OEE Implementation Guide

Summary

This document is a Best Practice Document that details the recommended method to implement OEE (Overall Equipment Effectiveness) for production lines in order to measure actual production against the industry standard target. The purpose of this guide is to help both OEMS and End Users with different experience levels understand how to effectively implement OEE to extract the most accurate and useful information in the most consistent, and easily repeatable manner. This document draws from best practices based on real world implementations from both equipment manufacturers and data collection/historian systems, all of whom are members of OMAC.

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1 - Contents

Contents

1 - Contents 1

2 – Executive Summary 3

2.2 Background 3

3 – What is OEE? 5

3.1 OEE 5

3.2 Availability 6

3.3 Performance 7

3.4 Quality 8

3.5 OEE Example 9

4 - Machine Level Metrics 10

4.1 OEE for a Single Machine 10

4.2 Inspection Equipment 11

4.3 Alternate Metrics 11

5 - Line Level OEE 13

5.1 Defining a Critical Asset 13

5.2 Multiple Critical Assets 13

5.3 Moving Critical Assets 14

5.4 No Critical Assets 14

5.5 V-Curve 15

5.6 Line Balancing 16

6 - PackML and PackTags 17

7 – Reference Information 17

7.1 Definitions and Abbreviations 17

7.2 References 19

7.3 Team Members 20

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2 – Executive Summary

2.1 PURPOSE

The purpose of this document is to empower OEMs and End Users to understand the how to calculate OEE and how to effectively implement it across individual machines or production lines, typically during Site Acceptance Testing.

This document details what information is required for individual machines or workstations but does not recommend that the OEE calculations be performed by the individual equipment on a production line. This document lists the signal information that should be continually provided in order to allow the OEE calculations to be performed.

Benefits for implementation;

- OEE can be applied to any production line where the three core metrics can be calculated
- OEE provides a common, simple performance metric that is easily understood
- Providing the required signals for calculating OEE can be done with as few as three signals
- The majority of OEMs and End Users are already familiar with OEE

2.2 Background

This document was created by the OMAC team to help both OEMs and End Users gain a better understanding of OEE, which is frequently used as part of Site Acceptance Testing (SAT). Due to the different potential ways that OEE can be calculated, this document was sourced to create a recommendation on what metrics to track and how to best track them and to identify areas where there may be deltas between how OEE is calculated.

2.3 PackML State Model

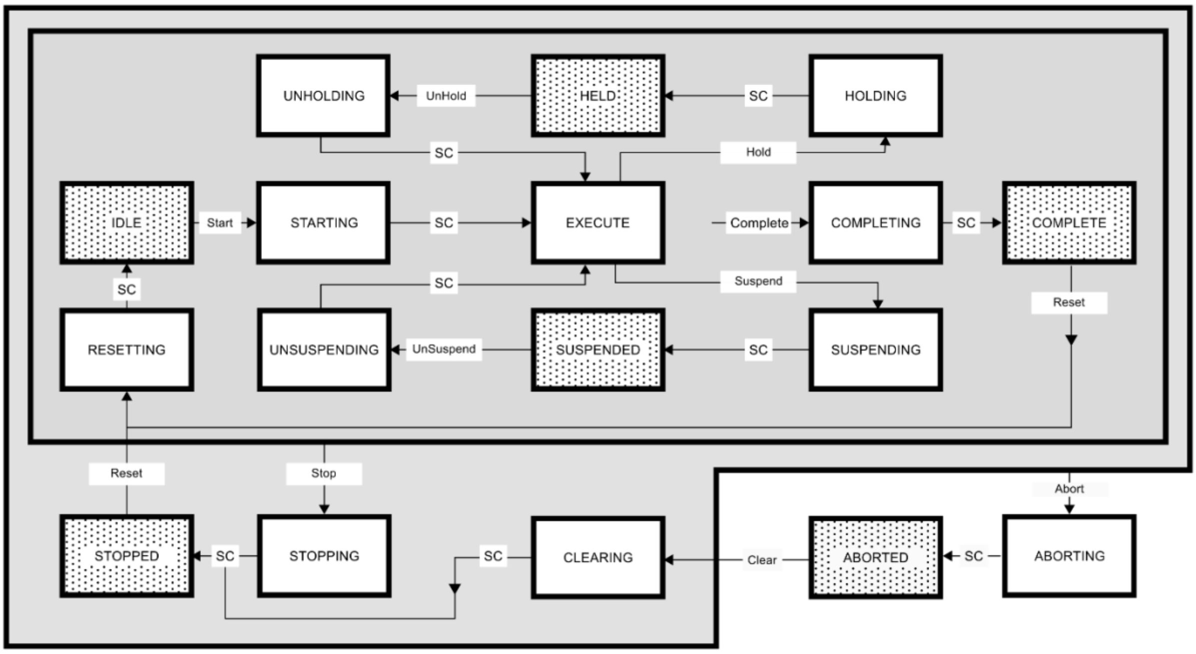
This document will make frequent mention to the PackML State Model. For those unfamiliar with PackML, please visit the following sites;
http://omac.org/workgroups/packml-unitmachine-implementation-guide/

https://webstore.ansi.org/standards/isa/isatr8800022015

http://omac.org/workgroups/packml-resources/

https://youtu.be/CQS-R5COOLw (OMAC's Youtube Channel)

As of the time of this initial writing, PackML is currently operating on the 2015 standard, specifically ANSI/ISA TR88.00.02-2015. Should the next release of PackML change functionality that affects this implementation guide, this document will be updated accordingly.



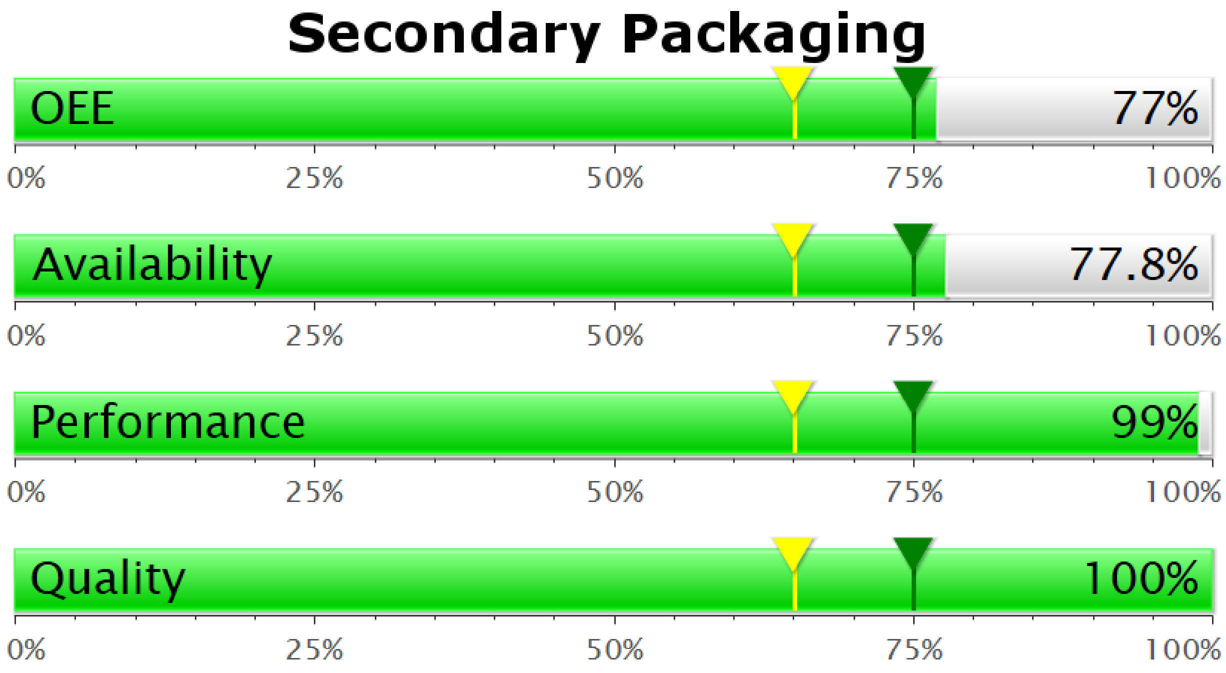
3 – What is OEE?

3.1 OEE

Overall Equipment Effectiveness, commonly referred to as 'OEE', is an industry best-practice calculation that is used to measure how well a line is performing by comparing its production to its expected utilization. OEE measures three separate metrics that can be captured from defined points across a line or piece of production equipment. These measurements calculated using a percentage between 0-100, then all three numbers are multiplied together, giving the final OEE number. The three metrics which are captured and calculated are Availability, Performance and Quality. Each metric captures a unique portion of the utilization process of an individual unit created on a production line.

By multiplying these three metrics, OEE ensures that no one portion of equipment utilization can overperform while creating a detriment in a different area. As an example – If a machine is set to a higher speed than it can reasonably sustain in order to meet a scheduled number of products (Performance), it may experience utilization losses related to both uptime (Availability) and poorly manufactured products (Quality). Inversely, if a machine is slowed to the point of running significantly slower to avoid any issues related to uptime (Availability), there will be a marked decrease in the Performance calculation as the equipment will not be manufacturing product at the expected rate.

While OEE is can be mentioned in reference to individual units of equipment, it is most effective in providing a view of an entire production line. In Line level calculations, specific points are measured across a production line and used to calculate Availability, Performance and Quality, giving a single utilization number for the whole production process.



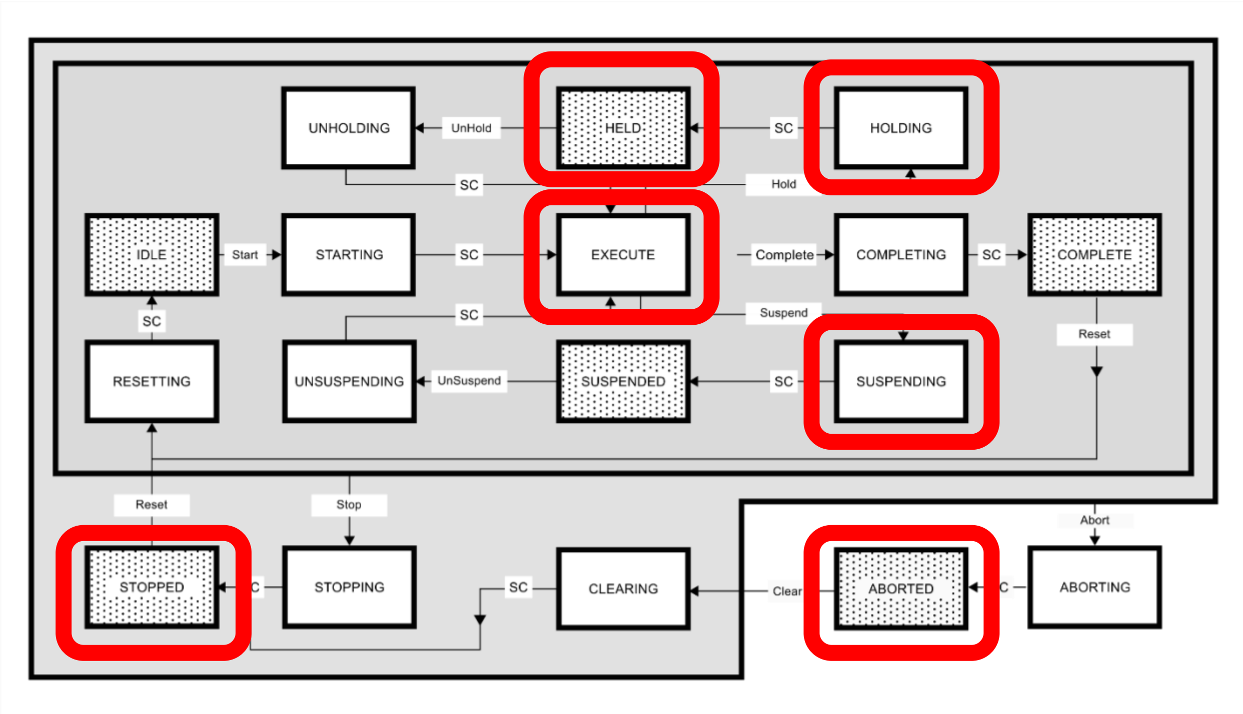
3.2 Availability

This metric is a measurement of time. Availability is a percentage of the time the equipment/line spent producing products (in the PackML Execute State, Suspending State and Holding State) compared to how much time it theoretically could have been in the producing (Execute State). This is commonly referred to as 'Uptime' and only measures when the equipment is in Execute, with no regard to the speed of the equipment/line or the quality of the products manufactured during this time.

Availability may vary between End Users and facilities, but for the purpose of Site Acceptance Testing (SAT) work, we should assume that all non-producing time periods, such as Planned Maintenance, Clean-In-Place, Changeovers, etc… are not included. Correlating to the PackML State Model, the time used in the calculation would consist of Held, Stopped, Aborted, Suspending, Holding and Execute (See image below).

Item of note – Some customers may request the inclusion of "Manual Mode" in the OEE calculations. The definition above does not include this mode as it is not always used in conjunction with equipment functions that would be include in an OEE calculation. Should a customer request that Manual Mode is included, it is suggested that the requirements and functions included are clearly defined in writing at the OEE definition state of a project.

PackML State Model



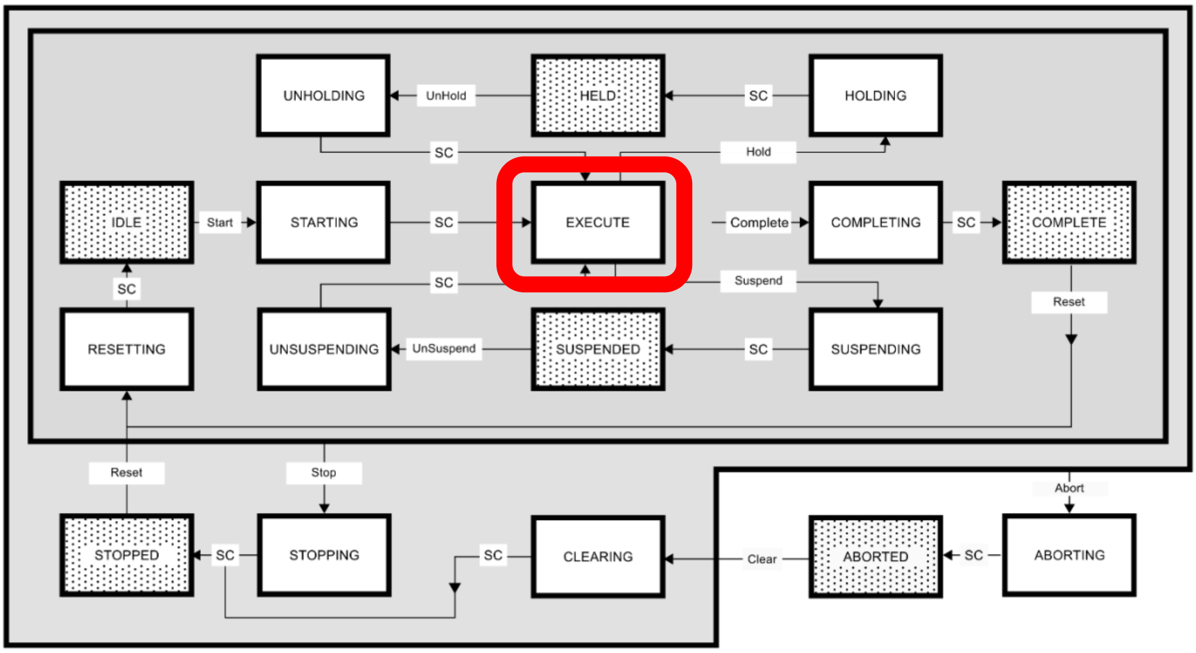
$$Availablity = \frac{Time\ machine\ is\ Producing\ Product\ (Execute + Holding + Suspending)}{Time\ machine\ is\ producing\ Product + Time\ when\ machine\ is\ in\ faliure\ (Held\ Stopped\ Aborted)}$$

PackTags Used		
Tag	**Used For**	**Description**
Status.StateCurrent	Time	Machine state ID related to the machines state model

3.3 Performance

Performance is the expected rate of production for a line or piece of equipment compared against the actual rate of production. Similar to Availability, the definition of Performance may vary between End Users or even facilities within the same company due the potential for Speed to be a variable between certain SKUs or other criteria. For the purpose of this document, focusing on Site Acceptance Testing, we will standardize on the Speed in performance being based on the Maximum Design Speed of the equipment/line we are implementing on.

Performance is calculated by multiplying speed by the time in the producing state, which for PackML is the Execute State, for a specified period of time. Then becomes the theoretical maximum speed for the equipment as it should not be able to produce a number higher than the one that has just been calculated. This is then used to compare against the actual number of products that have been produced, giving an exact view of how well the machine is utilized when it is in the Execute state.



$$Performance = \frac{Total\ Quantity\ Produced\ at\ this\ machine}{Time\ machine\ is\ producing\ Product(Execute) * Maximum\ Machine\ Speed}$$

PackTags Used		
Tag	**Used For**	**Description**
Status.StateCurrent	Time	Machine state ID related to the machines state model
Admin.MachDesignSpeed	Maximum Machine Speed	Set point for the speed of the equipment in primary pieces per minute
Admin.ProdProcessedCount[0].ACC	Product Output Counts	Counter of total products processed by the equipment
Admin.ProdProcessedCount[0].Count	Alternate Product Output Counts	If the .ACC address is not available (as it is not a required tag) the .Count address can be used in its place.

3.4 Quality

The Quality portion of the OEE calculation represents how many good products were produced when compared to the number of total production. This calculation does not count the amount of time in any of the states, it only compared good product vs total products. As we are discussing in terms of Site Acceptance Testing (SAT), we will only consider products that are considered good on the first-pass. Any rejects, rework, discarded or delayed products will not be entered into the Quality calculation as first-pass good.

$$Quality = \frac{Total\ Quantity\ Produced\ At\ Outfeed}{Total\ Quantity\ Produced\ at\ Infeed}$$

Frequently equipment will not contain both these counters, so this calculation becomes less meaningful at the Machine Level. It is also important to note that not all equipment will be able to perform all the necessary quality checks. This may result in downstream equipment being responsible for these checks, such as a checkweigher or metal detector. At the Line Level these points will need to be specified where to count and will not typically be the first and last counters on a line. Further detail on location counters can be found in the Machine Level and Line Level metrics in sections found later in this guide.

For equipment that does not count in primary units, nor has the ability to calculate in primary units, the Recipe for the line can be referenced for pack patterns and numbers, to calculate the primary units in different packages.

PackTags Used		
Tag	**Used For**	**Description**
Admin.ProdProcessedCount[0].ACC	Product Output Counts	Counter of **primary units** that have been produced at the machine. This counter is only reset through a factory reset.
Admin.ProdConsumedCount[0].ACC	Product at Infeed	**Primary units** that have entered the machine. This counter is only reset through a factory reset.
Admin.ProdProcessedCount[0].Count	Alternate Product Output Counts	Alternate counter of **primary units** that have been produced at the machine. Will reset at predefined rollover number.
Admin.ProdConsumedCount[0].Count	Alternate Product at Infeed	Alternate count of **primary units** that have entered the machine. Will reset at predefined rollover number.

Note: At the time of this writing the Admin.ProdConsumedCount is not a mandatory tag.

3.5 OEE Example

We have a Filler that is scheduled to run for 24 hours of full production during the Site Acceptance Testing (SAT) period. The Maximum Sustainable speed for this Filler is 75 bottles per minute. This equates to 1440 minutes for the sake of our calculation. As there are no planned stops, the total Available time is 1440 minutes. When the Filler runs, over the course of 24 hours it experiences a series of internal downtime events that add up to 160 minutes of downtime. Additionally, after those downtime events, the Filler does not start at full speed, but ramps up over a short period of time to full speed. There were also a number of occurrences where operations slowed the Filler down to avoid triggering new downtime events. Due to the unique nature of the Filler design, no product was lost inside the machine. By the end of the 24-hour run, the Filler has produced 77, 856 bottles. The calculation for OEE would be as follows;

$$OEE = Availability * Performance * Quality$$

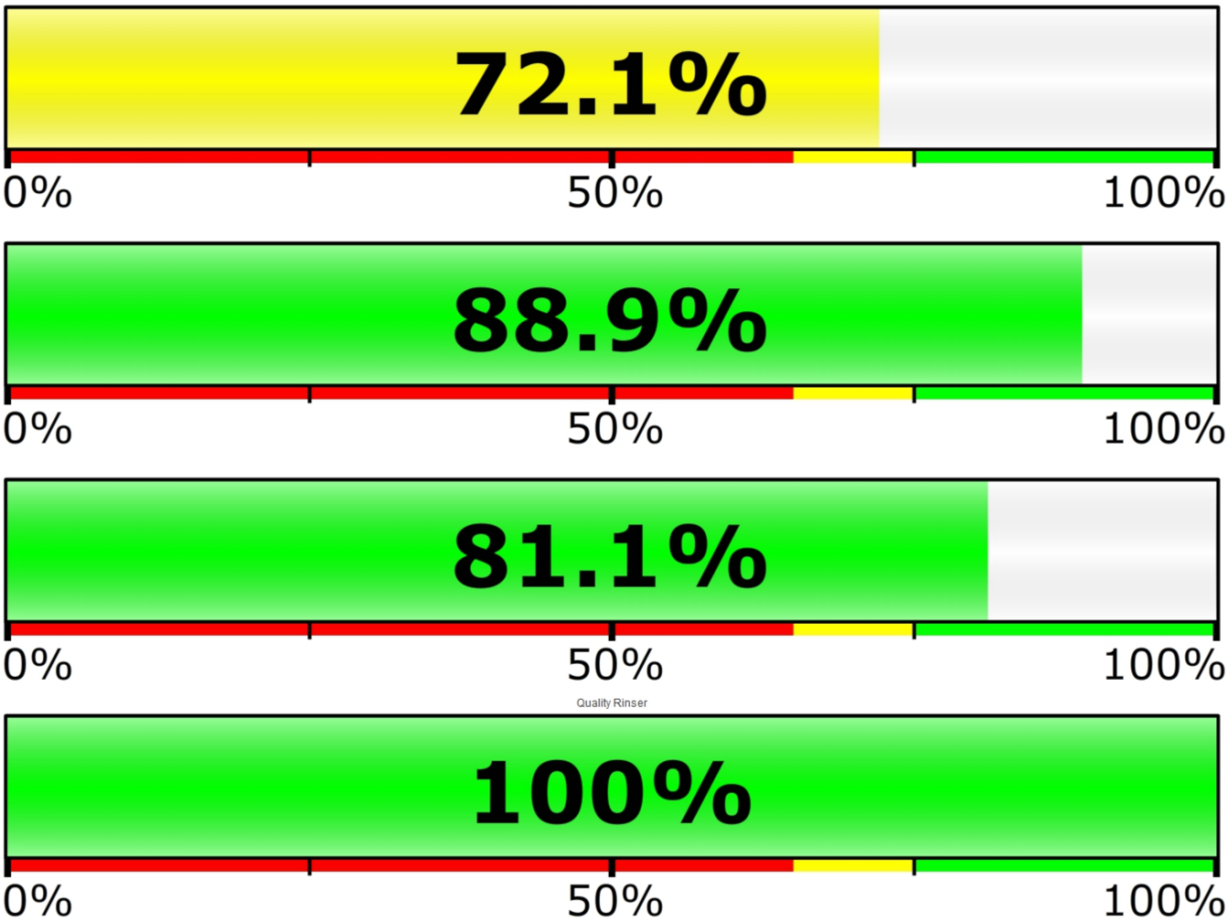
$$OEE = \frac{1280}{1440} * \frac{77856}{1280 * 95} * \frac{77856}{77856}$$

$$OEE = \frac{1280}{1440} * \frac{77856}{96000} * \frac{77856}{77856}$$

$$OEE = 88.9 * 81.1 * 100$$

$$OEE = 72.1\%$$

The Filler therefore has an OEE of 72.1% after encountering 160 minutes of downtime and a cumulative rate loss of 18,144 cartons.



4 - Machine Level Metrics

4.1 OEE for a Single Machine

Machine Level OEE should be based on either a single piece of equipment or should include the Inspection Equipment if found immediately after the machine. The equipment should always have enough product to run at full speed and enough room after the machine to avoid any downstream blockages. If either of these events occur, they will skew the data and give an incorrect value for Machine Level OEE.

A difference between Single Machine and Line OEE is that the Machine Level should not include the Suspended State as that unplanned stop refers to the unit/machine not producing due to an External

Condition.

Availability – This should be the Uptime calculation measured at the Machine. This should exclude upstream and downstream effects on this machine.

Performance, Speed – This should be the Maximum Sustainable Speed for the Machine.

Performance, Output – This should be the output counter of the machine, or the output counter of the inspection equipment if it is immediately after the machine.

Quality, Input – This should be the input counter of the machine.

Quality, Output – This should be the output counter of the machine, or the output counter of the inspection equipment if it is immediately after the machine. This counter should be the same counter that is used in the *Performance, Output* item listed above as there should not be a discrepancy between these numbers.

4.2 External Inspection Equipment

Inspection Equipment is machinery that is key to understanding OEE that is not necessarily reflective of its own performance. The most common type of equipment would be process verification equipment. These are units of operation that measure and verify the work of other machines on the line. Examples include, but are not limited to Checkweighers, Metal Detectors, X-Ray Inspection Units, Level Inspection, Vision Systems, and other types of inspection.

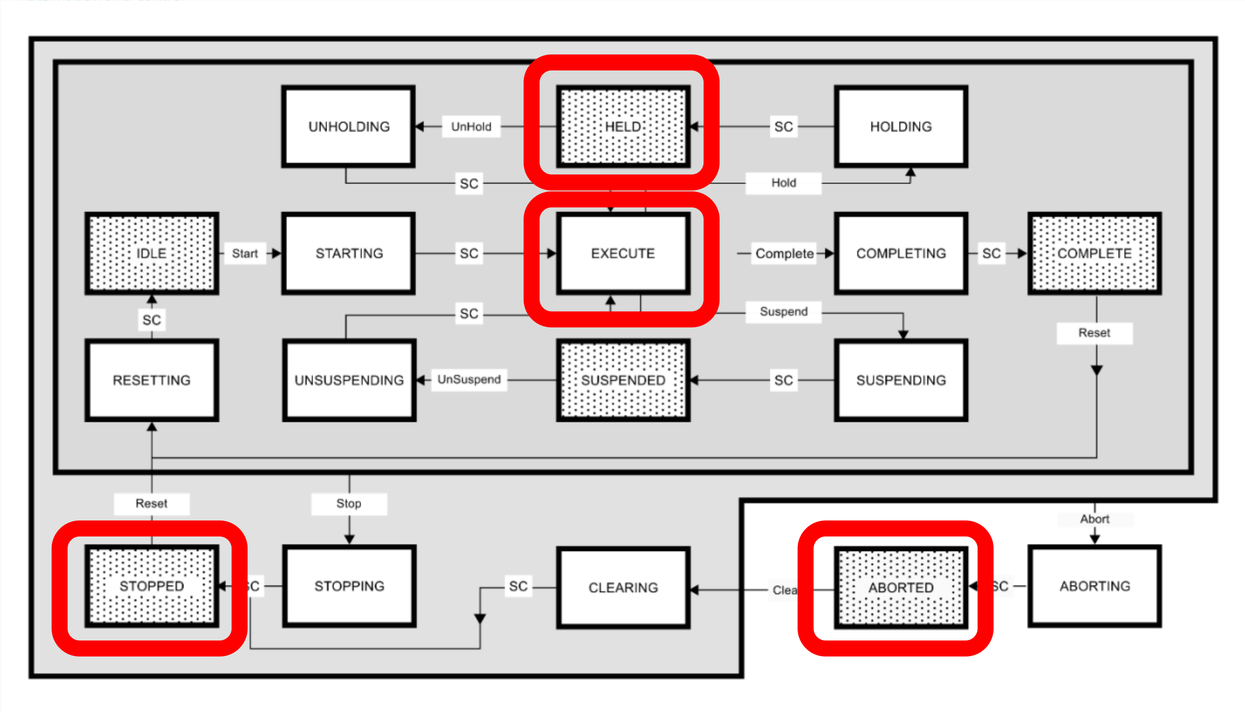
These units provide additional points for product rejection that are commonly outside of the equipment that performed the task. Example – Level Inspection unit downstream of the Filler. While the Level Inspection unit will capture and provide reject count information, the actual rejects should affect the OEE of the Filler, not the Level Inspection unit. Typically this equipment is not included as its own standalone performance metric, but provides much more in-depth reject information of another station on the production line.

4.3 Alternate Metrics

Machine Uptime

Machine Uptime is a more common and easily measured. It is also complimented by the simplicity of the calculation. It is essentially the Availability of a machine, with all outside factors removed. This metric will show how well a specific piece of equipment is performing relative to the time it has been given to perform.

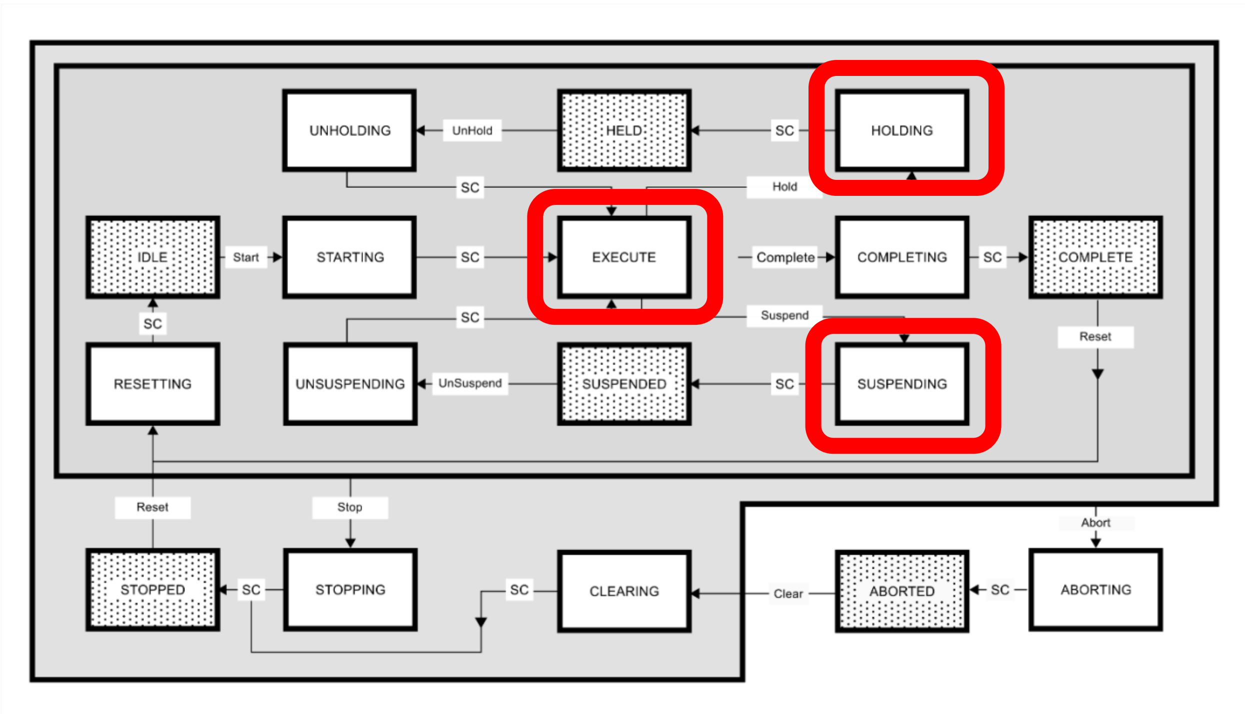
$$Machine\ Uptime = \frac{Execute}{Held + Execute + Stopped + Aborted}$$



Machine Efficiency

Machine Efficiency, also referred to as Output Utilization, is similar to Performance and calculates how much product should have been made and compares it to what was actually produced. The calculation for Machine Efficiency is to multiply the number of minutes in the Execute State, Suspending State and Holding State by the per minute maximum speed of the equipment.

$$Machine\ Efficiency = \frac{Total\ Units\ Produced}{(Time\ in\ Execute + Suspending + Holding) * \ Maximum\ Machine\ Speed}$$



5 - Line Level OEE

OEE is most effective when used for an entire production line. This gives a simple, single metric to show how well the line is being utilized. Despite different equipment designed for different purposes, likely built by different manufacturers, OEE can easily provide a view of the current state of production and whether it is achieving what is expected. For the purpose of this document, we will focus on Site Acceptance Testing (SAT). When a line is being commissioned, a target will typically be implemented for the line to perform at for a set period of time, such as a minimum of 85% OEE uninterrupted for a period of three hours.

For a Full Line implementation, specified points should be considered for OEE, not a cumulative value of individual OEE points across the line.

Availability – This should be the Uptime calculation measured from the Critical Asset on the Line. This should also be the slowest machine on the line, or the constraint point. Example – Filler.

Performance, Speed – This should be the Maximum Sustainable Speed for the Critical Asset on the Line. This should also be the slowest machine on the line, or the constraint point. This should be considered from the point of the two output counters listed below. Example – Filler Outputs.

Performance, Output – This should be the last point on the production line where product can be counted with separation. Example – Infeed Counter to Palletizer.

Quality, Input – This should be the first point the product is completed as a primary unit, or near as to completed as possible. This point should be selected based on the type of product being

Quality, Output – This should be the last point on the production line where product can be counted with separation. This counter should be the same counter that is used in the *Performance, Output* item listed above as there should not be a discrepancy between these numbers. Example – Infeed Counter to Palletizer.

5.1 Defining a Critical Asset

A Critical Asset is typically the slowest point in a production line and significantly affects the primary units in some way. In the V-Curve example in this document the bottom of the V-Curve is typically the critical asset.

Some lines have different critical assets depending on what equipment is being used or the recipe being produced. The Critical Asset(s) should be defined prior to line level OEE implementation.

5.2 Multiple Critical Assets

For a production line that features multiple pieces of parallel equipment at the Critical Asset point, the calculation should include metrics from each Critical Asset, while multiplying the denominator with however many new Critical Assets there are.

Example – A Line with two wrappers, that are defined as the Critical Asset for the line. The Availability calculation for a 24 hour run would look like this; (24 h = 1440 minutes)

$$Availability = \frac{Wrapper1\ Execute\ Time + Wrapper2\ ExecuteTime}{1440\ minutes * 2\ machines}$$

When OEE is calculated, as long as the denominator is adjusted, the calculation will work. The same duplication needs to be applied to Performance, but NOT to Quality.

$$Performance\ = \frac{Wrapper1\ Outputs + Wrapper2\ Outputs}{(1440\ min * Wrapper1\ Max\ Speed) + (1440\ min * Wrapper2\ Max\ Speed)}$$

5.3 Moving Critical Assets

Some production lines will have Critical Assets/Choke points that move throughout the line, dependent on what SKU they are producing. In the event the Site Acceptance Testing (SAT) period includes tests for a moving critical asset, each separate point must be identified and the Line Level OEE calculation should be run in each instance, for each product pairing.

Example – A filling line has both a Neck Bander and an Overwrapper for filled bottled. When the Neck Bander is in use, the line slows as it is an older piece of equipment, but it is not used on all SKUs. When the line not using the Neck Bander, it is bypassed and only the Overwrapper is used. In this case, the Filler then becomes the critical asset.

If SAT documentation requires it, the OEE value must be tested and measured using both the Neck Bander and Filler as critical assets during two separate sustained runs.

5.4 No Critical Assets

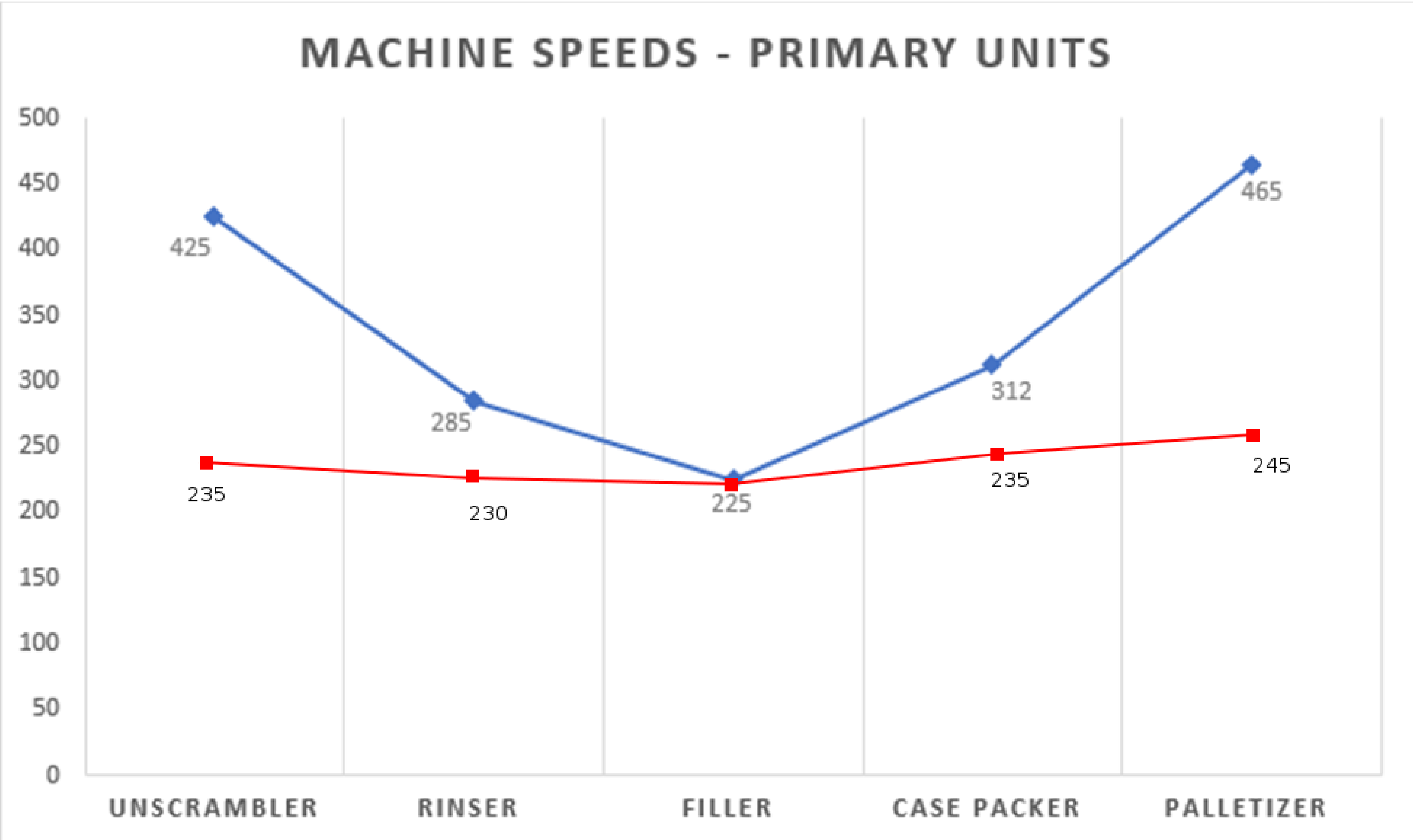
If the production line does not have an easily identifiable Critical Asset or is a line that does not have the speed variability of a V-Curve (see below) then a common point can be selected as the critical asset, as long as proper product separation exists and individual primary packages can be counted. This is ideally a machine on the line that has some direct interaction with the primary package, such as a wrapper or labeler and does not stop frequently while the surrounding equipment is running. The requirements would be that the common point is used across all measurement periods of the Site Acceptance Test (SAT). Example – Do not use a Palletizer if certain runs during the SAT will be hand-stacked or manually removed prior to the Palletizer.

5.5 V-Curve

The V-Curve refers to a design implementation for a production line where the surrounding equipment is designed to be able to outpace the critical asset/choke-point equipment by a significant factor. This ensures that if any of the surrounding equipment experiences unplanned stops, there is potential to keep the critical asset running while the other equipment is repaired.

The diagram below shows an example of this design feature for a line that features five machines. In the example, the further the equipment is away from the critical asset, the faster it is able to run. The Filler is the critical asset/choke point, while the surrounding Rinser and Case Packer can run faster, who themselves are surrounded by the Bottle Unscrambler and Palletizer that can run even faster. These speeds are theoretical maximum speeds based on the design of the equipment, and are represented by the blue line.

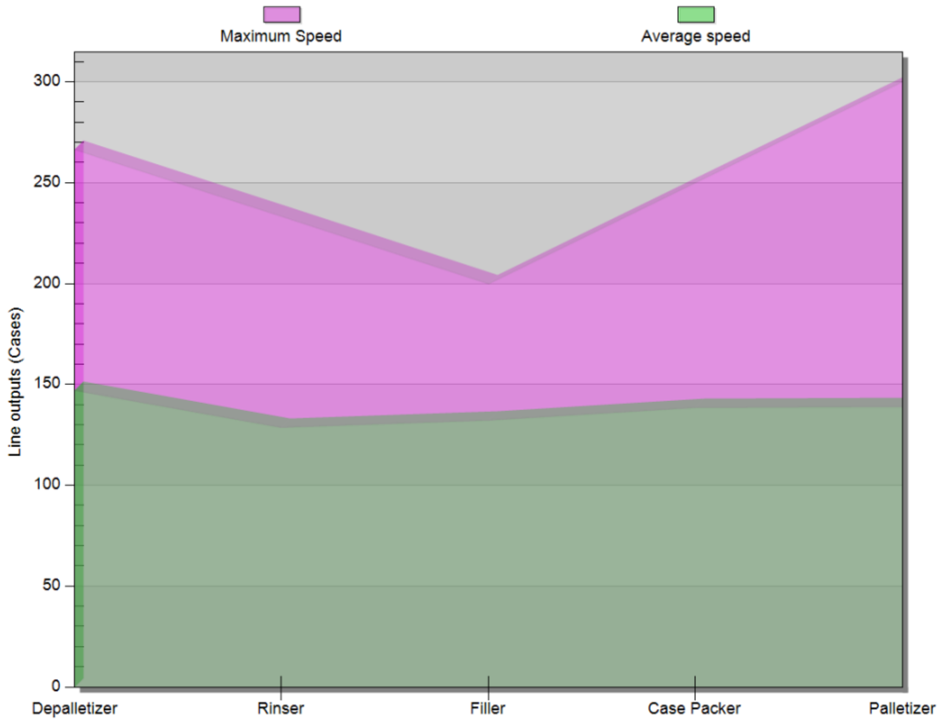
The red line in the diagram represents the nominal speed for the equipment, which means the speed the equipment typically operates at. This is to ensure that the production equipment is operating at a similar rate when no production problems are affecting the equipment.



5.6 Line Balancing

To confirm whether a line is balanced properly the machine speeds from the V-Curve section can be overlaid with actual counts from across the line. In the example below we can see that while the line is producing at constant rate through each of the units, the production speed is significantly lower than the Maximum Speed the equipment should be producing at.

If this occurs during production where there are no losses to availability or quality, it is likely that the speeds are incorrect on the equipment and will result in a loss to the Performance calculation. The terminology for this type of loss is a Rate Loss.



	Depalletizer	Rinser	Filler	Case Packer	Palletizer
Maximum Speed	266.67	233.33	200.00	250.00	300.00
Average speed	147.10	128.58	132.42	138.68	138.74

6 - PackML and PackTags

List of Pack Tags that are used in this document.

PackTags Used		
Tag	**Used For**	**Description**
Status.StateCurrent	Time	Machine state ID related to the machines state model
Admin.MachDesignSpeed	Maximum Machine Speed	Set point for the speed of the equipment in primary pieces per minute
Admin.ProdProcessedCount[0].Count	Product Output Counts	Counter of total products processed by the equipment
Admin.ProdConsumedCount[0].Count	Product at Infeed	Primary units that have entered the machine.
Admin.ProdProcessedCount[0].ACC	Cumulative Output Counter	This is an incremental output counter found in PackTags that is only reset after factory resets. This counter will therefore be more accurate from the .Count address.
Admin.ProdConsumedCount[0].ACC	Cumulative Infeed Counter	This is an incremental input counter found in PackTags that is only reset after factory resets. This counter will therefore be more accurate from the .Count address.

7 – Reference Information

7.1 Definitions and Abbreviations

List of definitions and abbreviations

Term	Definition
Speed	The rate of production that a machine or line is configured to produce at
Maximum Speed	The fastest sustainable speed the equipment or line was designed to run
Uptime	The total time the equipment is running and producing product
Availability	A measurement of the time the equipment/line spent producing products compared to how much time it theoretically could have been producing products

Performance	A measurement of the expected rate of production for a line or piece of equipment compared against the actual rate of production
Quality	A measurement of how many good first-pass products were produced compared to the number of total units produced
OEE	An industry best-practice calculation that is used to measure how well a line is performing by comparing its actual production to its expected utilization
Machine State	See PackML State Model
Utilization	Effective use of equipment or a line
PackML	An industry technical standard for the control of packaging machines and equipment.
PackTags	A uniform set of naming conventions for data elements used within the PackML state model
SAT	Site Acceptance Test- A process to confirm the equipment functions as designed and the integration into a production line is and in compliance with the agreed upon specifications
V-Curve	A design implementation for a production line where the surrounding equipment is designed to be able to outpace the critical asset
Primary Unit	Counter based on the customer facing unit, or initial produced unit for the production line.
Rate Loss	Performance losses when the machine is producing products, but at a rate that is lower than expected.
Recipe	The recipe this guide focuses on is the Control Recipe from the PackML Implementation Guide. The parameters within the Control Recipe are configuration parameters for Machines regarding production configurations.

Description	Explanation
PackML Gateway	A gateway that represents the PackML Interface State Manager and maps to the existing Machine State Manager of a specific machine (unit/machine).
PackML Software Design Specification	Function specification for a unit/machine, that specifies the behaviour of a unit/machine and specifies the Interface to the unit/machine from a PackML prospective.
PackML Data Identifier	PackTags are data elements that have been defined by the OMAC Packaging Workgroup to facilitate easy data exchange between packaging machines.
Programmable Logic Controller	A computer controlling instruments, motors, valves, etc.
Site Acceptance Testing	Test of the unit/machine being carried out on the site where it is installed. The test is carried out to ensure that delivery is in accordance with stated requirements.
Technical Report	Technical Report is an informative document on S88 implementation on discrete machines – It is the specification of PackML.

Add MTTR, MTBF, though not used in the OEE calcs.

7.2 References

List of references

Ref. no.	Document
[TR88]	ANSI/ISA-TR88.00.02-2015, Machine and unit/machine States, An Implementation example of ANSI/ISA-88.00.01.

7.3 Team Members

The following people served as active participants in preparation of this technical report:

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Christian	Juch	Festo
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8. Version History

Version log

Date [YYYY-MM-DD]	Initials	Description	Version
2019-02-14	CH	Initial Document Creation based on input from OMAC meetings from 2018 and early 2019	01A
2019-08-01	CH	Candidate version out for Peer Review	02
2019-10-10	CH	Updated candidate version based on feedback.	03
