13.4 At the short circuit termination, the measurement shall be made up to the point where the falling edge of the impedance is equal to 90 percent of the nominal impedance. For example, if the nominal impedance is 50 ohms, then the measurement can stop at the point where the measured value at the short circuit termination is equal to 45 ohms ($0.9 \times 50 = 45$). An example plot showing the measurement termination point is shown in Figure 5.

NOTE 1: The termination point can be verified by disconnecting the short circuit termination and observing that the impedance increases rapidly due to the open circuit.

14 Reporting Test Results

14.1 Report the type of Network Analyzer and the details of the Network Analyzer parameters used for the tests, including the bandwidth, the number of data points, the test frequency, and the frequency span (if any). An example data sheet is shown in Table 1.

14.2 Report the type of Time Domain Reflectometer used for the test.

14.3 Report the length of the cable assembly in terms of degrees at the nominal operating frequency.

14.4 Report the power dissipation in terms of dB (decibels) and percentage of power transfer.

14.5 Report the variation in characteristic impedance in terms of the minimum and maximum after the values have been scaled according to the reference 50-ohm load.

15 Related Documents

15.1 *IEEE Standards*[1]

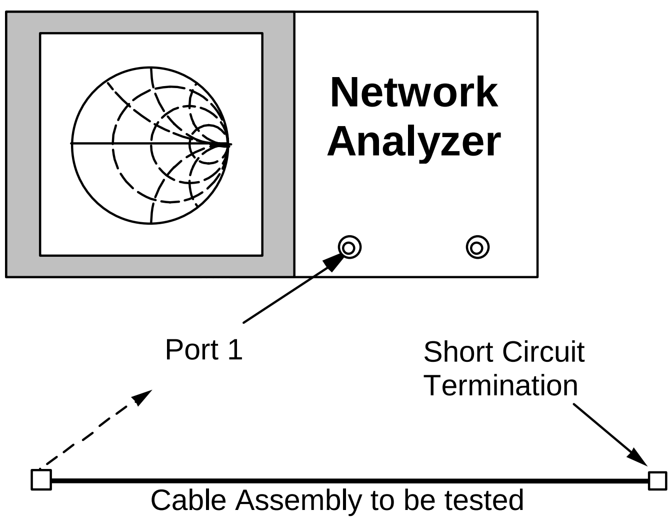
IEEE-STD-572 — IEEE Standard for Qualification of Class 1E Connection Assemblies for Nuclear Power Generating Stations

15.2 *MIL-Specifications*[2]

MIL-PRF-31031A — General Specification for Connectors, Electrical, Plugs and Receptacles, Coaxial, Radio Frequency, High Reliability, for Flexible and Semirigid Cables

MIL-STD-348A — Radio Frequency Connector Interfaces for MIL-C-3643, MIL-C-3650, MIL-C-3655, MIL-C-25516, MIL-C-26637, MIL-PRF-39012, MIL-PRF-49142, MIL-PRF-55339, and MIL C-83517

MIL-STD-220B — Test Method Standard: Method of Insertion Loss Measurement



NOTE: The reflection coefficient calibration is at the Port 1 output. The cable assembly to be tested (DUT) attaches to Port 1 and is terminated with a short circuit.

Figure 1
Schematic of the Network Analyzer Test Setup for the Electrical Length Measurement

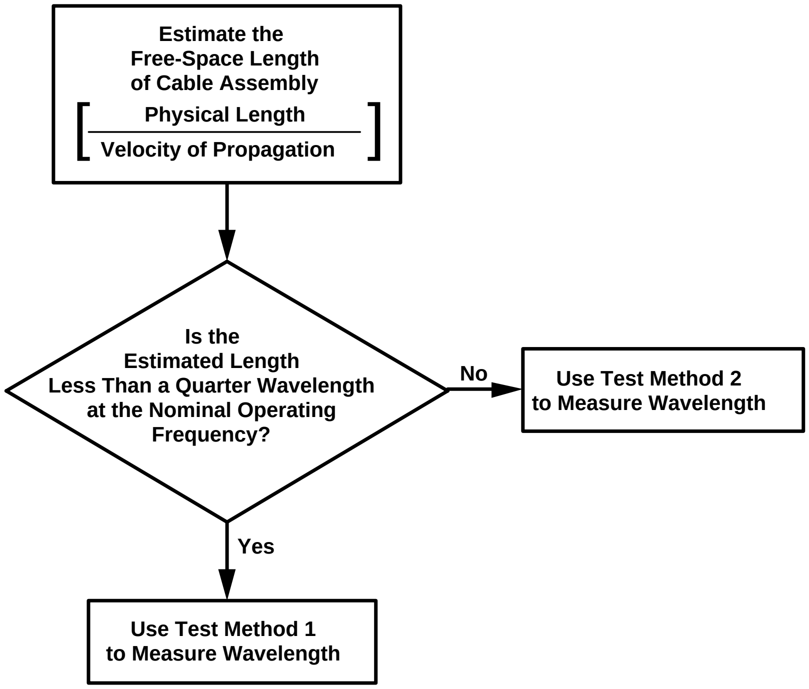
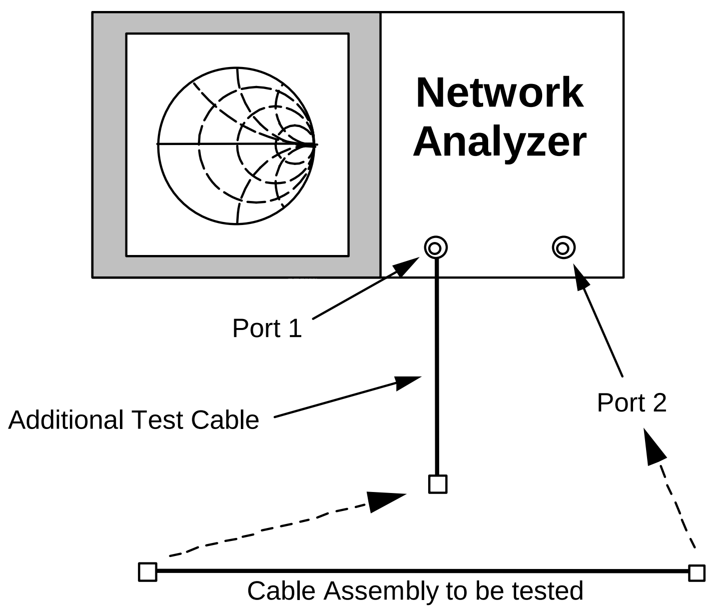
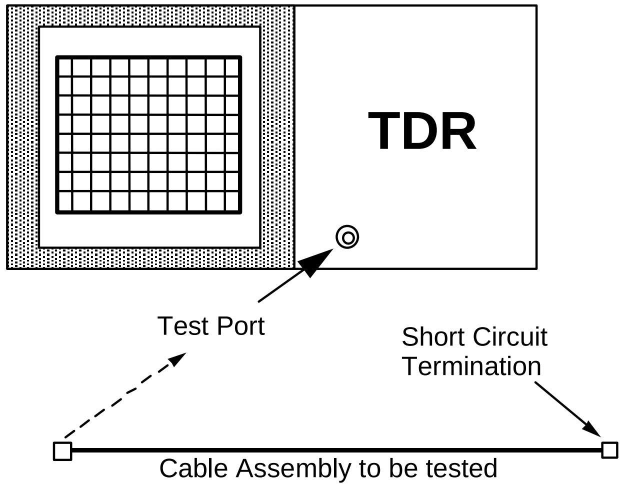


Figure 2
Flow Chart Showing the Steps to Chose the Appropriate Test Method for Determining Electrical Length of the Cable Assembly



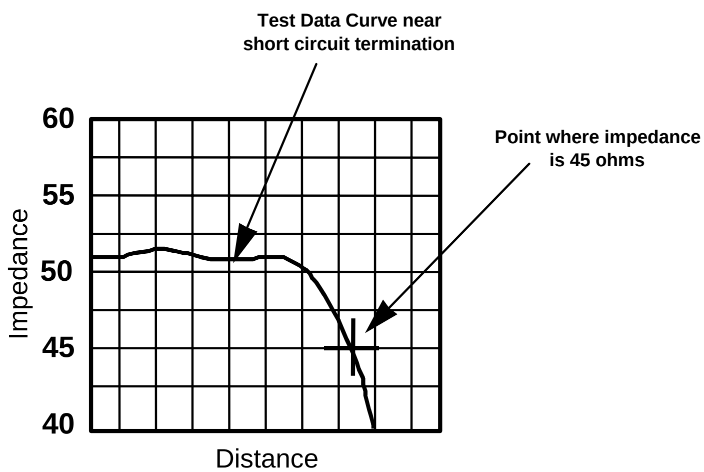
NOTE: Both the Port 1 and Port 2 outputs need to be used for the measurement. An additional test cable is needed for the transmission calibration between the two ports. The cable assembly to be tested (DUT) attaches between the additional test cable on Port 1 and Port 2.

Figure 3
Schematic of the Network Analyzer Test Setup for the Power Dissipation (loss) Measurement



NOTE: The cable assembly to be tested (DUT) attaches to the test port and is terminated with a short circuit.

Figure 4
Schematic of the Time Domain Reflectometer (TDR) Test Setup for the Characteristic Impedance Measurement



NOTE: The measurement termination point is defined as where the impedance at the short is equal to 0.9 times the nominal impedance value, which would be 45 ohms for a 50-ohm nominal impedance.

Figure 5
Example Plot of the Characteristic Impedance of a 50-ohm Cable Assembly Near the Short Circuit Termination

Table 1 Example Data Table for Presenting the Test Methods Parameters

Cable Length Test				
Instrument Parameters				
Model Number	Bandwidth (Hz)	Frequency (MHz)	Test Method (1 or 2)	Cable Assembly Length (°)
Power Loss Test				
Instrument Parameters				
Model Number	Bandwidth (Hz)	Frequency (MHz)	Loss (dB)	Power Transferred (%)
Characteristic Impedance Test				
Instrument Model Number	Normalization Factor	Minimum Impedance	Maximum Impedance	

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SEMI E115-0302^E
TEST METHOD FOR DETERMINING THE LOAD IMPEDANCE AND EFFICIENCY OF MATCHING NETWORKS USED IN SEMICONDUCTOR PROCESSING EQUIPMENT RF POWER DELIVERY SYSTEMS

This test method was technically approved by the Global Metrics Committee and is the direct responsibility of the North American Metrics Committee. Current edition approved by the North American Regional Standards Committee on March 30, 2002. Initially available at www.semi.org June 2002; to be published July 2002. Previously published March 2002.

^E This document was editorially modified in May 2002 to correct an errata. A change was made in Section 1.1.

1 Purpose

1.1 The purpose of this document is to define a test method used to determine the load impedance and efficiency of matching networks used in RF power delivery systems for semiconductor processing equipment.

2 Scope

2.1 This document specifies the testing procedures and test equipment required for determining the load impedance and power efficiency of a matching network based on the positions of the tuning elements in the matching network.

2.2 The primary focus for this specification is semiconductor processing equipment including, but not limited to, the following tool types:

- Dry etch equipment,
- Film deposition equipment (CVD and PVD).

2.3 This standard does not address any safety or performance issues related to RF emissions or electrical codes (e.g., Underwriter's Laboratory, Inc. (UL), the National Electrical Code (NEC®), Federal Communications Commission (FCC)). It is the responsibility of the users of this standard to conform to the appropriate local codes and regulations as applied to this type of equipment, some of which are covered by referenced documents.

2.4 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 This standard addresses RF Matching Networks used in RF systems that primarily operate in the frequency range of 0.2–100 MHz. It does not address higher frequency RF systems or microwave systems.

3.2 This standard is meant for analyzing matching networks that are designed to operate at fixed frequency with a 50-ohm input impedance.

3.3 International, national, and local codes, regulations and laws should be consulted to ensure that the equipment and procedures meet regulatory requirements in each location.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E113 — Specification for Semiconductor Processing Equipment RF Power Delivery Systems

4.2 *IEEE Standards*[1]

IEEE-STD-383 — IEEE Standard for Type Test of Class 1E Electrical Cables, Field Splices, and Connections for Nuclear Power Generating Stations

4.3 *Military Standards*[2]

MIL-PRF-39012D — General Specification for Connectors, Coaxial, Radio Frequency

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *CVD* — Chemical Vapor Deposition

5.1.2 *PVD* — Physical Vapor Deposition

5.1.3 *VSWR* — Voltage Standing Wave Ratio

5.2 *Definitions of Terms*

5.2.1 *complex conjugate load impedance* — the complex conjugate load impedance has the same real part of the load impedance and the negative of the reactive part of the load impedance. For example, the

1 Institute of Electrical and Electronics Engineers, IEEE Operations Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, New Jersey 08855-1331, USA. Telephone: 732.981.0060; Fax: 732.981.1721

2 Available through the Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120-5099, USA. Telephone: 215.697.3321

complex conjugate of a load impedance of 2.0 – j20 ohms would be 2.0 + j20 ohms.

5.2.2 *device under test (DUT)* — the matching network to be tested.

5.2.3 *harmonic frequency* — the harmonic frequencies are defined as integer multiples of the fundamental frequency. For example, the second harmonic of 13.56 MHz is 27.12 MHz.

5.2.4 *"L" type matching network* — this type of network consists of a tuning element that is connected to ground, which is often a variable capacitor, and another tuning element that is in series with the output connection. The series section of the "L" matching network typically consists of an inductor and a capacitor, one of which is variable.

5.2.5 *load and tune position* — for some matching networks, the tuning elements are referred to as the *Load Position* and the *Tune Position*. This terminology is common for "L" type matching networks, which have a tuning element that is connected to ground and another tuning element that is in series with the output connection. The *Load Position* corresponds to the tuning element that is grounded and is associated with matching to the real part of the load impedance. The *Tune Position* corresponds to the tuning element that is in series with the output and is associated with matching to the reactive part of the load impedance.

5.2.6 *load impedance* — the load impedance is the impedance to which a matching network is matched.

5.2.7 *load impedance simulator* — the Load Impedance Simulator is a device that presents a load impedance to which a matching network can match. Details of a typical Load Simulator can be found in the Related Information section of this test method.

5.2.8 *matched input impedance* — a matched load impedance is defined as typically having a magnitude of 50 ± 3.3 ohms at a phase angle of up to ± 3.8 degrees. In other words, the load is considered matched if the reflection coefficient is no greater than 0.032 at any phase angle.

5.2.9 *matching network* — the device used to transform the impedance of the load (chamber/chuck) to match the impedance of the generator/cable assembly, which is typically 50 ohms.

5.2.10 *power efficiency* — the ratio of the power exiting the matching network divided by the power entering the matching network.

5.2.11 *S-parameters* — the scattering matrix used to describe a network. The reflection coefficient is the S11 parameter and the transmission coefficient is the S21 parameter.

5.2.12 *tuning element position* — the position of the tuning element is defined as the output voltage or output encoder value that corresponds to the position of a variable tuning element in a Matching Network. For example, the voltage from a rotary potentiometer on the rotating shaft of a variable capacitor (the "Tuning Element") would be referred to as the capacitor's "Position". In this example, the position/voltage corresponds to a certain shaft location or position.

6 Test Apparatus

6.1 *RF Vector Network Analyzer* — The Network Analyzer is used to measure the load impedance and efficiency of the matching network. The Network Analyzer requires vector capability so that both the magnitude of phase of the reflection coefficient and transmission coefficient can be measured at the operating frequency. The Network Analyzer shall have an up-to-date calibration per the manufacturer.

6.2 *Coaxial Output Adapter* — An adapter to convert the output connection of the matching network to a standard coaxial interface is required for some of the tests.

6.3 *RF Adapters and Terminations* — Various adapters may be necessary to convert between different types of coaxial connectors (e.g., type N to type HN adapters, etc.). All adapters used shall have the same nominal characteristic impedance as the system, which is typically 50 ohms. For some measurements, additional coaxial cable assemblies are used. These cable assemblies shall also be of the same nominal characteristic impedance as the system. Standard terminations are also used, such as shorts, opens, and precision 50-ohm loads.

6.4 *RF Load Impedance Simulator* — A device that can be attached to the output of the DUT to act as a load for the DUT is required for some of the measurements. The load simulator shall have an impedance range to match a minimum of 80% of the tuning space of the matching network to be tested.

7 Safety Precautions

7.1 Work should be conducted in accordance with local safety requirements and test device manufacturer recommended safety procedures. The tests described in this document involve using low output power test instrumentation (typically less than 10 milli-Watt).

7.2 The area immediately surrounding the Test Setup shall be keep free and clear of unnecessary equipment and materials.

8 Test Setup for Determining Load Impedance and Efficiency

8.1 Two test methods are described for analyzing matching networks. The first method for determining the load impedance and efficiency measures the complex conjugate of the load impedance and then corrects for the matching network losses to determine the load impedance and efficiency. A schematic of the Test Setup is shown in Figure 1. The method uses a Network Analyzer to measure the reflection coefficient, which is related to the load impedance, and the transmission coefficient, which is related to the efficiency. The Test Setup for this approach consists of the Network Analyzer, the matching network to be tested (DUT), coaxial test cables, and the appropriate adapters (if any) to connect the DUT to the Network Analyzer.

8.2 The second method for determining the load impedance and efficiency uses a Load Impedance Simulator attached to the output of the matching network. A schematic of the Test Setup is shown in Figure 2. The Test Setup for this approach consists of the Network Analyzer, the matching network to be tested (DUT), the load simulator, coaxial test cables, the appropriate adapter (if any) to connect the DUT to the Network Analyzer, and the appropriate adapter to connect the load simulator to the DUT.

8.3 Prior to making any measurements, the Network Analyzer shall be turned on and allowed to warm up before the testing is to take place. This time will allow for electronics to come to a stable operating condition for the measurements.

9 Test Procedure for Determining Load Impedance and Efficiency

9.1 Two test procedures can be used to determine the load impedance and efficiency of the matching network. The first method is designed for "L" type matching networks, where the losses are dominated by the loss resistance of the inductor that is in series with the load impedance. For the case where there are finite losses in the shunt capacitor, the capacitor losses can be lumped in with the inductor losses without introducing significant error (usually less than 0.5% for typical values of < 0.1 ohms). Lumping the total losses into an overall series loss will also cause a slight shift in the reactive part of the impedance, but the magnitude of the shift is on the same order as the impedance measurement uncertainty and can be ignored.

9.2 The second method is designed for other matching network types and uses a load simulator to determine the load impedance and efficiency.

9.3 *Test Method 1 for Determining Matching Network Load Impedance and Efficiency*

9.3.1 This test method shall be used for "L" type matching networks of the type shown schematically in Figure 1, where the losses in the network are dominated by the loss resistance of the inductor, RLOSS. The efficiency for this type of matching network is given as

$$Eff = \frac{RLOAD}{RLOAD + RLOSS} \qquad (1)$$

where *RLOAD* refers to the real part of the load impedance and *RLOSS* refers to the losses of the matching network.

9.3.2 For this type of network, the real part of the complex conjugate impedance, Re(*Zout**), contains the real part of the load impedance plus twice the loss resistance, *RLOSS*.

$$\mathrm{Re}(Zout^*) = RLOAD + 2RLOSS \qquad (2)$$

9.3.3 The load impedance, therefore, is equal to the complex conjugate impedance less twice the loss resistance (along with the sign change of the reactive part of the conjugate impedance). For example, if the conjugate impedance is measured as 3 + j20 and RLOSS is determined to be 0.5 ohms, then the load impedance is 2 – j20 ohms.

9.3.4 The efficiency of the matching network and the loss resistance, *RLOSS*, can be determined by measuring both the transmission coefficient, S21, and the reflection coefficient, S11, in the Test Setup shown in Figure 1. Note that the reflection coefficient measurement, S11, is equivalent to measuring the complex conjugate impedance. If the matching network is considered as a test load with an impedance equal to the complex conjugate impedance, then the loss resistance is found by measuring the efficiency of the test load. This efficiency, *Effm*, can be expressed as

$$Effm = \frac{\mathrm{Re}(Zout^*) - RLOSS}{\mathrm{Re}(Zout^*)} \qquad (3)$$

where Re(*Zout**) is the real part of the complex conjugate load impedance, *Zout**. The measured efficiency, *Effm*, can be determined from the S21 and S11 measurements (as shown later in this section). Thus, the measurements of Re(*Zout**) and *Effm* can be used to determine *RLOSS* as

$$RLOSS = \mathrm{Re}(Zout^*) \times (1 - Effm) \qquad (4)$$

and the load impedance and power efficiency of the matching network can then be determined from

$$Effc = \frac{\mathrm{Re}(Zout^*) - 2RLOSS}{\mathrm{Re}(Zout^*) - RLOSS} \qquad (5)$$

$$RLOAD = \mathrm{Re}(Zout^*) - 2RLOSS \quad (6)$$

$$XLOAD = -\mathrm{Im}(Zout^*) \quad (7)$$

where *Effc* is the calculated power efficiency based on the measurement of Re(*Zout**) and *Effm*, *RLOAD* is the real part of the load impedance, and *XLOAD* is the imaginary part of the load impedance.

9.3.5 Calibrate the Network Analyzer at the desired operating frequency (e.g., 13.56 MHz). The Network Analyzer shall be calibrated for measuring the reflection coefficient at test Port 1 and for measuring the transmission coefficient at test Port 2 (see Figure 1) using the calibration kit provided with the Network Analyzer. This measurement requires measuring the S11 and S21 S-parameters and requires a full 2-port calibration. The calibration shall be performed at fixed frequency (continuous-wave operation) using the lowest bandwidth possible (typically 10 Hz). The calibration for each port shall include the additional test cables and any additional adapters.

9.3.6 After calibration of the Network Analyzer, the cable connected to Port 1 of the Network Analyzer shall be connected to the output of the DUT. The cable connected to Port 2 of the Network Analyzer shall be connected to the input of the DUT.

9.3.7 The tuning elements shall be moved to their minimum positions before the measurement is initiated. After all connections are visually inspected for proper contact and the Network Analyzer has stabilized, the value of the complex conjugate impedance (*Zout**), the magnitude of the reflection coefficient (S11), and the magnitude of the transmission coefficient (S21) shall be recorded.

9.3.8 The efficiency when the DUT is viewed as a test load, *Effm*, is determined from both the reflection and transmission coefficients. The efficiency can be calculated by taking the ratio of the output power divided by the input power. The output power is simply $(S21)^2$ and the input power is $(1\text{-}(S11)^2)$.

$$Effm = \frac{(S21)^2}{1-(S11)^2}$$

Typically, the reflection and transmission coefficients are expressed in terms of dB (decibels). The conversion between dB and efficiency is expressed as

$$Effm = \frac{10^{(\mathrm{S21\,in\,dB}/10)}}{1-10^{(\mathrm{S11\,in\,dB}/10)}}$$

For example, if the transmission coefficient is measured to be –10.2 dB and the reflection coefficient is measured to be –0.61 dB, then *Effm* would be 0.7288. The efficiency based on this measurement can then be used to calculate *RLOSS*, *Effc*, *RLOAD*, and *XLOAD* by using the equations previously shown. All of these calculated numbers using equations 3–6 shall be recorded, as well as the positions of the tuning elements of the matching network.

9.3.9 For the next measurement, Tune Position shall remain fixed, and the Load Position shall be increased by an increment equal to no more than 10% of the full-scale range of the tuning element position. For example, if the range of the tuning element is 10 volts, then the tuning element should be moved in increments of no greater than 1 volt. A smaller increment shall be used for the case where the incremental change in Load Position results in an incremental impedance change of more than 20% of the total impedance variation measured by the full-scale variation of the Load Position. For example, if the real part of the load impedance varies 15 ohms over the 10 volt variation of the Load Position, then a smaller Load Position increment shall be used if the real load impedance varies by more than 3 ohms between increments ($0.2 \times 15 = 0.3$). After the tuning elements have been moved to their new values, the previous measurement steps shall be repeated.

9.3.10 After the Load Position has been varied over its entire range, the Tune Position shall be increased by an increment equal to no more than 10% of the full-scale range of the tuning element position. The Load Position shall be moved back to its minimum position and the above steps shall be repeated until the entire tuning range of the matching network is measured.

9.3.11 The data shall be recorded and then presented in both graphical and tabular forms. An example of a typical impedance range graph is shown in Figure 3 for the real load impedance and in Figure 4 for the reactive load impedance. An example of a typical efficiency plot is shown in Figure 5. An example of data presented in tabular form is shown in Table I.

9.4 *Test Method 2 for Determining Matching Network Load Impedance and Efficiency*

9.4.1 This test method shall be used for matching networks that are not necessarily dominated by a series loss resistance as in an ideal "L" type network. This method uses a Load Simulator(s) attached to the DUT and assumes that the DUT has two tuning elements. The Load Simulator(s) shall have a tuning range that will cover no less than 80% of the tuning range of the matching network. Details of a typical Load Simulator can be found in the Related Information section of this Test Method. The test method outlined here assumes that the Load Simulator(s) contains variable tuning elements with position indicators to allow the load impedance to vary. An example of a load simulator would be a matching network used in reverse, where the output of the DUT would attach to the output of another matching network.

9.4.2 Calibrate the Network Analyzer at the desired operating frequency (e.g., 13.56 MHz). The Network Analyzer shall be calibrated for measuring the reflection coefficient at test Port 1 and for measuring the transmission coefficient at test Port 2 (see Figure 1) using the calibration kit provided with the Network Analyzer. This measurement requires measuring the S11 and S21 S-parameters and requires a full 2-port calibration. The calibration shall be performed at fixed frequency (continuous-wave operation) using the lowest bandwidth possible (typically 10 Hz). The calibration for each port shall include the additional test cables and any additional adapters.

9.4.3 After calibration of the Network Analyzer, the test cable connected to Port 1 of the Network Analyzer shall be connected to the input of the matching network to be tested (DUT). The Load Simulator shall be connected to the output of the DUT. The cable connected to Port 2 of the Network Analyzer shall be connected to the output of the Load Simulator.

9.4.4 The tuning elements shall be moved to their minimum positions (or the positions that can match to lowest tuning point of the Load Simulator(s)) before the measurement is initiated. The variable elements in the Load Simulator shall be adjusted until the input impedance of the matching network is matched (i.e., input impedance = 50 ohms). After all connections are visually inspected for proper contact and the Network Analyzer has stabilized, the value of the input impedance and the magnitude of the transmission coefficient (S21) shall be recorded. In addition, the positions of the tuning elements of the DUT and the Load Simulator shall be recorded.

9.4.5 The load impedance of the DUT corresponds to the input impedance of the Load Simulator. At this point in the process, the Load Simulator can be disconnected and its input impedance can be measured. Alternatively, the input impedance can be measured later by moving the Load Simulator tuning element values to the positions recorded in Section 9.4.4.

9.4.6 The efficiency of the Test Setup, which includes the DUT and the Load Simulator, is determined from the transmission coefficient. Typically, the transmission coefficient is expressed in terms of dB (decibels). The conversion between dB and percentage is expressed as:

$$Efficiency(\%) = 100 \times 10^{(\text{loss in dB}/10)}$$

For example, if the transmission coefficient is measured to be –3 dB, then the power transfer efficiency would be 50.1%. In other words, 49.9% of the power is lost in the Test Setup.

9.4.7 The efficiency of the DUT is determined by dividing the efficiency of the Test Setup by the efficiency of the Load Simulator. For example, if the efficiency of the Test Setup is 70% and the efficiency of the Load Simulator is 90%, then the efficiency of the DUT is 77.8% (0.7/0.9). The efficiency of the Load Simulator is typically determined separately (see Related Information Section at the end of this Test Method).

9.4.8 For the next measurement, one tuning element (element 1) shall remain fixed, and the other tuning element (element 2) shall be increased by an increment equal to no more than 10% of the full scale range of the tuning element position. For example, if the range of the tuning element is 10 volts, then the tuning element shall be moved in increments of no greater than 1 volt. A smaller increment shall be used for the case where the incremental change in tuning element position results in an incremental impedance change of more than 20% of the total impedance variation measured by the full-scale variation of the tuning element. For example, if the real part of the load impedance varies 15 ohms over the 10 volt variation of the tuning element, then a smaller tuning element increment shall be used if the real load impedance varies by more than 3 ohms between increments ($0.2 \times 15 = 0.3$). After the tuning elements have been moved to their new values, the previous measurement steps shall be repeated.

9.4.9 After the tuning element (element 2) has been varied over its entire range, the other tuning element (element 1) shall be increased by an increment equal to no more than 10% of its full-scale range. Tuning element 2 shall be moved back to its minimum position and the above steps shall be repeated until the entire tuning range of the matching network is measured.

9.4.10 The data shall be recorded and then presented in both graphical and tabular forms. An example of a typical impedance range graph is shown in Figure 3 for the real load impedance and in Figure 4 for the reactive load impedance. An example of a typical efficiency plot is shown in Figure 5. An example of data presented in tabular form is shown in Table 1.

10 Reporting Test Results

10.1 Report the type of Network Analyzer and the details of the Network Analyzer parameters used for the tests, including the bandwidth, the number of data points, and the test frequency. Also report which Test Method was used.

10.2 Report the matching network load impedance and efficiency as a function of tuning element positions. The data shall be presented in both graphical and tabular forms.

11 Related Documents

11.1 *IEEE Standards*[1]

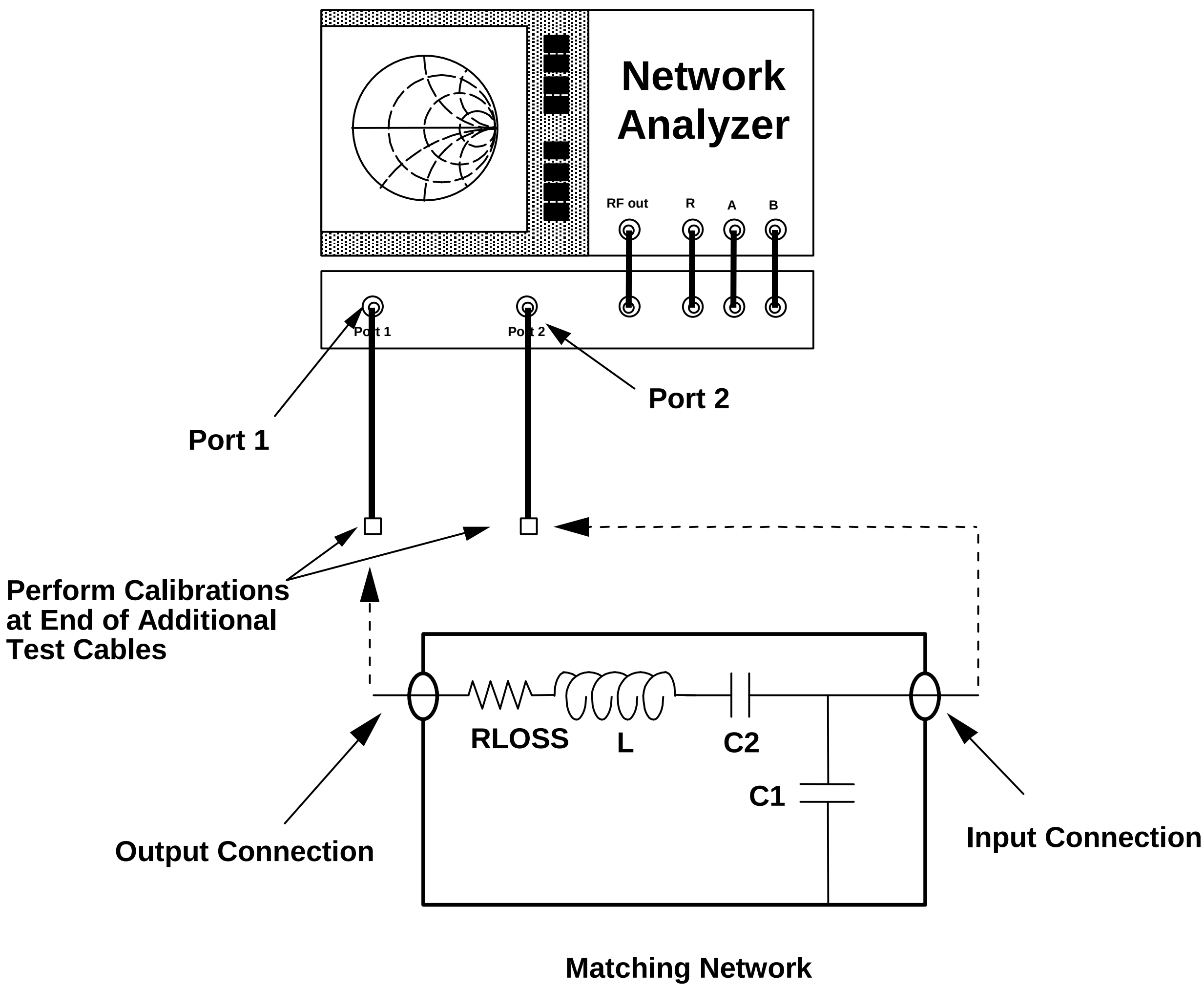
IEEE-STD-572 — IEEE Standard for Qualification of Class 1E Connection Assemblies for Nuclear Power Generating Stations

11.2 *Military Standards*[2]

MIL-PRF-31031A — General Specification for Connectors, Electrical, Plugs and Receptacles, Coaxial, Radio Frequency, High Reliability, for Flexible and Semirigid Cables.

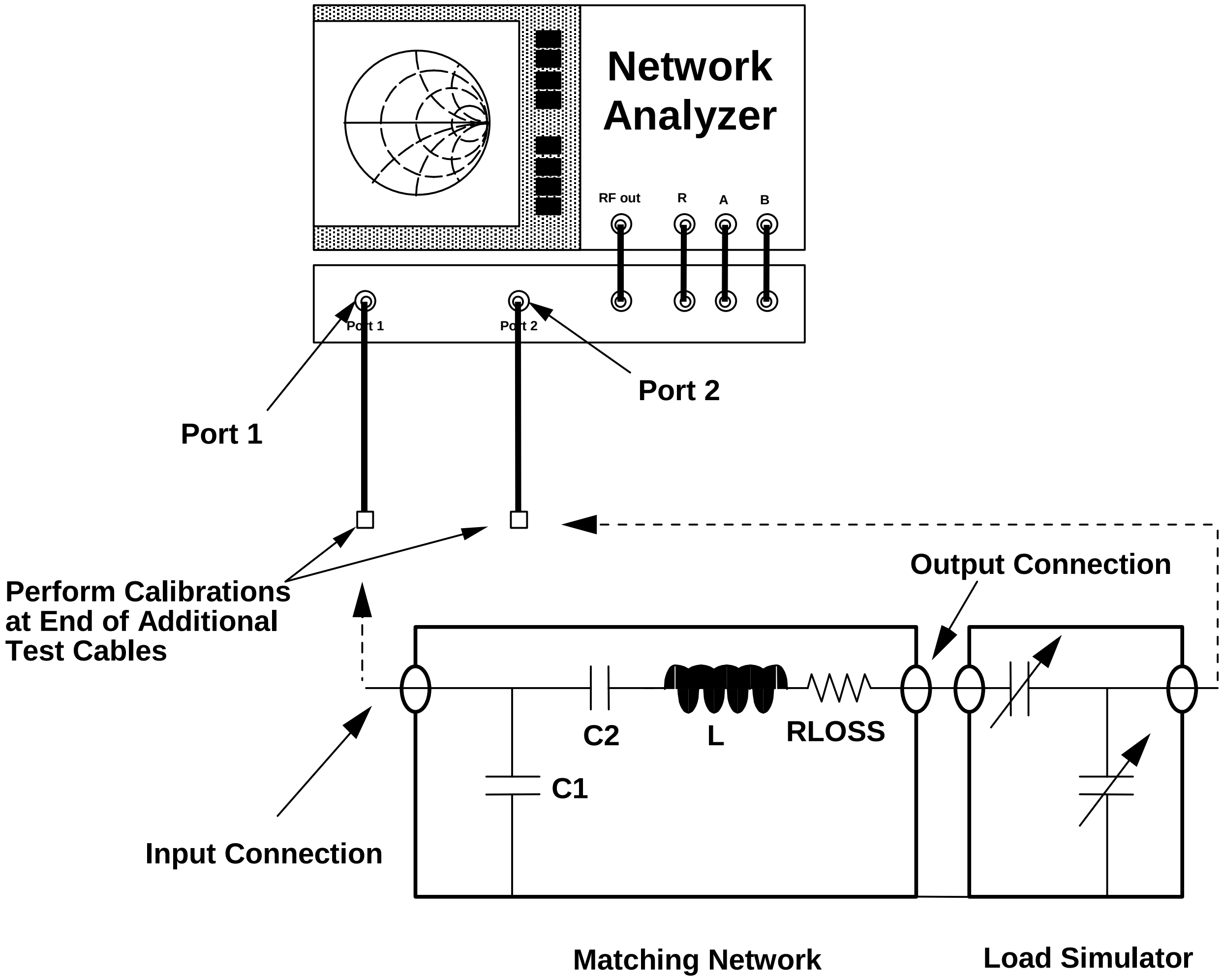
MIL-STD-348 — General Specification for Radio Frequency Connector Interfaces.

MIL-STD-220B — Test Method Standard: Method of Insertion Loss Measurement.



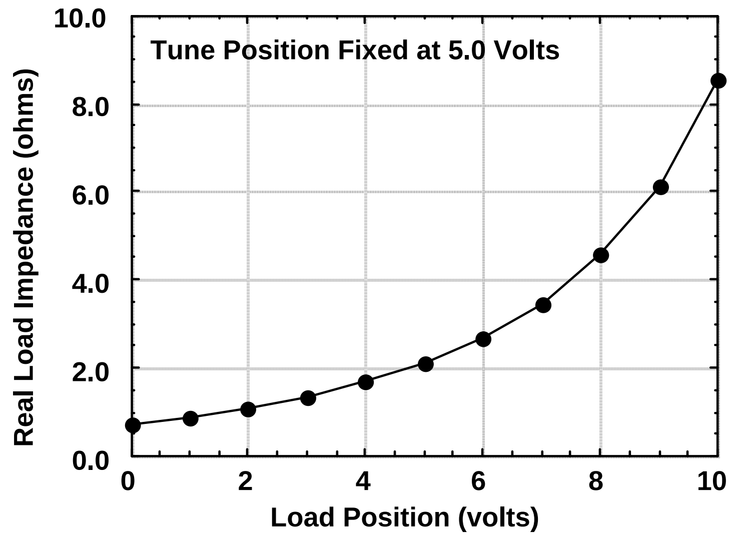
NOTE 1: Both the Port 1 and Port 2 outputs need to be used for the measurement. Additional test cables are needed for the transmission calibration between the two ports. The output connection of the matching network to be tested (DUT) attaches to Port 1 and the input connection of the matching network attaches to Port 2 of the Network Analyzer.

Figure 1
Schematic of the Test Method 1 Network Analyzer Test Setup for the Load Impedance and Efficiency Measurement for "L" Type Matching Networks



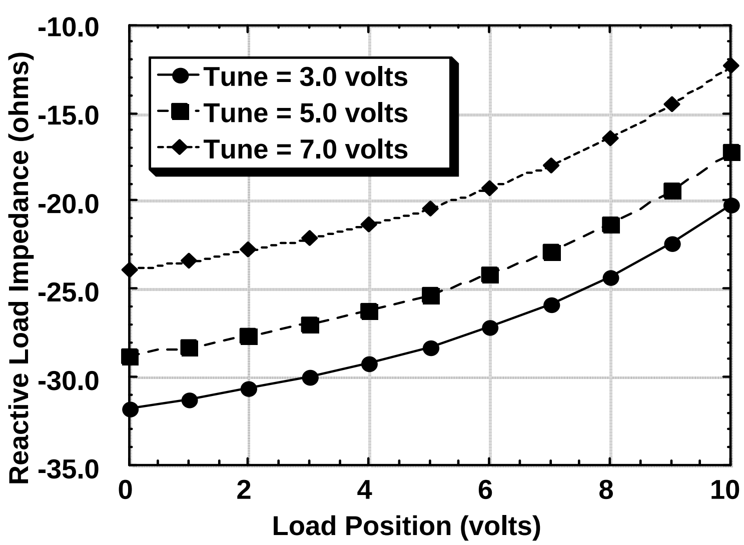
NOTE 1: Both the Port 1 and Port 2 outputs need to be used for the measurement and additional test cables are needed for the transmission calibration between the two ports. The input connection of the matching network to be tested (DUT) attaches to Port 1, the output connection of the matching network attaches to the input of the Load Simulator, and the output of the Load Simulator attaches to Port 2 of the Network Analyzer.

Figure 2
Schematic of the Test Method 2 Network Analyzer Test Setup for the Load Impedance and Efficiency Measurement



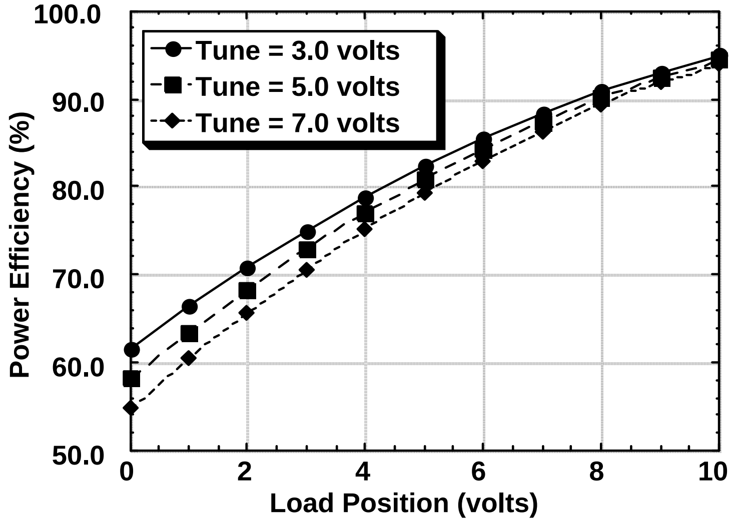
NOTE 1: For this example, the full-scale voltage for both the Tune and Load Positions is 10 V (i.e., Tune = 5.0 V corresponds to 50% of full scale).

Figure 3
Example Plot of the Real Part of the Load Impedance as a Function of the Load Position Tuning Element in the Matching Network



NOTE 1: The Tune Position is at the indicated fixed value for each set of data. For this example, the full scale voltage for both the Tune and Load Positions is 10 V (i.e., Tune = 3.0 V corresponds to 30% of full scale).

Figure 4
Example Plot of the Reactive Part of the Load Impedance as a Function of the Load Position Tuning Element in the Matching Network



NOTE 1: The Tune Position is at the indicated fixed value for each set of data. For this example, the full scale voltage for both the Tune and Load Positions is 10 V (i.e., Tune = 3.0 V corresponds to 30% of full scale).

Figure 5
Example Plot of the Power Efficiency as a Function of the Load Position Tuning Element in the Matching Network

Table 1 Example Data Table Showing the Matching Network Load Impedance and Power Efficiency as a Function of the Positions of the Tuning Elements

Load Position (Volts)	*Tune Position (Volts)*	*Real Load (ohms)*	*Reactive Load (ohms)*	*Efficiency (%)*
0	3	0.74	-31.75	61.51
1	3	0.91	-31.23	66.36
2	3	1.12	-30.64	70.86
3	3	1.38	-29.96	75.04
4	3	1.72	-29.18	78.88
5	3	2.15	-28.26	82.38
6	3	2.72	-27.17	85.56
7	3	3.50	-25.87	88.39
8	3	4.59	-24.31	90.90
9	3	6.18	-22.42	93.07
10	3	8.57	-20.15	94.91

NOTE 1: For this example, the full-scale voltage for both the Tune and Load Positions is 10 V (i.e., Tune = 3.0 V corresponds to 30% of full scale). This example only shows data for a fixed Tune position of 3.0 volts. Data is also required at a Tune position of 0.0 V, 1.0 V, etc.

RELATED INFORMATION 1
LOAD SIMULATORS

NOTE: This related information is not an official part of SEMI E115 and was derived RF Diagnostic Task Force in North America. This related information was approved for publication by full letter ballot on November 27, 2001.

R1-1 Types of Load Simulators

R1-1.1 Load Simulators are used to present a known load impedance to a matching network. One example of a Load Simulator would be a matching network used in reverse. This section will describe a Load Simulator that can be used with typical matching networks that operate at 13.56 MHz with capacitive load impedances. These applications include those networks used in parallel-plate capacitively coupled plasmas and also those networks used in wafer bias applications, where the plasma is mostly sustained by another power source, such as an inductively coupled plasma or a microwave ECR (electron cyclotron resonance) plasma.

R1-1.2 The typical impedance that is seen by the matching network depends on the geometry of the applicator (its capacitance to ground), the type of plasma (gases), the operating pressure, and the density of the plasma. Typical impedances seen by the matching networks operating at 13.56 MHz in capacitive-loading applications have a real part in the range of 0.5 to 10 ohms and a reactive part in the range of –10 to –50 ohms. If a transmission line is used between the output of the matching network and the applicator, the impedance will get transformed. The amount of transformation will depend on the length of the transmission line, but in general the effect will be to decrease the real part of the impedance and to decrease the reactive part of the load (make it less negative). If the transmission line is long enough, the impedance seen by the matching network may even look inductive instead of capacitive because of the impedance transformation.

R1-2 Load Simulator Design

R1-2.1 A typical design for a Load Simulator operated at 13.56 MHz uses two capacitors and a 50-ohm load. A schematic is shown in Figure R1-1. The Load Simulator consists of a series capacitor, C2, and a shunt capacitor, C1. The C1 capacitor is in parallel with a 50-ohm load. The 50-ohm load can be an input port to a Network Analyzer or a high-power 50-ohm load that can be used with high-power testing.

R1-2.2 A picture of a Load Simulator of this type of design is shown in Figure R1-2. Two vacuum variable capacitors are used, with a copper strap connecting them. The capacitors shown in the figure are variable from 8 to 1000 pF. Additional fixed capacitors can be easily added to the circuit to expand the operating range. The strap connecting the capacitors adds roughly 100 nH of inductance to the series part of the circuit for this example.

R1-2.3 The impedance range for this type of Load Simulator is fairly broad. A plot of the real part of the input impedance as a function of the value of the C1 shunt capacitor is shown in Figure R1-3. The real part of the load varies from close to 50 ohms to around 1.2 ohms at a C1 capacitance of 1500 pF. A plot of the reactive part of the input impedance is shown in Figure R1-4. The reactance can be varied as a function of both the C1 and C2 capacitances. A reactance range of –5 to –100 ohms is easily achieved for a C2 capacitance variation of 1500 pF to 100 pF.

R1-3 Measurement of Load Simulator Impedance and Efficiency

R1-3.1 The impedance and the efficiency of the Load Simulator can be measured in much the same way as a matching network. The test setup is shown in Figure R-5. A special fixture may be required to adapt the input connection of the Load Simulator to a coaxial connector.

R1-3.2 Calibrate the Network Analyzer at the desired operating frequency (e.g., 13.56 MHz). The Network Analyzer shall be calibrated for measuring the reflection coefficient at test Port 1 and for measuring the transmission coefficient at test Port 2 (see Figure R-1) using the calibration kit provided with the Network Analyzer. This measurement requires measuring the S11 and S21 S-parameters and requires a full 2-port calibration. The calibration shall be performed at fixed frequency (continuous-wave operation) using the lowest bandwidth possible (typically 10 Hz). The calibration for each port shall include the additional test cables and any additional adapters.

R1-3.3 After calibration of the Network Analyzer, the cable connected to Port 1 of the Network Analyzer shall be connected to the input of the Load Simulator. The cable connected to Port 2 of the Network Analyzer shall be connected to the output of the Load Simulator.

R1-3.4 The tuning elements (variable capacitors) shall be moved to their minimum positions before the measurement is initiated. After all connections are visually inspected for proper contact and the Network Analyzer has stabilized, the value of the input impedance, the magnitude of the reflection coefficient (S11), and the magnitude of the transmission coefficient (S21) shall be recorded. In addition, the positions of the tuning elements of the Load Simulator shall be recorded.

R1-3.5 The efficiency of the Load Simulator is determined from both the reflection and transmission coefficients. The efficiency can be calculated by taking the ratio of the output power divided by the input power. The output power is simply $(S21)^2$ and the input power is $(1-(S11)^2)$.

$$Load\ Simulator\ Efficiency = \frac{(S21)^2}{1-(S11)^2}$$

Typically, the reflection and transmission coefficients are expressed in terms of dB (decibels). The conversion between dB and efficiency is expressed as

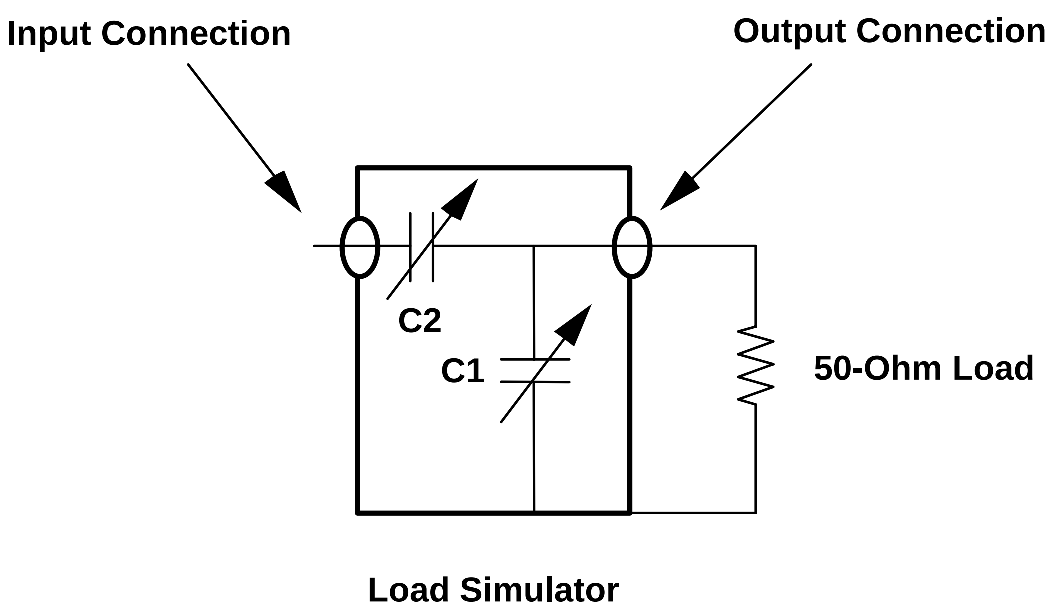
$$Load\ Simulator\ Efficiency = \frac{10^{(\mathrm{S21\,in\,dB}/10)}}{1-10^{(\mathrm{S11\,in\,dB}/10)}}$$

$$Power\ Transfer\ \% = 100 \times \frac{10^{(\mathrm{S21\,in\,dB}/10)}}{1-10^{(\mathrm{S11\,in\,dB}/10)}}$$

For example, if the transmission coefficient is measured to be –10 dB and the reflection coefficient is measured to be –0.5 dB, then the power transfer efficiency would be 91.95%. In other words, 8.05% of the power is lost in the Load Simulator.

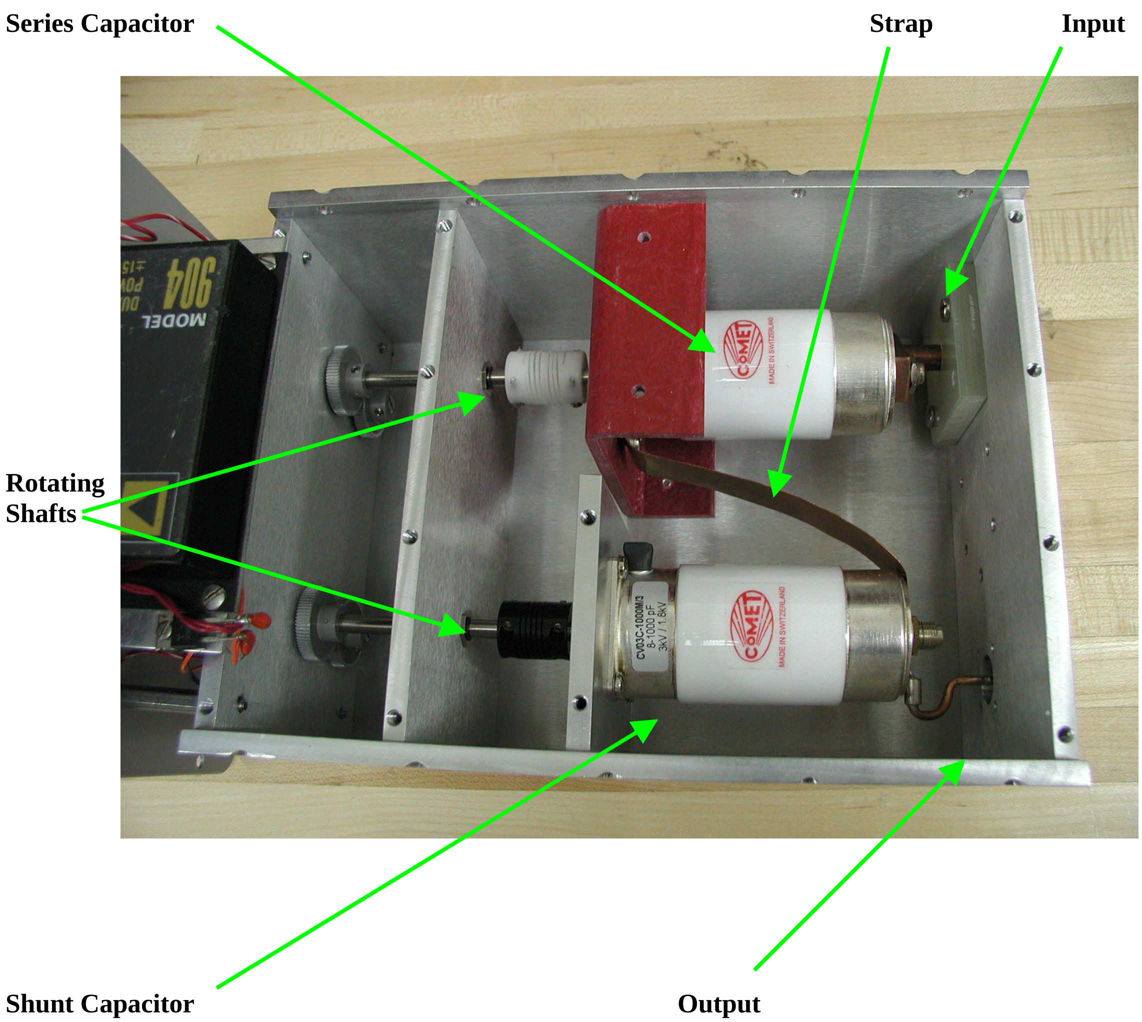
R1-3.6 For the next measurement, one tuning element shall remain fixed (C2), and the other tuning element (C1) shall be increased by an increment equal to no more than 10% of the full scale range of the tuning element position. After the tuning elements have been moved to their new values, steps 3.4 and 3.5 shall be repeated. This process shall be repeated until the tuning element (C1) has covered its entire range.

R1-3.7 After the tuning element (C1) has been varied over its entire range, the other tuning element (C2) shall be increased by an increment equal to no more than 10% of its full-scale range. The C1 tuning element shall then be moved back to its minimum position and the above steps (R1.3.4–R1.3.6) shall be repeated until the entire tuning range of the matching network is measured.



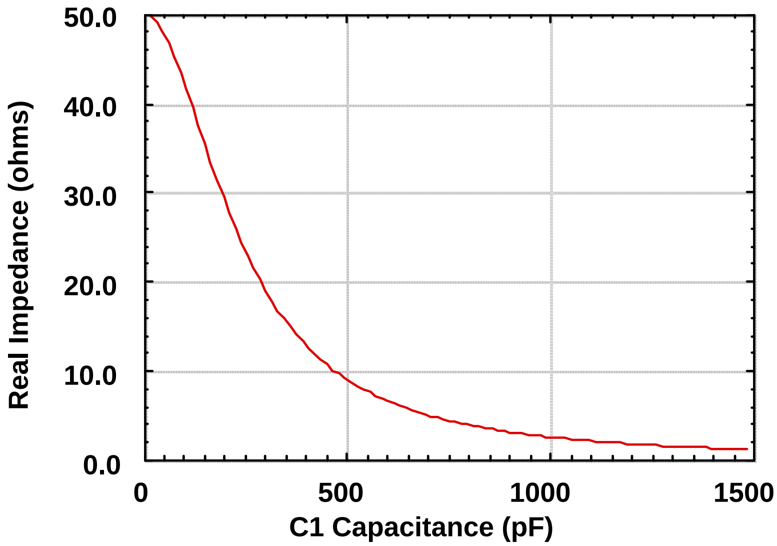
NOTE 1: The input connection is attached to a series variable capacitor, C2. The shunt variable capacitor, C1, is in parallel with a 50-ohm load.

Figure R1-1
Schematic of a Load Simulator



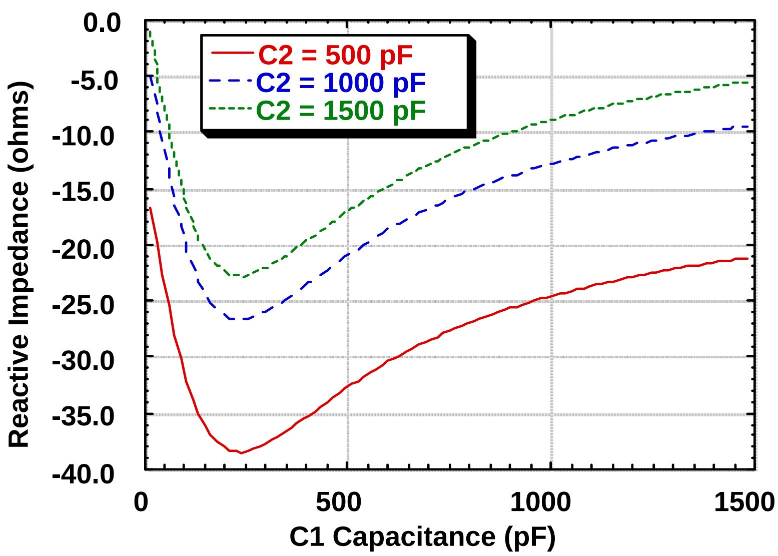
NOTE 1: Picture of a Load Simulator showing the variable capacitors. The capacitors are connected together by a strap that has an inductance of around 100 nH. The values of the capacitors are varied by rotating their shafts. The ends of the shafts are connected to a dial indicator to measure their positions.

Figure R1-2
Picture of a Load Simulator Showing the Variable Capacitors



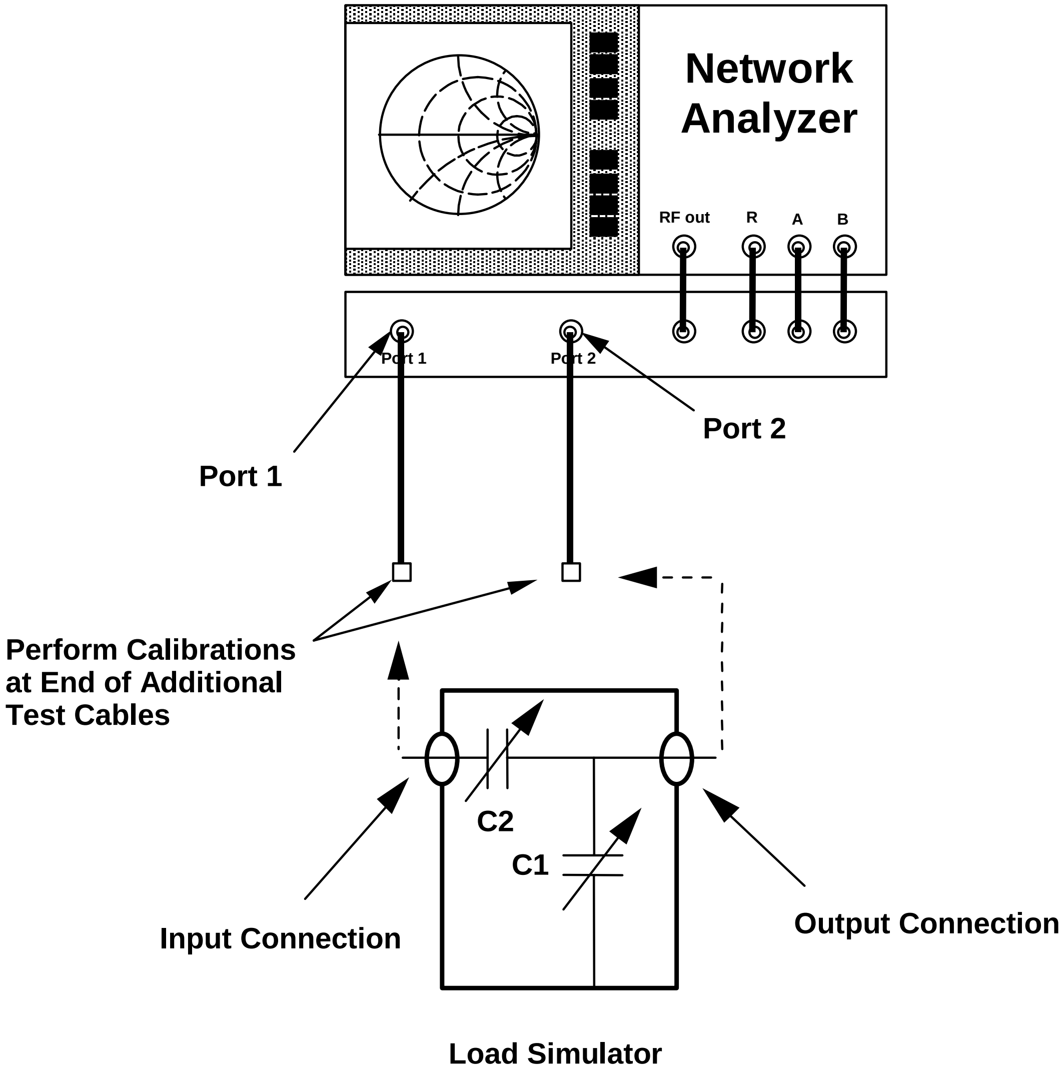
NOTE 1: The real impedance varies from 1.2 ohms to close to 50 ohms.

Figure R1-3
Example Plot of the Real Part of the Load Impedance as a Function of the C1 Shunt Capacitor in the Load Simulator



NOTE 1: The C2 capacitance is at the indicated fixed value for each set of data. For this example, the reactive impedance varies from around –40 ohms to –5 ohms. Decreasing C2 to 100 pF reduces the reactance to less than –100 ohms.

Figure R1-4
Example Plot of the Reactive Part of the Load Impedance as a Function of the C1 Shunt Capacitance in the Load Simulator



NOTE 1: Both the Port 1 and Port 2 outputs need to be used for the measurement. Additional test cables are needed for the transmission calibration between the two ports. The input connection of the Load Simulator attaches to Port 1 of the Network Analyzer. The output connection of Load Simulator attaches to Port 2 of the Network Analyzer.

Figure R1-5
Schematic of a Load Simulator Test Setup for the Load Impedance and Efficiency Measurement

SEMI E116-0705
PROVISIONAL SPECIFICATION FOR EQUIPMENT PERFORMANCE TRACKING

This specification was technically approved by the global Information & Control Committee. This edition was approved for publication by the global Audits and Reviews Subcommittee on April 7, 2005. It was available at www.semi.org in June 2005 and on CD-ROM in July 2005. Originally published July 2002; previously published November 2004.

1 Purpose

1.1 This document provides specification for implementing basic equipment performance tracking for production equipment. Provisions in this document enable the host computer to track basic equipment performance in an automated and consistent matter, without operator or host input. This document provides specification for equipment suppliers to:

- Track basic equipment states (no operator or host input required).
- Track basic equipment states in a modular manner, for both major modules and the overall equipment.
- Report basic equipment state changes to a host computer, at both module and equipment level.
- Report equipment's time in state to a host computer, at both module and equipment level.
- Report reasons to a host computer for why equipment is blocked from performing its task, at both module and equipment level.

1.2 Equipment users require the ability to track equipment performance without dependence on user input to eliminate inaccuracies due to incorrect or untimely input from the user. The ability to track equipment performance without user input is essential in 300 mm wafer factories where operational scenarios require minimal manual interaction. EPT defines concepts, behavior, and message services that enable the host computer to obtain the equipment data required for equipment performance tracking in an automated and consistent matter without operator or host input.

1.3 EPT enables factory managers to identify the current states of factory equipment, both at the equipment level and at the module level (e.g., processing chambers), without dependence on user input. EPT enables factory engineers to evaluate the time that equipment and modules spent in different states and identify areas for improvement. EPT enables factory engineers to obtain directly from the equipment the reasons why the equipment or module is prevented from performing. EPT provides industrial engineers the equipment data which, when combined with external data from the Manufacturing Execution System (MES), will enable accurate calculation of SEMI E10 states and SEMI E79 metrics at the equipment-level and the module-level. EPT enables automation engineers to develop reusable host interfaces by using a standardized collection event and data variables to collect equipment state data.

2 Scope

2.1 The Scope of this standard is to define equipment behavior states and the data required to track basic equipment performance for production equipment. These requirements are intended to facilitate equipment-level and module-level state tracking and to communicate state information to the host for simple equipment performance tracking, without requiring host or operator input.

2.2 Specifically, this document provides:

- An Equipment Performance Tracking (EPT) state model that defines triggers for state changes.
- Specification of data variables required to communicate basic equipment performance data to the host computer.
- Specification of event messages used to communicate basic equipment performance data to the host computer.
- Requirements for EPT compliance.

2.3 This standard specifies the concepts, behavior, and message services that enable the host computer to obtain the equipment data required for equipment performance tracking in an automated and consistent manner, without operator or host input. It does not specify the report of SEMI E10 states from the equipment to a host computer, as this information requires user input and is already specified by SEMI E58.

2.4 This standard does not conflict with SEMI E58 nor does it inhibit the equipment's ability to report out SEMI E10 states via SEMI E58.

2.5 This standard is a building block towards SEMI E10 and SEMI E79 by providing accurate equipment information required for SEMI E10 and SEMI E79 metrics, without dependence on operator or host input, eliminating inaccuracies due to incorrect or untimely input from the user. EPT assists both SEMI E10 and SEMI E79 by providing a modular approach to equipment performance tracking, allowing the state of the equipment to be determined by the states of its major modules. EPT assists SEMI E79 by providing task-level detail of the equipment or module's current activity, allowing performance metrics to be tracked at the task level.

2.6 This is a provisional standard. In order to have the provisional status removed, the following areas must be completed:

- Equipment Interlock Information
- Equipment Process Monitoring Information
- Equipment Maintenance Trigger Information
- Application of EPT State Model to load ports and internal buffers

NOTICE: 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 or other limitations prior to use.

3 Limitations

3.1 This standard applies to semiconductor production equipment. Other types of equipment have not been examined. However, it may be used for other types of equipment when applicable.

4 Referenced Standards and Documents

4.1 *SEMI Standards*

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

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

SEMI E30 — Generic Model for Communications and Control of Manufacturing Equipment (GEM)

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

SEMI E79 — Standard for Definition and Measurement of Equipment Productivity

SEMI E90 — Specification for Substrate Tracking

SEMI E98 — Provisional Standard for the Object-Based Equipment Model (OBEM)

SEMI 101 — Provisional Guide for EFEM Functional Structure Model

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

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *EFEM* — Equipment Front End Module

5.1.2 *EPT* — Equipment Performance Tracking

5.1.3 *GEM* — Generic Equipment Model [SEMI E30]

5.2 *Definitions*

5.2.1 *EPT module* — a major component of the equipment that affects processing or throughput.

5.2.1.1 For purposes of simplification, an EPT module executes one and only one task at a time. Each EPT Module has an EPT state model that is maintained by the equipment.

5.2.2 *EPT state* — the state of IDLE, BUSY, or BLOCKED within EPT state model.

5.2.3 *event report* — a message the equipment sends to the host on the occurrence of a collection event.

5.2.4 *fault* — an exception.

5.2.5 *host* — the factory computer system or an intermediate system that represents the factory and the operator to the equipment.

5.2.6 *intended function* — a manufacturing function that the equipment was built to perform. This includes transport functions for transport equipment, measurement functions for metrology equipment, as well as process functions such as physical vapor deposition and wire bonding. Complete equipment may have more than one intended function. [SEMI E58]

5.2.7 *material* — the basic unit of process. For the purposes of this standard, material is a set of one or more substrates.

5.2.8 *module* — a major component of equipment that contains at least one material location and performs some task on material. Equipment modules may be aggregates of equipment subsystems, I/O devices, and other modules. [SEMI E98]

5.2.9 *substrate* — the basic unit of material on which work is performed to create a product. Examples include wafers, die, plates used for masks, flat panels, circuit boards, and leadframes. [SEMI E90]

5.2.10 *task* — a planned and repeatable activity with an expected duration and a definite beginning and end (e.g., Move wafer from cassette to stage, Pre-align wafer, Align reticle, Preheat chamber, Increase vacuum). NOTE: Actual durations may vary.

5.2.11 *trigger* — an event that causes a change in the state of the equipment. Examples are changes in sensor readings, alarms, and messages received from the host, and operator commands.

5.2.12 *unit* — any wafer, die, packaged device, or piece thereof (included product and non-product units). [SEMI E10]

5.2.13 *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]

6 Requirements

6.1 An EPT compliant implementation requires provision of certain capabilities defined by other standards: accessibility to status information, event reporting, alarm management, and provision of an internal time-and-date clock. These requirements may be satisfied through compliance to SEMI E30 for the following sets of requirements:

- Clock Services
- Event Notification
- Status Data Collection

- Equipment Constants
- Alarm Management

6.2 An EPT compliant implementation requires a documented list of all EPT modules contained within the equipment.

6.3 An EPT compliant implementation requires an EPT state model for the equipment and for each EPT module.

6.4 Each EPT module shall have a documented list of tasks that the module may perform.

7 Conventions

7.1 This document follows the conventions for state model methodology and service definitions used by the SEMI standards referenced in §4.

7.2 *State Model Methodology*

7.2.1 A state model has three elements: definitions of each state and sub-state, a diagram of the states showing the valid transitions between states, and a corresponding state transition table that defines the triggers for each transition. The diagram of the state model uses the Harel State Chart notation. An overview of this notation is presented in an Appendix of SEMI E30. The definition of this notation is presented in Science of Computer Programming 8, "Statecharts: A Visual Formalism for Complex Systems", by D. Harel, 1987.

7.2.2 Transition tables are provided in conjunction with the state diagrams to explicitly describe the nature of each state transition. A transition table contains columns for Transition number, Previous State, Trigger, New State, Actions, and Comments. The "trigger" (column 3) for the transition occurs while in the "previous" state. The "actions" (column 5) includes a combination of:

1) Actions taken upon exit of the previous state.
2) Actions taken upon entry of the new state.
3) Actions taken that are most closely associated with the transition.

7.2.3 No differentiation is made between these cases.

#	*PREVIOUS STATE*	*TRIGGER*	*NEW STATE*	*ACTIONS*	*COMMENTS*
Transition #					

7.3 *Variable Data Item Definition*

7.3.1 The variable item dictionary contained in this document defines the variable name, description, type (format), access (read/write or read only), and comments about the variable. This is depicted in the format of the following table:

VARIABLE NAME	*DESCRIPTION*	*TYPE*	*ACCESS*	*COMMENT*

7.4 *Event Description*

7.4.1 The collection event description table contained in this document includes the event name, the state model transition, the description, and the data required for the event. This is depicted in the format of the following table:

EVENT NAME	*STATE MODEL TRANSITION NUMBER*	*DESCRIPTION*	*REQUIRED DATA*

8 Overview

8.1 This section defines the concepts that enable EPT to provide information required for determining equipment performance.

8.2 Equipment processing times, including throughput and cycle times, are determined by two factors: (1) the sequence of tasks performed by the equipment's EPT modules, including the number of each task performed, as well as the series and parallel relationships between tasks, and (2) the execution time of each individual task. By tracking equipment systems in terms of modules that perform tasks, it will be possible to precisely identify the affect of both factors toward overall system performance.

8.3 EPT enables tracking to this level of detail by introducing the concept of an EPT module and the concept of a task. EPT-compliant equipment are required to report events according to a breakdown of equipment operations into tasks and EPT modules. An EPT module is an equipment component that affects processing or throughput, and is capable of executing only one task at a time. Examples of EPT modules include process stations, process chambers, wafer handling systems, etc. A task is a planned and repeatable activity with an expected duration and a definite beginning and end. Examples of tasks include the following:

- Move wafer from cassette to stage
- Pre-align wafer
- Align reticle
- Preheat chamber
- Increase vacuum etc.

8.4 EPT-compliant equipment consist of EPT modules that perform tasks. Thus, the state of the equipment can be effectively modeled as a composition of the states of the EPT modules. In addition, EPT provides detailed information required for performance tracking by providing the task-level details for each EPT module.

8.5 EPT modules and tasks are to be defined such that each EPT module executes only one task at a time. An example is given in Related Information §R1-7. Each equipment system must have defined at least as many EPT modules as tasks that may be performed simultaneously by that system.

8.6 Each task should be defined such that the units involved (e.g., wafers, substrates, reticles), the EPT modules involved (e.g., process station, robot, etc.), and the task type (e.g., "process", "support", etc.) are constant throughout the duration of the task. A change in any of the following items should result in the start of a new task or completion of current task:

- Change in material involved (e.g., arrival of wafer, removal of wafer)
- Change of EPT modules involved (e.g., robot moves wafer, chamber processes wafer)
- Change in task type (e.g., purge recipe followed by production recipe)

NOTE 1: It is not practical for equipment to define tasks or modules at an indefinite level of detail. It is therefore recommended that in each instance for which the material involved, the EPT modules involved, and the task types are all constant, events for only one task should be reported. Any further breakdown is not required for EPT compliance. EPT places no limitations on supplemental event reporting within any task. However, these supplemental events should not be reported as EPT events.

9 EPT State Model

9.1 This section defines the basic Equipment Performance Tracking State Model, which is applied to the equipment and its EPT modules.

9.2 *EPT State Model Requirements*

9.2.1 The EPT state model is intended to capture the different states of the equipment and its EPT modules from an operational point of view:

- EPT module busy executing a task.
- EPT module blocked from executing a task.

- EPT module idle.

9.2.2 The equipment shall maintain an EPT state model for each major module (e.g., process stations and chambers, wafer handling systems, etc.) through which a unit passes throughout the entire equipment from removal of units from the carrier to the return of units to the carrier.

9.2.3 The equipment shall maintain an EPT state model for any major component of the equipment that impacts processing and throughput.

9.2.4 The equipment shall maintain its own EPT state model for the overall equipment.

9.2.5 The equipment is responsible for communicating all EPT state transitions.

9.2.6 The EPT state model can be applied to the Equipment Front-End Module (EFEM).

9.2.7 There are two types of EPT Modules: (1) Production EPT modules, and (2) EFEM/LoadPort EPT modules. Both types have a module-level EPT State Machine.

9.3 *EPT State Model Diagram*

9.3.1 Figure 1 shows the EPT state module diagram.

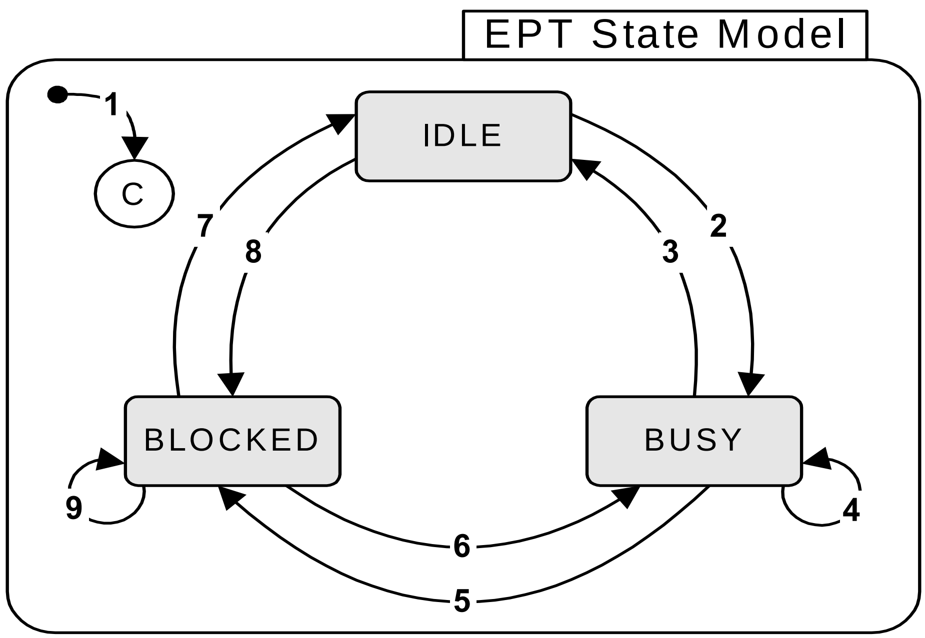


Figure 1
Equipment Performance Tracking State Model

9.4 *EPT State Definitions*

This section describes the EPT states.

9.4.1 *IDLE*

9.4.1.1 *EPT Module* — The following conditions are required for the module to be in the IDLE state:

- No material is present in the module and
- The module is not executing a task and
- No fault condition exists in the module that prevents it from starting a new task.

9.4.1.2 *Equipment* — The following conditions are required for the equipment to be in the IDLE state:

- No BLOCKED EPT modules prevent an EPT module from starting a new task, and
- There is no EPT module in the BUSY state with a task type of 1, 2, 3, 4 or 5.

9.4.1.3 For both the equipment and modules the following conditions may exist in the IDLE State:

- The equipment or module is maintaining and monitoring environmental requirements (e.g., background temperature, particle monitoring, etc).

9.4.2 *BUSY*

9.4.2.1 *EPT Module* — The following conditions are required for the module to be in the BUSY state:

- The module is executing a task and
- No fault condition exists in the module that prevents the execution of a task.

9.4.2.2 *Equipment* — The following condition is required for the equipment to be in the BUSY state:

- At least one EPT module is BUSY with a task type of 1, 2, 3, 4, or 5.

9.4.2.3 For both the equipment and modules the following conditions may exist in the BUSY State:

- Material is present.

9.4.3 *BLOCKED*

9.4.3.1 *EPT Module* — One or more of the following conditions are required for the module to be in the BLOCKED state:

- Conditions exist that do not allow the EPT module to continue or start execution of a task:
- A fault condition(s) exists that prevents the EPT module from completing its task.
- A fault condition(s) exists that prevents the EPT module from starting a new task.
- The EPT module is pausing (or aborting) as the result of a pause (or abort) directive.
- The EPT module has paused its task and is awaiting a resume directive.
- The EPT module fails to initialize upon start-up.

9.4.3.2 *Equipment* — The following condition is required for the EPT equipment to be in the BLOCKED state:

- No EPT module is BUSY with task type of 1, 2, 3, 4 or 5, and
- At least one BLOCKED EPT module prevents any EPT module from starting a new task or completing a current task.

9.4.3.3 For both the EPT equipment and modules the following conditions may exist in the BLOCKED State:

- Material is present.

9.5 *EPT State Transition Table – Module Level*

9.5.1 This section defines the state transitions for the EPT modules within the equipment.

9.5.2 For each status variable updated with the event change, the corresponding event variable shall also be updated (see Table 4).

Table 1 Basic EPT State Transitions – Module Level

#	*PREVIOUS STATE*	*TRIGGER*	*NEW STATE*	*ACTIONS*	*COMMENTS*
1	(No state)	EPT Module$_i$ initialization completed.	IDLE [OR] BLOCKED	• No EPT event is triggered • *EPTState$_i$* = IDLE or BLOCKED • *PreviousEPTState$_i$* = NoState • *PreviousTaskName$_i$* = "No Task" • *PreviousTaskType$_i$* = 0 • *EPTStateTime$_i$ = 0*	• If no Fault conditions exist and no material is present, transition to IDLE • If Fault conditions exist, or EPT module cannot be initialized, then transition to BLOCKED • If Material is present, then transition to BLOCKED
2	IDLE	EPT Module$_i$ starts execution of a new task.	BUSY	• *EPTStateChange$_i$* event is triggered • *EPTStateTime$_i$* is calculated • *EPTState$_i$* = BUSY • *PreviousEPTState$_i$* =IDLE • *TaskName$_i$* is set • *TaskType$_i$* is set	
3	BUSY	EPT Module$_i$ completes execution of task. [AND] Material is removed from the EPT Module$_i$.	IDLE	• *EPTStateChange$_i$* event is triggered • *EPTStateTime$_i$* is calculated • *EPTState$_i$* = IDLE • *PreviousEPTState$_i$*=BUSY • *TaskName$_i$* = "No Task" • *TaskType$_i$* = 0 • *PreviousTaskName$_i$* is set • *PrevoiusTaskType$_i$* is set	
4	BUSY	EPT Module$_i$ starts execution of a new task upon the normal completion of the previous task.	BUSY	• *EPTStateChange$_i$* event is triggered • *TaskName$_i$* is set • *TaskType$_i$* is set	EPTStateTime$_i$ does not change. Thus when the module transitions out of BUSY state, the value of EPTStateTime$_i$ will reflect the total time the module was BUSY. PreviousEPTState$_i$ does not change. Thus, PreviousEPTState$_i$ will continue to reflect the state of the module before it was BUSY.

#	*PREVIOUS STATE*	*TRIGGER*	*NEW STATE*	*ACTIONS*	*COMMENTS*
5	BUSY	A pause command is received that pauses the EPT $Module_i$. [OR] An abort command is received that aborts the EPT $Module_i$. [OR] A Fault condition occurs that prevents the EPT $Module_i$ from executing its task.	BLOCKED	• $EPTStateChange_i$ event is triggered • $EPTStateTime_i$ is calculated • $BlockedReason_i$ is set • $BlockedReasonText_i$ is set • $EPTState_i$ =BLOCKED • $PreviousEPTState_i$ =BUSY	$TaskName_i$ and $TaskType_i$ do not change. The variables continue to reflect the information of the task that is currently blocked from executing.
6	BLOCKED	All fault conditions that prevented task execution are cleared and the EPT $Module_i$ resumes execution of its task or starts execution of a new task. [OR] A resume command is received that enables the EPT $Module_i$ to resume its task.	BUSY	• $EPTStateChange_i$ event is triggered • $EPTStateTime_i$ is calculated • $EPTState_i$ = BUSY • $PreviousEPTState_i$ =BLOCKED • $TaskName_i$ is set • $TaskType_i$ is set • $BlockedReason_i$ = 0 • $BlockedReasonText_i$ = “Not Blocked”	
7	BLOCKED	All fault conditions that prevented task execution are cleared. [AND] All material is removed from the EPT $Module_i$. [AND] EPT $Module_i$ can begin a new task.	IDLE	• $EPTStateChange_i$ event is triggered • $EPTStateTime_i$ is calculated • $EPTState_i$ =IDLE • $PreviousEPTState_i$ =BLOCKED • $TaskName_i$ = “No Task” • $TaskType_i$ = 0 • $PreviousTaskName_i$ is set • $PrevoiusTaskType_i$ is set • $BlockedReason_i$ = 0 • $BlockedReasonText_i$ = “Not Blocked”	

#	PREVIOUS STATE	TRIGGER	NEW STATE	ACTIONS	COMMENTS
8	IDLE	Material arrives at the EPT Module_i and the EPT Module_i cannot begin executing a task on the material. [OR] A fault condition occurs which prevents the EPT Module_i from starting a new task.	BLOCKED	• *EPTStateChange*$_i$ event is triggered • *EPTStateTime*$_i$ is calculated • *BlockedReason*$_i$ is set • *BlockedReasonText*$_i$ is set • *EPTState*$_i$ = BLOCKED • *PreviousEPTState*$_i$ = IDLE	
9	BLOCKED	Fault conditions occur that prevent the EPT Module_i from resuming a blocked task, or starting a new task.	BLOCKED	• *EPTStateChange*$_i$ event is triggered • *BlockedReason*$_i$ is set • *BlockedReasonText*$_i$ is set	EPTStateTime_i does not change. Thus when the module transitions out of BLOCKED state, the value of EPTStateTime_i will reflect the total time the module was BLOCKED from processing. $\text{PreviousEPTState}_i$ does not change. Thus, $\text{PreviousEPTState}_i$ will continue to reflect the state of the module before it was BLOCKED from processing.

9.6 *EPT State Transition Table for Equipment*

9.6.1 This section defines the State Transitions for the Equipment, in terms of its EPT modules.

Table 2 Basic EPT State Transitions — Equipment Level

#	PREVIOUS STATE	TRIGGER	NEW STATE	ACTIONS	COMMENTS
1	(No state)	Equipment initiation completed (includes initialization of EPT modules)	IDLE [OR] BLOCKED [OR] BUSY	• *EPTStateChange* event is triggered • *EPTState* = IDLE or BLOCKED or BUSY • *PreviousEPTState* = NoState • *EPTStateTime* = 0 • *BlockedReason* may be updated • *BlockedReasonText* may be updated	
2	IDLE	At least one EPT module transitions to the BUSY state with task type of 1..5.	BUSY	• *EPTStateChange* event is triggered • *EPTStateTime* is calculated • *EPTState* = BUSY • *PreviousEPTState* = IDLE	

#	*PREVIOUS STATE*	*TRIGGER*	*NEW STATE*	*ACTIONS*	*COMMENTS*
3	BUSY	All EPT modules that were BUSY with task type of 1..5 transition either to IDLE or to BUSY with task type other than 1..5.	IDLE	• *EPTStateChange* event is triggered • *EPTStateTime* is calculated • *EPTState* = IDLE • *PreviousEPTState* = BUSY	
4	BUSY	Any EPT module transitions to BUSY state with task type 1..5.	BUSY		

5	BUSY	{
		
		At least one EPT module transitions to a BLOCKED state and prevents another EPT module from starting a new task or completing an existing task
		
		[AND]
		
		There are no other EPT modules BUSY with task type 1..5.
		
		} **[OR]** {
		
		Any EPT module that was BUSY with task type 1..5 transitions to either IDLE or BUSY with task type other than 1..5.
		
		[AND]
		
		There is at least one EPT module in BLOCKED state that is preventing another EPT module from starting a new task or completing an existing task.
		
		}
			BLOCKED	• *EPTStateChange* event is triggered
				• *EPTStateTime* is calculated
				• *EPTState* = BLOCKED
				• *PreviousEPTState* = BUSY
				• *BlockedReason* is set
				• *BlockedReasonText* is set	

6	BLOCKED	At least one EPT module transitions to BUSY with task type of 1..5.	BUSY	• *EPTStateChange* event is triggered • *EPTStateTime* is calculated • *EPTState* = BUSY • *PreviousEPTState* = BLOCKED	

#	*PREVIOUS STATE*	*TRIGGER*	*NEW STATE*	*ACTIONS*	*COMMENTS*
7	BLOCKED	All BLOCKED EPT modules that prevented another EPT module from starting a new task or completing a current task no longer prevents the EPT module from doing so. **[AND]** No EPT module is BUSY with task type 1.. 5.	IDLE	• *EPTStateChange* event is triggered • *EPTStateTime* is calculated • *EPTState* = IDLE • *PreviousEPTState* = BLOCKED	
8	IDLE	Any EPT module transitions to BLOCKED that prevents another EPT module from starting a new task.	BLOCKED	• *EPTStateChange event is triggered* • *EPTStateTime is calculated* • *BlockedReason is set* • *BlockedReasonText is set* • *EPTState = BLOCKED* • *PreviousEPTState = IDLE*	
9	BLOCKED	Any EPT module transitions to BLOCKED that prevents or continues to prevent another EPT module from starting a new task or completing a current task.	BLOCKED	• *EPTStateChange* event is triggered • *EPTStateTime* is calculated • *BlockedReason* is set • *BlockedReasonText* is set	EPTStateTime does not change. Thus when the equipment transitions out of BLOCKED state, the value of EPTStateTime will reflect the total time the equipment was BLOCKED from processing. PreviousEPTState does not change. Thus, PreviousEPTState will continue to reflect the state of the equipment before it was BLOCKED from processing.

10 EPTTracker Objects

10.1 The equipment shall provide SEMI E39-compliant EPTTracker objects to track performance of EPT Equipment and Modules. The equipment shall provide one EPTTracker object for the equipment and one EPTTracker object for each EPT Module (both Production and EFEM/LoadPort EPT Modules). The EPTTracker object is used to maintain and update the SEMI E116 attributes each time an SEMI E116 transition occurs. These EPTTracker objects will be owned at the equipment level. These objects shall be available immediately after equipment initialization, and shall be persistent until equipment shutdown. If certain attributes are identified as persistent, the object shall restore the value of these attributes on initialization. The Host can use SEMI E39 services (e.g., GetAttr) to access EPTTracker objects. The EPTTracker object format is specified in Table 3.

Table 3 EPTTracker Object Definition

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
ObjType	Object type	RO	Y	Text "EPTTracker"
ObjID	Object identifier. A name assigned by the Equipment designer uniquely identifying the instance of the EPTTracker object within this Equipment.	RO	Y	Text 1 to 80 characters. Shall conform to SEMI E39 restrictions on ObjID.
BlockedReason	A numeric code that identifies the most recent blocked condition of the related EPT module.	RO	Y	Enumerated: 0 = Not Blocked 1 = Unknown 2 = Safety Threshold 3 = Error Condition 4 = Parametric Exception 5 = Aborting, Aborted 6 = Pausing, Paused 7 = Reserved 8 = Reserved 9 = Reserved
BlockedReasonText	A description of the most recent blocked condition of this Equipment or EPT module. May provide further details to BlockedReason.	RO	Y	Text 0 to 80 characters This attribute must be defined for both equipment and module EPTTracker objects. For the Equipment, a BlockedReason value is determined by the blocked module.
DisableEventOnTransition	A list of zero to nine EPT State Model transitions for which event reporting to the host are disabled.	RW	Y	List of zero to nine integers in the range 1–9.
EPTElementType	A numeric code that indicates whether this EPTTracker object refers to the equipment or an EPT module.	RO	Y	Enumerated 0 = Equipment 1 = Production EPT Module 2 = EFEM/LoadPort EPT Module
EPTState	The current EPT state of this equipment or EPT module.	RO	Y	Enumerated 0 = Idle 1 = Busy 2 = Blocked
EPTStateTime	Time spent in the previous EPT State, prior to entering the current EPTState.	RO	Y	Unsigned integer Value in seconds
EPTElementName	A human-understandable name for this equipment or module, which must be unique among all objects of EPTTracker type.	RO	Y	Text 0 to 80 characters
PreviousEPTState	The previous EPT state of this equipment or EPT module, prior to entering the current EPTState.	RO	Y	Enumerated 0 = Idle 1 = Busy 2 = Blocked 3 = No State

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
PreviousTaskName	Name of the EPT Task previously running on this EPT module, prior to starting the current EPT Task.	RO	Y	Text 0 to 80 characters This attribute must be defined for both equipment and module EPTTracker objects. For the Equipment, the value of the PreviousTaskName attribute may be left blank (empty string).
PreviousTaskType	Type of the EPT Task previously running on this EPT module, prior to starting the current EPT Task.	RO	Y	Enumerated: 0 = No Task 1 = Unspecified 2 = Process -- adding value (e.g., exposing) 3 = Support -- incapable of adding value (e.g., Handling/Transport) 4 = Equipment Maintenance (e.g., Equipment-initiated clean cycle) 5 = Equipment Diagnostics (e.g., Equipment-initiated health check) 6 = Waiting (e.g., chamber waiting for a robot to remove a substrate) This attribute must be defined for both equipment and module EPTTracker objects. For the Equipment, the value of the PreviousTaskType attribute may be set to 0.
TaskName	Name of the EPT Task currently running on this EPT module.	RO	Y	Text 0 to 80 characters This attribute must be defined for both equipment and module EPTTracker objects. For the Equipment, the value of the TaskName attribute may be left blank (empty string).
TaskType	The type of EPT Task currently running on this EPT module.	RO	Y	Enumerated: 0 = No Task 1 = Unspecified 2 = Process -- adding value (e.g., exposing) 3 = Support -- incapable of adding value (e.g., Handling/Transport) 4 = Equipment Maintenance (e.g., Equipment-initiated clean cycle) 5 = Equipment Diagnostics (e.g., Equipment-initiated health check) 6 = Waiting) e.g., chamber waiting for a robot to remove a substrate) This attribute must be defined for both equipment and module EPTTracker objects. For the Equipment, the value of the TaskType attribute may be set to 0.

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
TransitionTimestamp	The timestamp when the most recent transition occurred and collection event was triggered that set the tracker to its current state.	RO	Y	Formatted numeric text: timestamp format – *list specifics* *16 characters YYYYDDMMHHMMSSCC*
Transition	The most recent transition that updated the tracker.	RO	Y	Enumerated: 1 = Transition 1 2 = Transition 2 … 9 = Transition 9
TrackerEventID	Numeric identifier for the event that is triggered for a change in the state model for this tracker.	RO	Y	Integer

10.2 The object attributes *TaskType* and *PreviousTaskType* may take on one of the following values:

0. No Task — Value for *TaskType* when the EPT module is IDLE, and value for the *PreviousTaskType* when the EPT module transitions out of the IDLE state or initial state (no state).
1. Unspecified — A placeholder for unspecified task types.
2. Process — Tasks expected under normal or desired manufacturing operations that are capable of adding value by either (1) a physical-chemical change or (2) providing critical process information (e.g., inspection, metrology). This includes tasks that are dependent on a recipe ID, dependent on parameters (e.g., target etch thickness), or recipe and parameter independent (e.g., fixed purge time for all recipes or regardless target etch thickness).
3. Support — Tasks expected under normal or desired manufacturing operations that are incapable of adding value according to the criteria for a process task. These include alignment, handling and other transport, and environmental changes by supporting EPT modules (e.g., pumpdown and vent operations in a load lock).
4. Maintenance — Any task that is intended to change the state of the equipment for the purpose of maintaining equipment functionality or performance. This includes clean cycles, purges not expected under normal or desired manufacturing operations, and certain reset operations that do not put the EPT module or equipment in a non-operational state.
5. Diagnostics — Any task that obtains information about the status of the equipment for the purpose of determining the equipment's health or identifying an equipment problem(s). This excludes any task that is intended to change the status of the equipment, as in a maintenance task. This also excludes metrology and inspection tasks that provide critical information about the process even if those tasks also provide equipment diagnostic information as a byproduct.
6. Waiting — An equipment-initiated task that indicates the module is encountering normal waiting periods as part of its normal wafer processing scenario. A "Waiting" task applies when the module is awaiting a task to be completed by an external source before it can continue/complete processing (e.g., processing chamber waiting for robot to remove wafer, load port waiting for host ID/slot map verification, module waiting for a host command to initiate processing and commence material unloading.) Material must be present in the module when this task occurs.

10.2.1 NOTES: The following notes resolve ambiguities that arise from limitations of the equipment or EPT module point of view. From the equipment or EPT module point of view:

- Process maintenance activities (e.g., monitor wafers) and engineering activities (e.g., new process qualification runs) may be indistinguishable from normal or desired manufacturing operations. These operations shall be reported as either process or support operations.
- Equipment maintenance activities (e.g., equipment qualification runs monitor wafers) may be indistinguishable from normal or desired manufacturing operations. These operations shall be reported as either process or support operations.
- Activities executed for exception handling (e.g., pausing, aborting, stopping, or otherwise moving to a safe state) may be indistinguishable from support tasks. Examples include handling/transporting wafers to safe locations, pumping, venting, purging, etc. If the equipment or module implementing EPT does not have

reasonable inherent knowledge of purpose regarding these activities, the tasks should be always declared as support tasks. If the equipment or module implementing EPT does have reasonable inherent knowledge of purpose regarding these activities, these activities shall be either (1) modeled as task faults or otherwise blocked conditions, or (2) exempted entirely from treatment under EPT. In case 2, the affected EPT module or modules must be in a BLOCKED state due to related conditions reported to the EPT state model(s).

10.3 *Blocked Reason Text Requirements*

- Fault Condition: Blocked reason text should begin with "Fault: - 'appropriate text'"
- Pause Condition: Blocked reason text should begin with "Pause: - 'appropriate text'"
- Abort Condition: Blocked reason text should begin with "Abort: - 'appropriate text'"

10.4 *Configurable Disabling Of Event Reporting For Selected Transitions*

10.4.1 The attribute DisableEventOnTransition may be used by the host to selectively disable EPT state model transition events for an individual EPTTracker object independently of whether the events are enabled at the equipment or not. This attribute is a simple list of integers 1–9 representing the disabled events.

10.4.2 For example, a list {1,4} indicates that no event reports should be sent for transitions 1 and 4. This attribute may be set by using the SEMI E39 service SetAttr for one or more objects.

11 EPT Events

11.1 This section defines the required events and variable data associated with transitions in the EPT state model.

11.2 Table 4 defines the data variables that are valid at the time of an EPT State Change event. When the equipment or EPT module triggers an EPTStateChange event, the value of the data variable shall be updated to reflect the data valid at the time the event occurred.

Table 4 Variable Data Definitions – Event Variables

VARIABLE NAME	*DESCRIPTION*	*TYPE*	*ACCESS*	*COMMENT*
EPTState	The new (resulting) EPT state of the module or equipment at the end of an EPT state transition.	Enumerated	RO	0 = IDLE 1 = BUSY 2 = BLOCKED
PreviousEPTState	The previous EPT state of the module or equipment of an end of an EPT state transition.	Enumerated	RO	0 = IDLE 1 = BUSY 2 = BLOCKED 3 = No State
EPTStateTime	Time spent in previous EPT state for the equipment or module.	Unsigned integer	RO	Seconds This is the time period between the entry into the previous EPT state and the entry into the current EPT State.
Clock	The time and date at the end of an EPT state transition.	Formatted numeric text: timestamp format	RO	When included in an event report, Clock represents the timestamp for the occurrence of the event.

VARIABLE NAME	*DESCRIPTION*	*TYPE*	*ACCESS*	*COMMENT*
TaskName	Name of the task that was started by the module or equipment at the occurrence of an EPT state transition.	Text, 0 to 80 characters	RO	TaskName is defined by the equipment supplier.
TaskType	The type of EPT Task currently running on this EPT module.	Enumerated	RO	0 = No Task 1 = Unspecified 2 = Process – adding value (e.g., exposing) 3 = Support – incapable of adding value (e.g., Handling/Transport) 4 = Equipment Maintenance (e.g., equipment initiated clean cycle) 5 = Equipment Diagnostics (e.g., equipment-initiated health check) 6 = Waiting (e.g., chamber waiting for a robot to remove a substrate)
PreviousTaskName	Name of the task that was completed by the module or equipment at the occurrence of an EPT state transition.	Text, 0 to 80 characters	RO	
PreviousTaskType	The type of the task that was completed by the module or equipment at the occurrence of an EPT state transition.	Enumerated	RO	0 = No Task 1 = Unspecified 2 = Process – adding value (e.g., exposing) 3 = Support – incapable of adding value (e.g., Handling/Transport) 4 = Equipment Maintenance (e.g., equipment initiated clean cycle) 5 = Equipment Diagnostics (e.g., equipment-initiated health check) 6 = Waiting (e.g., chamber waiting for a robot to remove a substrate)
BlockedReason	The number of the block condition that initiated the transition to the BLOCKED state for the module or equipment.	Enumerated	RO	0 – Not Blocked 1 – Unknown 2 – Safety Threshold 3 – Error Condition 4 – Parametric Exception 5 – Aborting, Aborted 6 – Pausing, Paused 7 – Reserved 8 – Reserved 9 – Reserved
BlockedReasonText	The reason why the transition was made to the BLOCKED state for the module or equipment.	Text, 0 to 80 characters	RO	Description of the Blocked reason

11.3 All events require the following data variables to be available:

< Clock > (*Clock* represents the timestamp for the occurrence of the event)
< EPTState >
<PreviousEPTState>
< EPTStateTime >
<TaskName>
<TaskType>
<PreviousTaskName>
<PreviousTaskType>
Additional data required for specific transitions are shown in Table 5.

Table 5 Events

EVENT NAME	*STATE MODEL TRANSITION NUMBER*	*DESCRIPTION*	*REQUIRED DATA*
EPTStateChange$_0$	1, 2, 3, 4, 5, 6, 7, 8, 9	Triggered by a EPT State change at the equipment-level.	<EqpName > The following additional data is required for Transitions 5, 8 and 9: < Blocked Reason> < BlockedReasonText>
EPTStateChange$_i$	1, 2, 3, 4, 5, 6, 7, 8, 9	Triggered by an EPT State change at the EPT module-level. There exist i+1 EPTStateChange events, where i is the number of EPT modules. EPTStateChange$_1$ is triggered by a state change at the 1st EPT module, EPTStateChange$_2$ is triggered by a state change at the 2nd EPT module, etc.	<ModuleName$_i$> The following additional data is required for Transitions 5, 8 and 9: < Blocked Reason> < BlockedReasonText>

12 Requirements for Compliance

12.1 Table 6 provides a checklist for EPT compliance.

Table 6 EPT Compliance Statement

Fundamental EPT Requirements	*EPT Section*	*Implemented*	*EPT Compliant*
EPT State Model for Equipment	9	☐ Yes ☐ No	☐ Yes ☐ No
EPT State model for each EPT module	9	☐ Yes ☐ No	☐ Yes ☐ No
EPTTRacker Objects	10	☐ Yes ☐ No	☐ Yes ☐ No
EPT Events	11	☐ Yes ☐ No	☐ Yes ☐ No

13 Related Documents

13.1.1 International SEMATECH Equipment Performance Management User Requirements Document

13.1.2 ISMT/J300E Equipment Performance Management Operator Requirements Document (URD)

13.1.3 Harel, D., "Statecharts: A Visual Formalism for Complex Systems," Science of Computer Programming 8 (1987) 231-274.

RELATED INFORMATION 1
EXAMPLES OF EQUIPMENT PERFORMANCE TRACKING (EPT)

NOTICE: This related information is not an official part of SEMI E116 and was derived from North American Information and Control. This related information was approved for publication by full letter ballot procedures on April 30, 2002.

R1-1 Examples of EPT Modules per Tool Type

R1-1.1 Table R1-1 lists examples of EPT modules for various equipment types. It is not required that each tool type support all or be limited to only the modules listed; rather, the listing is provided as an example only.

Table R1-1 Example EPT Modules

Tool Type	*Modules*								
CMP/ Planar	Loadports	Alignment Stage	Wafer Handler	Transport	Polish Table	Scrub Station	Rinse Station		
Linked Litho Track	Loadports	Central Wafer Handler Module	Spin Cup	Link Transfer Station	Buffer	Vapor Prime	Chill Plate	Soft Bake Oven	
Linked Litho Expose	Expose Stage	Wafer Transfer	Link Transfer Station – In port	Link Transfer Station – Out port	Reticle Stage	Reticle Library	Reticle Loader Arm		
Thin Film Sputter	Loadports	Central Wafer Handler(s)	Cool Down	PVD	Airlock	Argon Sputter Etch	Degas	In Situ Metrology	CVD
Diffusion Furnace	Loadports	Quartz Loading Station	Reactor Module	Wafer Transfer System	Buffer				
Implanter	Loadports	Central Wafer Handler(s)	Implant Chamber	Platen	Notch Aligner	Coldplate			
Plater	Loadports	Central Wafer Handler	Degas	Plate Chamber					
Thermal Anneal	Loadports	Central Wafer Handler	Bake Stage						
Wet Etcher	Loadports	Central Wafer Handler	Aligner	Bath CH 1	Bath CH 2	Buffer			
Dry Etcher	Loadports	Central Wafer Handler	Aligner	Chill Plate	Etch CH 1	Etch CH 2			
Wafer Sorter	Loadports	Central Wafer Handler	Aligner						

Tool Type	*Modules*								
Metrology	Loadports	Central Wafer Handler	Align-ment Stage	Measure-ment Stage					
Inspection	Loadports	Inspection Stage	Handler						
Probe / Test	Loadports	Probe/ Test Platform	Handler						

R1-2 EPT Module / Task Definition Example

R1-2.1 Figure R1-1 shows a simple module and the associated actions/tasks that correspond. The EPT Tasks have been diluted to the level that will allow a serial chain of tasks to occur. The Internal Tasks column is present to show that the equipment may have much more happening concurrently at a more detailed level. Table R1-2 shows a possible task-based process flow in this module.

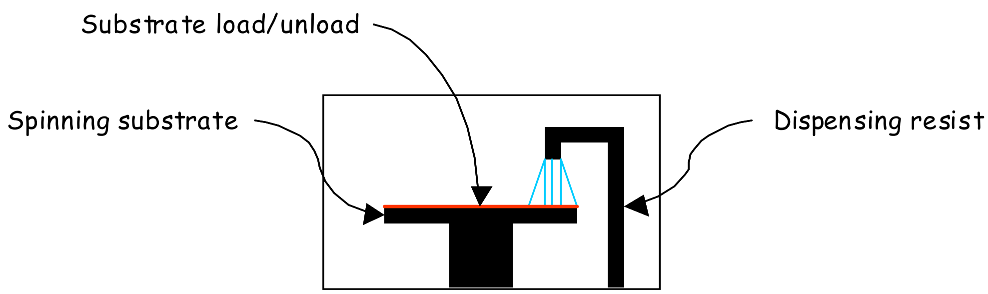


Figure R1-1
Example EPT Module

Table R1-2 Example EPT Tasks

Step	*Action*	*Possible Internal Tasks*	*EPT Active Task*
1	Loading the substrate	Receiving the substrate Substrate alignment	Substrate load
2	Coating the substrate	Substrate spin (accelerate) Substrate spin (steady) Dispense resist Substrate spin (decelerate)	Substrate coat
3	Unloading the substrate	Substrate alignment Substrate removal	Substrate unload

R1-3 An Example of Equipment Performance Tracking on a Carrier Handling Module

R1-3.1 This section provides examples of equipment performance tracking to clarify the application of the standard to modules that are part of the Equipment Front-End Module (EFEM).

R1-4 Carrier Handling Module (CHM)

R1-4.1 The Carrier Handler is a part of EFEM, excluding any Substrate Handler, which is defined in SEMI E101. A Carrier Handling Module is similar but different from the definition. It is a more general subsystem to handle carriers without handling substrates in EFEM that is applicable to various analyses and applications. The Carrier Handling Module is a logical module that may or may not represent an existing physical module.

R1-4.2 The advantages of applying Equipment Performance Tracking to the Carrier Handling Module are as follows:

- Any equipment, except certain specific ones such as an expose tool within a linked litho tool in the lithography process, has one or more Carrier Handling Modules.

The state of the Carrier Handling Module leads to whole input and output of material to and from an equipment.

- Monitoring the Equipment Performance Tracking state of the Carrier Handling Module helps control loading to or unloading from equipment on appropriate time.
- The state can reveal what related SEMI standards, i.e. SEMI E87 and SEMI E90, may not address.
- Estimation of capabilities about sub-components on a Carrier Handling Module is available with tracking the state.
- Each component that makes up the Carrier Handling Module may experience mechanical failure. This can cause the entire Carrier Handling Module to be in an out of service state. Tracking time between failures would be valuable.

R1-5 Components to track performance of Carrier Handling Module

R1-5.1 Generally, a Carrier Handling Module has the following components.

- Carrier Handoff PIO (SEMI E84) Port
- Carrier Transfer Mechanism
- Carrier ID Reader
- Carrier ID Writer
- FOUP Opener
- Carrier Slot Mapper

R1-5.2 This section investigates the following composition to represent examples for Fixed Buffer type and Internal Buffer type equipment. An example of a Carrier Handling Module is illustrated in Figure R1-2. Number of installed components are listed in the Table R1-3.

Table R1-3 Typical Composition of Carrier Handoff Module

Number Installed	*Carrier Handoff PIO*	*Carrier Transfer Mechanism*	*Carrier ID Reader*	*Carrier ID Writer*	*FOUP Opener*	*Slot Mapper*
Internal Buffer Type	2	4	2	1	1	1
Fixed Buffer Type	2	2	2	2	2	2

[#1] Several Carrier Transfer Mechanisms are usually docking mechanism for Fixed Buffer type. For Internal Buffer type, one of them is a Carrier Transfer Robot in internal buffer, one is a Docking Mechanism inside the internal buffer and the other one is Carrier Transfer Mechanism to pass carrier between Load Port and the Internal Buffer.

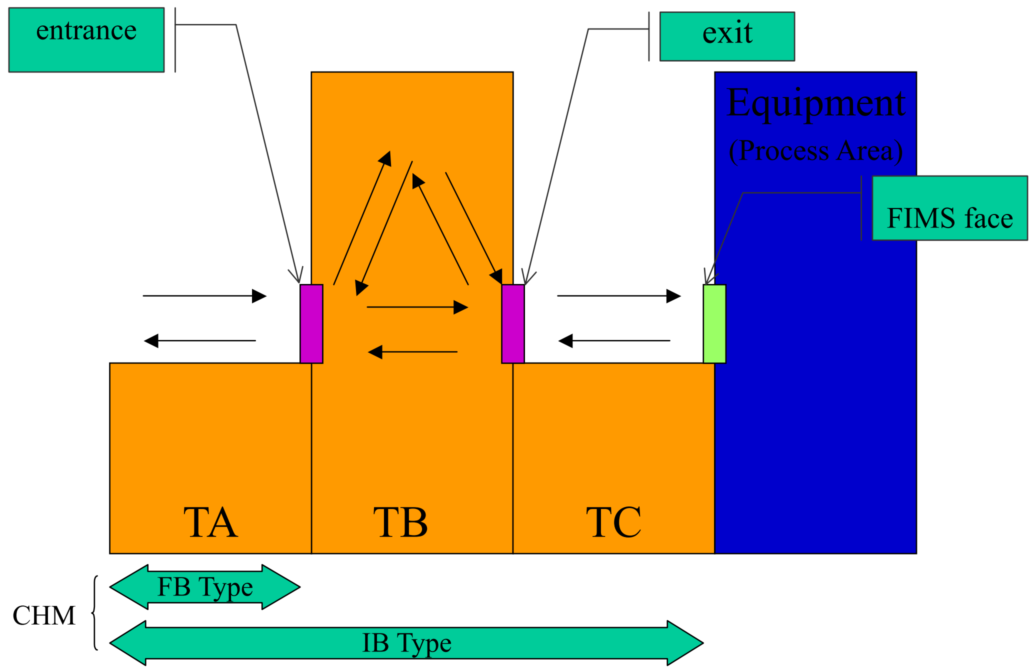


Figure R1-2
Carrier Handling Module

<u>In Diagram R1-2, the following translation applies</u>
FB Type = Fixed Buffer Type
IB Type = Internal Buffer Type
TA = Transport A
TB = Transport B
TC = Transport C

R1-6 Triggers of Transition for each Components of Carrier Handling Module

The following tables describe triggers to change the state of components for specific tasks.

Table R1-4 Triggers of Transitions for Specific Tasks of Carrier Handoff PIO

#	*Previous State*	*Trigger*	*New State*	*Action(s)*	*Comment*
2	IDLE	Receiving VALID signal in SEMI E84.	BUSY	Set off handoff sequence	Loading or Unloading sequence. Processing or moving wafers between carrier and process container before Unloading.
3	BUSY	Receiving COMPT signal in SEMI E84 or Timeout in handoff sequence.	IDLE	Waiting disconnected	Loading or Unloading sequence is completed or terminated. Processing or moving wafers between carrier and process container after Loading.

Table R1-5 Triggers of Transitions for Specific Tasks of Carrier Transfer Mechanism on Loadport of Fixed Buffer Type or FIMS Port of IB

#	*Previous State*	*Trigger*	*New State*	*Action(s)*	*Comment*
2	IDLE	Docking or Undocking Started	BUSY	None	Carrier moving sequence before docking. Processing or moving wafers between carrier and process container before undocking.
3	BUSY	Docking or Undocking Complete	IDLE	None	Processing or moving wafers between carrier and process container after docking.

Table R1-6 Triggers of Transitions for Specific Tasks of Carrier Transfer Mechanism in Internal Buffer Unit

#	*Previous State*	*Trigger*	*New State*	*Action(s)*	*Comment*
2	IDLE	Transfer Started	BUSY	Moves carrier to destination	
3	BUSY	Transfer Complete	IDLE	None	Ready to unload or remove from port.

Table R1-7 Triggers of Transitions for specific tasks of Carrier ID Reader

#	*Previous State*	*Trigger*	*New State*	*Action(s)*	*Comment*
2	IDLE	Reading Started	BUSY	None	Carrier moving sequence before reading.
3	BUSY	Reading Complete	IDLE	Verification	Processing or moving wafers between carrier and process container after opening.

Table R1-8 Triggers of Transitions for Specific Tasks of Carrier ID Writer

#	*Previous State*	*Trigger*	*New State*	*Action(s)*	*Comment*
2	IDLE	Writing Started	BUSY	None	Processing wafers before writing.
3	BUSY	Writing Complete	IDLE	Waiting next writing or any post writing action	Carrier moving sequence after writing.

Table R1-9 Triggers of Transitions for Specific Tasks of FOUP Opener

#	*Previous State*	*Trigger*	*New State*	*Action(s)*	*Comment*
2	IDLE	Opening or Closing Started	BUSY	None	Carrier moving sequence before opening.
3	BUSY	Opening or Closing Complete	IDLE	None	Processing or moving wafers between carrier and process container after opening.

Table R1-10 Triggers of Transitions for Specific Tasks of Slot Mapper

#	*Previous State*	*Trigger*	*New State*	*Action(s)*	*Comment*
2	IDLE	Scanning Started	BUSY	None	Carrier moving sequence before mapping.
3	BUSY	Scanning Complete	IDLE	Waiting next scan	Processing or moving wafers between carrier and process container after mapping.

Table R1-11 Triggers of Transitions Common for all Components of Carrier Handling Module

#	*Previous State*	*Trigger*	*New State*	*Action(s)*	*Comment*
1	(no state)	Initialization is complete	IDLE	None	
7	BLOCKED	Get Recovered	IDLE	None	
8	IDLE	Unable to do task	BLOCKED	None	
9	BLOCKED	Get another Fault	BLOCKED	None	

R1-7 Operation Scenarios for Carrier Handling Module

R1-7.1 A couple of following scenarios are typical for different type of Carrier Handling Module.

R1-7.2 *Carrier Handling Module for Fixed Buffer Type*

R1-7.2.1 Beside the number of Loadports, following table shows just one set of components out of them.

R1-7.2.2 Indicated subsystems: PIO = Carrier Handoff PIO Port, CID-R = Carrier ID Reader, X'fer Transfer Mechanism = Carrier Transfer Mechanism (Docking Mechanism), CID-W = Carrier ID Writer, Opener = FOUP Opener, Mapper = Carrier Slot Mapper.

Table R1-12 Scenario of Fixed Type Carrier Handling Module

Event #	*Description*	*Time*	*PIO*	*CID-R.*	*X'fer Mech*	*CID-W*	*Opener*	*Mapper*
0	Carrier Handling Module and all components starting in "IDLE"	0:00	IDLE	IDLE	IDLE	IDLE	IDLE	IDLE
1	Loading Started	0:30	BUSY	↑	↑	↑	↑	↑
2	Loading Completed	1:00	IDLE	↑	↑	↑	↑	↑
3	ID Reading Started	1:05	↑	BUSY	↑	↑	↑	↑
4	ID Reading Complete	1:10	↑	IDLE	↑	↑	↑	↑
5	ID Verification	-	↑	↑	↑	↑	↑	↑
6	Docking Started	1:20	↑	↑	BUSY	↑	↑	↑
7	Docking Complete	1:50	↑	↑	IDLE	↑	↑	↑
8	Opening Start	1:55	↑	↑	↑	↑	BUSY	↑
9	Opening Complete	2:25	↑	↑	↑	↑	IDLE	↑
10	Mapping Started	2:30	↑	↑	↑	↑	↑	BUSY
11	Mapping Complete	2:15	↑	↑	↑	↑	↑	IDLE
12	Slotmap Verification	-	↑	↑	↑	↑	↑	↑
13	Process Started	12:15	↑	↑	↑	↑	↑	↑
14	Process Completed	47:15	↑	↑	↑	↑	↑	↑
15	Writing Started	47:20	↑	↑	↑	BUSY	↑	↑
16	Writing Complete	48:10	↑	↑	↑	IDLE	↑	↑
17	Closing Start	48:10	↑	↑	↑	↑	BUSY	↑
18	Closing Complete	48:40	↑	↑	↑	↑	IDLE	↑
19	Undocking Started	48:45	↑	↑	BUSY	↑	↑	↑
20	Undocking Complete	49:15	↑	↑	IDLE	↑	↑	↑
21	Unloading Started	52:25	BUSY	↑	↑	↑	↑	↑
22	Unloading Complete	52:55	IDLE	↑	↑	↑	↑	↑
23	Carrier Handling Module and all components returning in "IDLE"	52:55	↑	↑	↑	↑	↑	↑

R1-7.3 *Carrier Handling Module for Internal Buffer Type*

R1-7.3.1 It is assumed that Carrier Slot Mapper and Carrier ID Writer are mounted at an FIMS port next to Internal Buffer located inside of the equipment. The following table shows the set of components of a single Loadport.

R1-7.3.2 Indicated subsystems: PIO = Carrier Handoff PIO Port, CID-R = Carrier ID Reader, X'fer A = Carrier Transfer Mechanism from Handoff position to Carrier In/Out position, X'fer B = Carrier Transfer Mechanism of Internal Buffer, X'fer C = Carrier Transfer Mechanism (Docking Mechanism) for internal FIMS port, CID-W = Carrier ID Writer, Opener = FOUP Opener, Map = Carrier Slot Mapper

Table R1-13 Scenario of Fixed Type Carrier Handling Module

Event #	*Description*	*Time*	*PIO*	*CID-R.*	*X'fer A*	*X'fer B*	*X'fer C*	*CID-W*	*Opener*	*Map*
0	Carrier Handling Module and all components starting in "IDLE"	0:00	IDLE	IDLE	IDLE	IDLE	IDLE	IDLE	IDLE	IDLE
1	Loading Started	0:30	BUSY	↑	↑	↑	↑	↑	↑	↑
2	Loading Completed	1:00	IDLE	↑	↑	↑	↑	↑	↑	↑
3	ID Reading Started	1:05	↑	BUSY	↑	↑	↑	↑	↑	↑
4	ID Reading Complete	1:10	↑	IDLE	↑	↑	↑	↑	↑	↑
5	ID Verification	-	↑	↑	↑	↑	↑	↑	↑	↑
6	Transfer Started	1:20	↑	↑	BUSY	↑	↑	↑	↑	↑
7	Transfer Complete	1:35	↑	↑	IDLE	↑	↑	↑	↑	↑
8	Moving Started	1:40	↑	↑	↑	BUSY	↑	↑	↑	↑
9	Moving Complete	2:25	↑	↑	↑	IDLE	↑	↑	↑	↑
10	Docking Started	2:30	↑	↑	↑	↑	BUSY	↑	↑	↑
11	Docking Complete	2:50	↑	↑	↑	↑	IDLE	↑	↑	↑
12	Opening Start	2:55	↑	↑	↑	↑	↑	↑	BUSY	↑
13	Opening Complete	3:25	↑	↑	↑	↑	↑	↑	IDLE	↑
14	Mapping Started	3:30	↑	↑	↑	↑	↑	↑	↑	BUSY
15	Mapping Complete	3:15	↑	↑	↑	↑	↑	↑	↑	IDLE
16	Slotmap Verification	-	↑	↑	↑	↑	↑	↑	↑	↑
17	Wafer Moving Started	3:30	↑	↑	↑	↑	↑	↑	↑	↑
18	Wafer Moving Completed	7:00	↑	↑	↑	↑	↑	↑	↑	↑
12	Closing Start	7:05	↑	↑	↑	↑	↑	↑	BUSY	↑
13	Closing Complete	7:20	↑	↑	↑	↑	↑	↑	IDLE	↑
21	Undocking Started	7:25	↑	↑	↑	↑	BUSY	↑	↑	↑
22	Undocking Complete	7:45	↑	↑	↑	↑	IDLE	↑	↑	↑
8	Moving Started	7:50	↑	↑	↑	BUSY	↑	↑	↑	↑
9	Moving Complete	8:35	↑	↑	↑	IDLE	↑	↑	↑	↑
17	Process Started	16:15	↑	↑	↑	↑	↑	↑	↑	↑
18	Process Completed	147:15	↑	↑	↑	↑	↑	↑	↑	↑
8	Moving Started	146:30	↑	↑	↑	BUSY	↑	↑	↑	↑
9	Moving Complete	147:15	↑	↑	↑	IDLE	↑	↑	↑	↑
10	Docking Started	147:20	↑	↑	↑	↑	BUSY	↑	↑	↑
11	Docking Complete	147:40	↑	↑	↑	↑	IDLE	↑	↑	↑
19	Writing Started	147:45	↑	↑	↑	↑	↑	BUSY	↑	↑
20	Writing Complete	148:10	↑	↑	↑	↑	↑	IDLE	↑	↑
12	Opening Start	148:10	↑	↑	↑	↑	↑	↑	BUSY	↑
13	Opening Complete	148:25	↑	↑	↑	↑	↑	↑	IDLE	↑
17	Wafer Moving Started	148:30	↑	↑	↑	↑	↑	↑	↑	↑
18	Wafer Moving Completed	152:00	↑	↑	↑	↑	↑	↑	↑	↑
12	Closing Start	152:05	↑	↑	↑	↑	↑	↑	BUSY	↑
13	Closing Complete	152:20	↑	↑	↑	↑	↑	↑	IDLE	↑
21	Undocking Started	152:25	↑	↑	↑	↑	BUSY	↑	↑	↑
22	Undocking Complete	152:45	↑	↑	↑	↑	IDLE	↑	↑	↑
23	Moving Started	152:50	↑	↑	↑	BUSY	↑	↑	↑	↑
24	Moving Complete	153:35	↑	↑	↑	IDLE	↑	↑	↑	↑
25	Transferring Started	153:40	↑	↑	BUSY	↑	↑	↑	↑	↑
26	Transferring Complete	153:55	↑	↑	IDLE	↑	↑	↑	↑	↑

27	Unloading Started	202:25	BUSY	↑	↑	↑	↑	↑	↑	↑
28	Unloading Complete	202:55	IDLE	↑	↑	↑	↑	↑	↑	↑
29	Carrier Handling Module and all components returning in “IDLE”	202:55	↑	↑	↑	↑	↑	↑	↑	↑

R1-8 Tracking Performance for Whole Carrier Handling Module

R1-8.1 Even composition and property of equipment are dependent on equipment type, operation and usage depends on equipment user. Because actual usage deeply affects the whole performance of the Carrier Handling Module and/or Equipment, the user is responsible for reconstructing the performance from performance tracking events for each component.

SEMI E116.1-1104
SPECIFICATION FOR SECS-II PROTOCOL FOR EQUIPMENT PERFORMANCE TRACKING (EPT)

This specification was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current edition approved by the North American Regional Standards Committee on August 16, 2004. Initially available at www.semi.org September 2004; to be published November 2004. Originally published March 2003.

NOTICE: This document was rewritten in its entirety in 2004.

1 Purpose

1.1 This document maps the services and data of the Equipment Performance Tracking Standard (EPT) to SECS-II streams, functions, and data definitions.

2 Scope

2.1 This document applies to all implementations of EPT that use the SECS-II message protocol (SEMI E5). Compliance to this standard requires compliance to both SEMI E116 and SEMI E5.

NOTICE: 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 or other limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E30 — Generic Model for Communications and Control of Manufacturing Equipment (GEM)

SEMI E39 — SECS-II Protocol for Object Services Standard (OSS)

SEMI E116 — Provisional Specification for Equipment Performance Tracking (EPT)

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

4 SECS-II Attribute Definitions

4.1 Table 1 provides the SECS-II structure definitions for the E116 EPTTracker Object. This must be compliant with the E39 (OSS) protocol. The host does not have the ability to create or destroy these objects. However, the host must be able to access all attributes via the default E39 GetAttr services (for all attributes) and SetAtt services (for RW attributes).

4.2 A subset of these object attributes are enumerated via SECS-II Data Variables that may be provided via event-reports. See the section on Variable Data Item Mapping in this document.

Table 1 EPTTracker Object SECS-II Attributes Definitions

Attribute Name	*Attribute Data Form: SECS-II Structure*
"ObjType"	20 (A[10]) must always be set to "EPTTracker"
"ObjID"	20 (A[1..80]) <OBJECTIDENTIFIER> ObjID is equipment defined. Examples are "EQUIPMENT", "CHAMBER A", "ROBOT ARM". Conforms to the restrictions of ObjID as specified in SEMI E39.1
"BlockedReason"	51 (U1) BlockedReason where the values are enumerated as: 0 = Not Blocked 1 = Unknown 2 = Safety Threshold 3 = Error Condition 4 = Parametric Exception 5 = Aborting, Aborted 6 = Pausing, Paused 7 = Reserved 8 = Reserved 9 = Reserved
"BlockedReasonText"	20 (A) BlockedReasonText Usage is equipment defined. Examples: "Abort – Host-requested Abort", "Fault – Reticle Stage Error"; "Pause – Host-requested Pause"
"EPTElementType"	51 (U1) EPTElementType where the values are enumerated as: 0 = Equipment 1 = Production EPT Module 2 = EFEM/Load Port EPT Module
"EPTState"	51 (U1) EPTState where the values are enumerated as: 0 = Idle 1 = Busy 2 = Blocked
"EPTStateTime"	54 (U4) EPTStateTime
"EPTElementName"	20 (A) EPTElementName Usage is equipment defined. Examples "EQUIPMENT", "CHAMBER A", "ROBOT ARM".
"PreviousEPTState"	51 (U1) PreviousEPTState where the values are enumerated as: 0 = Idle 1 = Busy 2 = Blocked 3 = No State
"PreviousTaskName"	20 (A[0..80]) PreviousTaskName Usage is equipment defined. Examples: "Loading", "Etching", "Pumping Down"

“PreviousTaskType”	51 (U1) PreviousTaskType where the values are enumerated as: 0 = No Task 1 = Unspecified 2 = Process -- adding value (e.g., exposing) 3 = Support -- incapable of adding value (e.g., Handling/Transport) 4 = Equipment Maintenance (e.g., Equipment-initiated clean cycle) 5 = Equipment Diagnostics (e.g., Equipment-initiated health check) 6 = Waiting (e.g., chamber waiting for a robot to remove a substrate)
“TaskName”	20 (A[0..80]) TaskName Usage is equipment defined. Examples: “Loading”, “Etching”, “Pumping Down”
“TaskType”	51 (U1) TaskType where the values are enumerated as: 0 = No Task 1 = Unspecified 2 = Process -- adding value (e.g., exposing) 3 = Support -- incapable of adding value (e.g., Handling/Transport) 4 = Equipment Maintenance (e.g., Equipment-initiated clean cycle) 5 = Equipment Diagnostics (e.g., Equipment-initiated health check) 6 = Waiting) e.g., chamber waiting for a robot to remove a substrate)
“TransitionTimeStamp”	20 (A[16]) YYYYMMDDhhmmsscc YYYY=Year 0000 to 9999 MM=Month 01 to 12 DD=Day 01 to 31 hh=Hour 00 to 23 mm=Minute 00 to 59 ss=Second 00 to 59 cc= Centisecond 00 to 99
“Transition”	51 (U1) Transition where the values are enumerated as: 1 = Transition 1 2 = Transition 2 . . . 9 = Transition 9
“TrackerEventID”	54 (U4) TrackerEventID where: This is identical to EPTStateChangeEvent$_i$ corresponding to this object (see the Events Mapping section in this document)
“DisableEventOnTransition”	L,n 1. 51 (U1) <Transition Number> 2. 51 (U1) <Transition Number> … n. 51 (U1) <Transition Number> where the elements of this list are can only have values in the range 1..9, in order, with no repeats. This list may be empty.

5 Events Mapping

5.1 Table 2 shows the specific SECS-II streams and functions that shall be used for SECS-II implementations of the events defined in EPT. A single collection event is generated for each of the equipment and the modules to report transitions occurring within the state model. This approach differs from state models that are defined in other 300 mm-related SEMI standards, which utilize a unique CEID for each transition in the state model. For example, a piece of equipment with 3 EPT modules would have 4 associated CEIDs. The CEID indexed 0 would report equipment-level events and 3 CEIDs corresponding to the equipment's 3 EPT modules indexed 1…3 would report EPT module-level events.

Table 2 Event Mapping Table

Event Name	*Stream, Function*	*SECS-II Message Name*
$\text{EPTStateChangeEvent}_i$	S6F11/F12	Event Report Send/Acknowledge

6 Variable Data Item Mapping

6.1 Table 3 shows the specific SECS-II data classes, and formats needed for SECS-II implementations of SEMI E116 EPT variable data items. The data variables must be updated as specified in the E116 standard when a transition occurs in the state-model for any of the EPTTracker objects implemented on the equipment. The Variable Names below match the object Attribute Names from which the variables are to be updated (see the section on EPT Tracker Object SECS-II Attribute Definitions)

These variables are tied to the occurrence of transitions in the state model and are not impacted by the DisableEventOnTransition attribute in the EPTTracker object.

Table 3 Event Variable Data Item Mapping Table

Variable Name	*Class*	*Format*
EPTState	DVVAL	51 (U1)
PreviousEPTState	DVVAL	51 (U1)
EPTStateTime	DVVAL	54 (U4)
TaskName	DVVAL	20 (A[0..80])
TaskType	DVVAL	51 (U1)
PreviousTaskName	DVVAL	20 (A[0..80])
PreviousTaskType	DVVAL	51 (U1)
BlockedReason	DVVAL	51 (U1)
BlockedReasonText	DVVAL	20 (A)

Table 4 Additional Data Item Mapping Table

Variable Name	*SECS-II Data Item*
Clock	CLOCK

SEMI E117-1104
SPECIFICATION FOR RETICLE LOAD PORT

This specification was technically approved by the Global Physical Interfaces and Carriers Committee and is the direct responsibility of the North American Physical Interfaces and Carriers Committee. Current edition approved by the North American Regional Standards Committee on August 16, 2004. Initially available at www.semi.org September 2004; to be published November 2004. Originally published November 2002; previously published March 2003.

1 Purpose

1.1 This specification defines dimensional requirements and options of reticle load ports on reticle stockers, lithography exposure equipment, and reticle inspection equipment. It is intended to promote a uniform physical interface between equipment and the factory, to facilitate the use of automated RSP transport systems, and/or to meet ergonomic requirements for manually loaded equipment.

2 Scope

2.1 This standard covers only load ports for reticle SMIF pods (RSPs) as specified in SEMI E100, E111, and E112. Similar requirements and options covering load ports for wafers are covered in SEMI E15 (for 200 mm wafers and smaller) and in SEMI E15.1 (for 300 mm wafers).

NOTICE: 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 health practices and determine the applicability or regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E15 — Specification for Tool Load Port

SEMI E15.1 — Specification for 300 mm Tool Load Port

SEMI E19.3 — Port Standard for Mechanical Interface of Wafer Cassette Transfer, 150 mm (6 inch) Port

SEMI E19.4 — 200 mm Standard Mechanical Interface (SMIF)

SEMI E72 — Specification and Guide for 300 mm Equipment Footprint, Height, and Weight

SEMI E100 — Specification for a Reticle SMIF Pod (RSP) Used to Transport and Store 6 inch or 230 mm Reticles

SEMI E111 — Provisional Mechanical Specification for a 150mm Reticle SMIF Pod (RSP150) Used to Transport and Store a 6 Inch Reticle

SEMI E112 — Provisional Mechanical Specification for a Multiple 150 mm Reticle SMIF Pod (MRSP150) Used to Transport and Store 6 Inch Reticles

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

4 Terminology

4.1 *Definitions*

4.1.1 *150 mm Multiple Reticle SMIF Pod* (MRSP150) — a minienvironment compatible carrier (as defined in SEMI E112) that is capable of holding six 6 inch reticles in a horizontal orientation during transport and storage and is compatible with a Standard Mechanical Interface (SMIF) per SEMI E19.3.

4.1.2 *150 mm Reticle SMIF Pod* (RSP150) — a minienvironment compatible carrier (as defined in SEMI E111) that is capable of holding one 6 inch reticle in a horizontal orientation during transport and storage and is compatible with a Standard Mechanical Interface (SMIF) per SEMI E19.3.

4.1.3 *200 mm Reticle SMIF Pod* (RSP200) — a minienvironment compatible carrier (as defined in SEMI E100) that is capable of holding one 6 inch reticle or one 230 mm reticle in a horizontal orientation during transport and storage and is compatible with a Standard Mechanical Interface (SMIF) per SEMI E19.4.

4.1.4 *Reticle SMIF Pod* (RSP) — a minienvironment compatible carrier that is capable of holding either one or six reticles in a horizontal orientation during transport and storage and is compatible with a Standard Mechanical Interface (SMIF) per SEMI E19.3 or SEMI E19.4.

NOTE 1: All other terminology from SEMI E100, E111, E112, and E15 also apply (except that in SEMI E15, the substrate must be assumed to be a reticle and not a wafer).

5 Ordering Information

5.1 The user must specify which RSPs will be used: RSP200, RSP150, MRSP150, or both RSP150 and MRSP150.

6 Requirements

6.1 *Figures and Tables* — The dimensional requirements for a reticle load port (and for the placement of an RSP on that load port) are given in Table 1 with reference to the figures in this document. Although the carrier transport systems shown in these figures represent an overhead transport system using an OHT delivery vehicle, they are intended to represent all types of transport systems (AGV, PGV, conveyor, overhead track, etc.).

6.2 *Orientation* — The reticles are to be oriented horizontally (chrome down) with zero nominal tilt when the RSP is placed on the load port. The tolerance in the horizontal plane is determined by the registration and alignment feature between the RSP and the load port, as specified in SEMI E19.3 or SEMI E19.4. The RSP shall be loaded and unloaded with its front (where reticles are inserted and extracted after the SMIF pod is opened) parallel to and away from the load face plane (see Figure 2).

6.3 *Side Clearances* — Clearances C1 and C2 are defined with respect to the maximum dimensions of the footprint of the RSP (as specified in SEMI E19.3 or SEMI E19.4), not to the rectangular carrier envelope (defined in SEMI E15). Note that C1 is lateral clearance to the left and right of the RSP, but C2 is a radial clearance from the nearest point of the RSP.

6.4 *Overhead Clearances* — All load ports intended for automated overhead access must be open from above to facilitate automatic RSP delivery. The open volume required for automated overhead delivery is defined by a projection of the load port area, including the area required for C1 and C2 clearances, projected upward to the top of the equipment. To allow space for overhead delivery above H2, D1 also defines the open volume. Note that this condition need only be met when the equipment is being loaded or unloaded. For example, the load port may be formed by a surface that extends outward during loading to provide overhead access.

6.5 *Easement for Overhead Transport* — As shown in Figure 1 and Figure 2, to add clearance for overhead RSP transport, no part of the equipment may be higher than H2 above the floor along an easement between the load ports of adjacent equipment down the bay. On a reticle stocker, on inspection equipment, and on lithography exposure equipment that has the load ports on the far end from the litho track, this easement is between the load face plane and a plane parallel to it that is D1 beyond the facial reference plane. On lithography exposure equipment that has the load ports on a side adjacent to the litho track, this easement is between two planes parallel to the bilateral reference plane at the furthest reach of clearance C1 to the left and right of the set of load ports. Such tools must also have an additional easement above H6 between the load face plane and a plane parallel to it that is D1 beyond the facial reference plane. It is recommended that transport equipment using these easements have extra clearance to avoid contacting any equipment boundaries.

6.6 *Loading Obstructions* — As shown in Figure 3, the maximum allowable height of an obstruction on the load port over which the RSP must be lifted (before being set down on the SMIF interface) is H1. Examples of such obstructions include alignment devices and identification tag readers (as well as the SMIF port itself). In the volume between the horizontal reference plane and H1 above it, clearances C1 and C2 no longer apply.

6.7 *Load Port Lead In* — The load port must provide a lead-in capability (in addition to that required on the SMIF port) that corrects an RSP misalignment distance of *R* in any horizontal direction.

6.8 *Adjacent Load Ports* — All reticle load ports for automated access must be on the same side of the equipment. All equipment must have at least one load port with access for automated overhead delivery. At least two of these load ports are recommended to support equipment throughput. Auxiliary load ports intended for manual delivery may be located on a different side of the equipment. On each piece of equipment, reticle load ports are numbered in increasing order (beginning with 1) from left to right (as seen by a person facing the load face plane) beginning with reticle load ports in the lowest level and then continuing (from left to right) with any reticle load ports at higher levels. Dimension S specifies the spacing between adjacent reticle load ports.

6.9 As shown in Figure 4, reticle load ports must conform to one of the following configuration options. If no option is specified, Option 1 is assumed.

6.9.1 In Option 1, the load port must nominally be at H, and it must be open from above to facilitate automatic carrier delivery from an overhead transport system. The open volume required for vertical delivery is defined by a projection of the tool load port area, including the area required for C1 and C2 clearances, projected upward to the top of the tool. Note that this condition need only be met when the tool is being loaded. For example, the load port may be formed by a surface that extends outward during loading to provide overhead access.

6.9.2 In Option 2 (which allows faster automatic carrier delivery from an overhead transport system), the top of the carrier must be ≤H2 (2900 for exposure