Notes:

Total Productive Maintenance & Maximizing Equipment Performance

Key Learning Points

1. Explain the concept of Maintenance Excellence.
2. Define Total Productive Maintenance (TPM).
3. Describe TPM implementation strategies.

What is Maintenance Excellence?

Maintenance excellence is the maximization of resource utilization through assuring high equipment consistency and dependability. It is based on a sound philosophy of guiding performance with Total Productive Maintenance (TPM) combined with strong tactical approaches for implementation (the seven pillars).

Traditional Maintenance Activities

- budgetary control and purchasing
- scheduling and work order systems
- data recording/collection
- safety and environmental review
- capital planning and life cycle analysis

The Seven Pillars

- Autonomous Maintenance

- Kaizen
- Planned Maintenance
- Reliability Centered Maintenance (RCM)
- Skills Development (training)
- Office TPM
- Safety, health and environment

Is TPM Needed?

When you look around your work area, do you see:

- Dirty equipment
- Leaks
- Build up of materials waste
- Tangled lines
- Dismantled equipment (for inspection)
- Clutter
- Laissez-faire responses to inquiries:
  - "What problem?"
  - "It has always been that way."
  - "This is not so bad."

What Can Be Achieved With TPM?

Benefits of implementing TPM are:

- Build pride/sense of ownership in employees
- Improved responsiveness
- Better on-time delivery performance
  - Permits implementation of planning and leveling customer demand, or heijunka
  - Higher productivity/efficiency (reduced loss)
- Improved image to customers
  - Less clutter

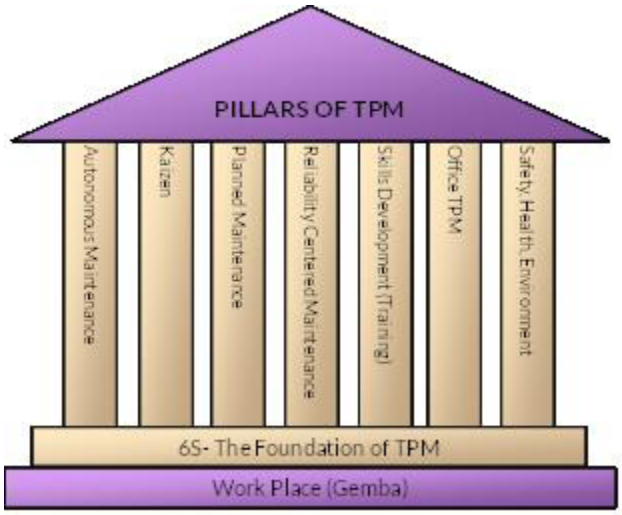
TPM targets reducing equipment related losses to zero, including losses related to:

- High incidence of equipment breakdowns

Notes:

- Long time to complete setup and adjustments
- High levels of defects due to faulty or poor performing equipment
- Equipment running at lower than rated speed
- High startup losses and poor yield performance related to equipment
- NVA stoppages and delays related to equipment

The Seven Pillars of TPM



As with the general Lean philosophy, 6S is the foundation of the TPM philosophy. The Seven Pillars are:

Autonomous Maintenance

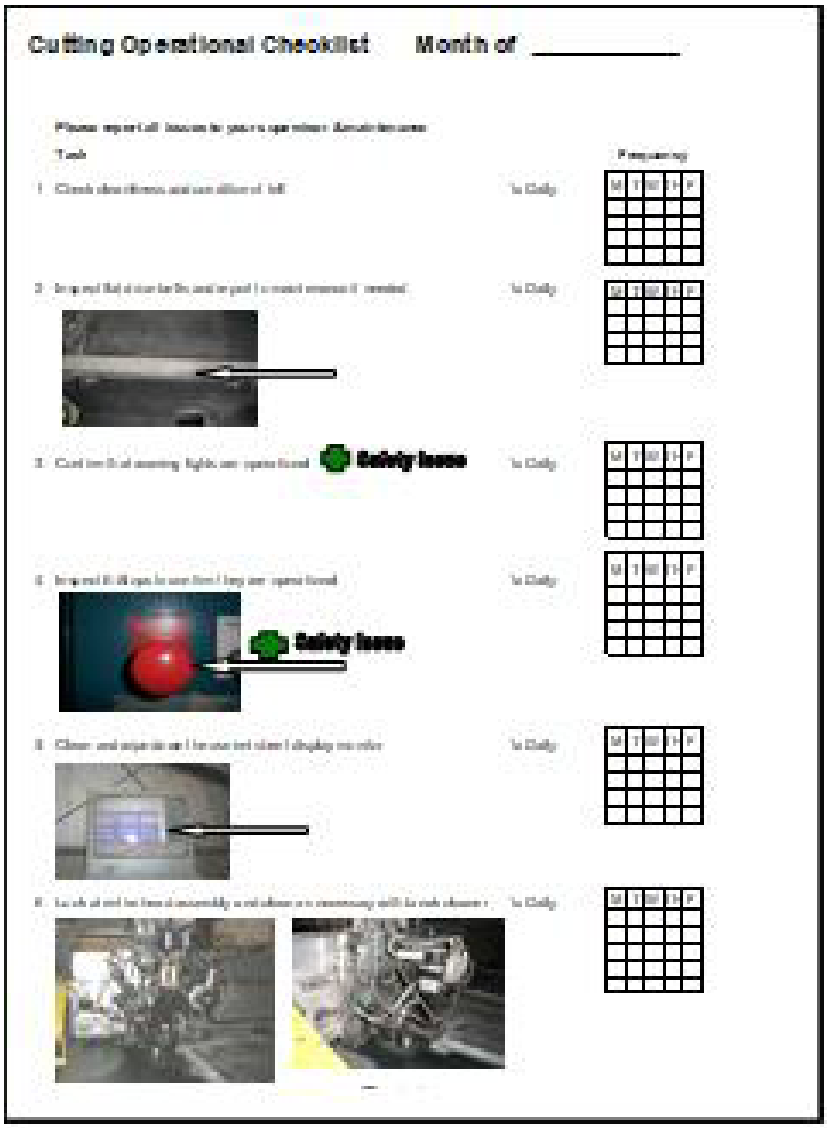
Autonomous maintenance is completed when an operator can take care of small maintenance tasks on their own. This frees up skilled maintenance people to spend time on more value-added activities.

TPM is a philosophy based on total employee involvement. Autonomous Maintenance is a primary tactic to implement that philosophy.
The operator of the equipment is the process expert and key to timely identification of issues.

The operator is in the best position to help drive improvements in accident rates, defect occurrence, and breakdown frequency.

Notes:

Autonomous Maintenance Checksheets



Checksheets are guidelines for production operators to engage in equipment maintenance.

These actions can be performed daily, weekly, monthly or at other time intervals; or by number of cycles/units

Autonomous Maintenance Actions

Actions to Facilitate Autonomous Maintenance activities within your operations:

- Prevent accelerated deterioration.
  - Clean and inspect
  - Equipment runs at design ratings

Notes:

- Use of the 6S red tag process

- Begin operator-controlled inspections.
  - General inspections to standards
  - Checksheet guided inspections
- Include targeted equipment in the visual factory.
  - Organized work area (S2)
  - Machine and area is clean (S3)
  - Equipment log
  - Maintenance log
  - Visual control methods (gauges, indicators, etc.)
- Involve all levels.
  - Rapid Improvement Events
  - Measures of performance (OEE—MTBF—MTTR)
  - Regular training

Notes:

Your Current Autonomous Maintenance Situation

What Autonomous Maintenance activities are used within your existing operations?

ACTION	YES	NO
Prevent accelerated deterioration.		
– Clean and inspect		
– Equipment runs at design ratings		
– Use of the 6S red tag process		
Begin operator-controlled inspections.		
– General inspections to standards		
– Checksheet guided inspections		
Include targeted equipment in the visual factory.		
– Organized work area (S2)		
– Machine and area are clean (S3)		
– Equipment log		
– Maintenance log		
– Visual control methods (gauges, indicators, etc.)		
Involve all levels.		
– Rapid Improvement/ Kaizen Events		
– Measures of performance (OEE—MTBF—MTTR)		
– Regular training		

Kaizen

Kaizen is when small improvements are carried out on a continual basis. It involves all people in the organization.

- Educate employees at all levels to support "many small improvements"
- Make involvement and visibility at the highest levels in the organization a necessity
- Select goals related to TPM
- Select executive sponsors/mentors and team leaders
- Involve everyone
- Select and prioritize projects
- Apply tools like 5 Whys and Mistake Proofing
- Measure and communicate progress
- Use activity boards
- Provide training
- Publicize and reward results

Notes:

Planned Maintenance

Planned maintenance is completed in order to have trouble free machines and equipment that produce defect free products for total customer satisfaction.

Planned maintenance includes:

- Preventative Maintenance
  - Consists of regularly scheduled service of machines and equipment based on historical trends and service life data
- Breakdown Maintenance
  - Quick response to breakdowns. Utilize the “pit crew” concept
- Corrective Maintenance
  - Changing design of existing equipment to improve reliability and reduce breakdowns
- Maintenance Prevention
  - Purchasing and installing equipment that needs little maintenance (e.g. self-lubricating bearings)

Reliability Centered Maintenance

Reliability centered maintenance is aimed toward delighting customers through producing higher quality goods that are defect free. It includes understanding what parts of the equipment effect product quality, and starts by eliminating current quality concerns, and then moving to potential quality concerns.

- TPM sets the overall philosophy and standards for maintenance. To complement this, a planning method is needed, a way to prioritize resources and actions. This is called RCM – Reliability-Centered

Notes:

Maintenance.

- RCM is the central pillar of TPM.
- The goal of RCM is to assure process reliability through data collection, analysis, and detailed planning of maintenance activities.
- Measurements of performance such as OEE, MTBF, and MTTR support effective RCM.

Is RCM Needed?

Look around/ Do you hear:

- "I didn't have enough people to do all (any) of the maintenance needed."
- "I don't have spare parts."
- "You won't let me have the equipment long enough to work on it."
- "This part always fails."

Do you see:

- Dirty Equipment
- Leaks
- Buildup of raw material waste
- Tangled lines (electrical, pneumatic, hydraulic)
- Dismantling of equipment for inspections
- Clutter
- Laissez-faire responses to inquiries:
  - "What problem?"
  - "It has always been that way."
  - "This is not so bad."

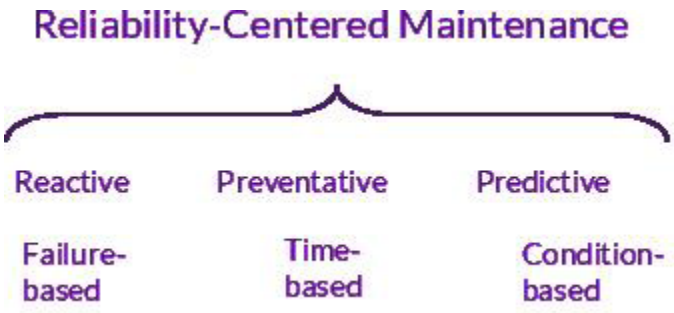
What Can Be Achieved With RCM?

RCM is key to successful TPM and helps achieve:

- Reduced inventories
- Shorter lead times
- Higher service levels
- More stable operations
- Improved job satisfaction

Notes:

RCM Focus



Notes:

Reliability-Centered Maintenance allows an organization to allocate the appropriate level of maintenance attention depending on machine type and breakdown history:

- Failure-based
  - Equipment is non-critical and causes little to no disruption if allowed to run to failure. Can be quickly and economically repaired, e.g. a panel indicator light.
- Time-based
  - The failure can be predicted based on time or number of cycles. Preventative maintenance is performed at the specified time or number of cycles, e.g. changing the oil in a gear box.
- Condition-based
  - The failure can be predicted based on machine or equipment performance characteristics, e.g. vibration analysis to understand when a machine needs service.

What is Reactive Maintenance

The Reactive Maintenance approach is to run equipment to failure.

Reactive Maintenance is used for:

- Non-critical components
- Redundant Equipment
- Small/simple items
- Low failure rates

- Examples:
  - Lamps
  - Electric Solenoid on valves
  - Overhead doors
  - Relay coils
  - All breakdowns

What is Preventative Maintenance

Preventative Maintenance is based on time intervals.

Preventative Maintenance is used for:

- Known failure patterns
- Normally something subject to wear
- A consumable component
- Examples:
  - Motor brushes
  - Bearing and gears
  - Filters
  - S-3: Sweep & Shine
  - Planned maintenance actions (i.e., checklist)

What is Predictive Maintenance

Predictive Maintenance focuses on equipment condition.

Predictive Maintenance is used for:

- The most critical components or machine
- Long lead time components (if not stocked)
- Random failure patterns
- Normally not subject to wear

Examples:

- Unique equipment
- Single machine vs. a group of the same machine
- A Swiss-made machine with limited US support

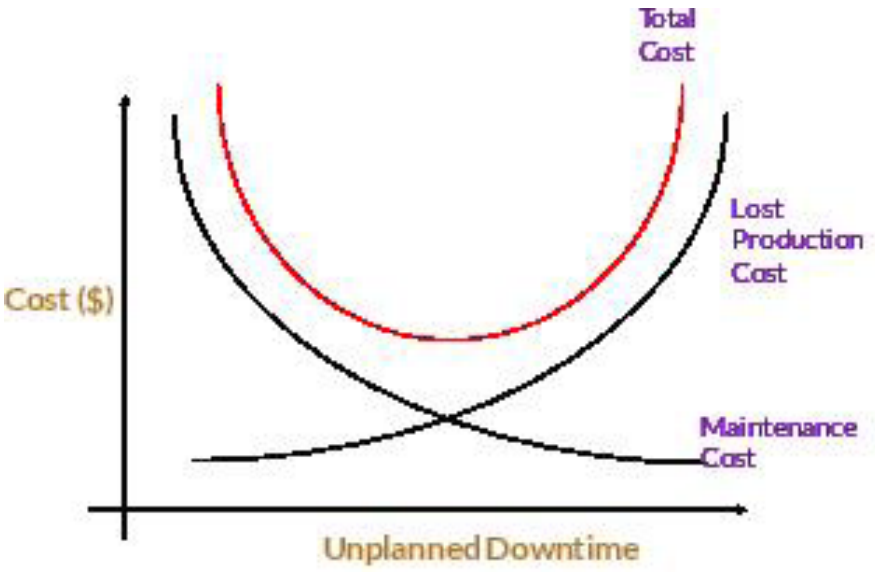
Notes:

Predictive Maintenance Tools

Methods to determine equipment condition are:

- Vibration analysis
- Infrared/temperature
- Lubrication analysis
- Ultrasonic or dye penetrant testing
- Current signature analysis
- Laser alignment
- High-speed video

What is the Cost Impact



Reactive Maintenance costs are 2 to 3 times more than Preventative Maintenance costs.

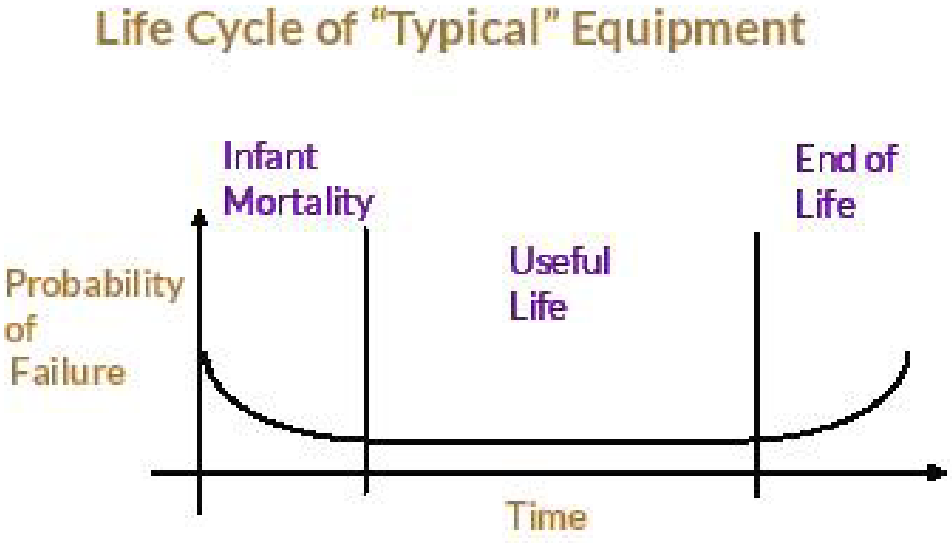
Preventative Maintenance costs are 2 to 3 times more than Predictive Maintenance costs.

The graph to the left shows the relationship between the cost of lost production and the cost of maintenance. With low levels of investment in maintenance, typically there are high levels of loss because of downtime and/or poor process capability. The goal is to balance the two so that total costs are minimized (related to equipment reliability).

The graph also shows that severely reduced spending on maintenance increases the impact of unplanned equipment downtime.

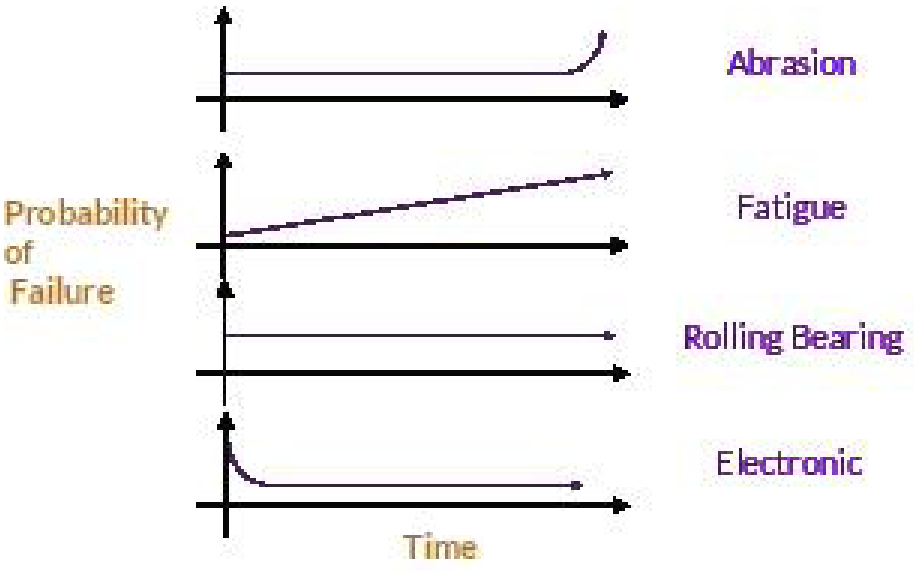
Notes:

What are Failure Modes?



- Also known as Weibull Analysis and the "bathtub curve."
- The curve shows the hypothetical failure rate versus time. The shape of the curve is dependent on the type of failure.
- There is a strong relationship between the curve and Mean Time Between Failure (MTBF).
- This analysis can also be used as a prediction tool for wear-out periods.

What are the Types of Failures?



Different wear-out patterns (bathtub curve) by failure type:

- Abrasion: Constant failure probability ending in a wear-out zone.

Notes:

- Fatigue: Slowly increasing probability of failure with no detectable wear-out age.
- Rolling Elements Bearing: Constant probability of failure occurring at all ages.
- Electronic: Starts with high-failure probability then drops to a constant level.

How is Improvement Measured?

Tier 1:

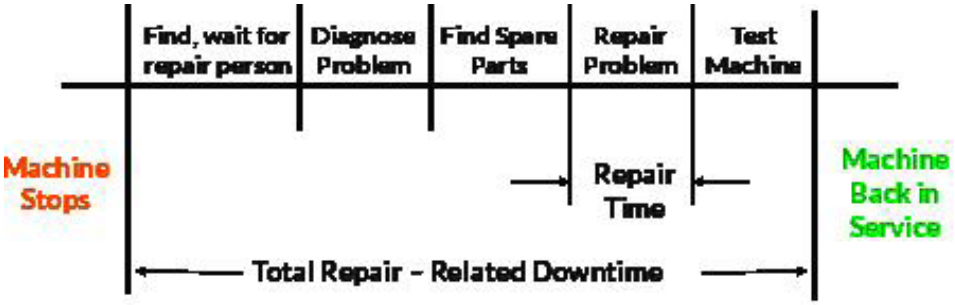
- Overall downtime (log book)
- Scrap/rework related to equipment condition
- Lost productivity

Tier 2:

- Mean Time to Repair (MTTR)
- Machine Availability (MA)
- Mean Time Between Failures (MTBF)
- Overall Equipment Effectiveness (OEE)

Maintainability (MTTR)

- Maintainability: Mean Time to Repair (MTTR)
- MTTR = (Sum of Downtime for Repair) / (Number of Repairs)



Machine Availability

Machine Availability (MA) = (Actual Running Time) / (Planned Running Time)

Mean Time Between Failures

Machine Time Between Failures (MTBF) = (Total Running Time) / Number of Failures

How to Measure

Overall Equipment Effectiveness (OEE): The cumulative effect of all losses

Notes:

because of equipment condition.

OEE Calculation

OEE = MA X ME X MQ

Machine Availability (MA) = (Actual Running Time) / (Planned Running Time)

Machine Efficiency (ME) = [(Total Units Produced) / (Actual Running Time)] / [(Rated Units) / (Time)]

Machine Quality Performance (MQ) = (Number of Good Units) / (Total Units Produced)

Types of Loss

- Machine Availability (MA)
- Machine Efficiency (ME): Less than design (i.e., running at reduced speed)
- Machine Quality Performance (MQ)

Skills Development (Training)

Improving skills through training is aimed at having multi-skilled employees and high morale. It includes training on how to identify problems and how to solve them. It also sets a goal to create an organization full of experts.

Skills development generally consists of training operators to spot abnormalities and other sources of accelerated deterioration. (overstressing machines) Look for:

- Heat
- Wrong/no lubrication
- Excessive vibration
- Loss of pressure
- Dirt/abrasions
- Incorrect setup/speed
- Tool problems/tool maintenance

Operator Skills

Train operators to know their machines and processes:

- How to perform daily checks and routine maintenance
  - Clean
  - Lubricate
  - Tighten

Notes:

- Adjust

- How to understand and follow operational guidelines and procedures
- How to fix simple problems and restore equipment function
- Cross-train employees to increase factory flexibility
- All employees should continually improve skills and knowledge

Office TPM

Once the first five Pillars of TPM have been begun, an organization should move on to begin Total Productive Maintenance in the office. This is aimed at improving productivity and efficiency in the administrative functions by identifying and eliminating losses.

The "office" is more than just a place where people work at desks. Office functions support the planning, logistics, financial, quality, and other key enterprise functions. The absolute availability and reliability of these functions is as critical to success as they are the equipment on the factory floor. In service, financial, and healthcare enterprises, these are, in fact, the engines of the enterprise.

- OEE, MTBF, and other key metrics apply to intelligent management of data processing equipment and computers. One can apply these principles to individual pieces of equipment, total systems, and the full infrastructure of an enterprise.
- With digitization, there are few differences between the management of computers and telecommunications. Again individual elements and total networks need to be managed with the principles of TPM.
- Databases, of course, reside on pieces of equipment, whether on the desk or in "the cloud," but the logical construct and maintenance of the availability and reliability of the data are needed apart from the physical manifestations. Experience has shown that the TPM principles which apply to physical machines also apply to logical and digital constructs in databases.
- While most of our office equipment is computer based, there are still other pieces of equipment and the facility that must be totally reliable in providing an infrastructure within which we work.

Safety, Health & Environment

This Pillar's focus is on creating a safe workplace and environment. It plays an active role in each of the other pillars. The first priority of production should be safety!

Safety is critical to all work activities

- A safe working environment reduces the loss from accidents in the workplace.

Notes:

The goal is zero-lost-time accidents

- Simplify work.
- Clean the area.
- Check for exposure to harmful conditions.
- Training is vital.
  - Equipment
  - Safety
  - Hazardous Materials

How to Create a Safe Workplace

Eliminate unsafe conditions!

- Identify and correct problems such as exposed moving parts, projecting parts, and the spattering of harmful substances.
- Take steps to correct problems related to covers, guards, etc.
- Establish and review work standards and daily check methods, etc.
- Check and improve performance of safety and disposal devices.
- Correct stressful working postures and methods.
- Assure workplace organization (6S) and maintain safe working environment.

Encourage everyone to take care of their own workplaces.

Sample Safety Checklist

Think about the area you work in or one you are very familiar with. Answer the questions below relative to that area.

Operation (Work Area):	Yes	No
Are aisles and work area kept clean and clear?		
Is equipment easy to take apart and reassemble?		
Can equipment be replaced easily when break-downs occur?		
Is the machine easy to lubricate?		
Do the people operating the equipment have the necessary knowledge and qualifications?		
Are there any potential dangers present?		
Other:		

Notes:

Other Tools Supporting TPM

Related Topics to Assist TPM Implementation:

- 6S
- Mistake Proofing
- FMEA
- Six Sigma Improvement
- Benchmarking

When to Use TPM

- TPM aims to use equipment at its maximum effectiveness by eliminating waste and losses caused by equipment malfunctions.
- TPM should be used whenever an organization experiences excessive breakdowns or requires frequent machine adjustments.
- It is the key method for using a team-based approach to identify, analyze, and solve maintenance problems in a steady stream of small improvements.

Pitfalls to Avoid

- Lack of management support
- Organizational silos
- Failure to educate on “whats and whys” of TPM
- Not starting with operator-involved maintenance
- Making inspections too technical
- Not reacting to inspection results
- Making low impact changes, too much window-dressing
- Poorly aligned incentives – maintenance may make more pay for reacting to broken equipment

Notes: