Generic Equipment Test Plan

SEMATECH
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Abstract: This document describes potential test variables evaluated for equipment entering SEMATECH's Integration Standards Development Lab (ISDL). The document is intended to be generic, providing guidelines for determining which variables to consider when developing a test plan for any type or piece of automated material handling equipment. The applicability, details, criteria, and relative priority of individual tests will be driven by equipment specifications and requirements and by member company needs.

Keywords: Computer Software Control Systems, Cost of Ownership, Equipment Specifications, Equipment Installation, Equipment Performance, RAM, Standards, Supplier Relations

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1 INSTALLATION AND GENERAL INSPECTION

1.1 Installation

Analyze the relative level of difficulty of installing the equipment, including the following:

- Transporting the equipment to the site and moving it into the facility
- Connecting all mechanical and electrical utilities
- Any special equipment needs, such as leveling, adjusting, physically or electrically isolating, cleaning, or “burning in” the equipment
- Any special facility requirements, such as unusual utility requirements, changes to floor or ceiling structure, etc.
- Adherence to SEMI tool accommodation standards (SEMI E6, E49-E49.9, E51)

1.2 Basic Mechanical Design

Inspect the equipment to gain basic familiarity with its functions and controls and to identify potential weaknesses. Items to consider are as follows:

- Basic function and operation of hardware
- Dependence on unproven technology
- Protection of electrically or mechanically sensitive components
- Identification of areas exposed to hostile (electrical, mechanical, chemical) environments
- Mechanical and electrical integrity
  - Material selection (quality of fasteners, paints, connectors)
  - Routing of electrical and chemical lines

1.3 Basic Software Design

Operate the system to verify proper software function and to determine potential limitations. Consider the following:

- Installation time (hardware and software requirements)
- Design of control systems, including software/source code structure and design (source code may not be accessible)
- Conformance of the software to Level 2 of the Software Engineering Institute’s (SEI) Capability Maturity Model (CMM) scale
- Completeness of tool integration software
- Sufficient instruction/prompting for any software configuration to be done by the user (configurability)
- Operator training requirements/usability
- Files produced, how/where they are stored
- Proper response to and recovery from power interruption

With the increase in both the amount of software used in tools and the reliance on that software (process control, equipment communications), several guidelines and standards for structured software development exist. Adherence by the supplier to such guidelines as those mentioned below may result in superior software quality, and a reduction in equipment downtime due to software failure. Some of the more widely used guidelines are listed below.

- SEI: CMM for Software, which defines levels of maturity for software
- SEMATECH: Standardized Supplier Quality Assessment (SSQA), Module 3, which is based on the International Organization for Standardization (ISO) standard and the Quality System Review (QSR) mentioned below
- ISO: ISO 9000-3
- Motorola, Inc.: QSR includes a software portion

1.4 Conformance to Dimensions

Measure the relevant physical dimensions of the equipment to ensure conformance with specifications and SEMI standards. Examples include the following:

- Equipment footprint and height
- Loadport height and size
- Location of mechanical and electrical connections
- Locations of specific interfaces and peripheral equipment, such as switches, video monitors, bar code readers, etc.

1.5 Documentation

Verify the adequacy of all required documentation, including the following:

- Operating instructions
- Maintenance schedules and instructions
- Troubleshooting guides
- Wiring diagrams
- State tables
- Software/source code documentation

2 SAFETY

2.1 General Safety

Identify all potential safety issues, including hazards to people, equipment, and materials. Determine conformance to all safety standards and regulations, such as

- SEMI S2 Safety standards
- SEMI S8 Ergonomic standards
- OSHA requirements
- EC (Europe) requirements

Also, verify the functionality of all interlocks and other safety features, and verify proper notification when interlocks are defeated (such as during maintenance procedures).

2.2 People

Identify all potential safety issues related to personal injury, including

- Protection from pinch points
- Protection from moving parts
- Adequate tag out/lock out protection
- Ergonomics issues, such as the need for people to lift heavy parts or perform repetitive motions

2.3 Equipment

Verify that equipment maintains safe conditions for itself and other nearby or integrated equipment at all times. For example, ensure that

- All safety features function properly
- Dangerous error or failure modes result in automatic shutdown procedures
- Moving equipment (such as robots) detect the presence of objects in their paths and take appropriate action
- Emergency machine off (EMO) and emergency power off (EPO) buttons are easily accessible and function properly

2.4 Material

Identify and analyze all possible conditions that could potentially damage product or consumables.

3 FUNCTIONALITY AND PERFORMANCE

3.1 Functionality

Verify that the equipment accomplishes all specified functions. Functionality refers to the equipment's motions or actions. For example, ensure that

- Moving components move as directed
- Valves and switches open and close as directed
- All operating modes (automatic, manual, maintenance, remote, etc.) function as required
- Sensors function properly and are responded to appropriately

3.2 Performance

Verify that all functions are accomplished at the specified levels of performance. Performance refers to how well the equipment performs its specific functions. For example,

- Moving components travel at specified speeds
- Valves allow specified amount of fluids to pass through
- Vacuum pumps achieve specified vacuum levels and pumpdown times
- Throughput and cycle times are met

Ensure that sensors and readouts are properly calibrated prior to taking any measurements.

3.3 Operability

Verify the effectiveness of the equipment's operating instructions. Review instructions for the following:

- Sufficiency
- Accuracy
- Timeliness
- Accessibility
- Clarity
- Level of complexity/simplicity

Also, determine the sensitivity of the order in which the instructions are performed.

3.4 Error Recovery

Determine the adequacy of the error recovery procedures. For example, ensure that

- Error states and codes are easily identified
- Error meanings and implications are clear
- Recovery procedures are clear for both operators and maintenance technicians and that access to maintenance functions is limited to qualified personnel

3.5 Flexibility and Adaptability

Verify that equipment is flexible and adaptable enough to meet both current and anticipated future needs, including the following:

- Increased throughput requirements
- Process changes (both to run different products and to change entire processes)
- Facility changes
- Hardware and software upgrades

3.6 Anomaly Testing

Verify that the equipment properly responds to and recovers from unexpected inputs, such as

- Operator error (starting incorrect process, performing operations in the wrong order, using wrong material, etc.)
- Incorrect or improperly aligned material
- Miscommunication with an external control system
- Changes in facility inputs (power, chemicals, air pressure, etc.)

3.7 Reliability

Perform sufficient long-term testing to determine the equipment's reliability. Maintain adequate error logs to measure mean time between failures (MTBF), mean cycles between failures (MCBF), mean time between assists (MTBA), etc. (See SEMI E10.) Inspect the system for "high wear" points.

3.8 Sensitivity to External Forces

Determine the sensitivity of equipment to various environmental forces and other circumstances, such as

- Electrostatic discharges (ESD)
- Electromagnetic interference (electromagnetic field [EMF], radio frequency [RF])
- Vibration
- Light, temperature and humidity
- Water pressure
- Equipment misadjustment

4 MAINTAINABILITY

4.1 Equipment Mechanical Design

Review the equipment's design to determine its maintainability. For example, determine the following:

- Accessibility of components
- Modularity of components
- Use of standard vs. custom components
- Frequency and difficulty of adjusting or calibrating components
- Adequacy of the recommended spare parts list, etc.
- Adequacy of preventive maintenance schedules (either too often or not often enough)

4.2 Equipment Software Design

Software maintainability concerns include the following:

- Sufficient supporting documentation
- Software upgrade procedure
- Failure recovery process
- Proper tracking/reporting of equipment state
- Reliability of software

4.3 Mean Time to Repair

Maintain adequate repair logs to determine the equipment's mean time to repair (MTTR) (see SEMI E10).

4.4 Technical Training and Support

Determine the adequacy of the equipment supplier's technical training and support. For example, review the following:

- The need for, and availability of, onsite versus offsite training
- Adequacy, clarity, accuracy, accessibility, etc. of all maintenance, repair and operating manuals and other "help" functions (e.g., electronic "help" files, phone or e-mail contact with the supplier, etc.)

5 EQUIPMENT INTERFACES

5.1 Mechanical Interfaces

Determine what the requirements are, particularly if any custom interfacing is necessary. Some of the relevant SEMI standards are as follows:

- E6—Facilities Interface Specifications Guideline and Format: a guideline for suppliers for documenting the tool's facilities requirements
- E15—Specification for Tool Load Port: standard for the interface between tools and wafer carrier transport systems (automated and human)
- E19.4—Standard Mechanical Interface (SMIF): describes an interface for clean transfer of wafers from carrier to tool
- E57—Kinematic Couplings for 300 mm Carriers: defines kinematic coupling dimensions
- E63—Box Opener/Loader to Tool Standard (BOLTS)
- Equipment communications connection standards
  - E4—Semiconductor Equipment Communication Standard (SECS-I)
  - E37—High Speed Message Service (HSMS)
- E64—Cart docking interface to tool
- Cluster tool module-specific standards (E21, E22, E25)

5.2 Software and Communications Interfaces

Review the equipment's ability to effectively interface with external computer systems. Verify the ability to communicate appropriately with other systems and databases, such as recipe downloading, data collection programs, statistical process control (SPC) programs, etc. Considerations include the following:

- Material control systems (MCS) and factory control systems (FCS) interfaces
- SEMI E5—Semiconductor Equipment Communication Standard (SECS-II): definition of messages between tool and host
- SEMI E30—Generic Equipment Model (GEM): interprets how SECS-II messages are used
- Compliance with the CIM Framework
- SEMI E58—Automated Reliability, Availability, and Maintainability Standard (ARAMS): standards for implementing and collecting SEMI E10 (see section 8.1) data on automated equipment
- SEMI E23—Specification for Cassette Transfer Parallel I/O Interface: describes the interface between two pieces of equipment for cassette transfer

5.3 Hardware

Review the equipment's ability to effectively interface with other equipment, such as other material handling system components (transport systems, stockers, tool loadports and indexers, SMIF pods and wafer cassettes).

5.4 People

Review the equipment's ability to effectively interface with operators, technicians, engineers, etc. (See Section 3.3, Operability; Section 3.4, Error Recovery; and Section 4.4, Technical Training and Support.)

5.5 Factory/Facility

Review the equipment's ability to effectively interface with the facility. (See Section 1.1, Installation; Section 3.8, Sensitivity to External Forces; and Section 6, Environmental Impact.)

6 ENVIRONMENTAL IMPACT

6.1 Contamination

Determine the system's impact on the cleanliness of its surroundings and environment. Review impacts on the following

- Material/wafer surface
  - Particulate contamination
  - Chemical contamination
  - Characterization of airflow within the tool

- Cleanroom
  - Particulate contamination
  - Chemical contamination
  - Disruption of cleanroom airflow

6.2 Other Impacts

Determine the system's other impacts on its environment, such as the following:

- RF generation
- ESD buildup
- Audible noise
- Vibration transmitted to the product, facility, or other equipment
- Heat generation

7 COST OF OWNERSHIP

Analyze all aspects of the system affecting cost, such as the following:

- Consumables used during normal processing
- Product loss
- Product rework
- Test wafer requirements
- Replacement parts
- Need for service contracts
- Operator and technician time requirements

8 CONFORMANCE TO STANDARDS

8.1 SEMI

Verify that equipment conforms to all relevant and specified SEMI standards and guidelines. There are many SEMI documents that may be applicable to any particular piece of equipment. These include the standards listed below. A graphic is included to assist in understanding the application of each standard to equipment being characterized.

- S2—Safety Guidelines: a minimum set of safety considerations
- S8—Ergonomic Guidelines: describes ergonomic/human factors design principles for equipment
- E5—SECS-II: definition of messages between tool and host
- E30—GEM: interprets how SECS-II messages are used
- E4—SECS-I: defines a communication interface between equipment and host
- E37—HSMS: defines a communication interface between equipment and host

- E38—Cluster Tool Module Communications (CTMC): standard for communication with and among cluster tool modules
- E1.9—300 mm Wafer Carriers: standard for multiple wafer carrier
- E6—Facilities Interface Specifications Guideline and Format: a guideline for suppliers for documenting the tool's facilities requirements
- E10—Standard for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)
- E58—Automated Reliability, Availability, and Maintainability Standard: standards for implementing and collecting SEMI E10 data on automated equipment
- E14—Measurement of particle contamination from tool: describes methods and procedures for determining the average particle contamination count due to wafer processing in the tool
- E15—Specification for Tool Load Port: standard for the interface between tools and wafer carrier transport systems (automated and human)
- E19.4—Standard Mechanical Interface: describes an interface for clean transfer of wafers from carrier to tool
- E23—Specification for Cassette Transfer Parallel I/O Interface: describes the interface between two pieces of equipment for cassette transfer
- E57—Kinematic Couplings for 300 mm Carriers: defines kinematic coupling dimensions
- Document 2472—300 mm Pod Dimensions
- Document 2502—300 mm Front Pod Door and Port
- Document 2708—Equipment Footprint and Height
- E35—Cost of Ownership Metrics: defines standard metrics and methods for evaluating the cost effectiveness of factory equipment
- E7—Specification for electrical interfaces (U.S. only)
- E33—Electromagnetic compatibility: standard for electromagnetic compatibility (EMC) of facilities and equipment

In some cases, the actual relevant standard may be E*x.y* rather than E*x*. Also, there may be additional standards and documents on ballot that are relevant, but not published at this time.

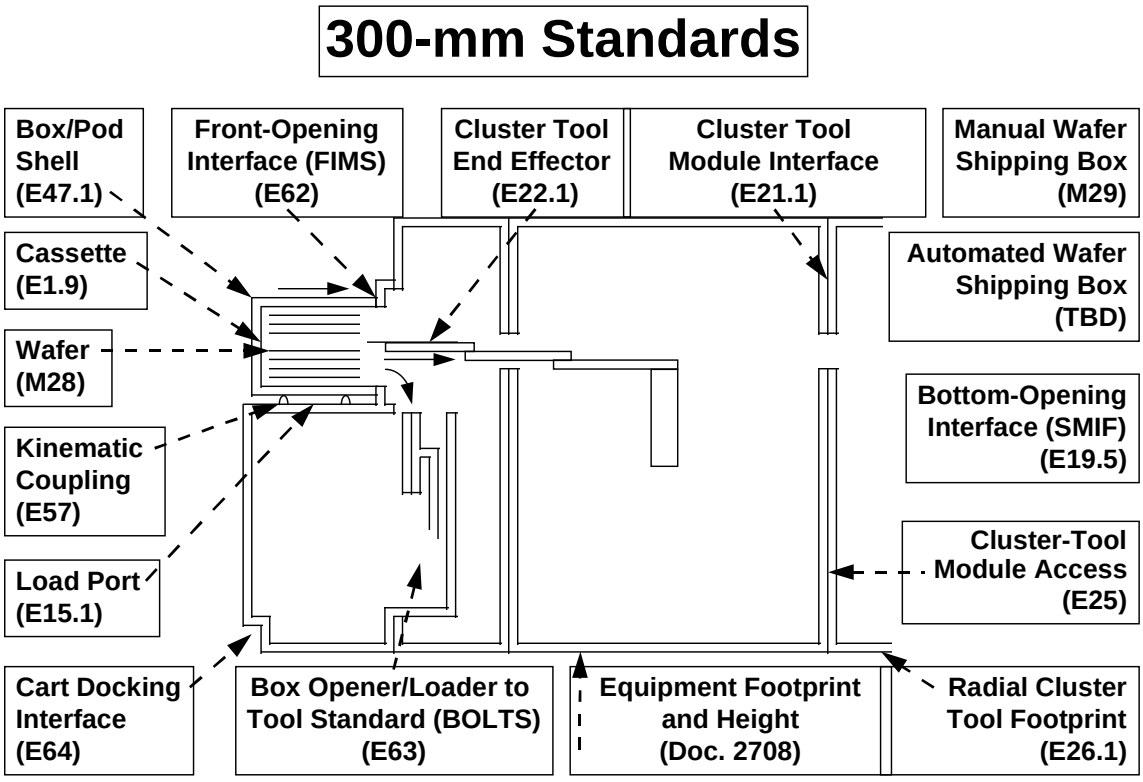

Figure 1 SEMI 200 mm Standards in Relation to Equipment Sites

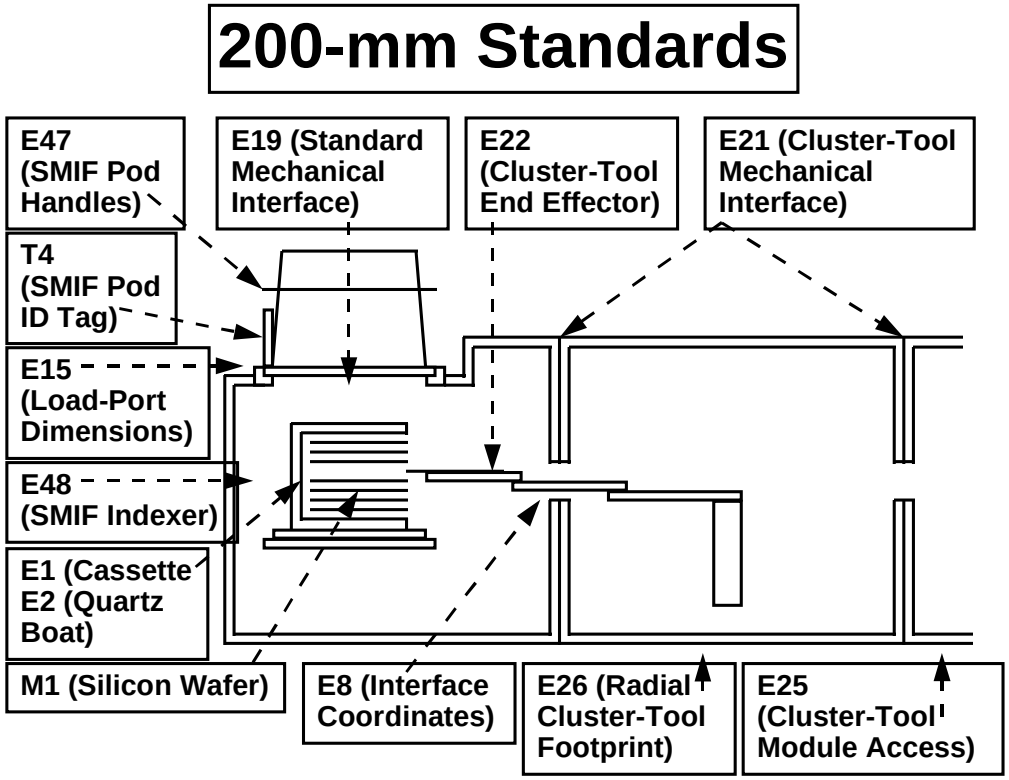

Figure 2 SEMI 300 mm Standards in Relation to Equipment Sites

8.2 Other

Other standards, guidelines and regulations may also apply, such as the following:

- OSHA
- EC (Europe)
- American National Standards Institute (ANSI)
- Other federal regulations
- Association guidelines or recommendations
- Site-specific requirements (such as lock out/tag out requirements, compliance with site safety standards, etc.)

9 SUPPLIER INTEGRITY, RELATIONS

9.1 Commitment to Quality

Determine the supplier's commitment to providing quality equipment and service. For example, review the following supplier capabilities:

- Responsiveness to requests
- Ability to quickly identify and resolve equipment problems
- Quality improvement programs
- Methods and plans to use test results to improve equipment design
- Adherence to guidelines and use of support and resources made available by SEMATECH's Software Process Improvement (SPI) Project and the SEI, for example.

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