effectiveness • Master improvement methods for maximizing equipment effectiveness	Production	Managers
Quality Maintenance	• Ensure 100% product quality by establishing and maintaining conditions for zero defects	Production	Managers and operators
MP System-building	• Create a system ensuring that information and techniques gained through in-house TPM activities are reflected in the design of machine tools sold outside the company	Machine tools plant	Engineering
		Tools and bearings plants	Production engineering
Education and Training	• Educate workers in equipment-related knowledge and skills • Improve and expand maintenance skills	TQC promotion office	TPM administration

Table TPM Development Program

Level of TPM activities	Level 1 Eliminate accelerated deterioration	Level 2 Eliminate failures	Level 3 Eliminate defects	Level 4 Operate profitably
Autonomous Maintenance Operators	Expose and correct abnormalities in equipment	Understand equipment functions and structure	Understand relation between equipment and quality	Facilitate autonomous maintenance of equipment
Steps	1. Conduct initial cleaning 2. Address the causes of dirty equipment 3. Improve areas that are hard to clean	4. Standardize maintenance activities 5. Develop general inspection skills	6. Conduct autonomous inspection 7. Organize and manage the workplace	8. Manage autonomously
Equipment Improvements	Eliminate chronic loss due to production bottlenecks	Maintain zero defects after retooling	Set conditions for zero defects	• PM circles set conditions for zero defects • Make equipment highly productive
Quality Maintenance			100% quality products through conditions control →	
MP System-Building		Incorporate information from users' TPM activities in new machine tools →		
Education and Training	• Educate workers in equipment-related knowledge and skills → • Cultivate in-house maintenance technicians →			

TPM and Total Quality

- TPM is an essential component of TQM
- TPM resembles TQM in following aspects:
  - Total commitment to the program by upper level management
  - Employee empowered to initiate corrective actions
  - Changes in employee mind-set towards their job responsibilities

Components of TPM

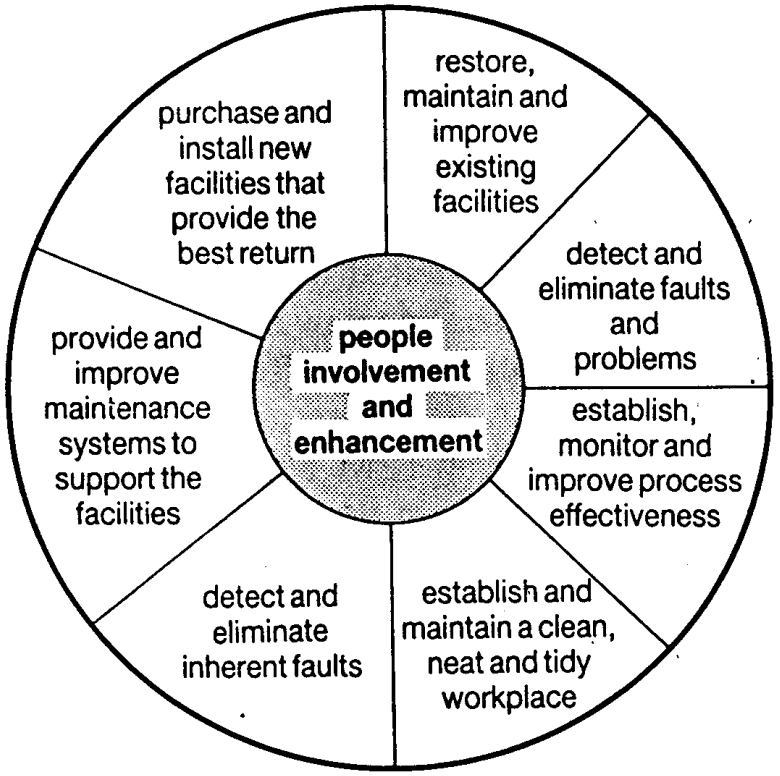


Figure The practical components of TPM

Practical Components of TPM

To be achieved through TPM team:

- **Restore, maintain and continuously improve the existing facilities**

Role of maintenance personnel	Role of operation personnel
o Carry out major repairs	o Maintain 'basic' machinery condition to prevent deterioration

Role of maintenance personnel (contd.)

- o Improve weak points and eliminate deterioration
- o Plan and carry out preventive maintenance
- o Analyze breakdowns and performance, and carry out predictive maintenance

Role of operation personnel (contd.)

- o Monitor machinery effectiveness
- o Regularly inspect to detect problems
- o Carry out simple improvements / repairs

Detect and eliminate faults and problems

Faults that:

o Cause breakdowns and/or stoppages

o Slow the process down

o Cause breakdowns and/or stoppages

Problems that:

o slow down the operator and make life difficult

o Make changeovers difficult

o Slow down the operator and make life difficult

Faults and Problems

Faults

- that cause breakdowns or stoppages
- that slow the process down
- that cause inconsistency
- that cause rejects
- that provide safety hazards

Problems

- that slow down the operator and make life difficult
- that make changeovers difficult
- that make the workplace dirty, oily and smelly
- that make the machinery dangerous to operate and set up
- that lead to injury

Figure 3.4 Types of faults and operating problems

Detect and eliminate faults and problems

Faults that:

o Slow the process down

o Cause inconsistency

o Cause rejects

o Provide safety hazards

Problems that:

o Make changeovers difficult

o Make workplace dirty, oily and smelly

o Make the machinery dangerous to operate and setup => lead to injury

Establish, monitor and improve process effectiveness

Following **six big losses** to recognize, measure and reduce:

1. Breakdown losses due to failures and repairs
2. Setup and adjustment losses

1and 2 = availability loss

Six big losses (Contd.):

3. Idling and minor stoppage losses
4. Speed losses
5. Scrap and rework losses
6. Start-up losses

3 and 4 = performance loss

5 and 6 = quality loss

Establish and maintain a clean, neat and tidy workplace

(This TPM component describes good house keeping)

Translation of 5 Japanese S's

1. ***Seiso*** => Shine / Cleanliness

   (Thoroughly clean the workplace)

Advantages:

- Pleasant and safer workplace and improved morale
- No wear, corrosion and failure of machinery due to dirt and debris

Seiso Advantages (contd.):

- Easy detection of oil leakage and spilage
- Psychological effects for improved reactions and performances
- Reduced hazards and more visible warning signs

2. ***Seiri*** => Sort / Arrangement

(Eliminate unnecessary items)

Better arrangement for ease of access and use of:

- Facilities, tools, fixtures and materials etc.

which brings substantial benefits

3. ***Seiton*** => Set In Order / Neatness

Efficient and effective storage method

- Defined location for storage of every facility required for production process
- Encourage people to return the facility after use

4. ***Shitsuke*** => Sustain / Discipline

(Sustain new status quo ‘everything in its place’)

Required to ensured that facilities are:

- Returned in proper location after use
- Kept clean and tidy
- Repaired / replaced if damaged

*5. **Seiketsu*** => Standardize / Order

Order and control to be established for:

- The above procedures and mechanisms
- Introduction of CAN DO activities at early stage
- Part of the company culture

- **Identify and eliminate inherent faults:**
  - Discover inherent faults either in design and manufacturing of machinery or in methods of operation
  - Try to reduce their effect wherever possible

Identify and eliminate inherent faults (contd.):

- Propose a project with a specially skilled small team to focus on inherent faults to improve overall effectiveness which includes:

  - ✓ Availability improvement through
    - ➢ Changeover and setup reduction
    - ➢ Reliability improvement
    - ➢ Maintainability improvement

- ✓ Performance improvement through
  - Chronic (big) loss analysis and improvement
  - Process improvement
  - Operational improvement

- ✓ Quality improvement through
  - Process capability study and improvement
  - Poka yoka (mistake proofing) design
  - Operational stability re-design

➢ Provide maintenance systems to support facilities

- Introduce more professional tools and techniques (autonomous maintenance) to establish and restore machinery condition
- Maintenance systems and resources are to be designed, implemented and continuously improved
- Specialist skills to provide for breakdowns, servicing and improvement of complex controls and mechanisms

➢ Purchase and install facilities that provide best return

The selection and purchase of new machinery must be approached:

- In a professional and structured way
- As an integral part of the overall manufacturing system

The selection and purchase of new machinery must be approached (Contd.):

- To conform the TPM philosophy of the company
- To meet the present and future need of the business
- To achieve world-class competitive performance in manufacturing

Measuring Effectiveness of Facilities

The effectiveness of facilities

- is its best possible return generated
- is calculated as percentage of each group of 6 big losses (discussed earlier)

Overall facilities effectiveness (OEE) =

%Availability x **%Performance** x **%Quality**

- Breakdown losses
- Set-up and adjustment losses

- Idling and minor stoppage losses
- Speed losses

- Scrap and rework losses
- Start-up losses

$$\%\textbf{Availability} = \frac{\text{Loading time} - \text{Breakdown \& Setup loss}}{\text{Loading time}} \times 100$$

Where loading time

= planned production/operation time – breaks – planned maintenance time

$$\%\ \textbf{Performance} = \frac{\text{Quantity produced}}{\text{Time run x Capacity/Given time}} \times 100$$

or

$$= \frac{\text{Time run} - \text{Minor stoppages} - \text{Reduced speed}}{\text{Time run}} \times 100$$

% Quality =

$$\frac{\text{Amount produced} - \text{Amount defects} - \text{Amount re-processed}}{\text{Amount produced}} \times 100$$

or

$$= \frac{\text{Time run} - \text{Defect time} - \text{Re-processing time}}{\text{Time run}} \times 100$$

Example 1

A medium volume manufacturing facility with a capacity of producing 2 parts/minute actually produced 800 parts in a planned running 2 shifts of 8 hours each. It had breaks and scheduled maintenance for 40 minutes and also faced 40 minutes breakdowns and 1 hour 20 minutes for changeover and adjustment. Number of rejects and re-works were 10 and 6 parts respectively. Calculate its overall effectiveness

Planned production time = 2x8 hrs. = 960 minutes

Loading time = 960-40 (breaks & scheduled maintenance) = 920 min.

Down-time =40 (Breakdowns) + 80(Changeover & adjustment)= 120

$$\textbf{\%Availability} = \frac{\text{Loading time} - \text{Down time}}{\text{Loading time}} \times 100 = \frac{920 - 120}{920} \times 100 = \textbf{87\%}$$

Example 1 (Contd.)

$$\%\textbf{Performance} = \frac{\text{Quantity produced}}{\text{Time run x Capacity/given time}} \times 100 = \frac{800}{(920-120)\times 2} \times 100 = \textbf{50\%}$$

$$\%\textbf{Quality} = \frac{\text{Amount produced} - \text{Amount defects} - \text{Amount re-work}}{\text{Amount produced}} \times 100$$

$$= \frac{800 - 10 - 6}{800} \times 100 = \textbf{98\%}$$

Overall effectiveness (OEE) = 0.87 x 0.5 x 0.98 x 100 = **42.6 %**

Example 2

A chemical plant was expected to run for 120 hours/week continuously with production capacity of 2400 metric tones /hour. At the end the week it produced 220,000 tones together with a waste of 3000 tones. It had120 minutes breakdowns and 460 minutes changeover and adjustment. Calculate plant overall effectiveness.

Planned production time = 120 hrs/week = 7200 minutes

For continuous production, breaks and scheduled maintenance = 0

Therefore, loading time = 7200-0 = 7200 min.

Down-time = 120 (Breakdowns) + 460(Changeover & adjustment) = 580

$$\%\text{Availability} = \frac{\text{Loading time} - \text{Down time}}{\text{Loading time}} \times 100 = \frac{7200 - 580}{7200} \times 100 = 92\%$$

Example 2 (Contd.)

$$\%\text{Performance} = \frac{\text{Quantity produced}}{\text{Time run x Capacity}} \times 100 = \frac{220{,}000}{(6620)\times(2400/60)} \times 100 = 83\%$$

$$\%\text{Quality} = \frac{\text{Amount produced} - \text{Amount waste}}{\text{Amount produced}} \times 100$$

$$= \frac{220{,}000 - 3000}{220{,}000} \times 100 = 98.6\%$$

Overall effectiveness = 0.92 x 0.83 x 0.986 x 100 = 75.3 %

Example 3 – Semi-automated Assembly

A semi-automated assembly machine, assembles and welds automotive components for a single shift of 7.5 hours, 5 days a week; planned throughput = 150 units/hour; actual output = 2875 units/week.
The following **losses** are encountered during assembly:

1. Incorrect assembly causes the machine to stop and needs re-set on average 5 times/hr. where 1 unit and 2 minutes are lost. (This leads to performance loss due to minor stoppage and also quality loss

2. Worn out electrodes are to be replaced once per week, it takes 1 hour when 30 units are scrapped => availability and quality losses

Example 3 (Contd.)

3. Burst out cooling hose causes a machine breakdown once in a month and replacement takes 5 hours => availability loss
4. Misaligned fixture causes a loss of 220 units/ week => quality loss
5. For different size parts, fixtures to be removed and replaced and electrode position to be adjusted 3 times/week which takes 2.25 hours where 24 units are scrapped each time => availability and quality losses
6. Actuating cylinder sometimes sticks for 30 minutes/ady causing production delay which takes double cycle time => performance loss
7. Application of rust protective spray by operator stopping the machine at the start and end of the day takes 5 minutes each time => minor stoppages thereby performance loss
8. Limit switches corrode once in every 6 weeks stopping the machine and replacement takes 6 hours => availability loss.

Example 3 (Contd.)

Calculation of all the losses:

Availability losses = 1 x 60 mins (No2) +
5 x 60/4 mins (Av No.3) +
2.25 x 3 x 60 mins (No.5) +
6 x 60/6 mins (Av No.8)
= 600 minutes/week

Performance losses = 2 mins x 5 x 7.5 x 5(No.1) +
15 mins x 5 (No.6) +5 mins x 2 x 5 (No.7)
= 500 minutes / week

Quality losses = 1 unit x 5 x 7.5 x 5 (No.1) +
30 units (No.2) + 220 units (No.4) +
24 units x 3 (No.5)
= 510 units/week

Example 3 (Contd.)

Loading time = 7.5 x 5 x 60 = 2250 minutes/week

$$\% \text{ Availability} = \frac{2250 - 600}{2250} \times 100 = 73\%$$

$$\% \text{ Performance} = \frac{1650 - 500}{1650} \times 100 = 70\%$$

OR

$$\% \text{ Performance} = \frac{2875}{(1650/60 \times 150)} \times 100 = 70\%$$

$$\% \text{ Quality} = \frac{2875 - 510}{2875} \times 100 = 82\%$$

Overall Machine Effectiveness (OME) = 0.73 x 0.70 x 0.82 x 100 = **42%**

Effectogram of Example 3 – Semi-automated Assembly

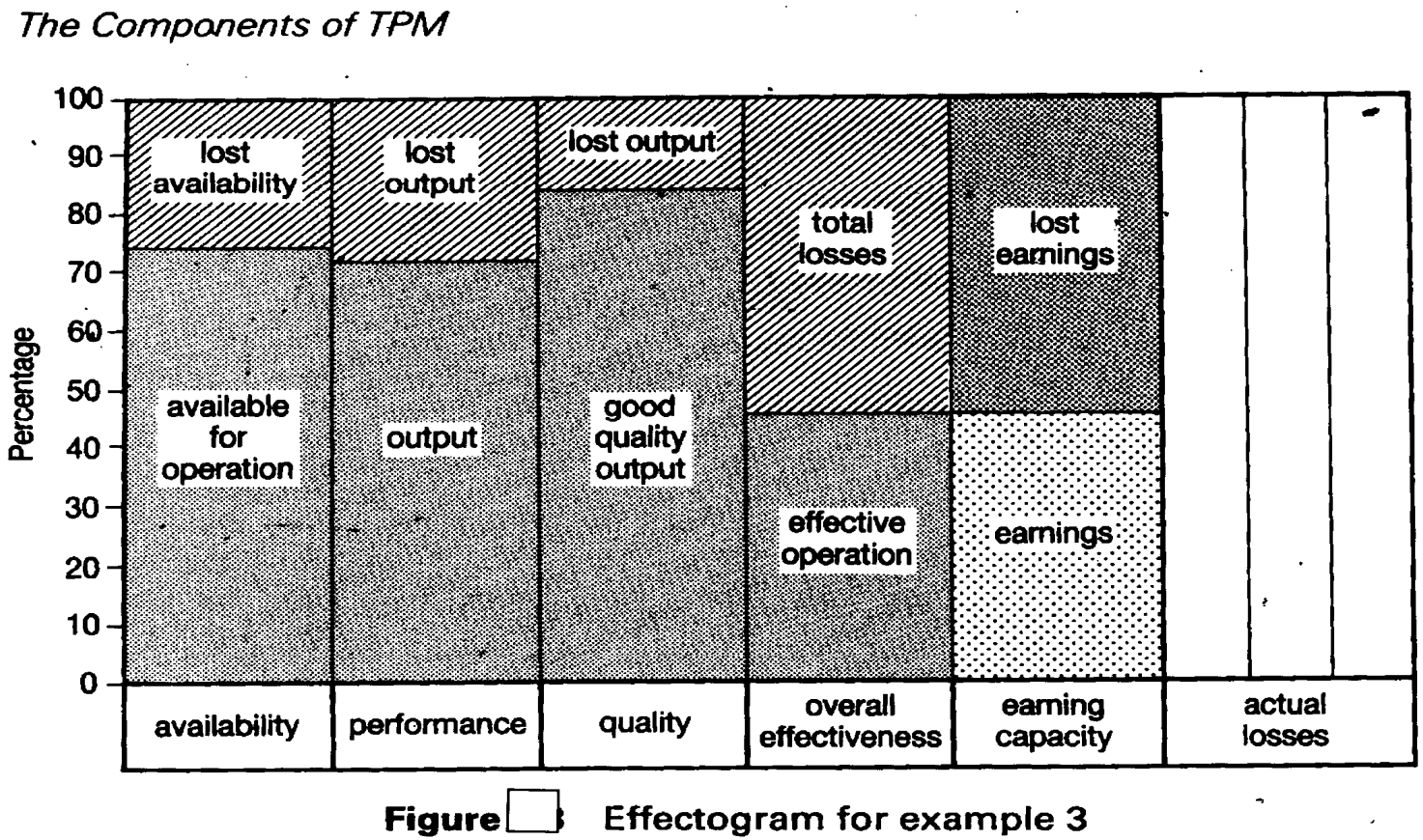


Figure Effectogram for example 3

Tangible and Intangible Benefits of TPM

- Tangible benefits:
  - Productivity up due to
    - ✓ Sudden breakdowns down
    - ✓ Overall facilities effectiveness up
  - Process defect rate down
  - Customer compliant/claims down
  - Products and work-in-process down
  - Shutdown accidents down
  - Pollution incidents down
  - Improvement suggestions up

Tangible benefits (contd.):

- Financial losses drop due to reduction in breakdowns
- Repair costs drop
- Maintenance labour-hours reduce
- Energy costs reduce
- Company's manufacturing profit ratio up

Intangible benefits:

- Achieving full-self management
  - ✓ Operators have ownership of their equipments
  - ✓ They look after it by themselves without direction

- Eliminating breakdowns and defects
- Growing confidence and ‘can-do’ attitude
- Making previously dirty and oily workplaces to a unrecognizably clean, bright and lively
- Giving better image to the visitors and thereby getting more orders

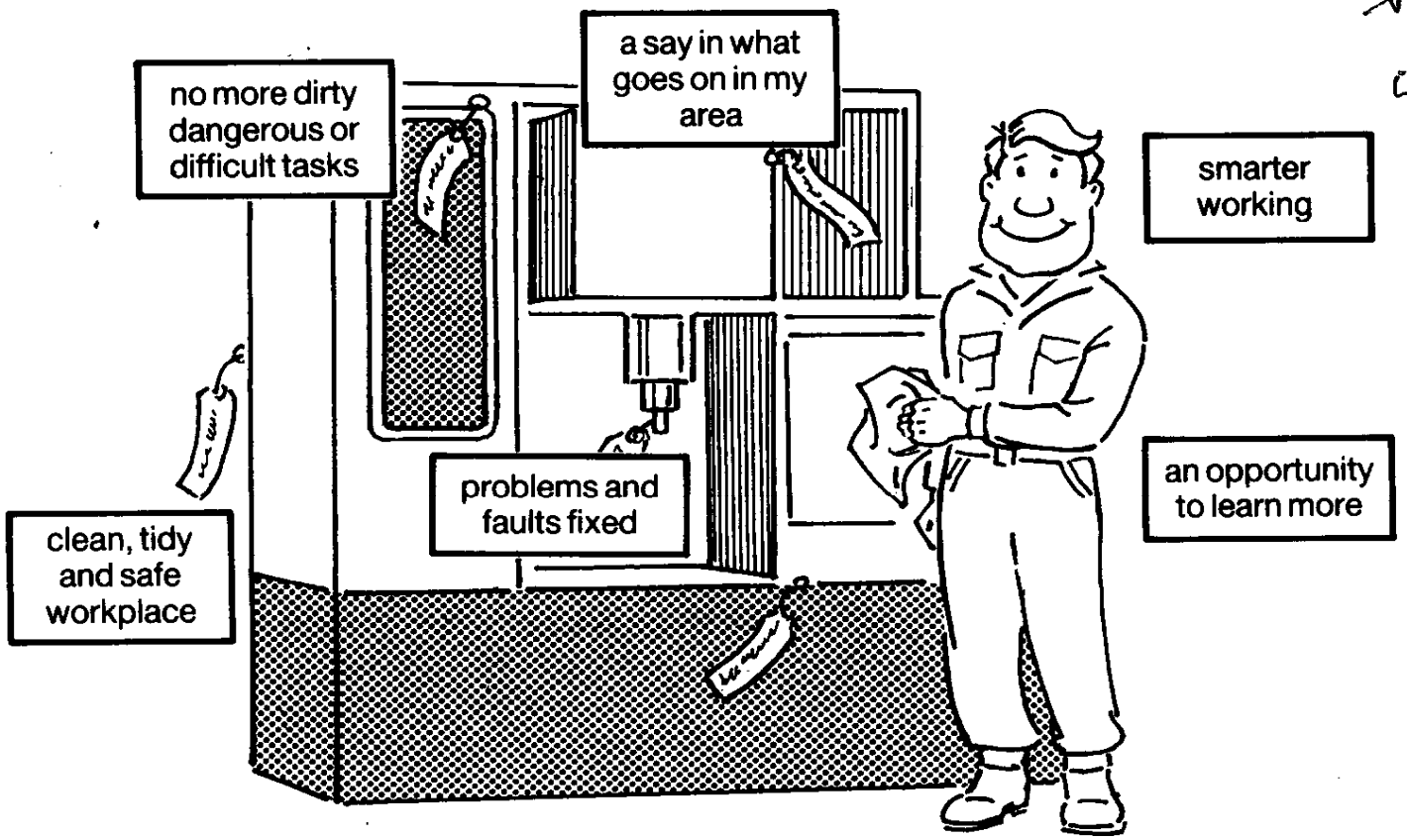


Figure The benefits for operators and craftsmen

Summarized Results of TPM

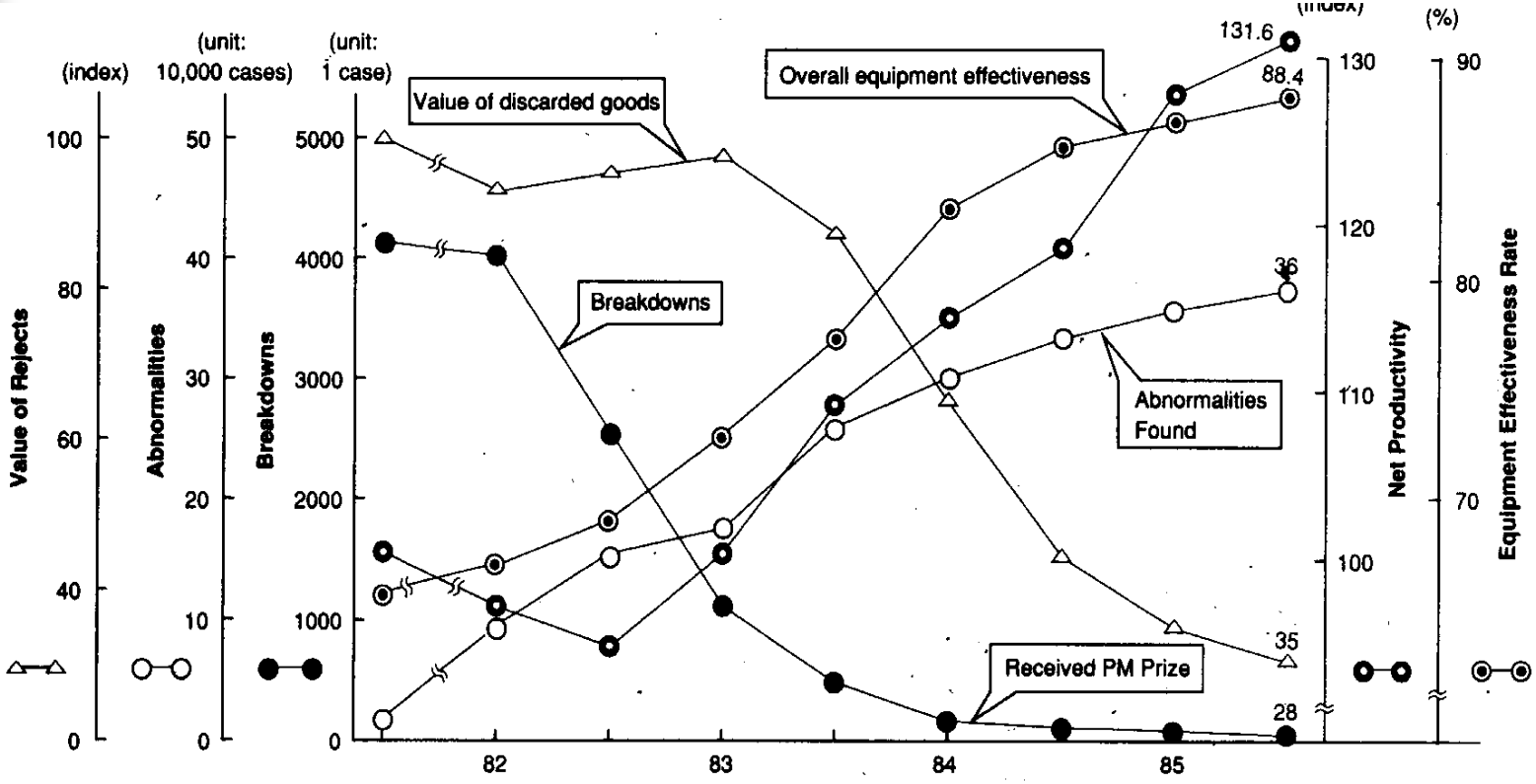


Figure **Effects of TPM Activities at Various Levels, 1982-85** of Nachi-Fujikoshi Corporation, Japan

Company Checklist

■ Audit of machine condition and attitudes within the area for TPM

Company.....

Department..... Date .....

Tick the box which most closely describes the conditions, situation and attitudes prevailing.

Machinery condition

The machinery and equipment is generally dirty.	Yes ☐	No ☐
Swarf is scattered on and around machinery.	Yes ☐	No ☐
Cutting oil is splashed on and around machinery.	Yes ☐	No ☐
The machinery leaks hydraulic fluid.	Yes ☐	No ☐
The machinery leaks lubricant.	Yes ☐	No ☐
Oil pans are full, often to overflowing.	Yes ☐	No ☐
Motors are coated with a layer of oil/grime.	Yes ☐	No ☐
Grime from cutters and grinders is caked on to the machinery.	Yes ☐	No ☐
Limit switches on machinery are covered with oil/grime.	Yes ☐	No ☐
Covers are used to protect certain machinery or machine areas but their internal parts are not cleaned or inspected.	Yes ☐	No ☐
Some machinery parts rattle and vibrate.	Yes ☐	No ☐
Machinery is positioned so that access for routine maintenance is difficult.	Yes ☐	No ☐
Oil cans are left around, often empty and dirty.	Yes ☐	No ☐
Drains and filters are clogged.	Yes ☐	No ☐
Wires and pipes are left in an untidy mess, making it hard to tell which goes where.	Yes ☐	No ☐
People do not mind seeing dirt, process waste, swarf and oil pile up on machinery, as they think it is normal.	Yes ☐	No ☐
Motors are allowed to get hot or make strange noises without it being detected.	Yes ☐	No ☐
Quick fixes are often put in place on machinery such as parts being wired up or the correct number of vee belts not being replaced.	Yes ☐	No ☐

Number of Yes ☐ Number of No ☐

Comments by auditor:

.....

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General conditions and performance

Machinery breakdowns occur quite frequently, at a rate of 3 per cent of operating time or higher.	Yes ☐	No ☐
Repairs generally take a long time to complete.	Yes ☐	No ☐
Minor problems occur quite regularly and often the repair is only temporary.	Yes ☐	No ☐
Breakdowns occur for the same reasons, time and time again.	Yes ☐	No ☐
Changeover and set-up adjustments take a lot of time.	Yes ☐	No ☐
People accept ongoing adjustments as normal.	Yes ☐	No ☐
Problems following changeover occur more (or less) often, depending upon who does it.	Yes ☐	No ☐
Minor stoppages happen very often. Automated machinery often needs a minder.	Yes ☐	No ☐
Re-working occurs at a rate of 3 per cent or more.	Yes ☐	No ☐
Scrap from machinery is running at 2 per cent or more.	Yes ☐	No ☐
Machinery speeds have been decreased to reduce scrap and/or wear.	Yes ☐	No ☐
Product specific standard cycle times have not been established.	Yes ☐	No ☐
Operators know the standard times but do not keep to them.	Yes ☐	No ☐
No one has analysed speed losses in the machinery.	Yes ☐	No ☐
There are no charts showing how effective the machinery is.	Yes ☐	No ☐
There are no procedures for cleaning, lubricating, etc.	Yes ☐	No ☐

Number of Yes ☐ Number of No ☐

Comments by auditor:

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Total number of Yes ☐ Total number of No ☐

Appendix 1

Interpretation of the results

Total Number of Yes	Comments
40+	Machinery condition and attitudes are very poor. Operating performance is well below par and morale is suffering. Immediate action is needed.
30–40	Poor machinery condition and bad attitudes are seriously affecting your operating performance. You need to address this urgently.
20–30	You have obviously understood the importance of machinery condition and taken some action. More progress can be made to significantly improve your operating performance.
10–20	Significant progress has been made or perhaps the emphasis has always been on keeping machinery in good condition. Keep up the good work and address the 'Yes' problems.
< 10	Well done! You are well on the way to top-class performance. Work towards zero.

Comments by auditor:

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