



SEMI E79-0299

STANDARD FOR DEFINITION AND MEASUREMENT OF EQUIPMENT PRODUCTIVITY

1. Purpose

1.1 The document provides metrics for measuring equipment productivity.

2. Scope

2.1 The document defines the metrics and calculations for measurement of equipment productivity.

2.2 In the context of this document, as with most discussions of equipment productivity, it is important to note that the term "equipment" refers to the entire context of a "node" (in industrial engineering terms) of production capacity within the larger context of the fab. The tool or piece of equipment is only one component (the most visible component) of that node. As such, it has become commonly used terminology to refer to the productivity of that node as "equipment productivity", even though it is impacted greatly by factors far beyond the equipment itself (operator, recipe, facilities, material availability, scheduling requirements, etc.).

2.3 Effective application of this standard requires that equipment performance is tracked using the metrics for Equipment Reliability, Availability, and Maintainability (RAM) established in SEMI E10. Additionally, the Automated Reliability, Availability, and Maintainability Standard (ARAMS), SEMI E58, can be used for equipment with ARAMS capability.

2.4 This document is currently limited to measuring equipment productivity through Standard Overall Equipment Effectiveness [OEE_s], but does not address the impact of productivity changes on cost, cycle time, or other measures.

2.5 Cluster tool OEE requires detailed understanding of tool configuration and use. Development of standards for effectively measuring cluster tool productivity are far from complete, though much is being written and proposed. The variables are numerous and their variability is huge, making a simple, yet comprehensive, set of standards and methods a difficult goal to attain. This document suggests the use of Simple Cluster Tool OEE [OEE_{sct}], for such measurements as a standard which can be easily and widely applied as a basic,

unambiguous metric until a more comprehensive set of metrics and methods is completed.

3. Referenced Documents

3.1 SEMI Standards

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

SEMI E38 — Cluster Tool Module Communications (CTMC)

SEMI E40 — Standard for Processing Management

SEMI E42 — Recipe Management Standard: Concepts, Behavior, and Message Services

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

3.2 Other Documents

SEMATECH Total Productive Manufacturing (TPM) Implementation Guide

TPM Encyclopedia; Edited by Japan Institute of Plant Maintenance, 1996

TPM in Process Industries; Edited by Tokutaro Suzuki, Productivity Press, 1994

(Originally published as *Sochi Kogyo no TPM*; Japanese Institute of Plant Maintenance, 1992.)

4. Terminology

4.1 *actual unit output* — The number of units processed by the equipment during productive time.

4.2 *cluster tool* — A manufacturing system made up of integrated processing modules mechanically linked together (the modules may or may not come from the same supplier) (see SEMI E10).

4.3 *downtime (equipment downtime)* — The time when the equipment is not in a condition, or is not available, to perform its intended function. It does not include any portion of non-scheduled time (see SEMI E10).

4.4 *equipment assignable rework* — Any units being reworked due to a fault or defect assignable to the subject equipment. The units may be reworked at



the equipment where the fault or defect occurred, or at other equipment.

4.5 equipment assignable scrap — Any units that are permanently removed from production due to a fault or defect assignable to the subject equipment. The units may be removed from production at the operation where the fault or defect occurred, or at a subsequent operation.

4.6 non-scheduled time — A period when the equipment is not scheduled to be used in production (see SEMI E10).

4.7 operations time — Total time minus non-scheduled time (see SEMI E10).

4.8 overall equipment effectiveness — An indicator of how well equipment is used in batch/lot production. The overall equipment effectiveness is obtained in relation to losses that can impede equipment effectiveness (see TPM Encyclopedia).

4.9 product — Any unit which is intended to become a functional semiconductor device. This includes functional engineering devices (see SEMI E10).

4.10 productive state — A period of time (*productive time*) when the equipment is performing its intended function (see SEMI E10).

4.11 recipe — The pre-planned and reusable portion of the set of instructions, settings, and parameters under control of a processing agent that determines the processing environment seen by the material. Recipes may be subject to change between runs or processing cycles (see SEMI E38, SEMI E40, and SEMI E42).

4.12 theoretical unit throughput — The number of units per period of time that could be processed by the equipment under ideal conditions of continuous *productive time* operation in which no equipment effectiveness losses are present. *Theoretical unit throughput* will vary by the recipe run on the tool. The calculation for *theoretical unit throughput* is detailed in Section 5.1.2.3 of this document.

4.13 total time — All time (at the rate of 24 hours per day, seven days per week) during the period being measured. In order to have a valid representation of *total time*, all six basic equipment states must be accounted for and tracked accurately (see SEMI E10).

4.14 unit — Any wafer, die, packaged device, or piece part thereof (includes product and non-product units) (see SEMI E10).

4.15 uptime (equipment uptime) — The hours when the equipment is in a condition to perform its intended function. It includes *productive, standby, and engineering time*, and does not include any portion of *non-scheduled time* (see SEMI E10).

5. Productivity Measurement

The OEE_s calculation has been stated in terms that are consistent with SEMI E10.

NOTE: Alternative equations for the OEE_s calculation are included in the Application Notes section of this document. These calculations provide users with additional options to measure specific elements of equipment productivity, as explained in the Application Notes.

NOTE: Sample calculations for each of the following equations are included in the Appendix 1, Application Notes in Section A1-1.

5.1 Standard Overall Equipment Effectiveness [OEE_s] — The efficiency of the equipment. See Figure 5.1 for the relationship between SEMI E10 and OEE.

$$\text{Standard Overall Equipment Effectiveness [OEE}_s\text{]} = (\text{Availability Efficiency}) \times (\text{Performance Efficiency}) \times (\text{Rate of Quality}) \times 100\%$$

5.1.1 Availability Efficiency — The fraction of the time that the equipment is in a condition to perform its intended function during total time.

$$\text{Availability Efficiency} = (\text{Equipment Uptime}) \div (\text{Total Time})$$

5.1.2 Performance Efficiency — The equipment productivity while the equipment is in a state capable of performing its intended function.

$$\text{Performance Efficiency} = (\text{Operational Efficiency}) \times (\text{Rate Efficiency})$$

5.1.2.1 Operational Efficiency — The fraction of uptime that the equipment is in the productive state.

$$\text{Operational Efficiency} = (\text{Productive Time}) \div (\text{Equipment Uptime})$$

5.1.2.2 Rate Efficiency — The efficiency of the equipment while it is operating in the productive state.

$$\text{Rate Efficiency} = \frac{[(\text{Actual Unit Output}) \div (\text{Productive Time})]}{(\text{Theoretical Unit Throughput})}$$

5.1.2.3 Theoretical Unit Throughput — The number of units per period of time that could be processed by



the equipment under ideal conditions of continuous *productive time* operation in which no equipment effectiveness losses are present.

$$\text{Theoretical Unit Throughput} = \sum_i \text{units}_i \div \sum_i (\text{units}_i / \text{UPH}_i)$$

where

units_i = units processed of
recipe i during the subject
time period

and

UPH_i is the theoretical
units per hour for recipe i .

5.1.3 Rate of Quality — The quality efficiency of the equipment while processing units in productive time.

$$\text{Rate of Quality} = \frac{[(\text{Actual Unit Output}) - (\text{Equipment Assignable Rework} + \text{Equipment Assignable Scrap})] \div (\text{Actual Unit Output})}{100\%}$$

5.1.4 Alternative OEE Calculation — An alternative to the Standard OEE calculation may be used when the detail of the efficiency losses is not required. This calculation provides the same value, but does not identify where losses may be occurring.

$$\text{OEE}_S = \frac{[(\text{Effective Unit Output}) \div (\text{Total Time})] \times 100\%}{\text{Theoretical Unit Throughput}}$$

5.1.5 Effective Unit Output

$$\text{Effective Unit Output} = (\text{Actual Unit Output}) - (\text{Equipment Assignable Rework} + \text{Equipment Assignable Scrap})$$