SEMI E30.5-0302
SPECIFICATION FOR METROLOGY SPECIFIC EQUIPMENT MODEL

This specification was technically approved by the Global Information and Control Committee and is the direct responsibility of the North American Global Information and Control Committee. Current edition approved by the North American Information and Control Committee on October 14 and November 27, 2001. Initially available at www.semi.org December 2001; to be published March 2002. Originally published July 2001.

The complete specification for this product includes all general requirements of SEMI E30.

1 Purpose

1.1 This document establishes a Specific Equipment Model (SEM) for Metrology equipment (MSEM). The MSEM consists of equipment characteristics and behaviors that are applicable to this class of equipment and are required to be implemented in addition to the SEMI E30 fundamental requirements and additional capabilities.

2 Scope

2.1 The scope of this document is limited to defining the behavior of Metrology equipment as perceived by a SEMI Equipment Communications Standard II (SECS II/SEMI E5) host that complies with the SEMI E30 model. It defines the view of the equipment through the SECS II link. It does not define the internal operation of the equipment. It includes a specific processing state model as the basis for all equipment behavior of this class.

2.2 This document assumes that the SEMI E30 fundamental requirements and all additional capabilities except those noted in SEMI E30 Capabilities Section in this document have been implemented on the MSEM equipment. This document expands the SEMI E30 Standard requirements and capabilities in the areas of the processing state model, collection events, Process Program management, remote commands, data item variables, and coordinate systems.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 The intent of this document is to facilitate the integration of Metrology equipment into an automated semiconductor factory. This document accomplishes this by defining an operational model for Metrology equipment as viewed by a factory automation controller. This definition provides a standard host interface and equipment operational behavior. This document applies specifically to Metrology equipment as used in a semiconductor factory environment. It is possible that this methodology and techniques may apply to other industries.

3.2 MSEM job parameters that specify material (e.g., carrier ID and substrate ID) and material locations (e.g., carrier location ID and carrier slot ID) are intended for metrology equipment for 200 mm and smaller substrate.

4 Referenced Standards

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4.1 *SEMI Standards*

SEMI E5 — SEMI Equipment Communications Standard II (SECS II)

SEMI M20 — Specification for Establishing a Wafer Coordinate System

SEMI M21 — Assigning Addresses to Rectangular Elements in a Cartesian Array

SEMI E37.1 — High Speed Messaging Service (HSMS-SS) Single Session

SEMI E58 — Automated Reliability and Availability Standard (ARAMS)

5 Terminology

5.1 *Definitions*

5.1.1 *alignment, n.* — a procedure in which a coordinate system is established on a substrate or a portion of a substrate.

5.1.2 *alignment mark, n.* — a feature on a substrate selectively used for alignment.

5.1.3 *alignment site, n.* — a point within a feature on a substrate selectively used for alignment.

5.1.4 *cleanup, n.* — deselection of the current Process Program and removal of all material to output locations and any equipment specific activities required to transition the equipment into the IDLE state.

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5.1.5 *factory automation controller, n.* — a computer system that provides integration of factory shop control and business systems with semiconductor equipment.

5.1.6 *feature, n.* — a distinctive item in a pattern, or a physical characteristic of the substrate. (e.g., line, point, a wafer flat).

5.1.7 *field, n.* — an exposure repeated in a regular manner on a substrate.

5.1.8 *global alignment, n.* — procedure which establishes a coordinate system for the entire substrate (see alignment). For silicon wafers, this coordinate system is defined in MSEM as the SEMI M20 coordinate system.

5.1.9 *global pattern alignment, n.* — a procedure which establishes a coordinate reference system relative to repeating features on an entire substrate. For silicon wafers, this coordinate system is defined in MSEM as the M20P coordinate system.

5.1.10 *logical port, n.* — one or more physical input or input/output ports that are controlled by the same execution of a Process Program.

5.1.11 *M20P, adj.* — a designation used for the global coordinate system defined within MSEM, that is established relative to a pattern on a silicon wafer.

5.1.12 *material, n.* — a piece or pieces of substrate, one or more substrate, a lot, a batch, or a run.

5.1.13 *metrology equipment, n.* — any equipment that collects and reports information on specific predetermined sites or features on a substrate with consistent data structure, or reports general information about the entire substrate.

5.1.14 *notch, n.* — a cut on the edge of a wafer that is commonly located with respect to a specific crystal plane that adheres to the SEMI M1 standard.

5.1.15 *pattern, n.* — the physical features on a substrate.

5.1.16 *pre-align, n.* — any alignment done prior to placing a substrate on a measurement process location.

5.1.17 *registration, n.* — positioning error between two features on different layers of a substrate.

5.1.18 *safe state, n.* — a state in which the equipment presents no danger to the product or user. This implies that safety interlocks are in place such that the equipment can be serviced without harm to the operator and that the material being processed has been removed from the processing station into an accessible location.

5.1.19 *secondary alignment, n.* — a procedure which improves the accuracy of the coordinate system mapping on a substrate in a limited area of the substrate.

5.1.20 *site, n.* — a single point on a substrate used for alignment, or the center of an area of the substrate within which measurements are made.

5.2 *Abbreviations and Acronyms*

5.2.1 *GEM, n.* — Generic Equipment Model

5.2.2 *SEM, n.* — Specific Equipment Model

5.2.3 *SEM, n.* — Scanning Electron Microscope

5.2.4 *TCP/IP, n.* — Transmision Communication Protocol/Internet Protocol.

6 Communication Requirements

6.1 It is required that any MSEM compliant equipment follow the Communications State Model in SEMI E30. In addition MSEM compliant equipment shall support the High Speed Messaging Service (HSMS-SS) communication Standard, and the SECS-I standard for sending SECS II messages over TCP/IP or RS232. The user may determine which of these two lower level transmission protocols is used in each installation. The reason for HSMS-SS requirement is the large volume of data that can be generated by this class of equipment.

7 State Models

7.1 In this section are defined the equipment-specific processing state model and other state models necessary to portray the expected operational states of the equipment to enable host tracking and control in place of a local operator. See SEMI E30 and Other References section for additional information on state charts general rules and utilization.

7.2 *Processing State Model Requirements* — The Processing state model is required to be implemented as defined in the next sections of this document. A state model consists of the following: state model diagram, state definitions and a state transition table. A state model represents the host's view of the equipment, not necessarily the actual equipment operation. All MSEM state model transitions shall be mapped sequentially into the appropriate actual equipment events that satisfy the requirements of those transitions. In certain implementations, the equipment may enter a state and have already satisfied all of the conditions required by the MSEM state model for transition to another state. The equipment makes the required transition without any additional actions in this situation.

7.3 Some equipment may need to include additional states. Additional states may be added, but shall not change the MSEM defined state transitions. All expected transitions between MSEM states must occur.

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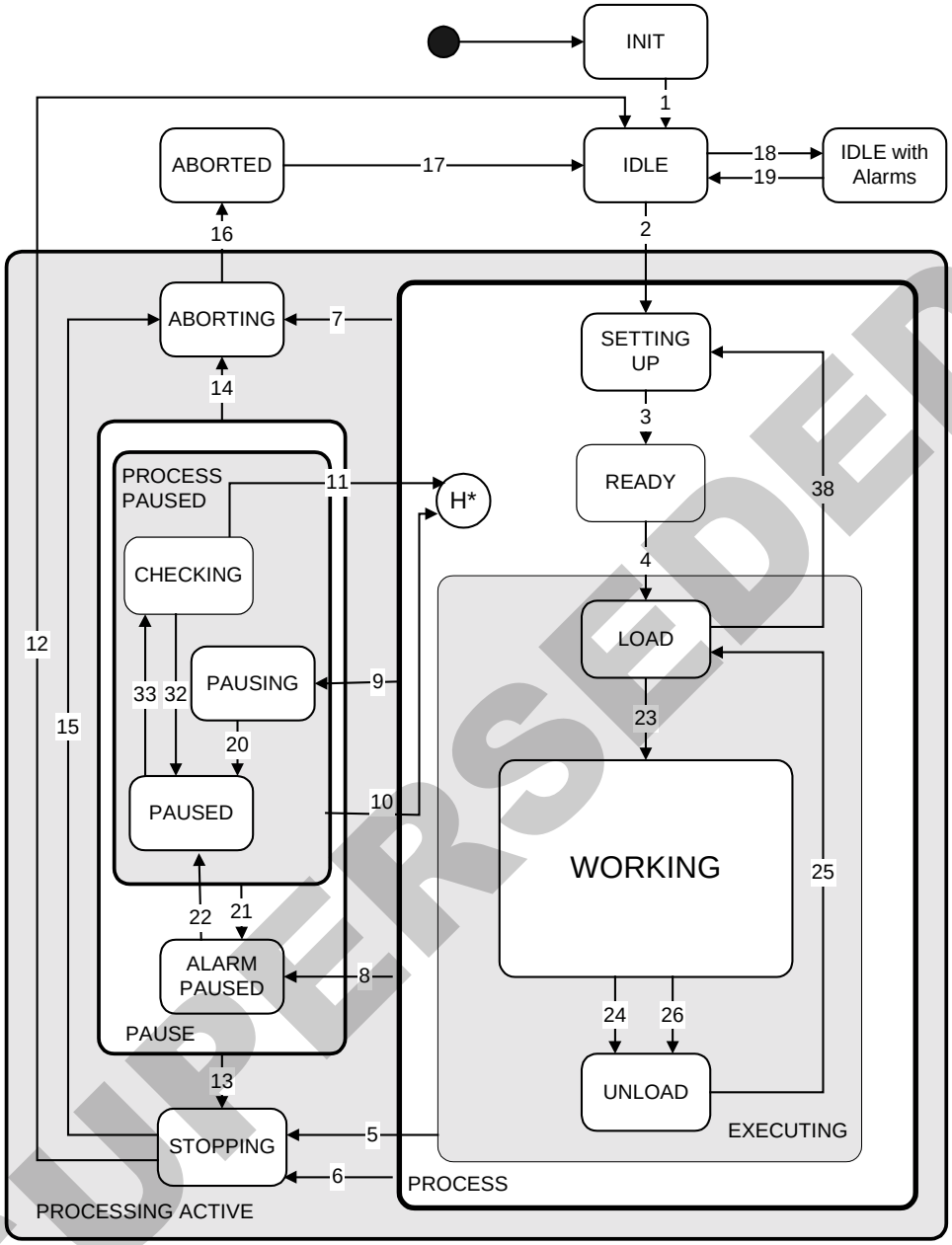

Figure 1
Generic MSEM Processing State Model Diagram

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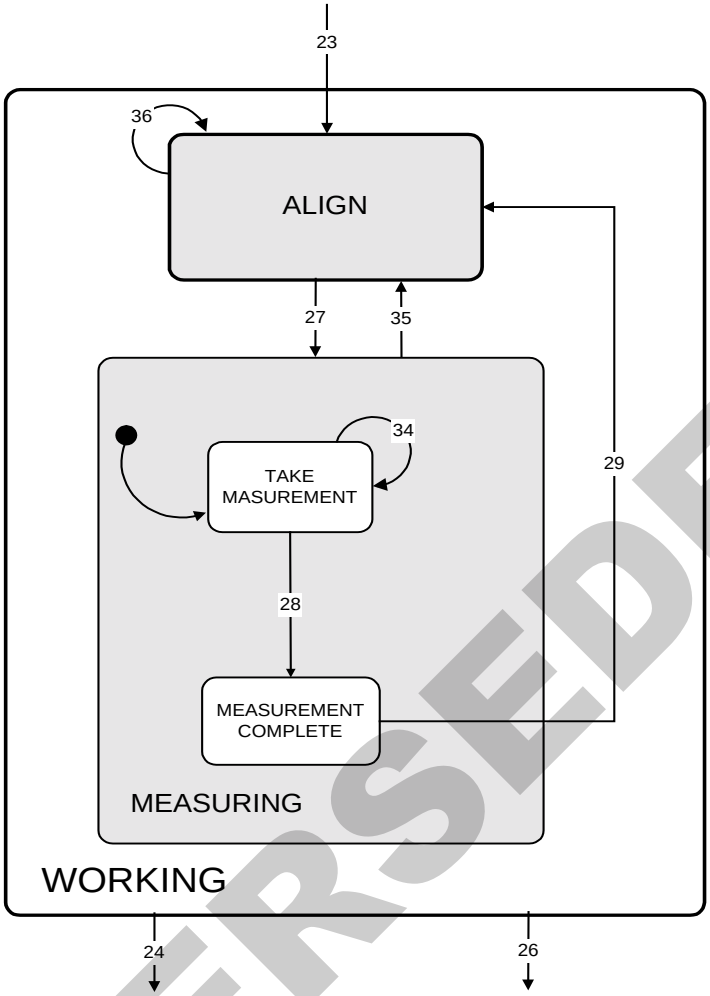

Figure 2
Working State of Processing State Model

7.4 *Processing State Model Diagram*

7.4.1 *Working State of Processing State Model*

7.4.2 *Working Sub-states of Processing State Model* — These states need not to be implemented in all Metrology equipment but if the equipment has the ability to multiple measurements at a site or provide raw scan date to the user this is how it is to be implemented.

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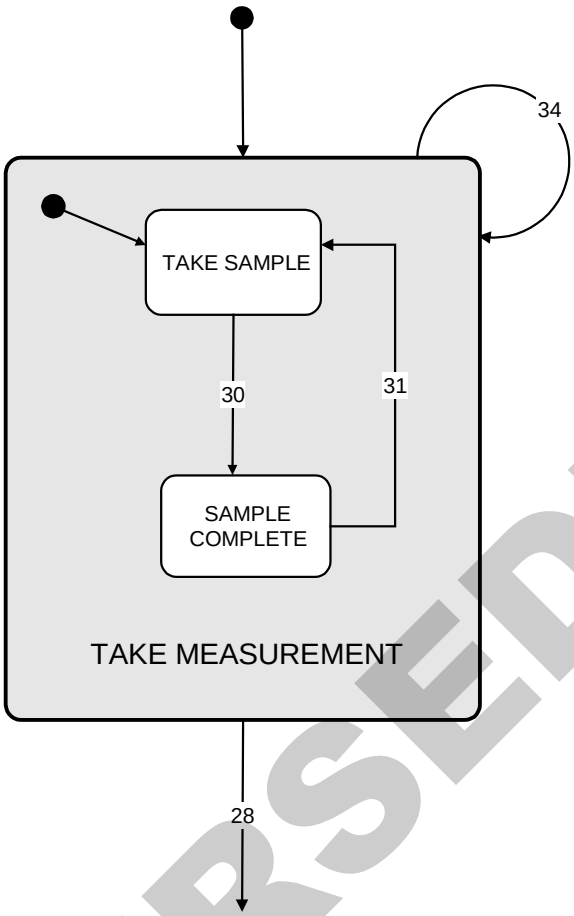

Figure 3
Working Sub-State of Processing State Model

7.5 *Processing State Definitions*

7.5.1 *ABORTED* — all activity is suspended as a result of an ABORT command. Any alarm and abort conditions must be cleared before exit from this state. The CLEANUP command is available to the operator or host to transition the equipment from the ABORTED state to IDLE state.

7.5.2 *ABORTING (PROCESSING ACTIVE Sub-state)* — the equipment has received an ABORT command. All normal activity is suspended. The equipment is taking appropriate action to put the equipment and material in a "safe state" where possible. Data may be invalid or not available.

7.5.3 *ALARM PAUSED (PAUSE Sub-state*) — an alarm has occurred in the Process or Process Pause states and the equipment is waiting for the alarm to be cleared.

7.5.4 *ALIGN (WORKING Sub-state)* — the equipment or operator is performing an alignment of the material to the equipment. Within this state the equipment shall refine or establish its SEMI M20 coordinate system and establish any secondary coordinate systems required.

7.5.5 *CHECKING (PROCESS PAUSE Sub-state)* — the equipment verifies that the updates made to the Process Program are valid. This is a similar procedure to that which is done in SETTING UP before the equipment is ready to transition to the READY state.

7.5.6 *EXECUTING (PROCESS Sub-state)* — the equipment is processing material automatically and can continue to do so without external intervention, but normally may include interaction with the host or operator.

7.5.7 *IDLE* — checks for queued process or awaits a command. IDLE is free of ALARM and error conditions. Any transitions into this state will clear the process area.

7.5.8 *IDLE with ALARMS* — an alarm has occurred in the IDLE state and the equipment is waiting for all alarms to be cleared.

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7.5.9 *INIT* — equipment initialization is occurring.

7.5.10 *LOAD (EXECUTING Sub-state)* — the equipment is determining if processing is complete. If not, then the substrate is being transferred to the equipment processing location, such as the stage. A pre-alignment procedure may be performed prior to the LOAD state.

7.5.11 *PAUSE (PROCESS ACTIVE Sub-state)* — PROCESS is suspended at the next opportunity. Actions to put the equipment in a "safe state" shall be performed. The equipment is awaiting a command (RESUME, PP-UPDATE, STOP or ABORT), or for alarm(s) to be cleared.

7.5.12 *PAUSED (PROCESS PAUSE Sub-state)* — PROCESS shall be suspended and the equipment is waiting for a command (RESUME, PP-UPDATE, STOP or ABORT).

7.5.13 *PAUSING (PROCESS PAUSE Sub-state)* — PROCESS has been suspended at the next opportunity and the equipment is put in a "safe state".

7.5.14 *PROCESS (PROCESSING ACTIVE Sub-state)* — this state is the parent of those sub-states which refer to the active preparation and execution of a Process Program.

7.5.15 *PROCESSING ACTIVE* — this state is the parent of all sub-states where the context of a Process Program execution exists.

7.5.16 *PROCESS PAUSE (PAUSE Sub-state)* — the equipment is free of alarm conditions in the PAUSE state.

7.5.17 *MEASUREMENT COMPLETE (MEASURING Sub-State)* — the equipment has completed collecting data relative to an alignment location.

7.5.18 *MEASURING (WORKING Sub-State)* — the equipment is preforming an action between alignments.

7.5.19 *READY (PROCESS Sub-state)* — the equipment is ready to begin processing and is awaiting a START command from the operator or host. If an AUTOSTART is included, then the equipment starts processing immediately.

7.5.20 *SAMPLE COMPLETE (TAKE MEASUREMENT Sub-state)* — the equipment determines if additional samples need to be taken at this site.

7.5.21 *SETTING UP (PROCESS Sub-state)* — the equipment is being set up so that external conditions are satisfied to start processing the material. This includes the receipt of any Process Programs and material to be processed and their validation. Additional information may come from the host during the processing.

7.5.22 *STOPPING (PROCESSING ACTIVE Sub-state)* — the equipment has completed a Process Program or has been instructed to stop processing and shall do so gracefully at the next opportunity. All cleanup necessary is being completed within this state with regard to material, data, control system, etc. Data is normally preserved. Any alarm or error condition is cleared before exit from this state.

7.5.23 *TAKE MEASUREMENT (MEASURING Sub-state)* — the equipment is in the process of collecting data relative to an alignment location. (e.g. Site, Region, Substrate).

7.5.24 *TAKE SAMPLE (TAKE MEASUREMENT Sub-state)* — the equipment collects data from a single structure or of a single sample.

7.5.25 *UNLOAD (EXECUTING Sub-state)* — the substrate is being removed from the processing location.

7.5.26 *WORKING (EXECUTING Sub-state)* — the equipment is processing a specific material.

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7.5.27 *Processing State Transition Table*

Table 1 Processing State Transition Table

Transition #	*Current state*	*Trigger*	*New State*	*Actions*	*Comments*
1	INIT	All equipment initialization is complete with no alarms or error conditions.	IDLE	None	If an alarm or error occurs during INIT, the equipment shall remain in this state.
2	IDLE	A process is queued or a command is received.	SETTING UP	The set up procedure is equipment dependent.	Commit has been made to set up.
3	SETTING UP	All setup activity has completed and the equipment is ready to receive a START command.	READY	The equipment is waiting for a START command. Start may be initiated by an operator.	The selected Process Program is available for execution.
4	READY	The equipment receives a START command.	LOAD	The equipment determines if processing is completed. If not, it transfers the next substrate to the processing location.	LOAD is an EXECUTING Substate.
5	EXECUTING	The processing is complete.	STOPPING	None	Equipment specific. Supplier must chose beween LOAD or UNLOAD states for completion.
6	PROCESS	The equipment has received a STOP command.	STOPPING	The equipment unloads the material and brings the equipment to a clean and safe state.	Data is typically preserved and is valid.
7	PROCESS	The equipment has received an ABORT command	ABORTING	The equipment is put in a "safe state" if necessary.	Data may be invalid or not available.
8	PROCESS	An alarm occurs.	ALARM PAUSED	PROCESS activity is suspended and the equipment is waiting for all alarms to be cleared.	ALARM PAUSED is a PAUSE Substate.
9	PROCESS	The equipment has received a PAUSE command.	PAUSING	PROCESS shall be suspended at the next opportunity. Actions to put the equipment in a "safe state" shall be performed.	PAUSING is a PAUSE Substate.
10	PROCESS PAUSED	The equipment has received a RESUME command.	Previous PROCESS State	Proceed with the suspended Substate.	PAUSED is a PROCESS PAUSE Substate.
11	CHECKING	The equipment has completed validating any updates made to the current Process Program being executed. Including a PP_UPDATE	Previous PROCESS State	Action is appropriate to the state and the changes made to the Process Program updated.	None

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Transition #	*Current state*	*Trigger*	*New State*	*Actions*	*Comments*
12	STOPPING	The equipment clean up is complete and the equipment is free of alarms.	IDLE	None	None
13	PAUSE	The equipment has received a STOP command.	STOPPING	The equipment proceeds with clean up.	Normally, data is preserved and is valid.
14	PAUSE	The equipment has received an ABORT command.	ABORTING	Any unsafe condition is resolved if possible.	Data may be invalid or not available.
15	STOPPING	The equipment has received an ABORT command.	ABORTING	Any unsafe condition is resolved if possible.	Data may be invalid or not available.
16	ABORTING	Unsafe conditions have been resolved where possible.	ABORTED	The equipment is waiting for alarm and ABORT conditions to be cleared.	The only state change allowed is to IDLE.
17	ABORTED	All alarms and abort conditions have been cleared.	IDLE	None	If needed the CLEANUP command clears the abort conditions. IDLE is a “clean” state.
18	IDLE	An alarm is set.	IDLE w/ ALARMS	The equipment waits for all alarms to be cleared.	None
19	IDLE w/ ALARMS	All alarms have been cleared.	IDLE	None	IDLE is free of alarms.
20	PAUSING	The equipment has achieved a “safe state”.	PAUSED	The equipment is waiting for a command (RESUME, STOP or ABORT).	None
21	PROCESS PAUSE	An alarm is set.	ALARM PAUSED	The equipment waits for all alarms to be cleared, or a STOP or ABORT command.	None
22	ALARM PAUSED	All alarms are cleared.	PAUSED	The equipment is waiting for a command (RESUME, PP_UPDATE, STOP or ABORT).	None
23	LOAD	Material transfer to processing location is complete and global alignment has been completed.	WORKING	The substrate is being processed.	None
24	WORKING	The processing of the specific material being processed ended normally.	UNLOAD	This material is transferred from the processing location.	“Normal” completion of the substrate.
25	UNLOAD	The material unload is complete.	LOAD	The equipment checks if processing is complete and, if not, transfers the next substrate to the processing location.	None

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Transition #	*Current state*	*Trigger*	*New State*	*Actions*	*Comments*
26	WORKING	The processing of the specific material being processed ended abnormally.	UNLOAD	This material is transferred from the processing location.	Abnormal exit from WORKING or Next Material command received.
27	ALIGN	The material alignment is complete.	MEASURING	The equipment determines if additional sites are required.	None
28	TAKE MEASURE-MENT	All data collection has been completed for the current site or alignment location.	MEASURE-MENT COMPLETE	The equipment determine if additional sites are required.	Determine if additional alignments are required or unload is required.
29	MEASURE-MENT COMPLETE	Additional sites are required.	ALIGN	The equipment moves and aligns to new data collection site.	None
30	TAKE SAMPLE	Data collection from scan or structure.	SAMPLE COMPLETE	Determine if additional samples are required.	None
31	SAMPLE COMPLETE	Additional samples are required.	TAKE SAMPLE	Start collecting next scan or structure data.	None
32	CHECKING	Validation of Process Program change fails or is cancelled. Includes PP_UPDATE.	PAUSED	The equipment is waiting for a new PP-UPDATE or RESUME command.	Process Program reverts to the conditions that existed prior to the PP-UPDATE.
33	PAUSED	The equipment receives a PP-UPDATE command.	CHECKING	The equipment begins validating the changes made to the Process Programs to be executed.	None
34	TAKE MEASURE-MENT	Another measurement is required at an alignment location.	TAKE MEASURE-MENT	The equipment performs a measurement.	None
35	MEASURING	An error or failure occurred during the measurement and a new alignment is required.	ALIGN	The equipment moves and aligns to new data collection site.	None
36	ALIGN	An error or failure occurred during alignment and a new alignment is required.	ALIGN	The equipment moves and aligns to new data collection site.	None
37	ASSIST	A failure occurred while executing and external assistance was required to continue.	PROCESS PAUSE	The execution is stopped and equipment waits for a resume command.	Resume command must be issued.
38	LOAD	Previous PROCESS-BLD-GROUP program has completed and there are additional process programs assigned to the “CARRIERBLD”. See Section 12.	SETTING UP	The equipment performs set up according to specifications of the next process program.	PROCESS-BLD-GROUP may include a AUTOSTART command within its body. Otherwise, the equipment waits for a START command.

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Table 2 Processing State Events and Associated Reports

CENAME	*From State*	*To State*	*Required DVVAL's or Reports*
END of RUN	STOPPING	IDLE	RUN complete report available. All jobs specified by PROCESS-BLD-GROUP command parameter(s) in a CARRIERBLD command parameter complete.
END of JOB	LOAD	SETTING UP	JOB complete report available. A job specified by a PROCESS-BLD-GROUP command parameter in a CARRIERBLD command parameter that specifies multiple jobs for the same material completes.
END of SUBSTRATE	UNLOAD	LOAD	SUBSTRATE complete report available.
END of SITE	TAKE MEASURE	MEASURE COMPLETE	SITE complete report available. Only required if supporting sampling.
END of SAMPLE	TAKE SAMPLE	SAMPLE COMPLETE	SAMPLE complete report available. Only required if equipment performs measurements on individual sites.

8 Collection Event List

8.1 The purpose of this section is to identify data collection events for Metrology equipment and define reporting levels.

8.2 *Requirements* — Only those collection events that are not associated with a change of state, and those requiring specific DVVAL's or Reports defined in the SEM, are required to be included in this section. All SEMI E30 required events are required by this SEM.

8.2.1 *Common collection events* — collection events common to, and required on, all equipment of the class being addressed.

8.2.2 *Configuration-specific collection events*— collection events associated with a specific configuration of the equipment class being addressed.

8.3 *Collection Event Tables* — The first table contains processing state event transitions and associated reports. The second table contains additional events or actions and associated reports.

8.3.1 All remote commands (S2F41) that are not preformed by the equipment before responding to the host (S2F42) must generate an event indicating when the task was completed and whether it was successful.

Table 3 Additional Required Collection Events

ACTION or COMPLETED EVENT	*Required DVVAL's or Reports*
Remote command MAP-CASSETTE completed successfully.	SlotList
Operator hits button on equipment control panel.	OperatorAction

9 Data Item Variables

9.1 The purpose of this section is to define the list of data item variables pertinent to the specific equipment. Values of these variables shall be available to the host via collection event reports and host status queries.

9.2 *Requirement* — all generic variable data items defined in SEMI E30 are required by all Measurement equipment. Data item variables are categorized as follows:

9.2.1 *Common Variables (CV)* — variables common to all equipment of the class being addressed. These variables are covered in Table 4 and must be used to regardless of the measurement tool type.

9.2.2 *Configuration-specific variables (CSV)* — variables associated with a specific configuration of the above equipment class.

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