TOTAL PRODUCTIVE MAINTENANCE, THE SIX BIG LOSSES, AND OVERALL EQUIPMENT EFFECTIVENESS AND THE TPM VISION

TOTAL PRODUCTIVE MAINTENANCE

Total productive maintenance (TPM) was first defined in 1971 by the Japan Institute of Plant Maintenance (JIPM). TPM is a company wide strategy to increase the effectiveness of production environments, especially through methods for increasing the effectiveness of equipment.

TPM became more broadly known in the Western world in the late 1980s when Productivity, Inc. published English editions of two books by JIPM expert Seiichi Nakajima: *Introduction to TPM* and *TPM Development Progra*m. TPM implementation involves applying continuous improvement methods to reduce losses. Because the actual process of adding value to products usually involves machines and equipment, TPM focuses its improvement activities on *equipment-related losse*s.

In an ideal factory, equipment would operate 100 percent of the time at 100 percent capacity, with an output of 100 percent good quality.

In real life, however, this is rare. The difference between the ideal and the actual situation is due to losses. Equipment operators face the results of these losses on a daily basis. TPM gives them the tools to identify the losses and make improvements.

A key strategy in TPM is identifying and reducing what we call the six big losses.

THE SIX BIG LOSSES

Looking at machine operation, we distinguish six types of waste we refer to as losses, because they reflect lost effectiveness of the equipment.

These six big losses are grouped in three major categories: downtime, speed losses, and defect losses.

The Six Big Losses

Loss Categories	The Six Big Losses
Downtime (Lost availability)	Equipment failures Set-up and adjustments
Speed losses (Lost performance)	Idling and minor stoppages Reduced speed operation
Defect losses (Lost quality)	Scrap and rework Start-up losses

(Currently, JIPM identifies cutting blade losses as a seventh loss. Since this is not a common loss to all machines, cutting blade losses should be categorized as either performance or downtime losses for the purpose of using the OEE Toolkit Downtime)

Loss Category 1 - Downtime: -

Refers to time when the machine should be running, but it stands still. Downtime includes two main types of loss: equipment failures, and set-up and adjustments.

Equipment Failures

Sudden and unexpected equipment failures, or breakdowns, are an obvious cause of loss, since a failure due to equipment means that the machine is not producing any output.

Set-up and Adjustments

Most machine changeovers require some period of shutdown so that internal tools can be exchanged. The time between the end of production of the last good part and the end of production of the next good part is downtime. This downtime loss often includes substantial time spent making adjustments until the machine gives acceptable quality on the new part.

Loss Category 2 - Speed Losses

A speed loss means that the equipment is running, but it is not running at its maximum designed speed. Speed losses include two main types of loss: idling and minor stoppages, and reduced speed operation.

Idling and Minor Stoppages

When a machine is not running smoothly and at a stable speed, it will lose speed and obstruct a smooth flow. The idling and stoppages in this case are caused not by technical failures, but by small problems such as parts that block sensors or get caught in chutes. Although the operator can easily correct such problems when they occur, the frequent halts can dramatically reduce the effectiveness of the equipment.

Reduced Speed Operation

Reduced speed operation refers to the difference between the actual operating speed and the equipment's designed speed (also referred to as nameplate capacity). There is often a gap between what people believe is the "maximum" speed and the actual designed maximum speed. The goal is to eliminate the gap between the actual speed and the designed speed. Significant losses from reduced speed operation are often neglected or underestimated.

Loss Category 3 - Defect Losses

A defect loss means that the equipment is producing products that do not fully meet the specified quality characteristics. Defect losses include two major types of loss: scrap and rework, and start-up losses.

Scrap and Rework

Loss occurs when products do not meet quality specifications, even if they can be reworked to correct the problem. The goal should be zero defects —to make the product right the first time and every time.

Start-up Losses

Start-up losses are yield losses that occur when production is not immediately stable at equipment start-up, so the first products do not meet specifications. This is a latent loss, often accepted as inevitable, and it can be surprisingly large.

OVERALL EQUIPMENT EFFECTIVENESS AND THE TPM VISION

Implementing TPM means striving toward a vision of the ideal manufacturing situation, a vision that encompasses

- Zero breakdowns
- Zero abnormalities
- Zero defects
- Zero accidents

The path to this ideal situation is a process of continuous improvement that requires the total commitment of everyone in the company, from operators to top management.

In the West, the measure of whether an improvement process is succeeding often rests on the ultimate result of the process: the money it makes or loses. This seems rational, since making money is the ultimate goal of industry. The financial bottom line, however, provides little or no information about what is actually going on within the process; thus it gives little real feedback and focus to the things we actually need to do to improve the process.

If there is a gap between our daily process and the ideal situation, it makes sense to focus on this gap and look for ways to eliminate it.

TPM helps us do this by focusing on the six big losses—the gaps—to improve the effectiveness of the equipment. By applying a gauge that measures the six big losses, we can focus on improving the right things—the losses we want to eliminate.

THE OVERALL EQUIPMENT EFFECTIVENESS METRIC

Most industries have some kind of gauge system on their equipment that measures quantities such as uptime, units produced, and sometimes even the production speed. These are appropriate things to look at if the focus is on what's coming out of the machine.

TPM takes a slightly different approach. Besides what's coming out of the machine, we also want to know what could have come out, and where we are losing effectiveness. Overall equipment effectiveness, or OEE, offers a simple but powerful measurement tool to get inside information on what is actually happening.

The OEE calculation is a metric that gives us daily information about how effectively the machine is running and which of the six big losses we need to improve. Overall equipment effectiveness is not the only indicator to assess a production system, but it is certainly very important if our goal is improvement.

THE ELEMENTS OF OVERALL EQUIPMENT EFFECTIVENESS

The three main categories of equipment-related losses—downtime, speed loss, and defect or quality loss—are also the main ingredients for determining the overall equipment effectiveness. Overall equipment effectiveness is calculated by combining three factors that reflect these losses: the availability rate, the performance rate, and the quality rate.

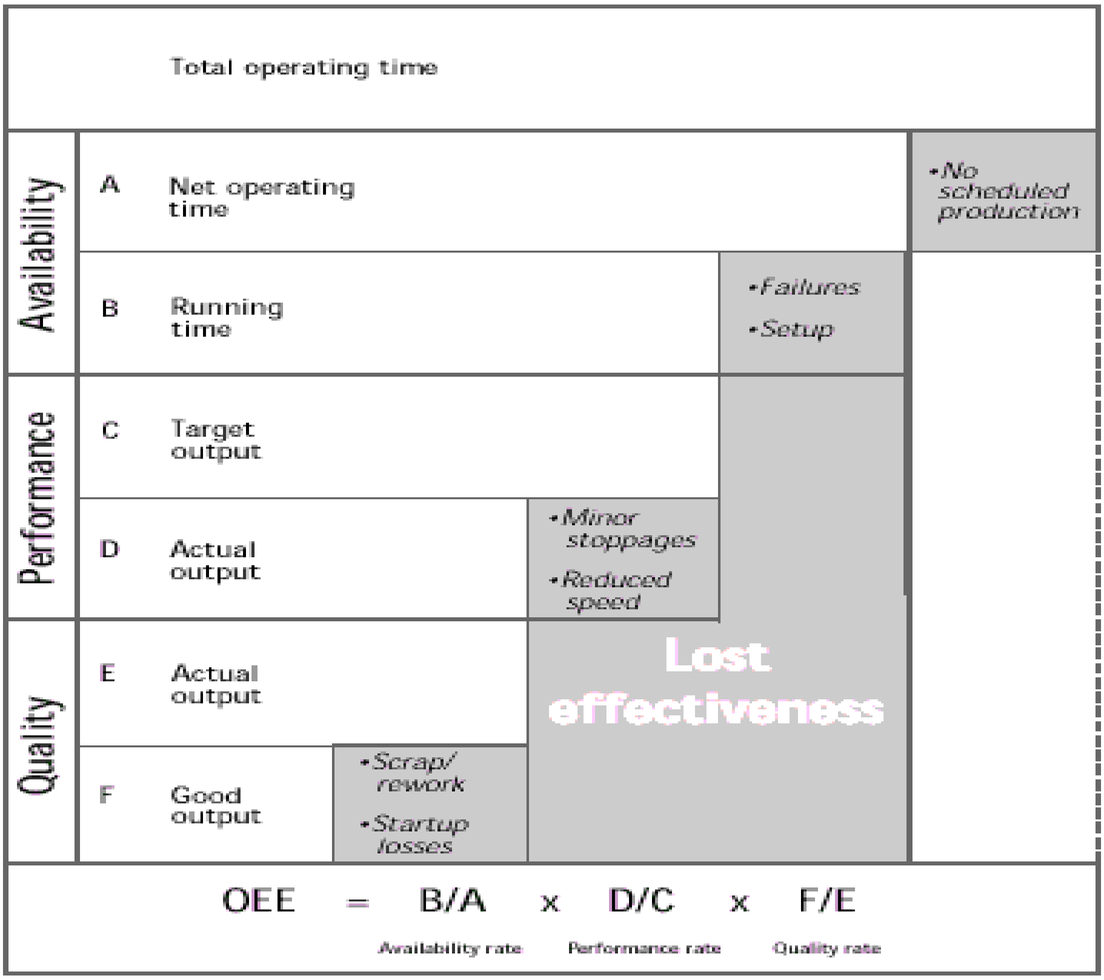
The *availability rate* is the time the equipment is really running, versus the time it could have been running. A low availability rate reflects downtime losses: • Equipment failures • Set-up and adjustments	$\text{Availability Rate} = \frac{\text{Operating Time} - \text{Downtime}}{\text{Total Operating Time}}$
The *performance rate* is the quantity produced during the running time, versus the potential quantity, given the designed speed of the equipment. A low performance rate reflects speed losses: • Idling and minor stoppages • Reduced speed operation	$\text{Performance Rate} = \frac{\text{Total Output}}{\text{Potential Output at Rated Speed}}$

The *quality rate* is the amount of good products versus the total amount of products produced. A low quality rate reflects defect losses: • Scrap and rework • Start-up losses	$\text{Quality Rate} = \frac{\text{Good Output}}{\text{Total Output}}$

To calculate OEE, we multiply the three factors together:

OEE = Availability Rate x Performance Rate x Quality Rate

Diagram of Overall Equipment Effectiveness



The inverted stair-step diagram above shows graphically how the losses in availability, performance, and quality work together to reduce the overall effectiveness of a machine. 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 set-up 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, a shorter fourth 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 start-up 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.

The Goal and Benefits of OEE Measurement

The goal of measuring OEE is to improve the effectiveness of your equipment. Since equipment effectiveness affects shop-floor employees more than any other group, it is appropriate for them to be involved in tracking OEE and in planning and implementing equipment improvements to reduce lost effectiveness. Let's look at some of the benefits of OEE measurement for operators and shift leaders or line managers.

We recommend that the operator collect the daily data about the equipment for use in the OEE calculation. Collecting this data will

- Teach the operator about the equipment
- Focus the operator's attention on the losses
- Grow a feeling of ownership of the equipment

The shift leader or line manager is often the one who will receive the daily operating data from the operator and process it to develop information about the OEE. Working hands on with the data will:

- Give the leader/manager basic facts and figures on the equipment
- Help the leader/manager give appropriate feedback to the operators and others involved in equipment improvement
- Allow the leader to keep management informed about equipment status and improvement results

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