Introduction to
Overall Equipment Effectiveness (OEE):
A Primer
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1. What is OEE?

The Overall Equipment Effectiveness (OEE) of a machine or set of equipment is a Key Performance Indicator (KPI) that indicates the equipment’s overall operational performance. In essence, OEE is a measure of the actual output that was produced with a machine, compared with the maximum output that could be expected from the machine over the same period of time. OEE takes into consideration the cumulative impact of three factors: the equipment’s availability (percent of scheduled production time in which units are actually produced, also called the Machine Operating Time), its performance rate (percent of material produced compared to standard), and the quality of its output (percent of good material produced compared to all material produced during the Machine Operating Time). In equation form, OEE is the multiplication of these three factors: OEE = % Availability x % Performance x % Quality.

Many manufacturers are already using OEE, both as a KPI and as a catalyst for change. OEE is a standard metric used to evaluate manufacturing performance by taking a broad view of all aspects of production. By using its three factors, OEE provides a manufacturer with the best measure of machine utilization and helps them focus on improvements that most directly impact their profits. As part of the lean manufacturing tool kit, OEE does this by identifying and driving all elements of waste out of manufacturing processes. For a more detailed description of the OEE standards and how they are provided in ProTech’s Remote Monitoring platform, refer to the last section of this Primer.

2. What are the benefits of using OEE to improve operational performance?

Continuously and visibly monitoring and reporting OEE provides the basis for achieving optimum operational efficiency. When implemented on key manufacturing equipment, all levels of the manufacturing organization will be able to take greater control of the daily management, and improve the utilization of those plant assets. In short, this will save the company money while increasing production output. In addition, utilizing automated data collection and OEE measuring systems that are highly visible and easy to use, such as ProTech’s Remote Monitoring solutions, saves enormous effort and delivers highly visible, real-time intelligence on the overall equipment effectiveness of a machine, a work cell, or a plant. This allows operators and supervisors to proactively track, monitor and respond to operational issues as well as measure and justify ongoing improvement efforts.

Typically, manufacturers are able to achieve rapid improvements upon the initial implementation of such systems, and when done well, small improvements can result in a big impact to the bottom line:

- An increase in OEE of around 10-15% can often be realized in the first year; this can translate to a 50% improvement in Return on Assets (ROA). [R. Hansen, OEE for Operators]
- OEE initiatives are generally ten times more cost-effective than purchasing additional equipment capacity [ibid], and over time can reduce major capital expenditures by 50%.
- In many major industries, an improvement of 1% in reduced downtime of a high value asset can translate to over $1 million in annual savings.
- As machine OEE increases, total energy consumption per unit produced is reduced. The manufacturer’s carbon footprint is reduced, while they enjoy lower costs.

3. How does OEE build and support a culture of Lean Manufacturing?
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The OEE metric provides for several critical elements of the most successful Lean Manufacturing initiatives. In these cases, OEE is used by lean practitioners on the shop floor to identify and eliminate the sources of losses in all areas of the operation. Everyone in the organization from upper management down to the shop floor is actively and highly visibly engaged in supporting the teams and giving them the resources needed to be successful. In the most successful companies, measurements become consistent, accessible, widely understood and accepted. To achieve this, they use clearly communicated standards and automated systems for collecting and interpreting data, as well as for reporting and distribution. In some cases, additional incentives are created in compensation systems that incorporate an element of OEE improvements.

When used properly, OEE is used to educate and train the workforce, to gain a common sense of purpose; it provides an accepted system of measurement that drives a common understanding for team problem-solving. Further, with the completion of each project, visible OEE improvements provide a source of motivation for the workforce by clearly showing the benefits of their efforts.

In particular, OEE dashboards and reports provide a platform for organizations to:

- Increase output by quickly identifying and responding to the highest priority sources of losses, thereby producing more in the same amount of time with the same equipment, with less energy consumed;
- Empower shop floor personnel by providing clear and visible measures of their performance compared to goals; and
- Support continuous improvement.

4. What are the benefits of an automated data collection, analysis and reporting system?

If done properly, manually executed OEE systems will identify losses and opportunities for improvement. However, collecting and interpreting data for evaluating OEE this way is a time-intensive process that is wrought with risk of error and inconsistency. The time and effort spent doing it this way would be much more efficiently used to work on actual improvement projects. In addition, at higher levels of OEE, it becomes more difficult to obtain further gains, which makes the time and effort in manual systems seem less worthwhile. In some cases this is because the losses are occurring at very high rates but also in very small amounts, and these are extremely difficult to capture with any manual data collection process.

Inevitably, most manufacturing continuous improvement projects and facilities using a manual collection method will quickly discover the value of automated systems. There are many benefits of automated OEE systems. They are powerful tools used to provide automated data collection, analysis and reporting of accurate and consistent, data-based OEE evaluation summaries and details. The following table provides a comparison of these two methods, and shows the powerful and cost-effective benefits of using the OEE productivity tools in ProTech’s Remote Monitoring platform.

<table>
<thead>
<tr>
<th>OEE Using Manual Spreadsheet</th>
<th>ProTech Remote Monitoring System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proper data collection and reporting can take up to</td>
<td>Data is captured automatically, reports are user-defined</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>20 man-hours per month, per work cell or line, and information accuracy and detail is limited</th>
<th>and generated on demand, or automatically generated based on schedules set by any user</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual alert system on shop floor when machine goes down slows communication to responsible support staff and extends time to resolution</td>
<td>Automatic email/SMS alerting for machine down or exceeded threshold of any machine or process parameter chosen by platform user, provides for fast response</td>
</tr>
<tr>
<td>Difficult, complex analytical methods to consistently apply, and then manually map results to sources of OEE shortfalls for subsequent analysis</td>
<td>Pareto analysis tools automatically provide top reasons for downtime losses, and the detailed data needed to identify and resolve the root causes</td>
</tr>
<tr>
<td>Errors can come from operator influence, data collection and reporting, missed stoppages, memory of events, and estimations; impact to OEE subject to interpretation and inconsistencies</td>
<td>Every production stop and performance loss is captured, validated and analyzed; down time reason codes can be assigned automatically by the machine and updated by authorized operator or engineer; OEE impact consistently applied per facility guidelines and industry standards</td>
</tr>
<tr>
<td>Timeliness and accuracy of data and level of detail is dependent on individuals involved, and organizational, political, and cultural influences</td>
<td>Data is analyzed in real time, and delivered with valuable information tailored to the requestor, whether operators, maintenance, engineers, or management</td>
</tr>
<tr>
<td>Spreadsheets must be analyzed, transcribed to reports and distributed manually; no control over subsequent editing unless access is limited</td>
<td>Unlimited, multi-user read-only access to a user-friendly system with standardized information, distributed on-demand or on a user defined schedule</td>
</tr>
<tr>
<td>Data storage and retrieval, and data integrity risks, due to above issues</td>
<td>Secure, backed up database with user access controlled by customer’s platform administrator</td>
</tr>
</tbody>
</table>

Table 1: Benefits of Using an Automated, Remote Monitoring OEE System

5. How is OEE Used?

OEE can be evaluated for a single piece of equipment or machine, or for multiple pieces of equipment, over a discrete period of time, or for a particular job or product. Like many standardized metrics, OEE has a set of basic rules to follow in its implementation, and the application of these rules can vary. The most important consideration to follow in an implementation of OEE metrics is to be consistent in the application of its rules, so that comparison and trending analysis from machine to machine and in tracking improvement efforts provides valid results.

The most important aspect, which is universally recognized, is that the practitioner should know how their particular organization’s interpretations and definitions are applied so that they can effectively use them to obtain improvements. Then, within a consistent framework and terminology that is accepted across the company, OEE is used to identify losses associated with each of its components: Availability, Performance, and Quality. Analysis of the respective losses is performed to prioritize improvement projects and determine root causes, and then the improvements are tracked for verification and further actions as needed. For smaller projects, formal process improvement tools and techniques may be used, such as FMEA, DOE, BD, DMAIC, and Plan-Do-Check-Act. More substantial opportunities would benefit from more systemic, business process improvement tools such as Value Stream Mapping and Kaizen, and sometimes from department- or company-level initiatives such as modified work schedules or supply chain changes.

The ProTech platform is flexible enough to provide for different interpretations, and robust enough to properly implement those differences consistently and accurately in both how it calculates OEE components and how it displays the results. For example, some companies differ in how they interpret...
what constitutes planned or unplanned down times in the measurement of their machines’ Availability or Performance. More advanced users of ProTech’s applications can tailor and automate them to fit such local customs and interpretations from within the Downtime Tracking module, with its assignment of individual downtime codes to different categories of downtime.

6. From where and when did OEE originate?

The concept of OEE was developed as a metric and tool to be used for improving operating efficiency of manufacturing plants. Its origins come from the framework of Total Production Maintenance (TPM), introduced by Seiichi Nakajima’s *Introduction to Total Productive Maintenance* in 1988. Since then, OEE has become widely known as the best metric from which to gain control, and then optimize the overall operational performance, and financial return on high value manufacturing assets.

7. How is the OEE Model implemented in ProTech’s Remote Monitoring platform?

The platform uses a cross-industry standardized model for OEE productivity data. It provides a visual illustration for each component of OEE (Availability, Performance, and Quality) and the component’s respective value, in a horizontal bar format. The model is designed to visually represent the calculated value of OEE as the amount of Good Material produced as its appropriate equivalent proportion of total calendar time. To accomplish this, the maximum values of the components Performance and Quality are graphically aligned with respect to their respective parent component. For example, the theoretical maximum speed of the machine for the amount of material produced is graphically aligned with the Machine Operating Time. This is intuitively logical as well because Performance is measured only over the period of time the machine is considered to be producing actual production material. Each of the three components itself is then divided by the proportional percentages of its respective elements, e.g. Good Material is shown graphically as the respective percentage of the Total Material produced.

![OEE Model Diagram](Diagram.png)

**Figure 1: Cross-Industry Standardized OEE Model**

Using this model, reporting of OEE productivity data in the remote monitoring platform is provided in two levels. The top level is an executive summary view, using an aggregate, simplified horizontal bar chart as shown in Figure 2. This is provided any time that a platform user requests a summary of OEE data for a discrete, i.e. non-trending, time period. The calculated value of OEE is provided in bold font at
the top of the chart, with the equation of its components appended for reference. Then only one bar is provided to illustrate a summary of each of the OEE components of Availability, Performance, and Quality, with each of the components’ associated value labeled above it. The top bar represents the full calendar time period for which the Availability of the machine is evaluated. It is divided proportionately by color for each of the standard types of downtime, with planned and unplanned downtime combined into one color (grey) for simplicity. Each additional component of OEE is then graphically aligned with its parent component as described in the model above, and is similarly divided proportionately by its respective elements. A more detailed description of this format is provided below.

![OEE Chart Example](image)

**Figure 2: Example of executive view format for summary of OEE**

The second level of OEE reporting provided by the remote monitoring system is a detailed breakdown of OEE component elements with their respective values. This format, shown here in Figure 3, provides the equivalent detailed summary data, numerically by component, and is color coded to match the top level bar chart. This is provided for the lean manufacturing practitioner to drill down into the details for further analysis toward the design and execution of actionable improvement plans.

![OEE Component Details](image)

**Figure 3: Example of format for OEE component details**

The top level summary of data shown in Figure 2 provides the value of calculated OEE for the selected time period at the top of the chart, above the component bars. Each component bar is defined and formatted as follows:
**Availability:**

The numerical value of Availability is a measure of the time a machine has been up and running and making any production material. This metric is dependent upon the time that the machine has been scheduled for production. Data acquired directly from the machine is used to compute the downtime called the Availability Loss, as the amount of time that the machine has not been creating production material during the Plant Operating Time. The Plant Operating Time is defined by the operating shift schedule for the machine, and does not include Scheduled Downtime. Availability Loss may be further sectioned into Planned and Unplanned Downtime. This is accomplished either automatically or manually by the practitioner, through the use of downtime codes that are acquired either directly from the machine or through manual assignment using the platform. Planned Downtime such as operator breaks or planned maintenance during normal operating hours are included in Availability Loss because this is fully burdened time that is available to operate the machine. For example, in cellular work flow designs, special arrangements can be made to rotate break periods and operators so planned bottlenecks don’t stop running during breaks, and maintenance can be planned during scheduled plant shutdown periods.

The Machine Operating Time is shown in a light green color, with the remaining time portion of the Plant Operating Time shown in grey. All loss in Available time, whether planned or unplanned downtime, is shown in this grey portion. Time that the machine or plant is not scheduled to operate, if there is any such time in the selected calendar time period, is shown in white (no color) on the right side of the bar. The total length of the bar represents the calendar time period selected for the report.

**Performance:**

The performance portion of the OEE Metric represents the average speed at which the machine was operated during the Machine Operating Time of the calendar time period chosen, as a percentage of the theoretical maximum speed that the machine can operate. It is a measure of the quantity of units actually produced as a percentage of the quantity of units that would have been produced in that same time period if the machine were running at maximum speed. This method is equivalent to an evaluation in which a machine’s performance is represented by the ideal, or minimum time it should take to produce a unit of material as a proportion of the average time it actually took to produce a unit of material during the Machine Operating Time of the selected calendar time period.

The maximum speed can be defined by the machine “nameplate” speed, which is the maximum design speed of the machine. This is the default method of evaluating OEE, which can be used for benchmarking productivity analyses across work cells or plants. Alternately, OEE can be evaluated for specific jobs, products or materials being produced on the machine. In this case, the maximum speed can be defined as the “standard” or ideal speed for a particular job, product or material being produced as determined by the manufacturing or process engineer who developed the process for the machine. This product- or job-based method of evaluating OEE can also be informally called the “Rated OEE”, to reflect that the evaluation was rated to a specific product or job, and to differentiate from the default, machine nameplate speed based OEE evaluation. In the platform, the Rated OEE is administered using the Job Management tools.
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The total quantity of units produced during the Machine Operating Time is represented as the entire bar (light blue + grey), with the portion shown in light blue representing the ideal time it would have taken to produce the same quantity of units at the theoretical maximum machine speed. The type of units of production are defined by the particular machine and its available control parameters, and set up by the platform administrator.

Quality:

The numerical value of Quality is the quantity of Good Material produced as a percentage of the Total Material produced during the Machine Operating Time of the time period chosen. This is commonly referred to as First Pass Yield. More sophisticated monitoring systems will take into account relevant, on-machine quality assurance or inspection steps, to better represent the Quality performance of the machine operation. In some cases downstream inspection devices can be monitored and directly related to production on the machine. Once the material being produced is off the machine, however, care must be taken to consider only the quality aspects of the particular machine operation being measured.

The total quantity of units produced during the Machine Operating Time is shown as the entire bar (yellow + grey), with the portion shown in yellow representing the quantity of units produced that meet specification (good units).

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