SEMI E79-0422
SPECIFICATION FOR DEFINITION AND MEASUREMENT OF EQUIPMENT PRODUCTIVITY

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NOTICE: Paragraphs entitled 'NOTE:' are not an official part of this Standard or Safety Guideline and are not intended to modify or supersede the official Standard or Safety Guideline. These have been supplied by the global technical committee to enhance the usage of the Standard or Safety Guideline.

NOTICE: The section symbol (§) is used to reference a numbered section, paragraph, or header and all subordinate paragraphs, headers, and embedded material (i.e., EXCEPTIONs, lists) therein. The paragraph symbol (¶) is used to reference a particular numbered paragraph and embedded material therein. When duplicated (i.e., §§ and ¶¶) the symbols are used to reference more than one section or paragraph, respectively.

1 Purpose

1.1 This Specification provides metrics for measuring equipment productivity of manufacturing equipment in the semiconductor and related industries.

2 Scope

2.1 This Specification defines metrics and calculations for measurement of equipment productivity, including overall equipment efficiency (OEE).

NOTICE: SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the Documents to establish appropriate safety and health practices, and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 This Specification is currently limited to measuring equipment productivity using time-based OEE as the primary metric. This Specification does not address any reliability, availability, and maintainability (RAM) issues over and above those specified in SEMI E10.

NOTE 1: Refer to ¶ 6.1.3 for more information contrasting the time-based overall equipment 'efficiency' (OEE) metrics in this Document with the traditional total productive maintenance (TPM) overall equipment 'effectiveness' (also using the same acronym OEE) metric, which is based on units of production.

3.2 It is important to note that equipment productivity is impacted greatly by factors far beyond the equipment system itself, including user actions, recipe settings, facility issues, material availability, and scheduling requirements.

3.3 Effective application of this Specification requires that equipment performance is tracked using the metrics for equipment RAM and utilization specified in SEMI E10.

3.3.1 Productivity metrics for intended process sets (IPSs) and multipath cluster tools (MPCTs) require tracking of SEMI E10 equipment states and recipes at the level of individual processing equipment modules.

3.4 Automated tracking of equipment states and performance is not within the scope of this Specification, but is partially addressed by the SEMI E58 and SEMI E116.

NOTE 2: SEMI E58 is currently in Inactive Status and has not been updated to be consistent with and to support the later versions of SEMI E10. Refer to SEMI E10 Related Information 4 regarding the specific relationship between the SEMI E116 states and those needed by this Specification.

3.5 The results of the calculations contained in this Specification are dependent on the operational conditions (e.g., specifications, processes, recipes, environment, maintenance strategies, human factors) for each user and equipment system type.

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3.6 This Specification does not address the impact of productivity changes on cost or other performance metrics. SEMI E35 (Cost of Ownership [COO]) provides the methodology for determining the impact of productivity changes on cost.

4 Referenced Standards and Documents

4.1 *SEMI Standards and Safety Guidelines*

SEMI E10 — Specification for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM) and Utilization

SEMI E35 — Guide to Calculate Cost of Ownership (COO) Metrics for Semiconductor Manufacturing Equipment

SEMI E58 — Automated Reliability, Availability, and Maintainability Standard (ARAMS): Concepts, Behavior, and Services

SEMI E116 — Specification for Equipment Performance Tracking

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *COO* — cost of ownership

5.1.2 *CVD* — chemical vapor deposition

5.1.3 *DEE* — demand equipment efficiency

5.1.4 *ENG* — engineering state

5.1.5 *IEE* — intrinsic equipment efficiency

5.1.6 *IPS* — intended process set

5.1.7 *IPS/MPCT* — intended process set or multipath cluster tool

5.1.8 *MPCT* — multipath cluster tool

5.1.9 *NST* — nonscheduled state

5.1.10 *PRD* — productive state

5.1.11 *OEE* — overall equipment efficiency

5.1.12 *OROEE* — optimized-recipe overall equipment efficiency

5.1.13 *ORTHT* — optimized-recipe theoretical production time per unit

5.1.14 *PEE* — production equipment efficiency

5.1.15 *ROEE* — reference overall equipment efficiency

5.1.16 *RAM* — reliability, availability, and maintainability

5.1.17 *RTHT* — reference theoretical production time per unit

5.1.18 *RTP* — rapid thermal process

5.1.19 *SBY* — standby state

5.1.20 *SPCT* — single-path cluster tool

5.1.21 *TEU* — total effective units

5.1.22 *TEUOEE* — total effective units OEE

5.1.23 *THT* — theoretical production time per unit

5.1.24 *THTP* — theoretical unit throughput by recipe

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5.1.25 *TPM* — total productive maintenance

5.1.26 *UDT* — unscheduled downtime state

5.1.27 *VAOEE* — value-added in-process overall equipment efficiency

5.1.28 *VTHT* — value-added in-process theoretical production time per unit

5.2 *Terminology Applicable to Calculation of the OEE Metric*

5.2.1 *actual unit output* — the number of units processed by the equipment system during production time.

5.2.2 *availability efficiency* — the fraction of total time that an equipment system is in a condition to perform its intended function when required.

5.2.3 *cluster tool* — an equipment system made up of multiple integrated processing equipment modules, with or without nonprocessing equipment modules, mechanically linked together. The equipment modules may or may not come from the same supplier. [SEMI E10]

5.2.4 *component part* — a constituent part, which can be separated from or attached to an assembly, not normally considered capable of independent operation. Also sometimes just called part. [SEMI E149]

5.2.5 *consumable material* — the material used by or in support of the equipment system at any time. Examples include gases (e.g., Ar, air), liquids (e.g., acids, solvents, ultrapure water, cooling water, mold compounds), solids (e.g., implant sources, bonding wire, lead frames). Examples do not include equipment component parts (e.g., consumable parts), support tools (e.g., carriers, probe cards), production substrates (e.g., wafers, die, assembly components), monitor/filler units (e.g., test wafers), and facility utilities (e.g., electricity, exhaust). [SEMI E10]

NOTE 3: Since the source of these consumable materials may vary from equipment to equipment, site to site, and company to company, this definition does not distinguish consumable materials based on the delivery method. For example, process cooling water may be provided by a dedicated heat exchanger for the equipment or by a facility distribution system, but it should be treated in a consistent manner.

5.2.6 *consumable part* — component part of the equipment that is used up, depleted, damaged, or destroyed by the process operation of the equipment with a predictable life expectancy (e.g., of less than one year) as agreed upon between the user and the supplier. It requires periodic replacement to allow the equipment to perform its intended function. [SEMI E10]

NOTE 4: Life expectancy concept comes from SEMI E35.

5.2.7 *downtime* — during an observation period, the accumulated time when the equipment system is not in a condition to perform its intended function. Downtime includes scheduled downtime and unscheduled downtime. [SEMI E10]

5.2.8 *effective unit output* — the number of units processed by the equipment system during production time that were of acceptable quality. In general, effective unit output is actual unit output less equipment-assignable rework and equipment-assignable scrap.

5.2.9 *engineering state (ENG)* — the equipment state when the equipment system is in a condition to perform its intended function, but is operated to conduct engineering experiments, especially where the usage of the equipment system during ENG is not indicative of normal production. ENG includes any activities required to restore the equipment system to a condition where it may perform its intended function. [SEMI E10]

5.2.10 *engineering time* — during an observation period, the accumulated time when the equipment system is in the engineering state (ENG). [SEMI E10]

5.2.11 *equipment* — the combination of hardware and software required to perform an operation or activity (e.g., processing, transporting, storing), including all direct auxiliary support or peripheral equipment (e.g., vacuum pumps, heat exchangers, effluent/exhaust treatment equipment). [SEMI E149]

5.2.12 *equipment-assignable rework units* — any units being reworked due to a fault or defect assignable to the subject equipment system. The units may be reworked at the equipment system where the fault or defect occurred, or at other equipment systems.

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5.2.13 *equipment-assignable scrap units* — any units that are permanently removed from production due to a fault or defect assignable to the subject equipment system. The units may be removed from production at the operation where the fault or defect occurred or at a subsequent operation.

5.2.14 *equipment module* — an indivisible entity within an equipment system that if separated into individual parts is not capable of performing its portion of the intended function of the equipment system. An equipment module may be either a nonprocessing equipment module or a processing equipment module. [SEMI E10]

5.2.15 *equipment system* — a system of equipment generally capable of independently accommodating units for processing, inspection, metrology, or support operations (e.g., transportation, storage, pump down) or subsystem for which the independent tracking of performance (i.e., reliability, availability, and maintainability [RAM], utilization, productivity) is desired. Equipment systems include subsystems, noncluster tools, equipment modules, single-path cluster tools (SPCTs), intended process sets (IPSs) in multipath cluster tools (MPCTs), and MPCTs. [SEMI E10]

5.2.16 *host* — the factory computer system or an intermediate system that represents the factory and the user to the equipment or other lower level control system. [SEMI E168]

5.2.17 *intended function* — a manufacturing function that the equipment was built to perform within specified operating conditions agreed upon between the user and the supplier. This includes transport functions for transport equipment and measurement functions for metrology equipment, as well as process functions such as physical vapor deposition and wire bonding. The period of time equipment is performing its intended function includes equipment initialization and reaching base operating environmental conditions (e.g., temperature, pressure). Complex equipment may have more than one intended function. [SEMI E10]

5.2.18 *intended process set (IPS)* — a predetermined set of equipment modules that is used to achieve a process and is specified by the user for equipment operation. A multipath cluster tool (MPCT) may have one or more such intended process sets (IPSs). An IPS may include alternative equipment modules at one or more steps of the process. An IPS may therefore contain one or many process paths. [SEMI E10]

5.2.19 *multipath cluster tool (MPCT)* — a cluster tool in which the units visit a subset of the equipment modules in sequences that vary from unit to unit. [SEMI E10]

5.2.20 *noncluster tool* — an equipment system made up of only one processing equipment module. [SEMI E10]

5.2.21 *nonprocessing equipment module* — an equipment module within an equipment system that supports the movement or conditioning of units through the equipment system. Examples of nonprocessing equipment modules include robotic handlers, load/unload locks, and prealigners. [SEMI E10]

5.2.22 *nonscheduled state (NST)* — the equipment state when the equipment system is not in the productive state (PRD), standby state (SBY), engineering state (ENG), scheduled downtime state (SDT), or unscheduled downtime state (UDT). [SEMI E10]

5.2.23 *nonscheduled time* — during an observation period, the accumulated time when the equipment system is in the nonscheduled state (NST). NST includes any activities required to restore the equipment system to a condition where it can perform its intended function, but no activities that would normally be tracked in the productive state (PRD), engineering state (ENG), scheduled downtime state (SDT), or unscheduled downtime state (UDT). [SEMI E10]

5.2.24 *observation period* — a specified continuous interval of calendar time (e.g., 72 hours, 6 weeks, 3 months, 1 quarter, 90 days) during which equipment system performance is tracked. [SEMI E10]

5.2.25 *operational efficiency* — the fraction of uptime that an equipment system is performing its intended function.

5.2.26 *operations time* — the time when the equipment system is in the productive (PRD), standby (SBY), engineering (ENG), scheduled downtime (SDT), and unscheduled downtime (UDT) states (i.e., total time minus nonscheduled time). [SEMI E10]

5.2.27 *operator* — any person who communicates locally with the equipment through the equipment's control panel. [SEMI E10]

5.2.28 *overall equipment efficiency (OEE)* — a metric of equipment system performance, expressed as the fraction of total time the equipment system is processing effective units assuming theoretically efficient time standards.

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NOTE 5: The OEE metric accounts for all losses that reduce equipment system performance from its maximum potential performance, assuming no alterations to the existing equipment system design or recipe specifications.

5.2.29 *performance efficiency* — the fraction of uptime that an equipment system is processing actual units assuming theoretically efficient time standards. This metric is the same as the product of operational efficiency and rate efficiency.

5.2.30 *process path* — a specific set of equipment modules a unit passes through for which each equipment module is unique and has no alternative equipment modules. [SEMI E10]

5.2.31 *processing equipment module* — an equipment module within an equipment system. Examples of processing equipment modules include chambers and stations that provide functions for processing, metrology, inspection, testing, and packaging of units. [SEMI E10]

5.2.32 *product* — units produced during productive time (refer to unit). [SEMI E10]

5.2.33 *production time* — the sum of all periods of time in which a processing equipment module is performing its intended function. For a noncluster tool, a single-path cluster tool (SPCT), or an individual processing equipment module within a multipath cluster tool (MPCT), production time is equivalent to the SEMI E10 productive time for that entity. For an intended process set (IPS) or an MPCT, production time is the sum of the SEMI E10 productive times of all processing equipment modules.

5.2.34 *productive state (PRD)* — the equipment state in which the equipment system is performing its intended function. [SEMI E10]

5.2.35 *productive time* — during an observation period, the accumulated time when the equipment system is in the productive state (PRD). [SEMI E10]

5.2.36 *quality efficiency* — the fraction of theoretical production time for actual units that an equipment system is processing effective units assuming theoretically efficient time standards.

5.2.37 *rate efficiency* — the fraction of production time that an equipment system is processing actual units assuming theoretically efficient time standards.

5.2.38 *recipe* — the preplanned and reusable portion of the set of instructions, settings, and parameters under control of a processing agent that determines the processing environment experienced by the units in the entire equipment system (i.e., processing equipment modules and nonprocessing equipment modules). Recipes may be subject to change between runs or processing cycles. [SEMI E10]

5.2.39 *scheduled downtime* — during an observation period, the accumulated time when the equipment system is in the scheduled downtime state (SDT). [SEMI E10]

5.2.40 *scheduled downtime state (SDT)* — the equipment state when the equipment system is not in a condition to perform its intended function due to scheduled activities or conditions. SDT includes any activities required to restore the equipment system to a condition where it can perform its intended function. [SEMI E10]

5.2.41 *single-path cluster tool (SPCT)* — a cluster tool in which all units follow only one process path. [SEMI E10]

5.2.42 *standby state (SBY)* — the equipment state, other than the nonscheduled state (NST), when the equipment system is in a condition to perform its intended function and consumable materials and facilities are available, but the equipment system is not operated. [SEMI E10]

5.2.43 *standby time* — during an observation period, the accumulated time when the equipment system is in the standby state (SBY). [SEMI E10]

5.2.44 *state* — a static set of conditions and associated behavior. While all of its conditions are met, the state is current (active). Behavior within a given state includes the response to various stimuli. [SEMI E58]

NOTE 6: Within the scope of this Document, the term 'state' generally refers to one of the following six basic equipment states defined in SEMI E10: productive (PRD), standby (SBY), engineering (ENG), scheduled downtime (SDT), unscheduled downtime (UDT), and nonscheduled (NST).

5.2.45 *supplier* — provider of equipment and related services to the user (e.g., unit manufacturer). Also called equipment vendor or original equipment manufacturer (OEM). [SEMI E10]

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5.2.46 *theoretical production time* — the production time during a period that is theoretically required to complete the unit quantities of the production recipes undertaken during the period. Theoretical production time is computed as the aggregation over all recipes of the theoretical production time per unit for the recipe applied to the unit quantity of that recipe. For multipath cluster tools (MPCTs), theoretical production time is the sum of the theoretical production times for all processing equipment modules.

5.2.47 *theoretical production time per unit (THT)* — the minimum time per unit to complete processing, given the specified recipe, equipment system design, continuous operation, and no efficiency losses.

5.2.48 *theoretical unit throughput by recipe (THTP)* — for a given production recipe, the number of units per period of time that theoretically could be processed by the equipment system. For each recipe, theoretical unit throughput is equal to the reciprocal of theoretical production time per unit.

5.2.49 *total time* — all time (at the rate of 24 hours/day, 7 days/week) during the observation period. In order to have a valid representation of total time, all six basic equipment states shall be accounted for and tracked accurately. [SEMI E10]

NOTE 7: For a multipath cluster tool (MPCT), total time is defined in SEMI E79 as the aggregate total time of all processing equipment modules.

5.2.50 *unit* — any wafer, substrate, die, packaged die, or similar piece part. [SEMI E10]

5.2.51 *unscheduled downtime* — during an observation period, the accumulated time when the equipment system is in the unscheduled downtime state. [SEMI E10]

5.2.52 *unscheduled downtime state (UDT)* — the equipment state when the equipment system is not in a condition to perform its intended function due to unplanned or unscheduled activities or conditions. UDT includes any activities required to restore the equipment system to a condition where it can perform its intended function. [SEMI E10]

5.2.53 *uptime* — during an observation period, the accumulated time when the equipment is in a condition to perform its intended function. Uptime includes productive, standby, and engineering times, and does not include any portion of unscheduled downtime, scheduled downtime, or nonscheduled time. [SEMI E10]

NOTE 8: For a multipath cluster tool (MPCT) in SEMI E79, uptime is the aggregate uptime of all processing equipment modules.

5.2.54 *user* — any entity interacting with the equipment, either locally as an operator or remotely via the host. From the equipment's viewpoint, both the operator and the host represent the user. [SEMI E58]

5.3 *Terminology Applicable to Calculation of Additional Productivity Metrics Defined in Appendix 1*

5.3.1 *demand equipment efficiency (DEE)* — a measure of equipment productivity during the time that products are planned to be available to process at the equipment system.

5.3.2 *equipment down no product time* — the period of equipment system downtime during which there are no units available at the equipment system to process.

5.3.3 *intrinsic equipment efficiency (IEE)* — a measure of equipment system productivity that measures the combined productivity losses due to rate efficiency, recipe design, and equipment system design.

5.3.4 *IPS/MPCT parallel productivity efficiency (IPS/MPCT PPE)* — a measure of equipment system efficiency during productive time where idling in parallel processing equipment modules is discounted as an efficiency loss.

5.3.5 *no product time* — the period of standby time that the equipment system is idle because there are no units available at the equipment system to process.

5.3.6 *optimized-recipe overall equipment efficiency (OROEE)* — a measure of equipment system productivity assuming recipes are optimized for minimum theoretical production time.

5.3.7 *optimized-recipe theoretical production time per unit (ORTHT)* — the theoretical production time per unit required to process a given recipe assuming the recipe specification is optimized for minimum theoretical production time. ORTHT is based on minimum durations for the objective processing steps (e.g., implant time for ion implanters) plus minimum allowances for any additional supporting process steps (e.g., heating, cooling, gas stabilization) that are deemed absolutely necessary. ORTHT shall be defined to be less than or equal to the corresponding theoretical production time per unit (THT) used in calculating OEE.

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5.3.8 *planned no product time* — the period of operations time that the factory model or production schedule expects the equipment system to be idle because there are no units available to process at the equipment system.

5.3.9 *production equipment efficiency (PEE)* — a measure of equipment system productivity during the time that products are available to process at the equipment system.

NOTE 9: One application of PEE is to measure the productivity of nonconstraint equipment systems, which are expected to have periods of idle time due to lack of available work.

5.3.10 *reference overall equipment efficiency (ROEE)* — a measure of equipment system productivity relative to a benchmark theoretical production time.

5.3.11 *reference theoretical production time per unit (RTHT)* — the theoretical production time per unit required to process a given recipe on benchmark equipment (i.e., the fastest equipment system design of similar type) for a benchmark product and process design. RTHT shall be defined to be less than or equal to the corresponding theoretical production time per unit (THT) used in calculating OEE.

5.3.12 *total effective units (TEU)* — a subset of effective units used in OEE that additionally discounts nonequipment-assignable scrap units and nonequipment-assignable rework units. The count of total effective units is always less than or equal to the count of effective units.

5.3.13 *total effective units OEE (TEUOEE)* — a measure of equipment system productivity assuming total effective units. This metric reflects the effect on a subject equipment system of quality losses external to the subject equipment system.

5.3.14 *value-added in-process overall equipment efficiency (VAOEE)* — a measure of equipment system productivity assuming that only the value-added portion of processing cycles for effective units is efficient.

5.3.15 *value-added in-process theoretical production time per unit (VTHT)* — the theoretical production time per unit that credits only the objective processing steps that add value to products. VTHT shall be defined to be less than or equal to the optimized-recipe theoretical production time per unit (ORTHT) used in calculating optimized-recipe overall equipment efficiency (OROEE).

6 Overview

6.1 *Efficiency Measurement and OEE*

6.1.1 All efficiency metrics in this Document are time-based efficiencies, where one accounting of accumulated equipment system time is compared to another. Some of these accounts of equipment system time are based on direct monitoring of the equipment system, such as total time, uptime, and productive time defined in SEMI E10. Other accounts are based on theoretical models of equipment system time.

6.1.2 All efficiency and loss metrics in this Document are bounded from zero to one (i.e., decimal fractions) for ease of calculation, but may also be expressed in percentages if the user prefers. Metrics values outside these boundaries represent errors in tracking, modeling, and/or calculation.

6.1.3 Efficiency metrics in this Specification are variations or components of a popular, traditional measurement from total productive maintenance (TPM) literature called overall equipment 'effectiveness' (also using the same acronym 'OEE' used in this Specification for overall equipment 'efficiency'). Some literature examples are given in § 9. This alternate effectiveness metric is based on units of production and traditionally expressed in terms of units. In this Specification, the efficiency metrics are expressed in terms of equipment system time. Overall equipment efficiency (OEE) is the more correct term for the time-based calculations defined in this Specification. Traditional unit-based 'effectiveness' calculations and the time-based OEE calculations within this Specification yield essentially the same results.

6.1.4 Component metrics of OEE are defined as follows:

- availability efficiency
- operational efficiency
- rate efficiency
- quality efficiency

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6.1.4.1 These components are defined in this Specification in terms that are consistent with SEMI E10, as shown in Figure 1.

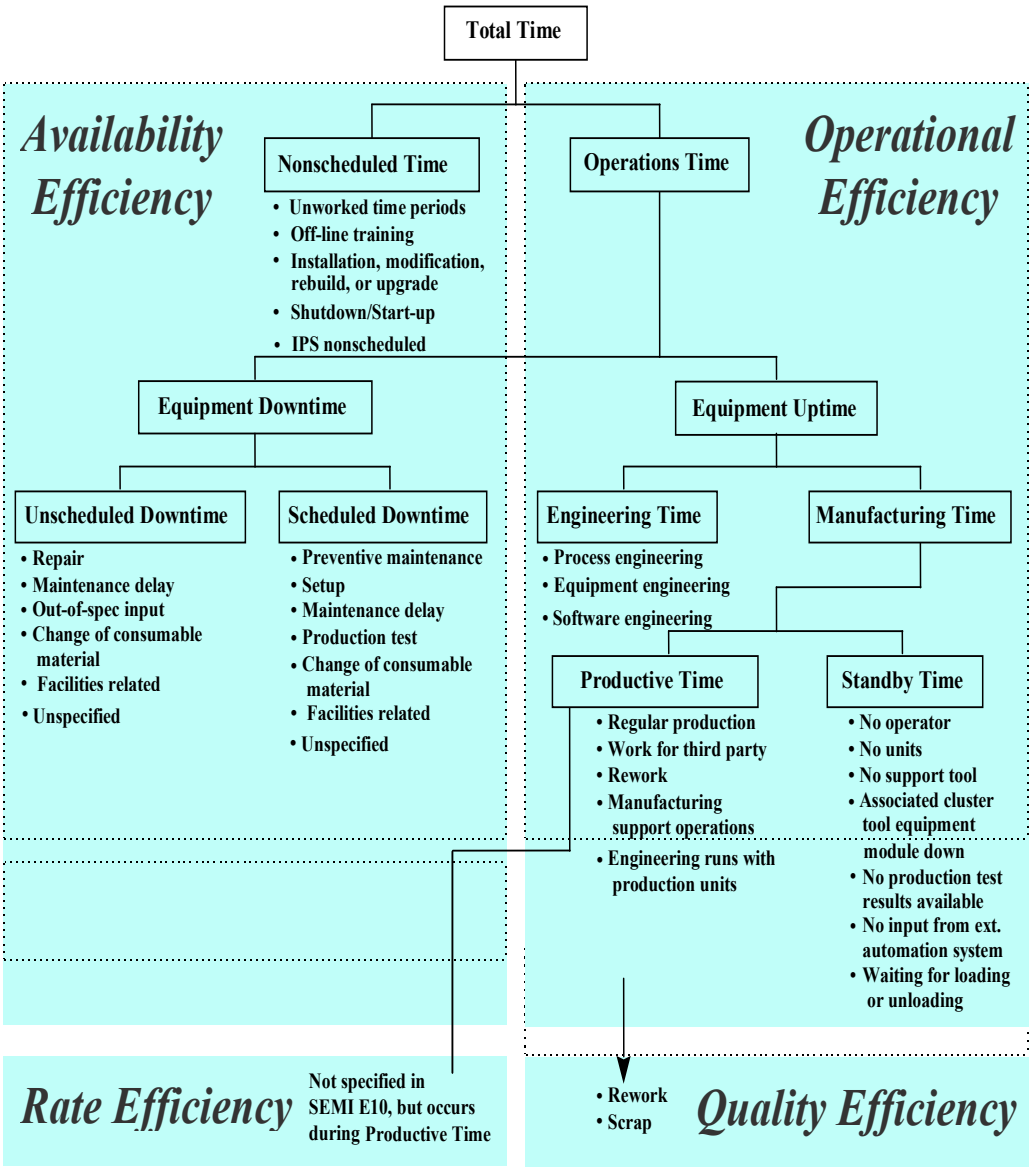

Figure 1
Relationship Between SEMI E10 and OEE

6.2 *Theoretical Production Time Standards by Recipe*

6.2.1 This Specification requires the development and application of a set of theoretical production time standards by recipe, where each time standard is referred to as the theoretical production time per unit of recipe i (THT_i):

$$THT_i = \text{theoretical production time per unit of recipe } i \quad (1)$$

NOTE 10: Theoretical production time per unit of recipe i may also be calculated as the reciprocal of theoretical unit throughput of recipe i.

6.2.2 THT_i is applied to the count of the units output during the observation period to obtain a theoretically 'earned' time for the equipment system that is considered efficient.

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6.2.3 THT_i is the strictly theoretically efficient time assuming the specified recipe, the specified equipment system design, and continuous operation.

6.2.3.1 Recipe specifications and settings for THT_i are the ones actually used in production and are not idealized.

6.2.3.2 To accurately represent the specified equipment system design, optimal times for material handling and other support tasks shall be included where those tasks cannot occur in parallel with processing tasks.

6.2.3.3 Equipment systems of the same design (e.g., same make, model, configuration) are expected to have the same THT_i values, whereas equipment systems of a different design may have different THT_i values even if they perform the same intended function.

6.2.3.4 Continuous operation requires that equipment system loading is optimized for throughput and there are no internal or external interruptions or delays to processing.

6.2.3.5 Given the constraints of a specified recipe, an equipment system design, and continuous operation, THT_i shall not include allowances for any other efficiency losses (e.g., slower-than-ideal changes in temperature or pressure, longer-than-ideal reaction times for valves or moving parts, different moments within a maintenance cycle, different moments in the life-cycle of a consumable material or consumable part).

6.2.4 For accurate measurement of the metrics rate efficiency and OEE (e.g., to guarantee that they are always correctly bounded between zero and one), THT_i shall be defined so that it is less than or equal to the actual productive time for any unit of recipe i.

$$THT_i \leq \textit{actual production time for any unit of recipe } i \tag{2}$$

6.2.5 For noncluster tool, single-path cluster tools (SPCTs), or individual processing equipment modules, the set of THT_i standards is based on the equipment system as a whole. For intended process sets (IPSs) or multipath cluster tools (MPCTs), the set of THT_i standards is based on each of the individual processing equipment modules of the IPS or MPCT (IPS/MPCT).

NOTE 11: Additional guidance for establishing THT_i standards is provided in Related Information 3.

7 Fundamental Quantities of Equipment System Productivity Measurement

7.1 The metrics in this Specification require the following fundamental quantities as inputs:

- Total time
- Uptime
- Production time
- Theoretical production time for actual units
- Theoretical production time for effective units

7.1.1 Figure 2 indicates how these SEMI E79 fundamental quantities are related to time in SEMI E10 equipment states and how they delineate various sources of efficiency loss. The domain for improvement of all losses, except operational loss, is shared between the equipment system supplier and equipment system user. Improvement of operational loss is the exclusive domain of the equipment system user.

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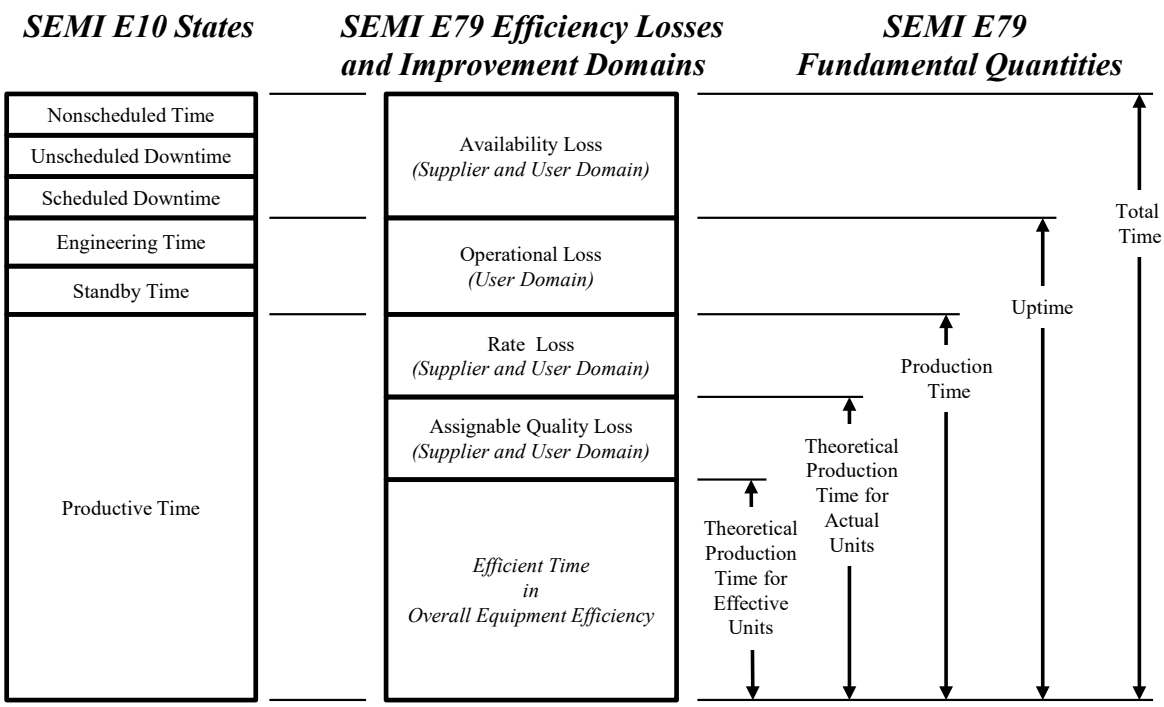

Figure 2
Stack Chart of Productivity Losses and Improvement Domains

7.1.2 Total time, uptime, and production time are based on SEMI E10 equipment state tracking. Theoretical production time for actual units and theoretical production time for effective units are based on unit output of each recipe and processing time standards per unit for each recipe.

7.1.3 For noncluster tools, SPCTs, or individual processing equipment modules, these fundamental quantities are determined in a straightforward manner considering the equipment system as a whole.

7.1.4 For IPSs/MPCTs, each fundamental quantity is calculated as the aggregate sum of that fundamental quantity over all processing equipment modules in the equipment system. For example, MPCT production time is the sum of production time for all of the processing equipment modules in the MPCT.

7.1.5 Unlike certain MPCT metrics in SEMI E10, all MPCT metrics in this Document are calculated directly and do not depend on calculating IPS metrics first.

NOTE 12: Because for any MPCT, multiple IPSs may operate simultaneously, it may not be practical or insightful to measure IPS efficiency over just any observation period. Better measurements may result when observation periods are selected such that only one IPS is operating. Selecting an observation period when multiple IPSs are operating is likely to result in a distorted measurement of each IPS.

7.1.6 It is recognized that interactions between modules within IPSs/MPCTs may impose varying amounts of standby time on the individual processing equipment modules. The approach to IPS/MPCT measurement in this Specification treats these interactions as standby losses for the IPS/MPCT. No allowances are made for these interactions in theoretical production time for effective units, in theoretical production time for actual units, or in production time.

7.2 *Total Time*

7.2.1 Total time is defined in SEMI E10 as all time during the observation period for an equipment system at the rate of 24 hours/day, 7 days/week.

7.2.2 For a noncluster tool, an SPCT, or an individual processing equipment module, total time is the duration of the observation period.

$$\textit{total time} = \textit{duration of observation period} \tag{3}$$

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7.2.3 For an IPS/MPCT, total time is the aggregate total time for all the processing equipment modules in the IPS/MPCT.

$$\textit{IPS/MPCT total time} = \Sigma_j \textit{ total time for processing equipment module } j \quad (4)$$

$$= (\textit{duration of observation period}) \times (\textit{number of processing equipment modules in the IPS/MPCT}) \quad (5)$$

7.3 *Uptime*

7.3.1 Uptime is defined in SEMI E10 as the time when the equipment system is in a condition to perform its intended function. It includes productive, standby, and engineering times, and does not include any portion of downtime or nonscheduled time.

7.3.2 For a noncluster tool, an SPCT, or an individual processing equipment module, uptime is the sum of productive time, standby time, and engineering time during the observation period.

$$\textit{uptime} = \textit{productive time} + \textit{standby time} + \textit{engineering time} \quad (6)$$

7.3.3 For an IPS/MPCT, uptime is the aggregate uptime for all the processing equipment modules in the IPS/MPCT.

$$\textit{IPS/MPCT uptime} = \Sigma_{\text{all j}} \textit{ uptime for processing equipment module } j \quad (7)$$

$$\begin{aligned} = \Sigma_{\text{all j}} (&\textit{productive time for processing equipment module } j \\ &+ \textit{standby time for processing equipment module } j \\ &+ \textit{engineering time for processing equipment module } j) \end{aligned} \quad (8)$$

7.4 *Production Time*

7.4.1 Production time in this Specification is very closely related to SEMI E10 productive time, which is the time when an equipment system is performing its intended function. Production time always includes time for loading and unloading units for all equipment systems.

7.4.1.1 For a noncluster tool, an SPCT, or an individual processing equipment module, production time is the same as SEMI E10 productive time.

$$\textit{production time} = \textit{productive time} \quad (9)$$

7.4.1.2 For an IPS/MPCT, production time is the aggregate sum of SEMI E10 productive time, including time for loading and unloading units, for all processing equipment modules in the IPS/MPCT. This quantity is not the same as the temporal-mapped productive time used in SEMI E10 metrics.

$$\textit{IPS/MPCT production time} = \Sigma_{\text{all j}} (\textit{production time for processing equipment module } j) \quad (10)$$

NOTE 13: For an IPS/MPCT, time for a transport operation that repositions a unit from one processing equipment module to another is intentionally credited to both processing equipment modules, as this shared operation consumes time from both equipment modules.

7.5 *Theoretical Production Time for Actual Units*

7.5.1 Theoretical production time for actual units is defined as the subset of production time that is earned by actual units during the observation period at strictly theoretically efficient rates assuming the specified recipes, the specified equipment system design, and continuous operation. This quantity requires a set of time standards for theoretical production time per unit of recipe i, THT_i, as presented in § 6.2.

7.5.2 For a noncluster tool, an SPCT, or an individual processing equipment module, the set of THT_i standards is based on the equipment system as a whole. Theoretical production time for actual units is then calculated for the equipment system as a whole.

$$\textit{theoretical production time for actual units} = \sum_i (\textit{actual unit output of recipe } i \times THT_i) \quad (11)$$

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7.5.3 For an IPS/MPCT, the set of THT_i standards is based on the individual processing equipment modules. Theoretical production time for actual units is calculated for each individual processing equipment module, then summed over all the processing equipment modules in the IPS/MPCT.

$$\textit{IPS/MPCT theoretical production time for actual units}$$

$$= \Sigma_{\text{all j}} (\textit{theoretical production time for actual units for processing equipment module j}) \quad (12)$$

$$= \Sigma_{\text{all j}} \Sigma_{\text{all i}} (\textit{actual unit output of recipe i on processing equipment module j} \times THT_i) \quad (13)$$

7.6 *Theoretical Production Time for Effective Units*

7.6.1 Theoretical production time for effective units is defined as the subset of theoretical production time for actual units that is earned by effective units during the observation period at strictly theoretically efficient rates assuming the specified recipes, the specified equipment system design, and continuous operation. This quantity is calculated using the same set of processing time standards as used in theoretical production time for actual units (refer to § 7.5), but uses a subset of actual unit output called effective unit output.

7.6.2 Effective unit output is actual unit output less equipment-assignable rework units and equipment-assignable scrap units of the subject equipment system. For any equipment system and observation period, the count of effective units shall always be less than or equal to actual units.

$$\begin{aligned} \textit{effective unit output} = \textit{actual unit output} \\ - \textit{equipment-assignable scrap units} \\ - \textit{equipment-assignable rework units} \end{aligned} \quad (14)$$

NOTE 14: Effective unit output still includes unit quality losses that are not assignable to the subject equipment system (e.g., losses due to misprocessing on other equipment systems). Appendix 1 presents a metric called Total Effective Units OEE (TEUOEE) that considers nonequipment-assignable sources of unit quality loss in addition to equipment-assignable sources.

7.6.3 For a noncluster tool, an SPCT, or an individual processing equipment module, the set of THT_i standards is based on the equipment system as a whole. Theoretical production time for effective units is then calculated for the equipment system as a whole.

$$\textit{theoretical production time for effective units} = \Sigma_{\text{all i}} (\textit{effective unit output of recipe i} \times THT_i) \quad (15)$$

7.6.4 For an IPS/MPCT, the set of THT_i standards is based on the individual processing equipment modules. Theoretical production time for effective units is calculated for each processing equipment module, then summed over all processing equipment modules in the IPS/MPCT.

$$\textit{IPS/MPCT theoretical production time for effective units}$$

$$= \Sigma_{\text{all j}} (\textit{theoretical production time for effective units for processing equipment module j}) \quad (16)$$

$$= \Sigma_{\text{all j}} \Sigma_{\text{all i}} (\textit{effective unit output of recipe i on processing equipment module j} \times THT_i) \quad (17)$$

8 Productivity Metrics

NOTE 15: Example calculations for each of these equations are provided in Related Information 1.

8.1 *Efficiency Metrics*

8.1.1 *Overall Equipment Efficiency (OEE)* — The fraction of total time that an equipment system is processing effective units assuming theoretically efficient time standards.

$$\textit{OEE} = (\textit{theoretical production time for effective units}) / (\textit{total time}) \quad (18)$$

8.1.2 OEE may be calculated directly, as above, or as the product of the four following component efficiency metrics: availability efficiency, operational efficiency, rate efficiency, and quality efficiency. Each of these metrics can be used to measure the relative value of distinct equipment system efficiency losses.

$$\textit{OEE} = (\textit{availability efficiency}) \times (\textit{operational efficiency}) \times (\textit{rate efficiency}) \times (\textit{quality efficiency}) \quad (19)$$

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