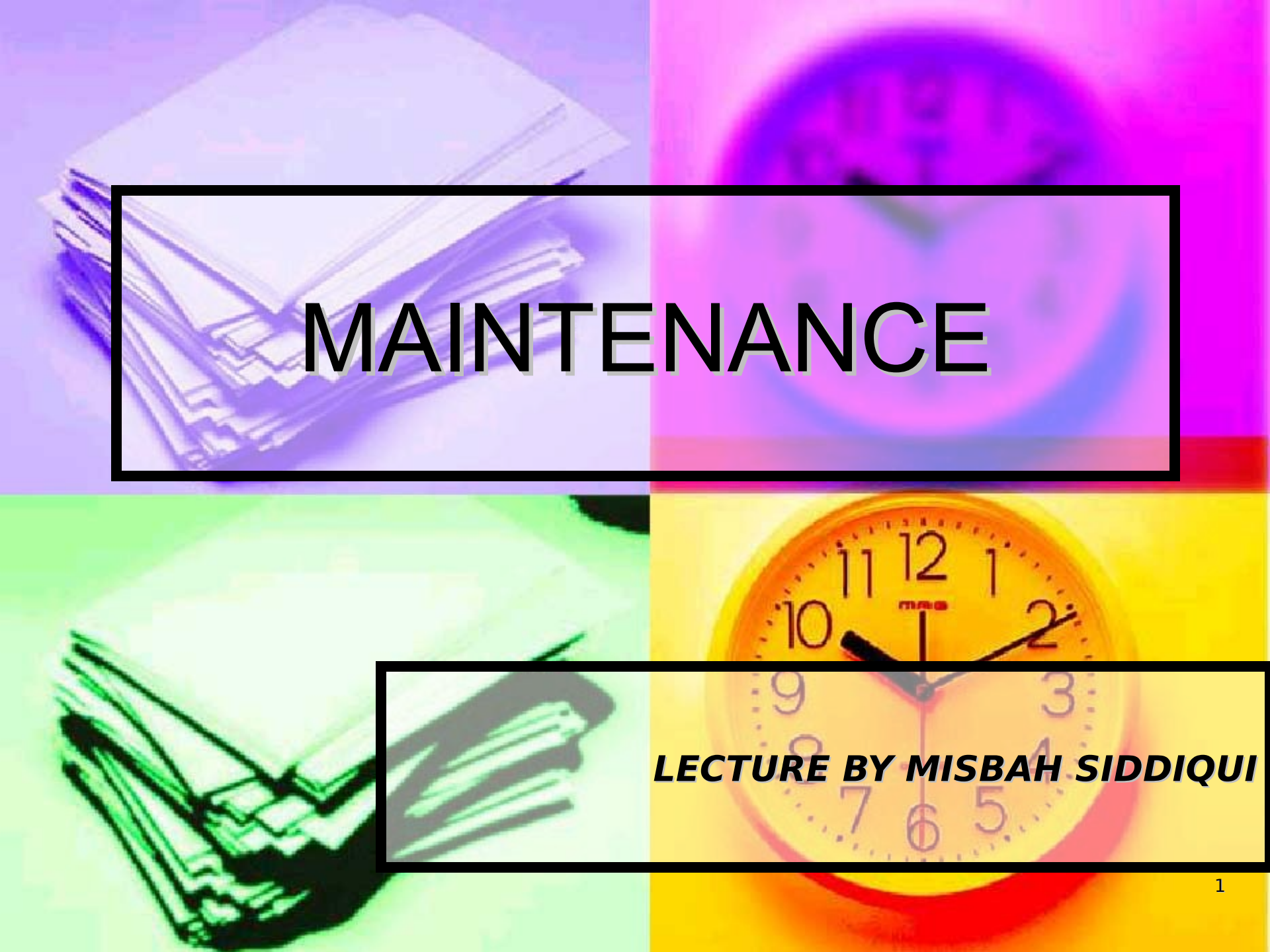
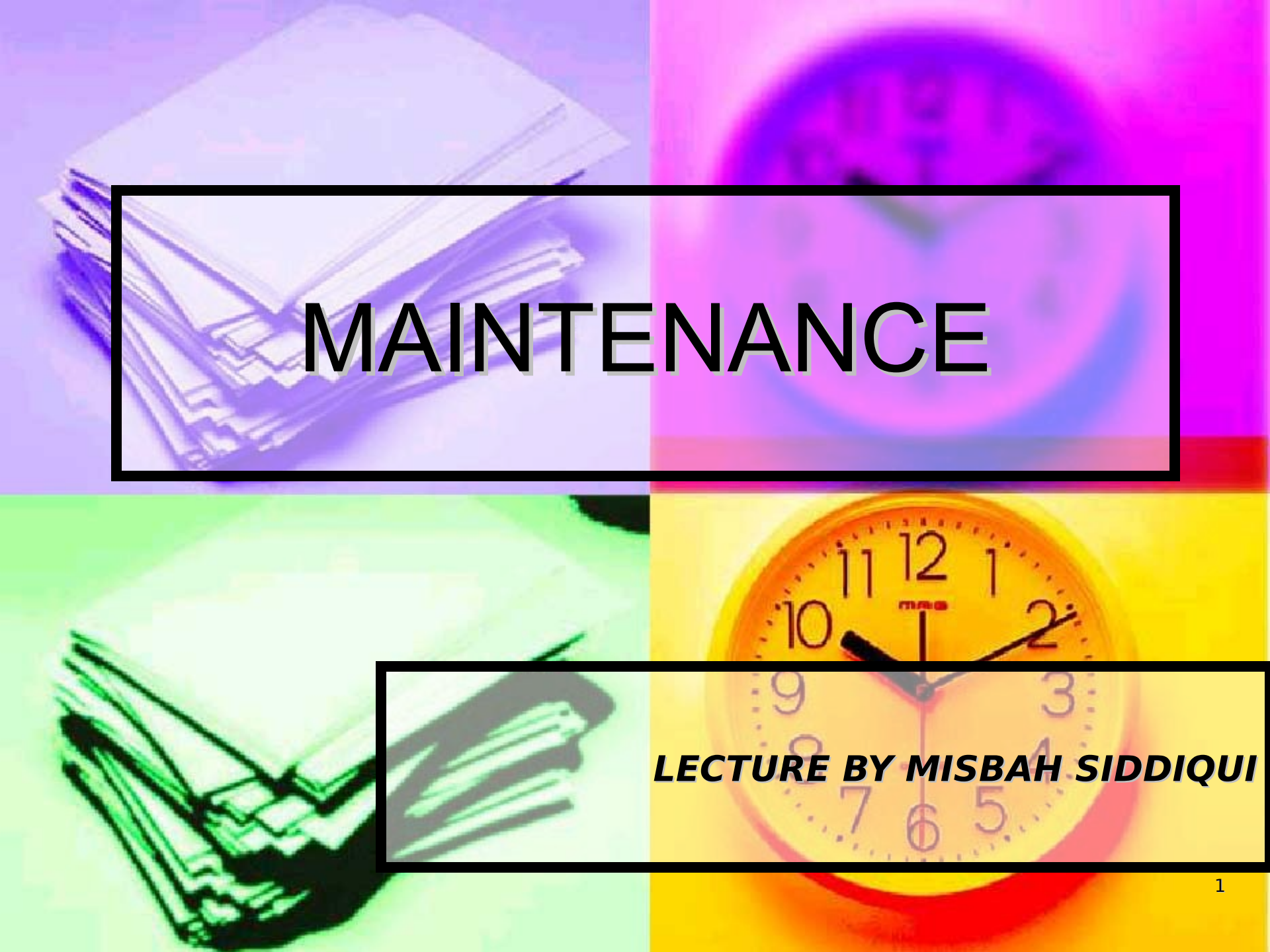




MAINTENANCE



LECTURE BY MISBAH SIDDIQUI



OBJECTIVES

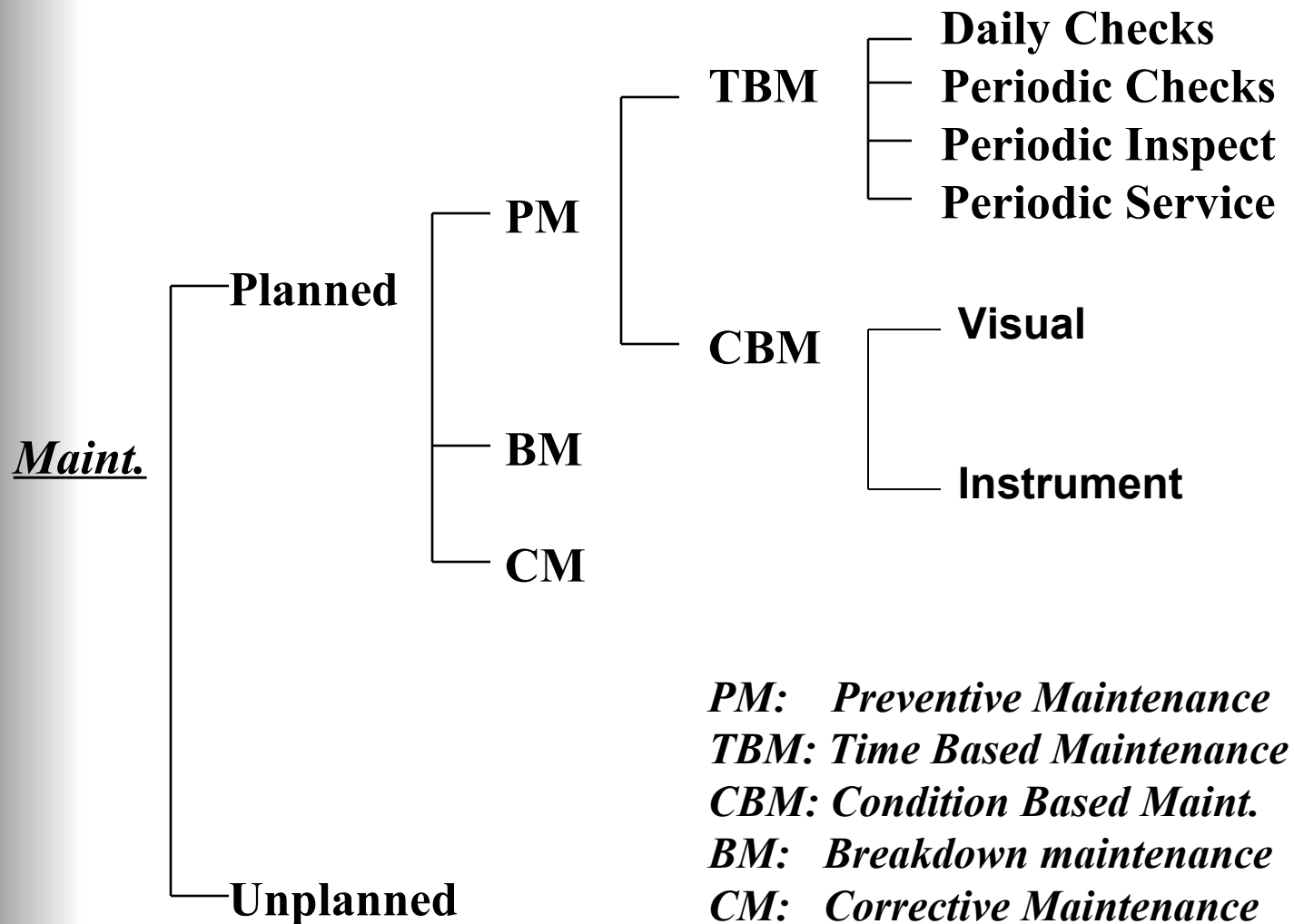
- Explain the importance of maintenance in production systems.
- Describe the range of maintenance activities.
- Discuss preventive maintenance and the key issues associated with it.
- Discuss breakdown maintenance and the key issues associated with it.
- State how the Pareto phenomenon pertains to maintenance discussions.



DEFINITION

- ***WHAT IS MEANT BY THE TERM “MAINTENANCE” ?***
- Maintenance encompasses all those activities that maintain facilities & equipment in good working order so that a system can perform as intended.
- Maintenance can also be termed as asset management system which keeps them in optimum operating condition.

APPROACH TO MAINTENANCE.



NOTE:- Structured recording of all the activities is vital.



GOAL OF MAINTENANCE

- The goal of maintenance is to keep the production system in good working order at minimal cost.
- Decision makers have 2 basic options with respect to maintenance. They are: -
 - BREAKDOWN MAINTENANCE.
 - PREVENTIVE MAINTENANCE.



TYPES OF MAINTENANCE

- BREAKDOWN MAINTENANCE:-
 - Real approach,
 - Dealing with breakdowns or problems when they occur...
- PREVENTIVE MAINTENANCE:-
 - Proactive approach;
 - Reducing breakdowns through a program of lubrication, adjustment, cleaning, inspection, and replacement of worn parts.



- The best approach is to seek a balance between preventive maintenance and breakdown maintenance. The same concept applies to maintaining production systems.
- The age and condition of facilities and equipment, the degree of technology involved,
- The type of production process,
- The decision of how much preventive maintenance is desirable.

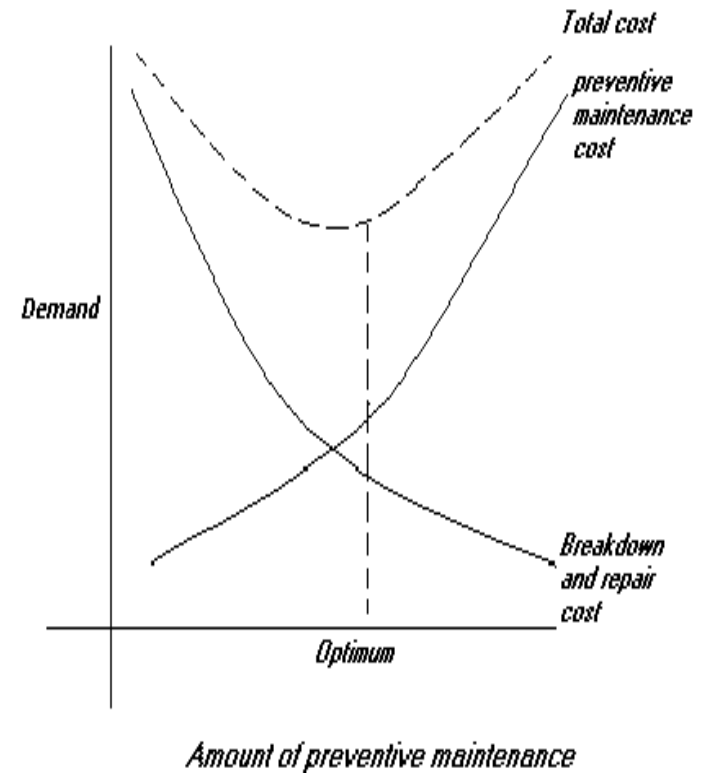


FIG .1.Total maintenance cost a function of preventive maintenance

PREVENTIVE MAINTENANCE

- More and more organizations are taking a cue from the Japanese and transferring routine maintenance (e.g., cleaning, adjusting, inspecting) to the users of equipment, in an effort to give them a sense of responsibility and awareness of the equipment they use & cut down the abuse & misuse of the equipment.

PREVENTIVE MAINTENANCE

- Preventive maintenance extends back to the design and selection stage of equipment and facilities.
- Poor design can cause equipment to wear out at an early age or experience a much higher than expected breakdown rate.
- Durability and ease of maintenance can have long term implications for preventive maintenance programs.
- Training employees in proper operating procedures and in how to keep equipment in good operating order – and providing the incentive to do so – are also important.



PREVENTIVE MAINTENANCE

The goal of preventive maintenance

- Preventive maintenance is *periodic*.
- Preventive maintenance is generally scheduled using some of the following contributions:-
 - The result of planned inspections that reveal a need for maintenance.
 - According to the calendar (passage of Time).
 - After a predetermined no. of operating hours.



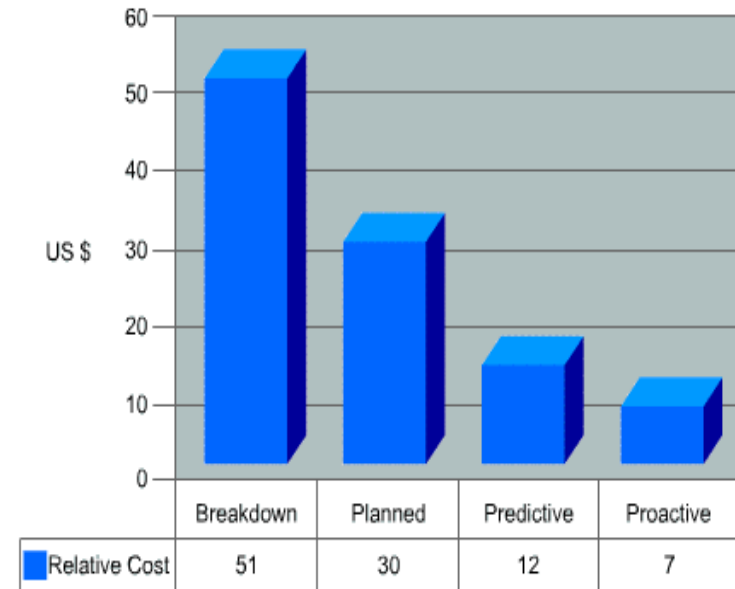
PREDICTIVE MAINTENANCE

PREDICTIVE MAINTENANCE

- This is an attempt to determine when best to perform preventive maintenance.
- The better the predictions of failures are, the more effective preventive maintenance will be.

Predictive Maintenance

- Predictive Maintenance is one of the four tactical options available to ensure the reliability of any asset to ensure it fulfils its function and it focuses primarily on maintaining equipment based on its known condition. Each of these strategies: on-failure, fixed time, predictive and design out, has a place in an optimized maintenance plan, the distribution of the mix being dependent on many factors.



ASME: Hudachek & Dodd



Predictive Maintenance

- Predictive maintenance is often the most attractive concept, since action is only undertaken when knowledge of the asset indicates that failure or underperformance is imminent, making it a cost effective asset management option.
 - Many other benefits, some intangible such as the increased motivation of the workforce through increased competency, exist. Others include:
 - Equipment may be shut down before severe damage occurs or can be run to failure if required.
 - Production can be modified to extend the asset's life i.e. until the next planned shutdown.
 - Required maintenance work can be planned
- All of the above lead to increased safety, plant output and availability and lead to improvements in final product quality.



Predictive Maintenance

- Predictive maintenance is a process that requires clear roles and responsibilities. As such we develop company appropriate predictive maintenance processes, supported by definitions of responsibilities, and communication paths, which integrate into the Reliability effort as a whole.
- Condition monitoring facilitates Predictive Maintenance.
- Condition monitoring is a knowledge-based activity, so for it to be successful and sustainable, it requires comprehensive skills training. Any successful predictive maintenance program, not only has a technology element, but requires a measurement system that continuously accounts for the benefits.

Asset Performance Troubleshooting

- Often it is a couple of poor performing assets with a chronic repeated failure condition that absorb the majority of the maintenance budget. Some commentators state that approximately 80% of a typical maintenance budget is stored away for chronic failures, making these the most cost depletive of all maintenance expenditures.
- The following methodologies are key in any multi-technology condition monitoring program :
 - **Root Cause Failure Analysis**
 - **Tribology And Lubrication Engineering Services**
 - **Specialist Condition Monitoring Services**

ROOT CAUSE FAILURE ANALYSIS

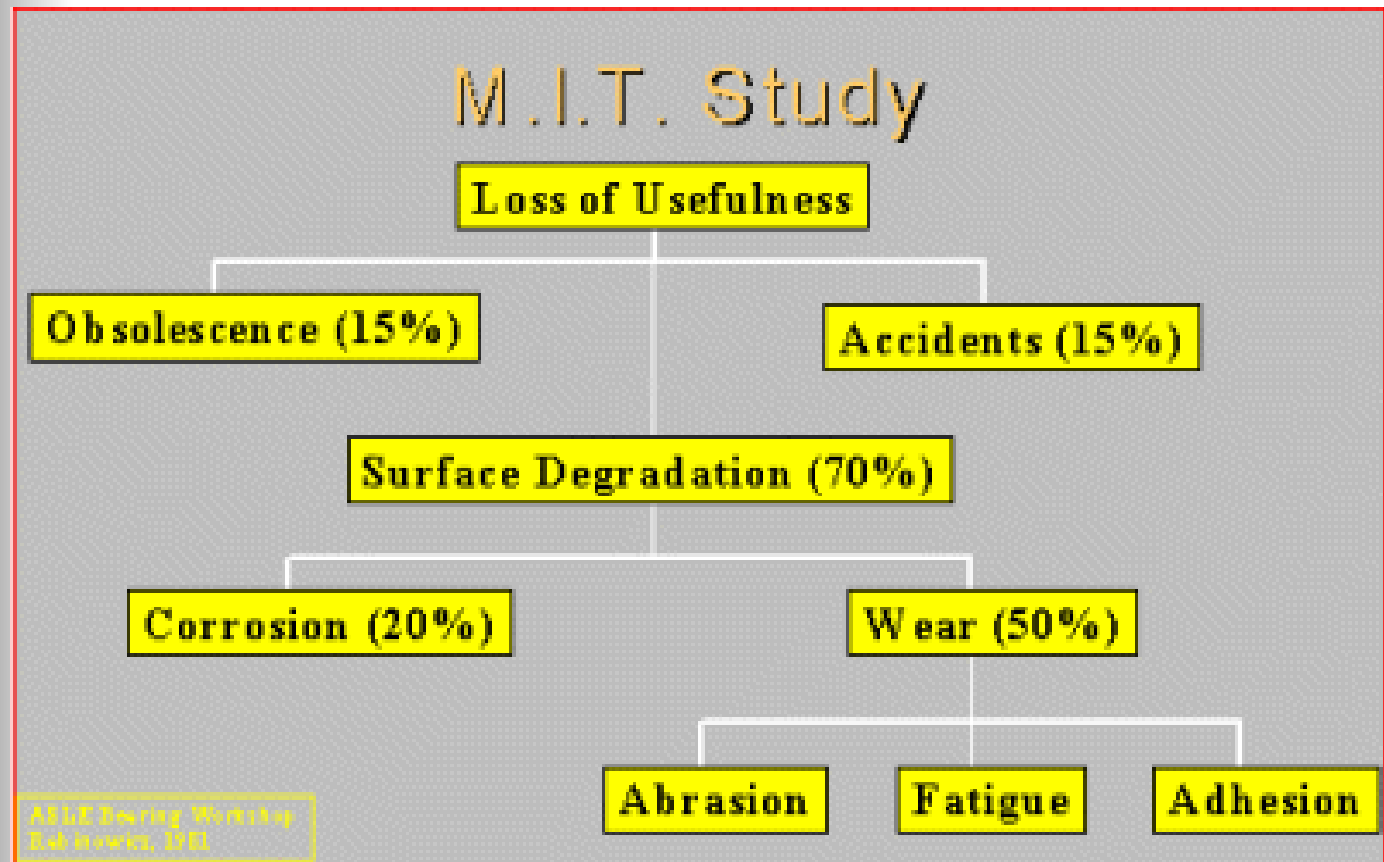
- Root Cause Failure Analysis (RCFA) is both a process and a set of technical skills, which in combination find out why a particular failure or problem exists and sets in place a set of defense actions correcting those causes.
- Typically, when assets fail most organizations have always found some understanding and rationale leading to an explanation as to why it broke. But root cause failure analysis takes you beyond that to the latent roots, which are the management system weaknesses. Once you've found these, you have the means to solve many other potential problems that haven't yet occurred.



Tribology And Lubrication

- Tribology is the study of wear and lubrication. Tribology as it is estimated that component wear and lubrication problems are responsible for at least 70 % of mechanical failures.

Tribology And Lubrication



Condition Monitoring

- In industry, condition monitoring is the measurement of parameters which may indicate a fault condition either by an increase or decrease in overall measured value or by some other change to a characteristic value.
- When used as part of a pro-active maintenance plan, the use of condition monitoring enables the operation of a predictive maintenance policy and provides major improvements in productivity.
- Condition monitoring depends on selecting the right mix of parameters that match expected faults and using the correct measurement technique, location interval and processing, it is also important to record enough information in order to be able to carry out monitoring and diagnosis.



Condition Monitoring

- **Considerations include:**

- Type of measurement
- Measurement interval
- Accuracy of measurement
- Repeatability

- **Condition monitoring falls into two distinct classes:**

- Monitoring which can be carried out without interruption to the operation of the machine
- Monitoring which requires the shutdown of the unit, or at least the releases of the machine from its prime duty
- The range of methods in use is very wide, from simple techniques such as visual surface inspections to more complicated procedures like spectral vibration analysis.

A vertical strip of four images: a clock, a clock, a book, and a book.

PREVENTIVE MAINTENANCE

TOTAL PREVENTIVE MAINTENANCE

- JIT approach where workers perform preventive maintenance on the machines they operate.
- This approach is consistent with JIT systems and lean production, where employees are given greater responsibility for quality, productivity and the general functioning of the system.



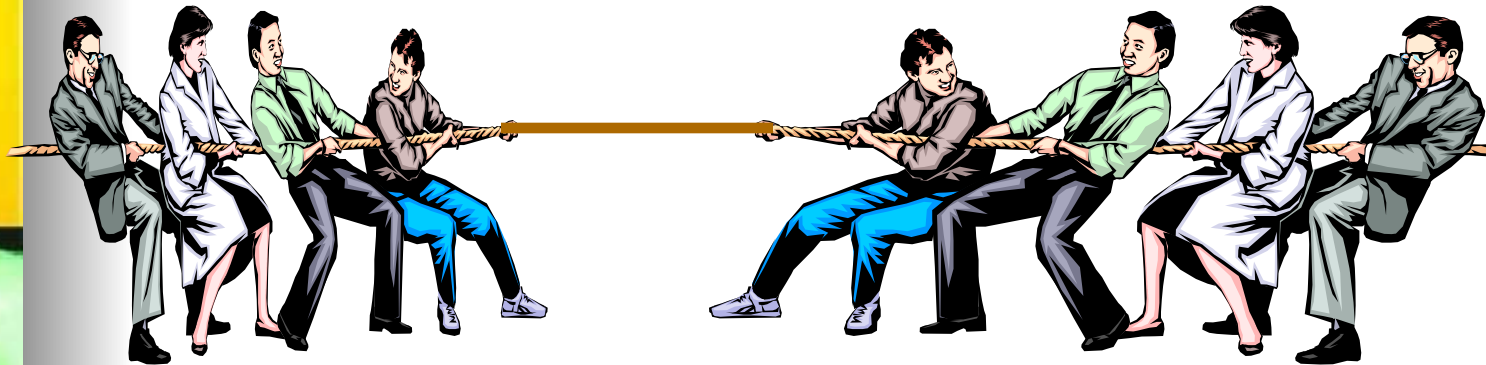
The TPM Concept

- Develop a Company-wide philosophy to maximize the effectiveness of production systems.
- Build an organization that prevents every type of loss
 - zero accidents
 - zero defects
 - zero failures
- Involve all departments in TPM implementation.
- Involve everyone from top management to shop-floor operators
- Use small groups (teams) to make improvements.

The “Total” in TPM

- Total effectiveness:
 - pursuit of economic efficiency and profitability
- Total PM:
 - establishing a maintenance plan for the life of the equipment - preventative maintenance - improved maintainability
- Total Participation:
 - autonomous maintenance by operators and team based approach to problem solving

Before TPM Implementation



Maintenance

Operations

Engineering

After TPM Implementation

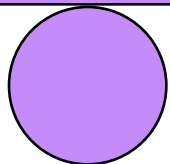
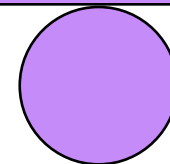
A Team Effort

Operations + Engineering + Maintenance

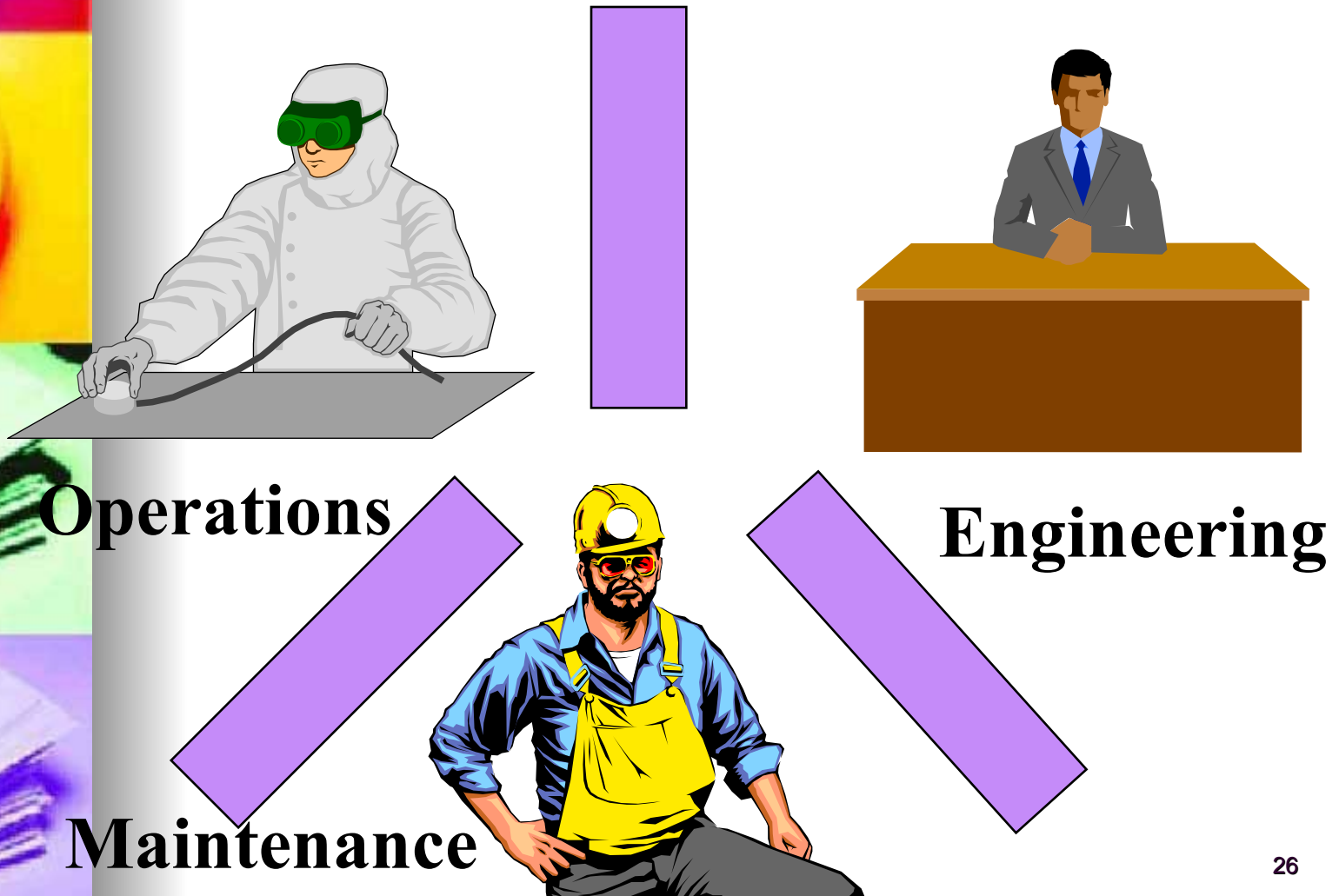


**Waste
Downtime
Defects**

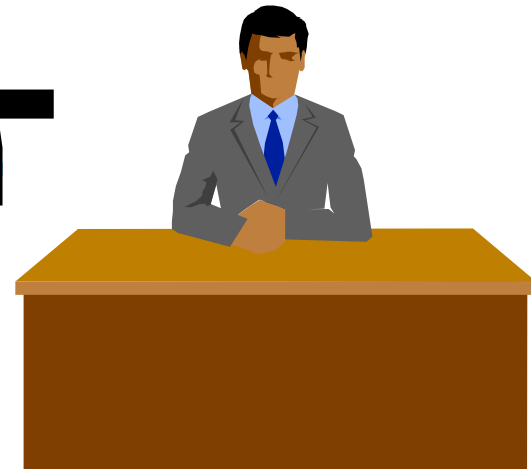
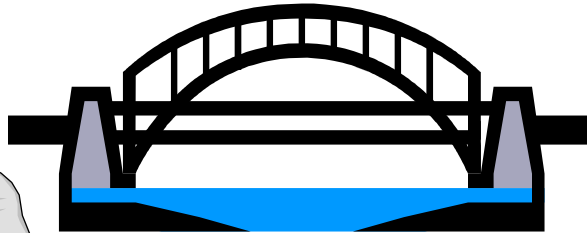
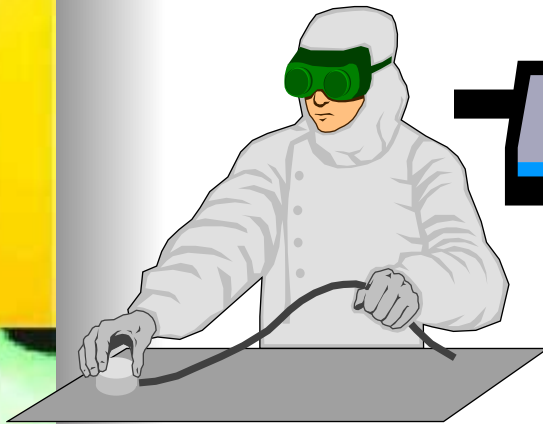
The Common Enemies



Before TPM Implementation: Barriers



TPM Builds Bridges



Operations

Engineering



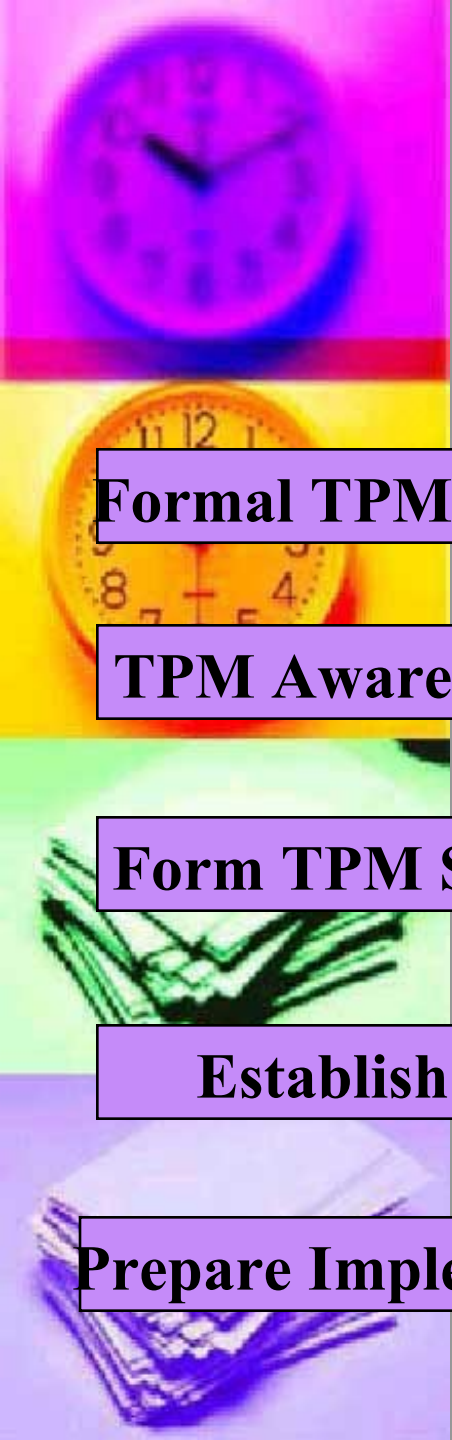
Maintenance



The TPM Prerequisite

**Only by adopting a proactive approach
and putting in the time, effort, and resources
required can TPM be profitable for an
Organization**

A Model for TPM Development



Formal TPM Announcement

TPM Awareness Education

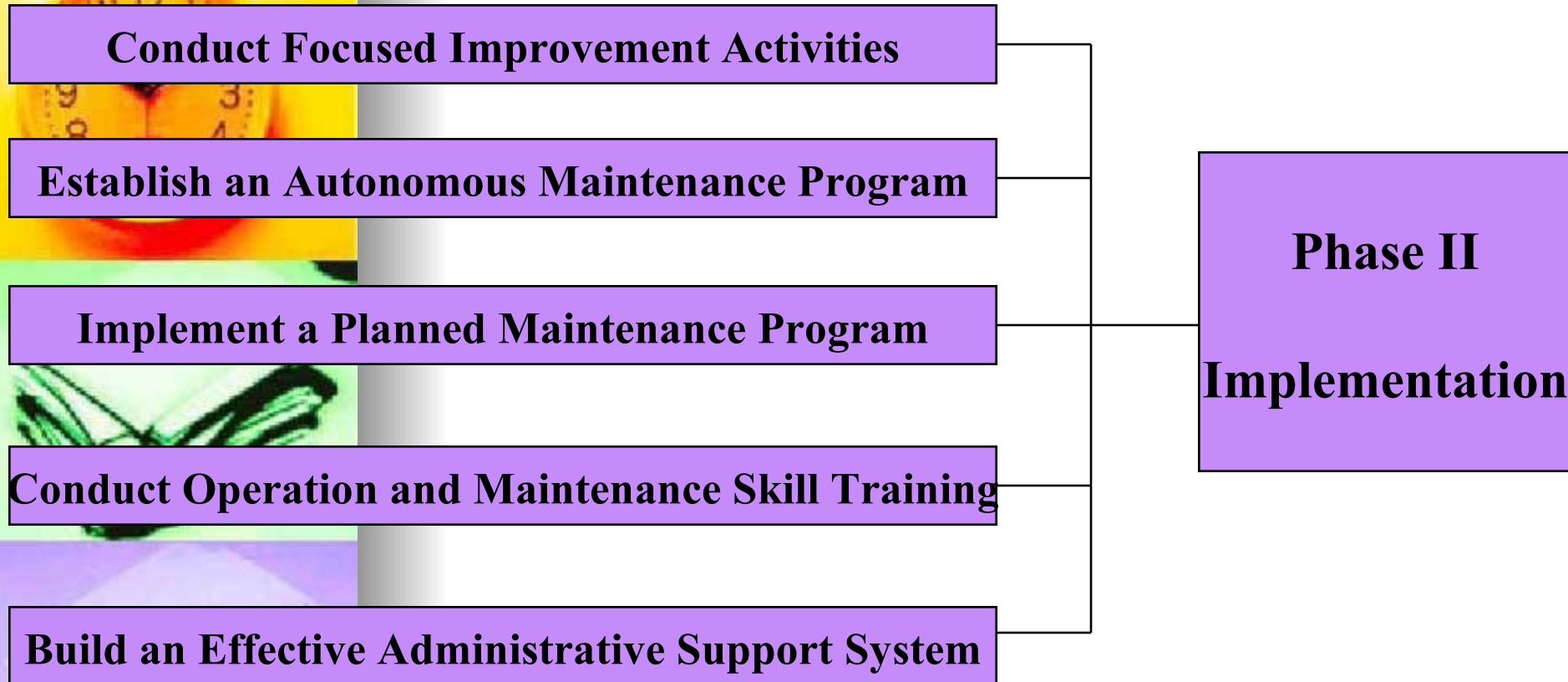
Form TPM Steering Group

Establish TPM Goals

Prepare Implementation Plan

Phase I
Preparation

The TPM Development Model Continued



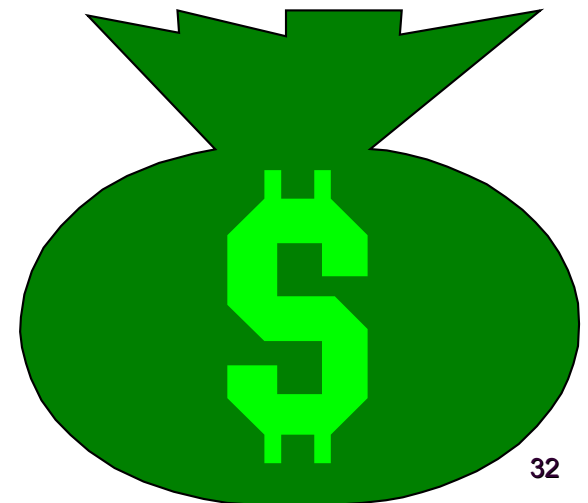
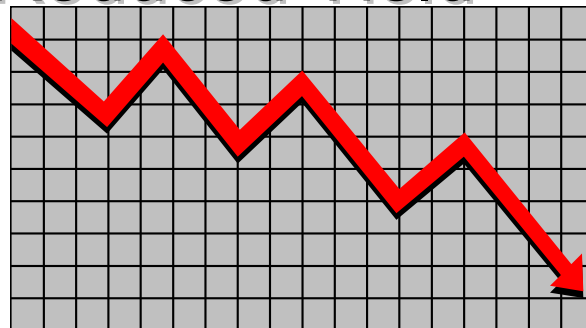


Core TPM Activities

- Focused Improvement Projects
- Autonomous Maintenance
- Planned (Preventive) Maintenance
- Education and Training
- Early Management (Equipment Design and Installation)
- Quality Maintenance
- Administrative and Support Activities
- Safety and Environmental Management
- Diagnostic and Predictive Maintenance

The Major Plant Losses

- Equipment Failures
- Process and Equipment Set-ups And Adjustments
- Idling and minor stoppages
- Reduced Processing Speed
- Quality Defects
- Reduced Yield





Ultimate Improvement Goals for Chronic Losses

Type of Loss	Goal	Explanation
1. Equipment Failures	0	Reduce to zero for all equipment
2. Setup and Adjustments	minimize	Continuous effort to reduce setup times
3. Idling and minor stops	0	Reduce to zero for all equipment
4. Reduced Processing Speed	0	Bring operating speed to design speed; then improve speed beyond design level
5. Quality Defects	0	Small levels might be acceptable (6-sigma)
6. Yield Losses	minimize	

A vertical strip of four images on the left side of the slide. From top to bottom: a blue clock face on a blue background, a red clock face on a red background, a green book on a green background, and a blue book on a blue background.

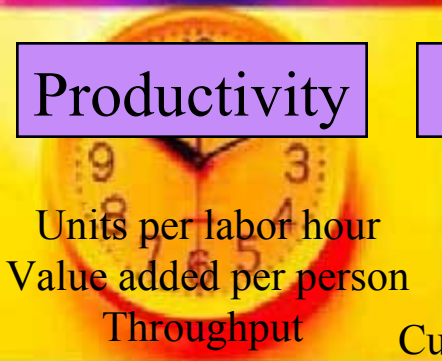
Measurement

Measurement Is Necessary for Improvement.

People Do How They Are Measured!



Basic TPM Outcome Measures



Productivity

Units per labor hour
Value added per person
Throughput
Downtime
Number of Breakdowns

Quality

Product Defects
Warranty Costs
Customer Satis. Index
Re-worked units
Scrap/Waste

Costs

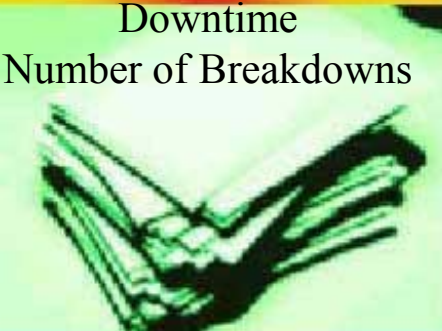
Labor Costs
Maintenance Costs
Energy Costs

Delivery

On-time shipments

Safety

Lost time Accidents
Incidents
Near Misses



Employee Satisfaction



Number of Improvement Ideas
Number of Teams
Employee Satisfaction Index



Measuring Effectiveness

Overall Equipment Effectiveness -- OEE

$$\text{OEE} = \text{Availability} \times \text{Performance Rate} \times \text{Quality Rate}$$

OEE: A Measure of the Percentage of Time that the Equipment is Adding Value



Calculating OEE

$$\text{OEE} = A \times P \times Q$$

where:


$$A \text{ (Availability)} = \frac{\text{planned time} - \text{downtime}}{\text{planned time}}$$


$$P \text{ (Performance rate)} = \frac{(\text{standard time/unit})(\text{units produced})}{\text{Operating time}}$$

$$\text{Operating Time} = (\text{planned time} - \text{downtime})$$


$$Q \text{ (quality rate)} = \frac{(\text{total production}) - (\text{number of defectives})}{\text{total production}}$$

OEE Example

The Plant operates 1,440 minutes per day (3 shifts) Downtime averages 120 minutes per day. Daily production averages 900 units with a 20 % defect rate. The standard time per unit is .8 minutes. (Assume that A, P, and Q are equally weighted.)

Compute OEE



Computing OEE Weightings on A, P, and Q



In many instances Availability, Performance rate and Quality rate are not considered to be equal in importance. Instead they are weighted differently. For example:

$$k_A = .3 \quad k_P = .2 \quad k_Q = .5$$


$$OEE = A^{.3} \times P^{.2} \times Q^{.5}$$



Compute OEE using these weights.

OEE Component Targets

- 
- Availability (A) $\geq .90$
 - Performance Rate (P) $\geq .95$
 - Quality Rate (Q) $\geq .99$
- } unweighted targets
-
- Availability (A) $\geq .90^{kA}$
 - Performance Rate (P) $\geq .95^{kP}$
 - Quality Rate (Q) $\geq .99^{kQ}$
- } weighted targets

OEE Examples

Source: Japan Institute of Planned Maintenance

Criteria	Automated Machinery	Automatic Assemblers	Automatic Packers
1. Overall Effectiveness	51.3 - 78.4	38.0 - 80.7	72.0
2. Availability	95-98	95	90
3. Performance	54-80	40-85	80
4. Operating Speed Rate	90-100	100	100
5. Net Operating Rate	60-80	40-85	80
Remarks:	20-40% of losses due to idling and minor stoppages	15-60% of losses due to idling and minor stoppages	20% of losses due to idling and minor stoppages



Overall Equipment Effectiveness-- OEE

OEE Is

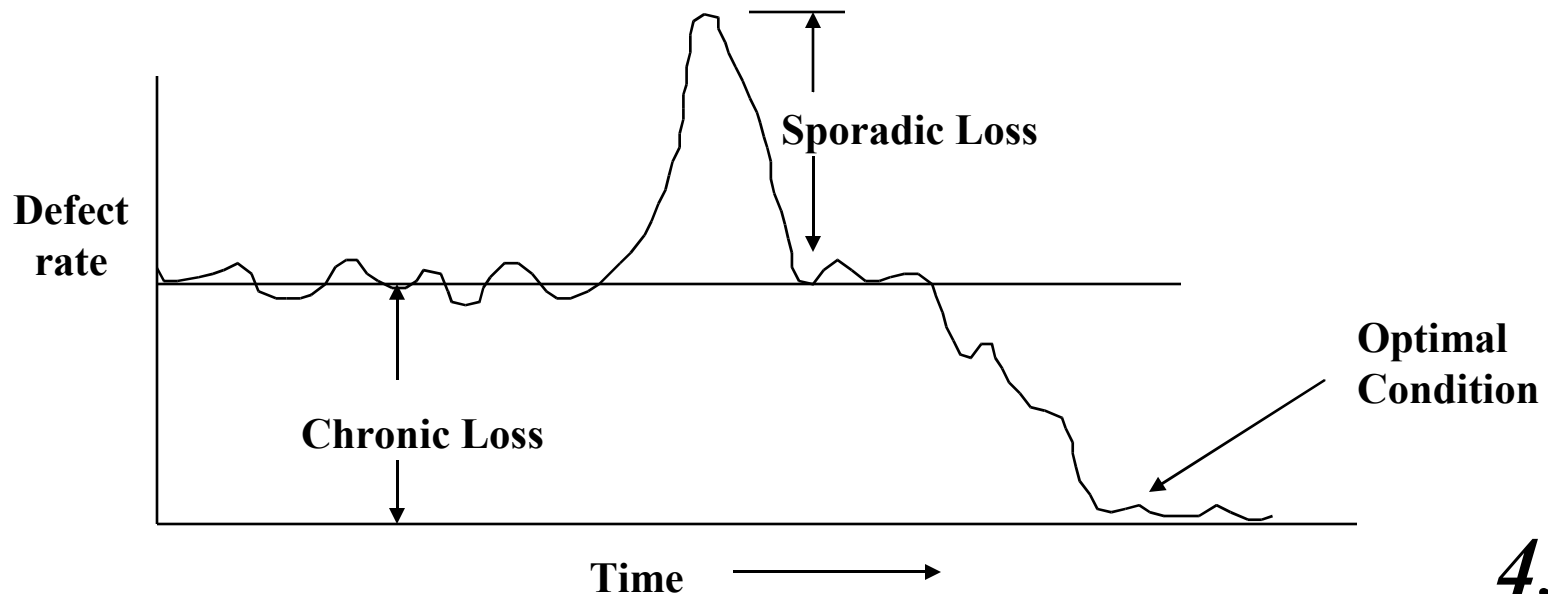
- **A Measure of TPM Progress**
- **Manufacturing Contribution to Quality Improvement**
- **A Method to Identify Opportunities for Improvement**

OEE Is Not

- **Synonymous with TPM**
- **To be used to compare facilities**
- **The same as utilization**
- **Easy to calculate**

Chronic and Sporadic Losses

- *Chronic Losses*: Losses that occur repeatedly within some range of distribution
- *Sporadic Losses*: Sudden occurrences that go beyond the normal range



Chronic and Sporadic Losses

Sporadic Losses

Chronic Losses

Latency

Conspicuous

Hidden

Causation

**Cause-and-effect
easy to determine**

**Often unclear - rarely
a single cause**

**Types of
Action**

**Direct Fixes can
be made**

May take many tries

**Economic
Impact**

Can be very costly

**Cumulative effect can
can be very costly**

How Chronic Losses are Reduced

- Increasing Equipment Reliability
- Restoring Equipment to its Original Condition
- Identify and Establish Optimal Operating Conditions
- Eliminating Small Defects that are Often Overlooked

Reliability Issues

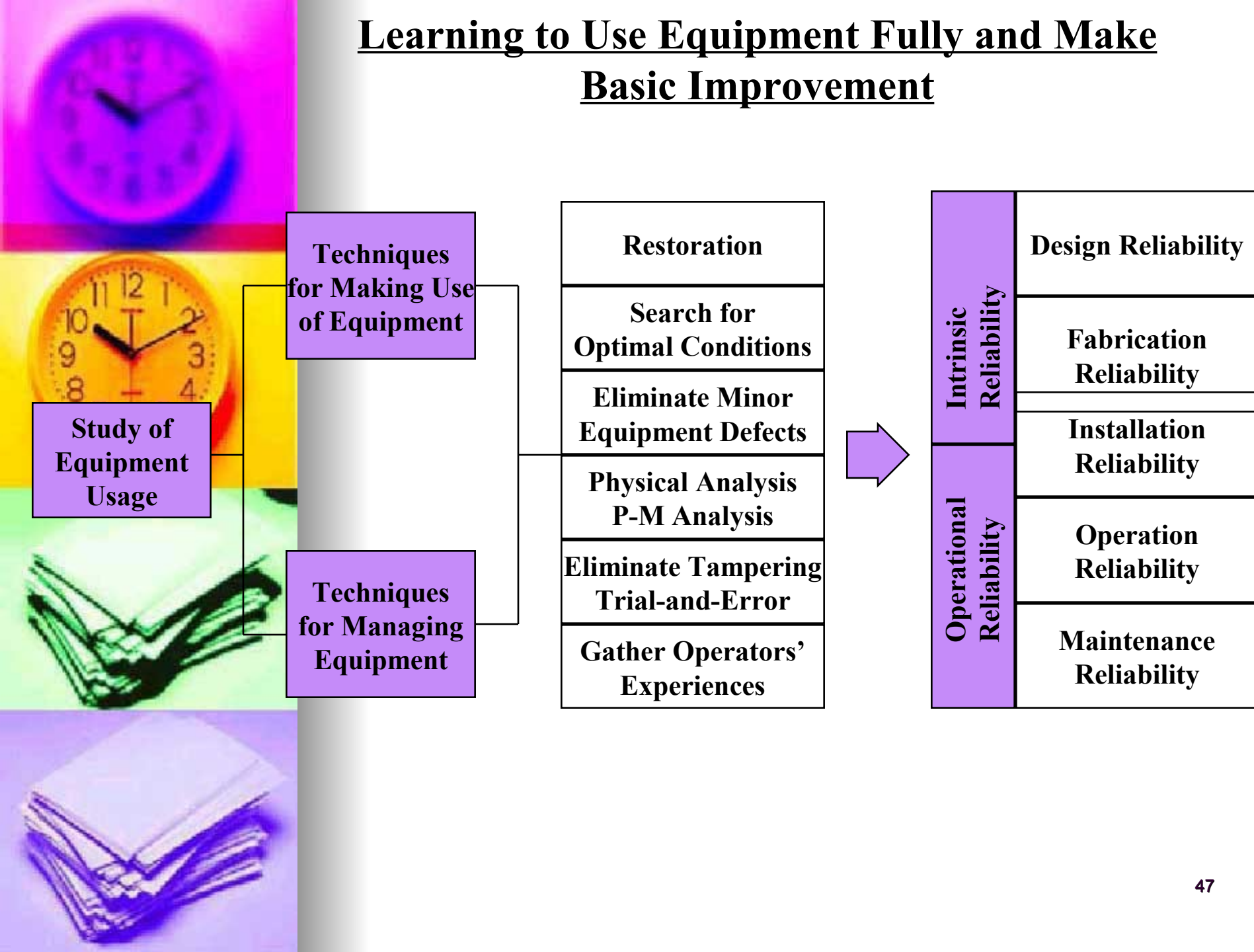


Intrinsic Reliability	Operational Reliability
Design Reliability Manufacturing Reliability Installation Reliability	Operation Reliability Maintenance Reliability

Based on Equipment Design

Based on Use (conditions)

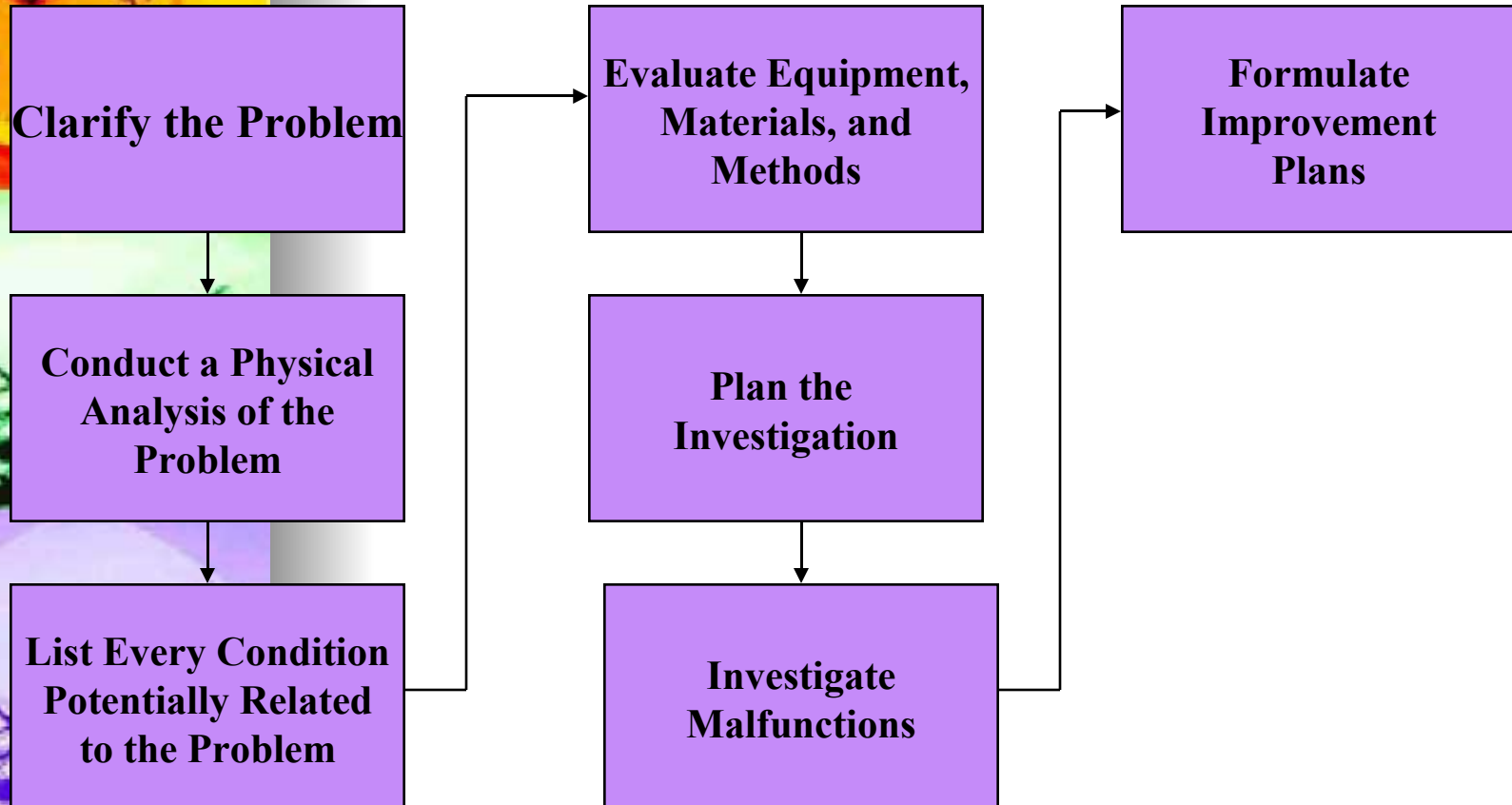
Learning to Use Equipment Fully and Make Basic Improvement



P-M Analysis

P Phenomena- physical-problem—
M machinery-manpower-material

All pertinent factors in a chronic loss are efficiently identified and eliminated.





Raising Employee Skills Through TPM

A TPM Goal is to Improve Employee Skill Levels

- Attention
 - concentration, discernment
- Judgment
 - logical thinking, make sound decisions
- Take Correct Action and provide Appropriate Treatment
 - Prompt action, pride of ownership
- Preventative
 - understanding of equipment, measurement
- Prediction Skills
 - subtle signs, knowledge of equipment



Focused Improvement

Focused Improvement is an active priority of any TPM program - It begins simultaneously with the start of TPM

“Focused Improvement includes all activities that maximize the overall effectiveness of equipment, processes, and plants through uncompromising elimination of losses and improvement of performance.”

Focused Improvement



**A High
Priority
Doable
Short-term**

Select a Project

**4-7 people
Cross-
functional
Empowered**

Form a Project Team

**Establish
Status
Access to
Resources
Commitmen
t**

Register the Project

**Follow the P-M Analysis
Cycle**

**ongoing training and
education
Measure Progress and
results**

Preparation by Improvement Teams

Teams should prepare in the following ways.

- Understand the philosophy of focused improvement
- Understand the significance of losses and the rationale of improving overall effectiveness
- Understand the production process well
- Gather data on failures, trouble, and losses and plot over time
- Clarify the basic conditions necessary to assure proper functioning of equipment and define what factors contribute to its optimal state
- Understand the necessary techniques for analyzing and reducing failures and losses



Focused Improvement

Step-by-Step Procedure

Activity/Step	Detailed Outline
Step 0: Select the Project	Select and Register the Project Form the Project Team Plan Activities
Step 1: Understand Situation	Identify bottleneck processes Measure failures, defects, and other losses Use baseline to set targets
Step 2: Expose and Eliminate Abnormalities	Carefully Expose all Abnormalities Restore deterioration and correct minor flaws Establish basic equipment conditions
Step 3: Analyze Causes	Stratify and Analyze Causes Apply analytical techniques (P-M Analysis) Conduct experiments

Focused Improvement

Step-by-Step Procedure (continued)

Activity/Step	Detailed Outline
Step 4: Plan Improvement	Draft Improvement Proposals Compare cost-effectiveness of alternative proposals List disadvantages of each alternative
Step 5: Implement Improvement	Carry out improvement plan Provide instruction related to implemented changes
Step 6: Check Results	Evaluate improvement over time and the project proceeds Check whether targets have been achieved If not, go to step 3 and continue
Step 7: Consolidate Gains	Draw up control standards to sustain results Formulate work standards Feed information back into the maintenance prevention program



Analytical Techniques for Improvement

- P-M Analysis
- Ask Why 5 times
- Fault tree Analysis (FTA)
- Failure Mode and Effect Analysis
- Industrial Engineering
- Value Analysis
- Seven Basic Tools of Quality
- The “New Seven” Tools of Quality



Autonomous Maintenance

Maintenance Performed By the Equipment Operators



One of the most important basic building blocks in any TPM Program



Goals of Autonomous Maintenance:

- **Prevent equipment deterioration through correct operation and daily checks**
 - **Bring equipment to its ideal state through restoration and proper management**
 - **Establish the basic conditions needed to keep equipment well-maintained**
- 



Autonomous Maintenance

Step-by-Step Implementation

Activity/Step	Detailed Outline
 Step 1: Perform Initial Cleaning	Eliminate Dust, Dirt, and Grime Expose any irregularities Correct minor flaws
Step 2: Eliminate Sources of Contamination	Reduce housekeeping by eliminating sources of dirt . Improve access to difficult areas
 Step 3: Establish cleaning and checking standards	Formulate standards for cleaning, lubricating, and tightening with minimal time and effort. Improve efficiency of checking gauges and visual display controls
 Step 4: Conduct General Equipment Inspections	Provide inspection skills training Modify equipment to facilitate inspection Chart inspection results - quantify when Possible.



Autonomous Maintenance

Step-by-Step Implementation (continued)

Activity/Step	Detailed Outline
 Step 5: Perform General Process Inspections	Train and Educate Operators to achieve process-competent operators Prevent inspection duplications and omissions by incorporating individual equipment inspection standards into process or area inspection plans.
 Step 6: Do Systematic Autonomous Maintenance	Establish clear procedures for autonomous maintenance Reduce Setup Procedures Establish system for self-management for spares, tools, data, etc.
 Step 7: Practice Full Self-Management	Keep accurate maintenance records Perform proper data analysis Take appropriate action



Necessary Accomplishments for Process-Competent Operators



Level 1:

- Understand Process Performance and Function
- Operates Process Correctly

Level 2:

- Understands the properties of the materials handled
- Performs correct adjustment and settings



Level 3:

- Detects abnormalities promptly
- Takes emergency action against abnormalities



Level 4:

- Recognizes sign of abnormality
- Deal with abnormalities correctly
- Performs periodic overhaul checking and parts replacement



Keys to Successful Autonomous Maintenance

- Introductory Education and Training
 - TPM Objectives, TPM Benefits, TPM Overview
- Cooperation Between Departments and Shifts
 - Consensus agreement on how to support TPM and AM
- Group Activities
 - small groups with leadership from shop floor to management
- AM is not voluntary
 - mandatory and necessary
 - management must provide leadership and support

Keys to Successful AM (continued)

- Practice
 - practical application versus conceptual understanding
- Progressive Education and Training
 - gradual skill development - step-by-step - as needed
- Aim for Measurable Results
 - clear, appropriate measures (and goals)
- Operators Should Determine Standards to Follow
 - operators set standards and criteria for maintenance consistent with organizational objectives
- Management Should Audit the AM Progress
 - provide guidance, support and critique



Keys to Successful AM (continued)

- Use Model Projects
 - Use as examples for the rest of the organization
- Correct Equipment Problems Promptly
 - Maintenance department must react quickly to fix problems uncovered by AM activities - will require commitment and appropriate staffing
- Take Time to Perfect AM
 - Don't rush the process - make sure the skills are there

Measures of Preventive Maintenance Results

- Downtime Trend
- Operating Rate
- Failure Frequency
- Failure Severity (length of failure downtime)
- Maintenance Time per Incident
- Quality Defect Rate
- Failure Costs
- Emergency Repair Time
- Ratio of Maintenance Cost to Unit Production Cost



IMPLEMENTATION SUMMARY OF PM

- Step 1: Evaluate Equipment and Understand Current Conditions.
- Step 2: Restore Deterioration and Correct Weaknesses.
- Step 3: Build an Appropriate Information System.
- Step 4: Build a Periodic Maintenance System
- Step 5: Build a Predictive Maintenance System.
- Step 6: Evaluate the Preventive Maintenance System.

Like everything associated with TPM, successful implementation of a preventive maintenance system will take time and support.

BREAKDOWN MAINTENANCE

- The risk of a breakdown can be greatly reduced by an effective preventive maintenance program.
- The major approaches used to deal with breakdowns are:-
 - Standby or backup equipment can be quickly pressed into service.
 - Inventories of spare parts.
 - Operators who are able to perform at least minor repairs on their equipment.
 - Repair people who are well trained and readily available to diagnose and correct problems with equipment.

BREAKDOWN MAINTENANCE

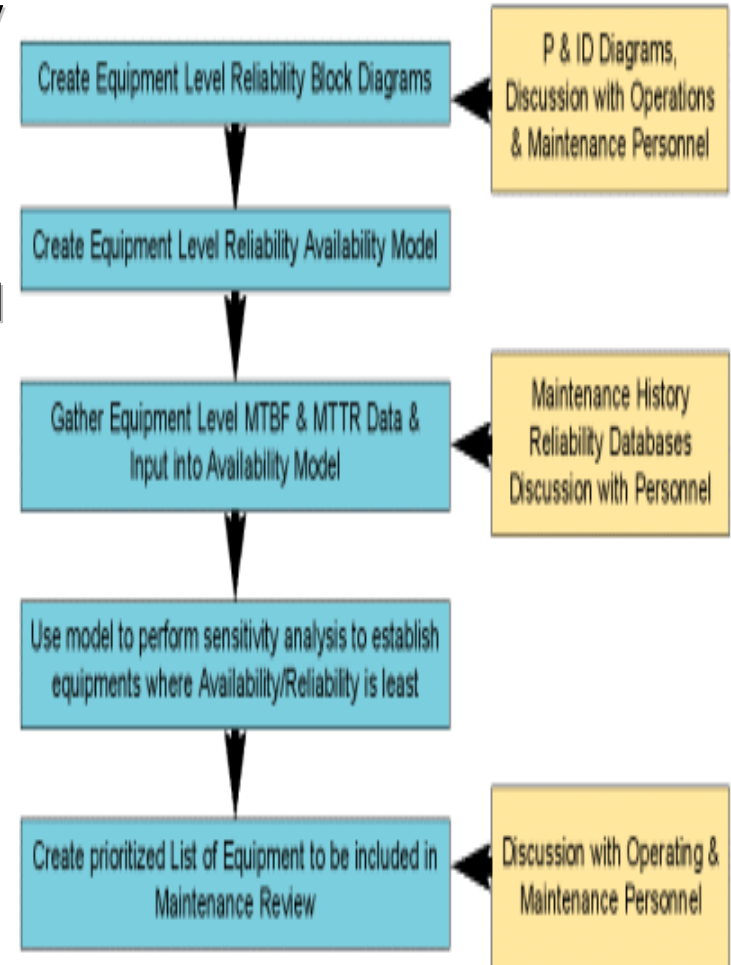
- Breakdown programs are most effective when they take into account the degree of importance a piece of equipment has in the production system
- The ability of the system to do without it for a period of time.

Review of Equipment Maintenance

- The Review of Equipment Maintenance (REM) is an incremental approach, designed to deliver financially driven results at minimum cost and time. It provides optimum results when a review of equipment maintenance is required to ensure that:
- The most effective maintenance plan is adopted
- Preventive, scheduled, design put and on-failure maintenance are integrated into a cohesive strategy
- The maintenance plan needs to respond to changes in plant operation
- The review may also be required to introduce a new technique, such as condition monitoring, or to adjust changes in maintenance resources. Typically REM requires only 30-50% of the resource input that would be required for RCM, while achieving similar results.

Review of Equipment Maintenance

- REM focuses primarily on maintenance strategy arising from business drivers, such as demand and operating patterns and can be considered in two major stages:
- Reliability and criticality analysis
- Maintenance review



Review of Equipment Maintenance

The output of a REM study is an optimized maintenance plan, where the appropriate risk based defence of the asset is defined. This takes in to account the goals of the organisation, the criticality of the asset, the resources available, and the level of technology employed by the organization. This is a working document, which can be translated into the physical reality of conducting operational maintenance.



PARETO DIAGRAMS

- Pareto diagram is an important quality tool used in prioritizing & deciding the course of action in maintenance management.
- Of all the problems that occur, only a few are quite frequent/costly.
- The others seldom occur/cost less.
- The problems are grouped and labeled as *vital few and trivial many*.



PARETO DIAGRAMS

- Pareto principle lends support to the 80/20 rule.
- Pareto diagrams help quickly identify the critical areas for management's attention.



STEPS FOR CONSTRUCTING PARETO DIAGRAMS

- STEP 1
Decide on data categorization system by problem type, type of conformity (critical, major, minor) or whatever else seems appropriate.
- STEP 2
Determine how relative importance is to be judged i.e., whether it should be based on cost or frequency of occurrence.
- STEP 3
Rank the categories from most important to least important.
- STEP 4
Compute the cumulative frequency of the data categories in their chosen order.
- STEP 5
Plot a bar graph showing the relative problem of each problem area in descending order.



STEPS FOR CONSTRUCTING PARETO DIAGRAMS

■ STEP 6

Identify the vital few that deserve immediate attention.

PARETO DIAGRAMS

<u>PROBLEM TYPE</u>	<u>DESCRIPTION</u>	<u>% OF OCCURENCE</u>	<u>ANNUAL COST (IN \$1000)</u>	<u>CUMMALITIVE % OF OCCURENCE</u>
A	Substandard quality of raw material	40	20	40
B	Improper setting of machine	20	6	60
C	Inadequate operator training	14	3	74
D	Poor storage of finished parts	10	2	84
E	Drop in hydraulic pressure impresses	8	2	92
F	Cutter not sharp	5	1.5	97
G	Electrical breakdowns	3	1.8	100



PARETO DIAGRAMS

