300 mm Automation Software Compliance Testing

International SEMATECH
Technology Transfer # 00063970A-ENG

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Acroynms

The following acronyms are used in this document:

AGV – Automated Guided Vehicle

AMHS – Automated Material Handling System

CIM – Computer Integrated Manufacturing

EIATUG – Equipment Integration and Automation Test User's Group

FOUP – Front Opening Unified Pod

GEM – Generic Equipment Model

GEM300 – Generic Equipment Model for 300 mm Equipment

GJG – Global Joint Guidance

IC – Integrated Circuit

SECS – Semiconductor Equipment Communications Standard

Selete – SEmiconductor Leading Edge Technology (Japan)

SEM – Specific Equipment Model

SEMI – Semiconductor Equipment and Materials International

1 EXECUTIVE SUMMARY

With the adoption of new standards and guidelines for automation in 300 mm factories, new requirements have been placed on equipment software communication and control. Software implementations of these new requirements need to be verified for compliance and performance. The Equipment Integration and Automation Testing Users Group (EIATUG) was created under the direction of the Factory Integration Working Group (FIWG) in the Manufacturing Methods and Productivity Division at International SEMATECH (ISMT). The EIATUG charter is to define and make available test scripts to verify new standards-defined functionality compliance. This document presents a list of reports created under the EIATUG guidance through a contract with two software testing suppliers.

ISMT member companies defined the test plans for several reasons:

1. To provide suppliers and users with common test plans that enable member companies to understand the maturity levels of any equipment being considered for use in the factory.
2. To define test plans that can be used in member company procurement documents. This allows each member company to use the same test plan or baseline requirement, thus reducing the cost of implementing the functionality by unifying requirements from the user community.
3. To allow equipment suppliers to test their developing equipment implementations throughout the defined tests plans and process simulation (i.e., dry run). This shortens the software development process and reduces the supplier’s implementation cost.

2 INTRODUCTION

Full automation, common tool operation and standardization are the key drivers in the semiconductor industry to reduce cost and improve performance in factories. With the introduction of larger wafer sizes and requirements for automation and control, equipment has become not only more complex, but critical for day-to-day operations.

In the past, each semiconductor manufacturer specified individual factory scenario operations based on their corporate policies and procedures. To minimize the number of software implementations needing support from equipment suppliers, the industry decided to identify most of the common operations in a factory. Several areas of common operations were identified as candidates for standardization. Specific equipment models (SEMs) were specified for material handling (e.g., stocker, intrabay, interbay) as well as other models for controlling jobs and material in the equipment (e.g., control job management, carrier management and substrate tracking). With standardization came the need to verify compliance and functionality implemented. The EIATUG was chartered to develop common tests and scenarios for tool operation. These tests and scenarios will be used by the industry to verify compliance to the defined standards reducing the amount of individual tests and options when possible.

This document is intended to provide the reader with an overview of the deliverables from the EIATUG project and present these deliverables comprehensively. The list of deliverables from the EIATUG project presented in this document are currently listed at the ISMT public website and can be freely read and downloaded.

3 EIATUG MEMBERSHIP

The EIATUG focuses on formalizing the compliance testing process of equipment communications interfaces for all member companies. The chartered group participation is open to all ISMT members, and its current distribution list includes all consortium members. However, its current core participants are from IBM, Intel, Lucent Technologies, SC300 (Infineon/Motorola), and Texas Instruments. The EIATUG has been instrumental in the development of test specifications for verifying equipment compliance with the 300 mm software-based standards and operational scenarios.

3.1 Additional Participation

In addition to the EIATUG membership participation in the definition of scenarios, Japan's Semiconductor Leading Edge Technologies (Selete) has provided feedback and developed with ISMT examples of basic tool operation scenarios for fixed buffer and internal buffer tools. These scenarios have been included in the equipment operational flowchart document developed by the EIATUG.

The EIATUG also has worked actively with Semiconductor Equipment and Material International (SEMI), which has served as a forum and platform for driving standardization. Through SEMI and its committees, several documents have been updated and standardized, and are currently being adopted by equipment suppliers. A list and a brief description of these standards are included in this document as a reference to which standards the testing scripts and test plans cover.

4 300 mm GUIDELINES AND SOFTWARE COMMUNICATION RELATED STANDARDS

During the early development of factory guidelines and computer integrated manufacturing (CIM) related requirements for the 300 mm factories, semiconductor industry participants decided to create new documents and review existing ones to define the needs for full factory automation. The move to this full automation was predicated on the following factors:

- Substrate carriers are heavier for continuous lifting by operators during manufacturing shifts.
- The carrier content value is higher, making accidental dropping of carriers an expensive event.
- The cost of reprocessing, or the loss of wafers due to misprocessing, is much higher.
- Substrate contamination must be minimized.
- Equipment optimization and higher utilization are needed to recover high investment driven by tool cost.

4.1 Global Joint Guidelines

The International 300 mm Initiative (I300I) and the Japan J300E initiative have produced several documents that represent a strategy and approach for 300 mm factories' needs and requirements. While these documents are defined as guidelines, they are essential for implementations and definition of 300 mm factories. These documents include the following:

- *I300I Factory Guidelines: Version 5.0*, Technology Transfer # #97063311G-ENG; I300I, April 2000

- *CIM Global Joint Guidance for 300 mm Semiconductor Factories: Release 5,* Technology Transfer #98063534D-ENG; I300I and J300, April 2000
- *300 mm Integrated Vision for Semiconductor Factories: Release Three*, Technology Transfer #99013659C-ENG; I300I and J300E, November 1999

CIM Global Joint Guidance for 300 mm Semiconductor Factories is being used to guide the development of 300 mm software-based communication standards. This document lists several guidelines that are related to different aspects of automation. Each guideline listed in these documents specifies a high level requirement that is satisfied by a standard or set of standards. An example of a guideline from this document is shown in Figure 1.

1.2 Compliance to Communication Standards
Production equipment must comply with SECS-II standard messages to communicate with the Host. Production equipment must also use standard state models for control and data processing. Automation software products must comply with these same standard messages and state models when communicating with and controlling production equipment. HSMS Single Session Mode is a minimum requirement.

REQUIREMENTS:	3. International Participation is Essential 9. Increase Control of Factory Logistics and Production Scheduling 11.3 Factory Automation
STANDARDS:	SEMI E5, E30, E37, E37.1
REFERENCES:	I300I Factory Guideline 2.13
RECOMMENDATIONS:	Process equipment should be fully (100%) GEM capable. Metrology equipment should be fully GEM capable with the exception of Trace Data Collection and Limits Monitoring.

1.3 Utilization and Reliability Management
Production equipment must communicate utilization and reliability data to host systems using standard messages and state models. This is required to enhance data collection and analysis of equipment performance.

REQUIREMENTS:	5. Increase Equipment Utilization 17. Decrease Equipment Costs
STANDARDS:	SEMI E10, E58, and E58.1. Action required for SEMI to standardize light tower signal usage corresponding to ARAMS states and S2.
REFERENCES:	Not Applicable

Figure 1 Examples of Guidelines from I300I and J300E CIM GJG (Version 5.0)

4.2 SEMI Standards

In addition to the factory and CIM guidelines defined by the IC manufacturers, a set of standards pertaining to 300 mm automation also was developed and defined. A significant effort was made by several major IC makers to work together and determine a standardized approach toward several aspects of factory automation. Standards include both physical and logical requirements; for example, dimension of a loadport, exact size and thickness of a wafer, and communications between manufacturing equipment and factory host systems. By developing standardized interfaces, equipment behavior, and communication protocols, both equipment suppliers and IC makers are expected to realize cost/savings as well as reduced effort in communication interface implementation.

The CIM GJG identifies the use of standards for compliance to the guidelines. Some of these standards specify the requirements in functional areas with little or no direct relationship with each other. However, there are some implied relationships among the various standards. For instance, consider the standards for various material movement functions. While these standards do not necessarily require each other, some of them are needed to transport material to and from the equipment and to move material between pieces of equipment. These different aspects of the standards relationships are shown in Figure 2, which depicts the software-based standards and their domain or use in the equipment.

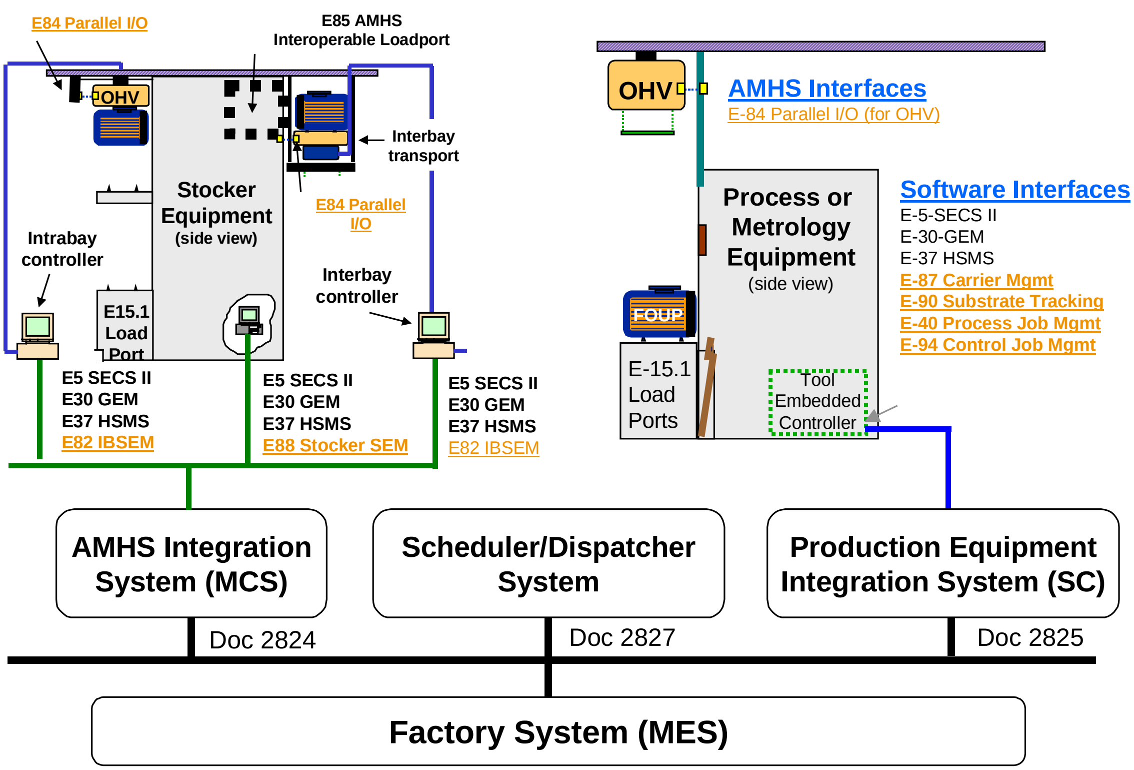

Figure 2 Functional Areas of the SEMI 300 mm Software Standards

Some of the standards related to 300 mm equipment communication and control that have been targeted for testing and verification for standard compliance by the EIATUG are listed in Table 1 below. These standards can be divided into two major groups: standards related to material handling, and standards related to production equipment. This distinction is shown later in this document and as part of the deliverables of the EIATUG project.

Table 1 lists the standards of interest in the EIATUG Project and provides a brief description of each document. These standards are discussed in relation to their functional area in subsequent sections within this document. There are other standards considered strictly hardware-based, as previously described (e.g., specifications for a loadport or dimensions for a 300 mm wafer) that are not listed here.

Table 1 SEMI Specification Descriptions

ID	Brief Title	Acronym	Description
E5	SEMI Equipment Communications Standard 2	SECS-II	Contains data and message formats that support defined messages in base standards.
E30	Generic Equipment Model	GEM	A generic approach to basic equipment behavior defined in the form of functional capabilities
E37.1	High Speed Messaging Service – Single Session	HSMS-SS	A standard interpretation of transmission control protocol/Internet protocol (TCP/IP) for a single session connection
E39	Object Services Standard	OSS	Provides a definition of objects and available generic services for manipulating the objects.
E40	Processing Management	PM	Describes the processing requirements for a set of wafers through process jobs.
E82	Intra/Inter Bay Specific Equipment Module	IBSEM	Provides scenarios with definition of events and messages to be used for communication with interbay and intrabay automation equipment
E84	Enhanced PI/O	EPIO	A 16-signal interface to support the actual handoff of carriers between the AMHS and equipment
E87	Carrier Management Standard	CMS	Describes the request for carrier handoff mechanisms as well as verification methods for carrier ID and slot map.
E88	Stoker Specific Equipment Model	STKSEM	Provides with a state model that represents the stocker equipment as view by the host. Defines messages and events to monitor and control the equipment
E90	Substrate Tracking Standard	STS	Provides mechanisms for tracking the transport and processing status of substrates (wafers) within the actual equipment.
E94	Control Job Management	CJM	Describes the scheduling requirements of process jobs through the use of control jobs.

All documents in Table 1 are available from SEMI at www.semi.org

5 COMPLIANCE TESTING

Compliance testing of equipment communication interfaces has become a necessary part of the development, test, and customer acceptance cycles. With communications interfaces becoming more complex and the IC makers' requirement for equipment that is compliant on the day of delivery, formal test processes become a necessity.

5.1 What is Compliance Testing?

There are many ways to measure how the equipment meets the needs of the IC maker. These needs typically are determined within standards, operational scenarios, or factory specifications. Meeting the requirements of these various specifications is defined as being compliant with them. Thus, suppliers and IC makers perform a process of compliance testing on the equipment prior to delivery, or during the early stages of factory installation.

The EIATUG is attempting to identify most ways the 300 mm standards will be used together in the factory, and incorporate them into test plans. The ultimate goal of the EIATUG is for a high percentage of possible equipment test cases to be incorporated into the test document. This will assist in suppliers' interpretation of the standards and reduce the amount of "custom" work done by the supplier. Common base scenarios also are helping to reduce the variations of tool operations. The EIATUG's current role is to advise on and review questions regarding test implementation, and continue driving standardization of tests for base tool operations.

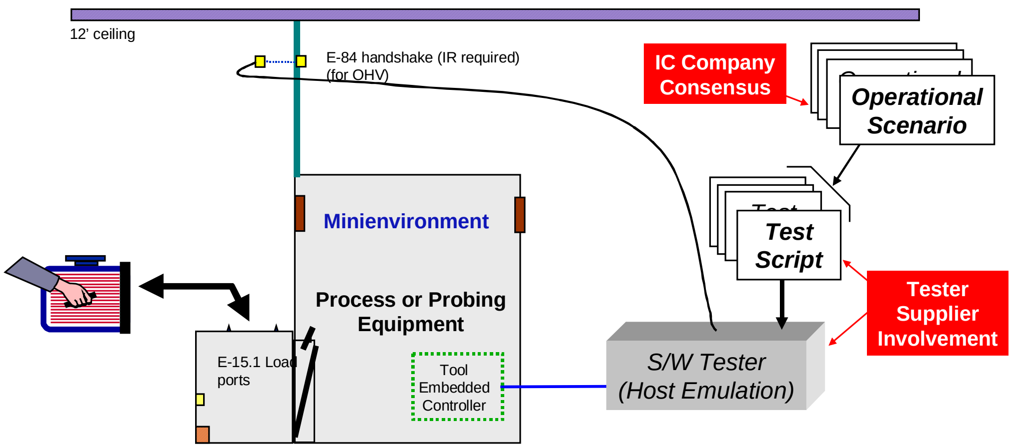

Figure 3 Testing Strategy

Figure 3 shows a view of the EIATUG testing strategy to be used during compliance testing. The idea is to make it easier for equipment suppliers and the IC maker to test for compliance. The tester can simulate signals required for handshake when automated material handling systems are not available. The tester also selects from a particular test case scenario that was derived from an industry consensus on a material movement and a processing selection. As the test case scenario is run, individual test scripts are executed that correspond to the particular scenario being tested. This strategy cuts down on the amount of tests being defined and tests cases to be validated. Validation of the defined tests is also a goal of the EIATUG project.

As part of the compliance testing, the EIATUG identified a need to separate some standards into their respective areas of applications. Two areas were selected: material handling equipment and production equipment. Material handling equipment includes all standards required to transport a carrier from one area in the factory to another, or from one piece of equipment to another. Production equipment includes all standards required to coordinate the acceptance of material into the equipment, as well as the processing and tracking of the material. To test equipment before it is delivered to the customer or before it has all the necessary process resources connected, the equipment must support dry run. Dry run requires the equipment to be able to simulate processing in some cases of compliance testing.

6 STANDARD TEST METHODS FOR MATERIAL HANDLING AND STORAGE EQUIPMENT

Material handling and storage equipment standards consist of three fundamental groups:

- Carrier Management

- Intrabay and Interbay Automated Material Handling
- Material Storage

This section describes the test areas and the standards tested. These deliverables are result of an ISMT contract with GW Associates.

6.1 Carrier Management

Carrier Management includes all the standards required for managing material carriers within production and material handling equipment. Two documents are of interest in this area: Carrier Management (SEMI E87) and Enhanced Parallel I/O Standards (SEMI E84). One document specifies the messages and protocols needed for the exchange of material that includes communications needed for interaction with the host systems; the other specifies the handshake signals required during the material exchange from one piece of equipment to another. The test plans measure the compliance to the following standards and guidelines.

6.1.1 Provisional Specification for Carrier Management (CMS) (SEMI E87)

This standard specifies the state models and main functionality required for carrier management. The test plan must measure the compliance to the state models and functionality defined in this document.

The test verifies the state models and the movement of carriers between and within production equipment. Some of the functionality defined includes carrier to loadport association, carrier ID and slot map verification, and movement of carriers to internal buffer, remote commands, and events.

6.2 Intrabay and Interbay Automated Material Handling

The industry in general has agreed that 300 mm semiconductor factories will be broken up into areas of tools known as bays. Movement of material within the bay is considered intrabay material handling. This movement may be from production tool to stocker, or production tool to production tool.

6.2.1 Intra/Interbay Specific Equipment Model (SEMI E82)

This standard specifies the state models and main functionality required for intrabay and interbay automated material handling equipment. The test plan measures the compliance to the state models and functionality defined in this document. Several scenarios are provided as part of the document and are used to define the test for compliance. Although the scenarios are considered examples to illustrate standard usage, they were chosen for verifying the compliance to the standard.

6.3 Material Storage

Storage devices known as stockers serve the bays described in the previous section. The stockers are used to store material for the process tools contained within the bay. The industry defined a specific equipment state model for this type of equipment and a set of remote messages. There are also scenarios defined within the standard that were chosen to be used by the test scripts to verify compliance to the standard.

6.3.1 Specification for AMHS Storage SEM (Stocker SEM) (SEMI E88)

This document defines the state models and main functionality required for material storage equipment. The test plan measures the compliance to the state models and functionality defined in this document.

7 STANDARD TEST METHODS FOR PRODUCTION EQUIPMENT

The following deliverables were required to satisfy and complete the tasks defined by the EIATUG project for production equipment testing. These deliverables are the result of a contract between ISMT and CCS Technologies:

- Unit Tests
- 300 mm Operational Flowcharts
- Round Trip Test Plans

7.1 Unit Tests

These documents detail the order and the messages that pass from the host simulator to the equipment (or equipment simulator) being tested. In addition to detailing the messages, the physical actions required by the equipment (to support the functional area, standard, or guideline), and methods for and timing of observing these actions are documented. The document also includes cross-references from the messages or group of messages used and the particular SEMI standard and CIM Global Joint Guidance or Factory CIM Guideline also addressed by the test.

Unit test specifications are test cases that exercise the fundamental capabilities defined within an individual standard. For example, in the case of E90 (Substrate Tracking), a test case outlines the SECS messages needed to pass between host and equipment to check for the value of a particular substrate attribute.

Example:

SEMI E90-0200 Substrate Tracking Unit Test (R00-Beta-001)

1. Test Procedure Setup for E90 Unit Test
2. E90 – Fundamental Requirements
    - 2.1. E90 – Status Variable Namelist Request
    - 2.2. E90 – Status Variable Request
    - 2.3. E87 – Collection Events
        - 2.3.1. Setup E87 Carrier Object State Model (COSM) Events
    - 2.4. E90 – Collection Events
        - 2.4.1. Setup E90 Substrate Object State Model (SOSM) Events
        - 2.4.2. Setup E90 Substrate Location Object State Model (SLSM) Events
    - 2.5. E90 – Create Substrate Object and Get Object Attributes
    - 2.6. E90 – Get Substrate Location Object Attributes from Equipment

Production Equipment testing includes three groups of unit tests:

- Process Management Unit Test
- Control Management Unit Tests
- Substrate Tracking Unit Test

7.1.1 Process Job Management Standard (SEMI E40)

Process Job Management includes the definition and specification of messages needed for the creation, execution, and management of jobs for the processing of materials, including single and multiple lots within production equipment.

7.1.2 Control Job Management Standard (SEMI E94)

Control Job Management defines a mechanism to define multiple process jobs and specify specific mechanisms for the handling of the material defined in the jobs. Control Job Management also includes mechanisms for the execution and management of the control Jobs. This includes communications and messages needed for interaction with the host systems.

This standard defines the state models and main functionality required for control job management. The test plans measure the compliance to the state models and functionality defined in these documents.

7.1.3 Substrate Tracking Standard (SEMI E90)

The equipment tracks and reports to the host the location of all substrates contained within the equipment or within carriers located on or at the equipment. SEMI E90 is used to specify this document. This standard defines the state models and main functionality required for substrate tracking.

7.2 300 mm Operational Flowcharts

To assist in the application and usage of the standards in actual processing scenarios, ISMT has developed a series of operational flowcharts that depict various operational conditions while utilizing the standards. The document that the EIATUG produced is the *International SEMATECH 300 mm Operational Flowcharts (Production Equipment.* This document contains flowcharts describing initialization, material movement, queue management and product processing. An example of a flowchart is shown in Figure 4. This document is designed for use by IC makers as-is, or as a guideline in developing their own operational scenarios.

The 300 mm operational flowcharts describe expected host/equipment interactions through the use of actions that incorporate the interleaving of the 300 mm standards. The actions and events defined in this document are examples of the standard-defined functionality. The flowcharts help visualize the sequential actions that the equipment might go through while operating. As part of the development of new factory guidelines and automation requirements for 300 mm substrate manufacturing process, operational scenarios were added. These scenarios, which were developed under ISMT/Selete collaboration, include two basic tool types: Fixed Buffer and Internal Buffer. These scenarios are being included in the *Operational Flowcharts* document.

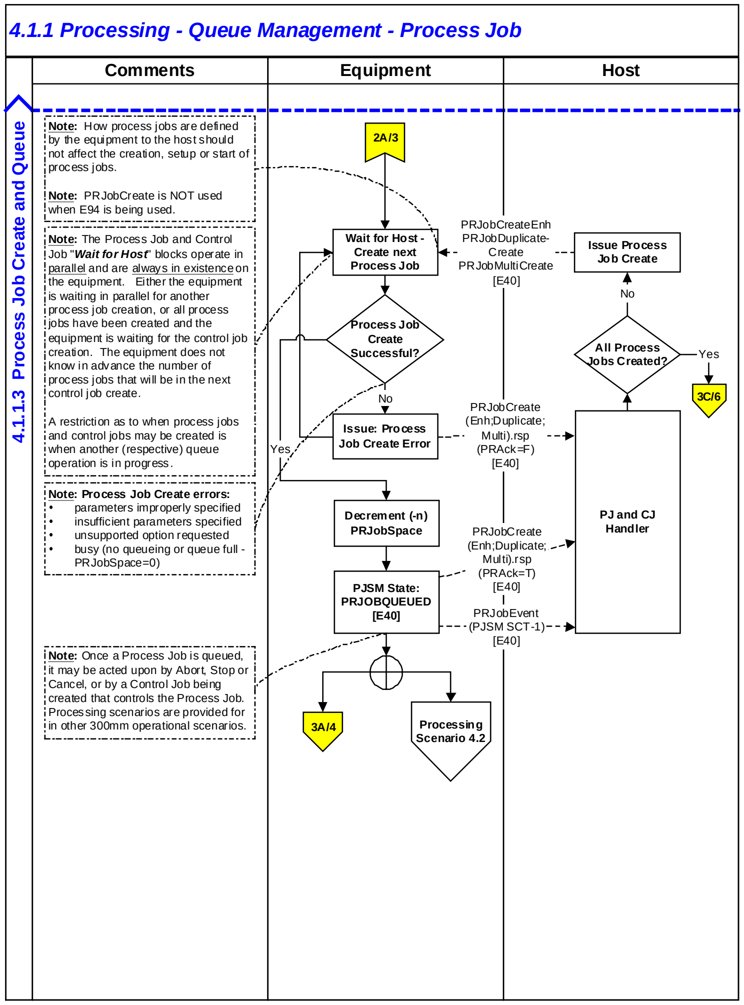

Figure 4 Example of 300 mm Operational Flowchart

7.3 Round Trip Test Plans

Round trip test specifications are test plans that are derived from the 300 mm equipment operational flowcharts and test for specific equipment configuration and functionality. These tests require Move in–Processing–Move Out operations.

The prior sections in this document described the static procedures on how to test for compliance with a series of messages or for logical existence of a state model. The procedures detailed above do not describe how to run dynamic tests on equipment to measure how well equipment complies with a particular set of standards. Since most of the factories would have minimal operator involvement, there will be requirements for automated delivery, host execution of jobs and recipe control, and finally automated pickup. The need to develop standard methods of testing was key to ISMT member companies and a primary objective of the EIATUG.

Each test level is guided by test plans, which is a series of test cases. A test case is a well-defined set of data, steps, and algorithms necessary to verify a set of related requirements. By taking a series of test cases and placing them in a specified order, the requirements of the module or system are verified in a pre-defined, repeatable manner.

Typically, a test plan is divided into sections or groups of test cases according to functional areas. This structure is depicted in Figure 5.

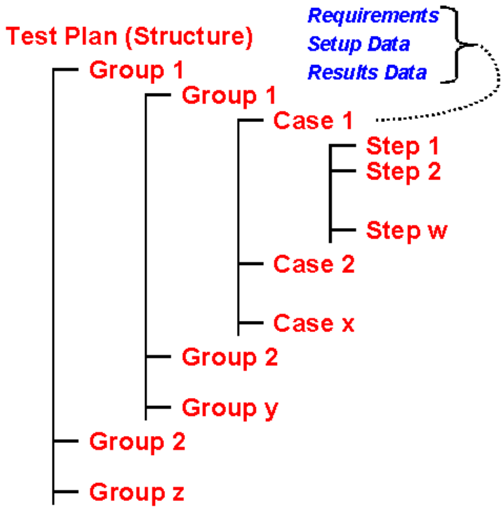

Figure 5 Test Plan Structure

An example of how a test plan works is depicted in Figure 6. In this example, a carrier is being automatically delivered and automatically started through a method defined in the process job.

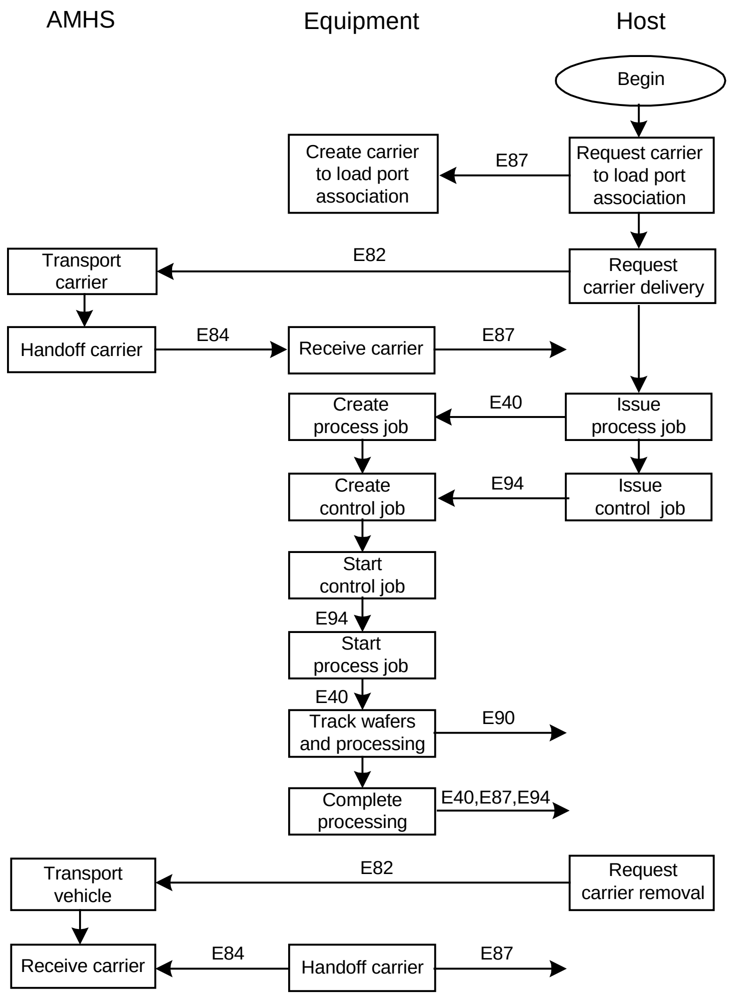

Figure 6 Round Trip Example – Auto Delivery, Auto Start

8 DOCUMENT AVAILABILITY

Several of the documents mentioned in this report are available through the ISMT public website at http://www.sematech.org/public/resources/300mm/methods.htm. Additional information on production equipment compliance testing is available at the sites of GW Associates (www.gwa.com) and CCS Technologies (www.ccstechnology.com).

8.1 Document Development

The EIATUG provided direction to CCS Technologies and GW Associates in the development of the testing documents. The tool operational scenarios contain flowcharts that describe expected equipment behavior. In some cases, EIATUG members included additional equipment behavior not explicitly defined in the standards. The equipment behavior provided in the flowcharts is based on the participating member company interpretation of the standards and guidelines for implementation.

8.2 Document Status

These are draft documents provided as an example for purposes of specifying test cases to verify compliance of equipment and AMHS software with communications standards and guidelines. The AMHS test method documents are based on 1999 versions of the SEMI standards. These standards have been updated recently, and future revisions of these tests are currently under consideration.

Several of these documents have not been validated for full functionality to the standards. Part of the project outcome is the validation of these tests by using actual tools. These validation tests will be published as part of the project. The current timeframe for publishing the results is the end of 3Q 2000. Tool availability and software implementations will determine the completion of these tests.

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