APPENDIX 2
RELIABILITY GROWTH OR DEGRADATION MODELS

NOTICE: This appendix was approved as an official part of SEMI E10 by full letter ballot procedure. It offers detailed information related to Section 8.

A2-1 Introduction

A2-1.1 E-$MTBF_p$ may be substituted for $MTBF_p$ in all calculations in this section.

A2-1.2 If the times between failures (known as "interarrival times") of a repairable system or piece of equipment are independent random times sampled from the same exponential distribution, then the (theoretical) *rate of occurrence of failures* ("ROCOF") is a constant λ and the $MTBF_p$ is just $1/\lambda$. This situation is known in the reliability literature as a *homogeneous poisson process* (HPP).   An HPP assumption underlies the definition of $MTBF_p$ given in Section 6, and the confidence limit factors described in Section 7 and Appendix 1. These concepts are described in detail in Ascher and Feingold [1] and Tobias and Trindade [2].

A2-1.3 If reliability is either improving or degrading with time, then the ROCOF is no longer a constant and a $MTBF_p$ calculation will be misleading.

A2-1.4 This appendix contains a simple test for trend that may be applied if a time-varying ROCOF is suspected, as well as a description of a well known and powerful model that may be used when reliability improvement trends are evident in the equipment failure time data.

A2-2 Testing for Trends

A2-2.1 A non-parametric *reverse arrangement test* (RAT) devised by Kendall [3] and further developed into a table by Mann [4] will be described. Begin by writing the interarrival times in the order they occurred. For a period with r failures, these might be X_1, X_2, …, X_r. Starting from left to right, define a reversal as any instance in which a lesser value occurs before any subsequent greater value in the sequence. In other words, any time we have $X_i < X_j$ and $i < j$, we count it as a reversal.   For example, suppose a piece of equipment has $r = 4$ failures at 30, 160, 220, and 360 hours of productive time. The interarrival times are 30, 130, 60, and 140. The total number of reversals is $3 + 1 + 1 = 5$.

A2-2.2 A larger than expected number of reversals indicates an improving trend; a smaller number of reversals than expected indicates a degradation trend.

A2-2.3 For r up to 12, use Table A2-1 below (adapted from [2]) to determine whether a given number of reversals, R, is statistically significant at the $100 \times (1 - \alpha)$ confidence level.

A2-2.4 For r greater than 12, approximate critical values for the number of reversals (based on Kendall's normal approximation) can be calculated from:

$$R_{(r;\,1\text{-}\alpha)} = z_{critical}\sqrt{\frac{(2r + 5)(r - 1)r}{72}} + \frac{r(r - 1)}{4} - \frac{1}{2}$$

Table A2-1 Critical Values $R_{r;1\text{-}\alpha}$ the Number of Reversals for the Reverse Arrangement Test at a Given Confidence Level

Sample Size	Single-Sided Lower Critical Value (Too Few Reversals Provide Evidence of Degradation)			Single-Sided Upper Critical Value (Too Many Reversals Provide Evidence of Improvement)		
r	99%	95%	90%	90%	95%	99%
4		0	0	6	6	
5	0	1	1	9	9	10
6	1	2	3	12	13	14
7	2	4	5	16	17	19
8	4	6	8	20	22	24
9	6	9	11	25	27	30
10	9	12	14	31	33	36
11	12	16	18	37	39	43
12	16	20	23	43	46	50

A2-2.5 In this equation $z_{critical}$ comes from the critical values of the standard normal distribution (for 90% significance, $z_{critical} = 1.282$, for 95% significance, $z_{critical} = 1.645$, and for 99% significance, $z_{critical} = 2.33$). The formula calculates the critical value for detecting an improvement trend. For degradation trends (a small number of reversals) use $(r)(r - 1)/2$ minus $R_{r;1-\alpha}$ as the critical value. Note that $(r)(r - 1)/2$ just the total possible number of reversals when there are r failures.

A2-2.6 For example, with 17 failures, the formula for $R_{r;1-\alpha}$, using 95% significance, gives a critical number of reversals of $R_{17,95} = 88$. The maximum number of reversals is $17 \times 16/2 = 136$. That means that observing 88 or more reversals signals a likely improvement trend, while observing $136 - 88 = 48$ or less reversals signals a likely degradation trend.

A2-2.7 The example given in the next section shows an application for the reverse arrangement test using Table A2-1.

A2-2.8 The *AMSAA Reliability Growth Model*: Assume the sequence of interarrival time indicates an improvement trend. This will typically be the case during reliability improvement testing, where failures are analyzed down to root causes and actions are taken to improve the equipment's reliability. Duane [5] observed that a plot of t_k/k versus t_k, where t_k is the system age at the time of kth failure, typically appears linear on log versus log graph paper. The slope β of this line measures the rate of reliability growth. Typical empirical values of β lie between 0.3 and 0.6. Crow [6] developed this empirical observation into the power relationship model used by the U.S. Army Materials Systems Analysis Activity (AMSAA model). This model has proved successful in a wide range of applications.

A2-2.9 The AMSAA model assumes that during reliability improvement testing the $MTBF_p$ is improving with time and has an instantaneous value denoted by $MTBF_I(t)$. When the test ends at time T, the $MTBF_p$ becomes a constant with the value $MTBF_I(T)$. An estimate of the $MTBF_p$ after a test of T hours with r failures is given by:

$$MTBF_I(T) = \frac{T}{r \times (1 - \beta)} \quad (1)$$

A2-2.10 In this equation, β is the reliability improvement (Duane) slope, β is estimated by

$$\beta = 1 - \frac{r - 1}{\sum_{i=1}^{r} \ln \frac{T}{t_i}} \quad (2)$$

using the *modified maximum likelihood estimates* given by Crow [6]. Crow developed confidence limits for $MTBF_I(T)$ that are described in [2] and [6].

A2-2.11 *Example*: During a calendar quarter a tool has 550 hours of productive time. Eleven failures were recorded at the following points of productive time: 18, 20, 35, 41, 67, 180, 252, 287, 390, 410, and 511 hours. Determine whether there appears to be an improvement trend and use the AMSAA model to estimate the achieved $MTBF_I$ at the end of the quarter.

A2-2.12 *Solution:* The interarrival times are: 18, 2, 15, 6, 26, 113, 72, 35, 103, 20, and 101. The number of reversals is $7 + 9 + 7 + 7 + 5 + 0 + 2 + 2 + 0 + 1 = 40$. Using Table A2-1, this is significant at greater than the 95% confidence level, indicating an improvement trend is likely. Figure A2-1 shows the Duane plot, which appears to show a linear improvement trend on log-log paper. The AMSAA model equations give an improvement slope estimate of 0.43 and an instantaneous $MTBF_P$ estimate at 550 hours of 87.2. Note that a standard calculation ignoring the improvement trend would yield an $MTBF_P$ estimate of $550/11 = 50$, which is a 43% underestimate.

A2-2.13 Figure A2-2 summarizes the recommended procedure to follow when analyzing system or equipment reliability data, with appropriate references to SEMI E10 sections or appendices.

A2-3 References

1. Ascher, H. and H. Feingold, *Repairable Systems Reliability*, Marcel Dekkar, Inc., New York, 1984

2. Tobias, P.A. and D.C. Trindade, *Applied Reliability, Second Edition*, Van Nostrand Reinhold, Inc., New York, 1995

3. Kendall, M.G., "A New Measure of Rank Correlation", *Biometrika*, 1938, volume 30, pages 81-93

4. Mann, H.B., "Nonparametric Test Against Trend" *Econometrica*, 1945, volume 13, pages 245-25

5. Duane, J.T., "Learning Curve Approach to Reliability Monitoring," *IEEE Transactions on Aerospace*, 1964, volume 2, pages 563-566

6. Crow, L.H., "Reliability Analysis for Complex Repairable Systems," *Reliability and Biometry*, F. Proschan and R.J., Serfling, eds., SIAM, Philadelphia, 1974; pp. 126-134
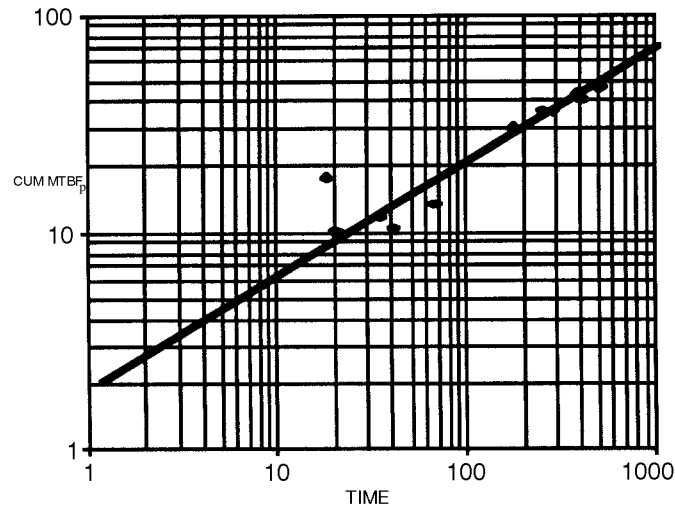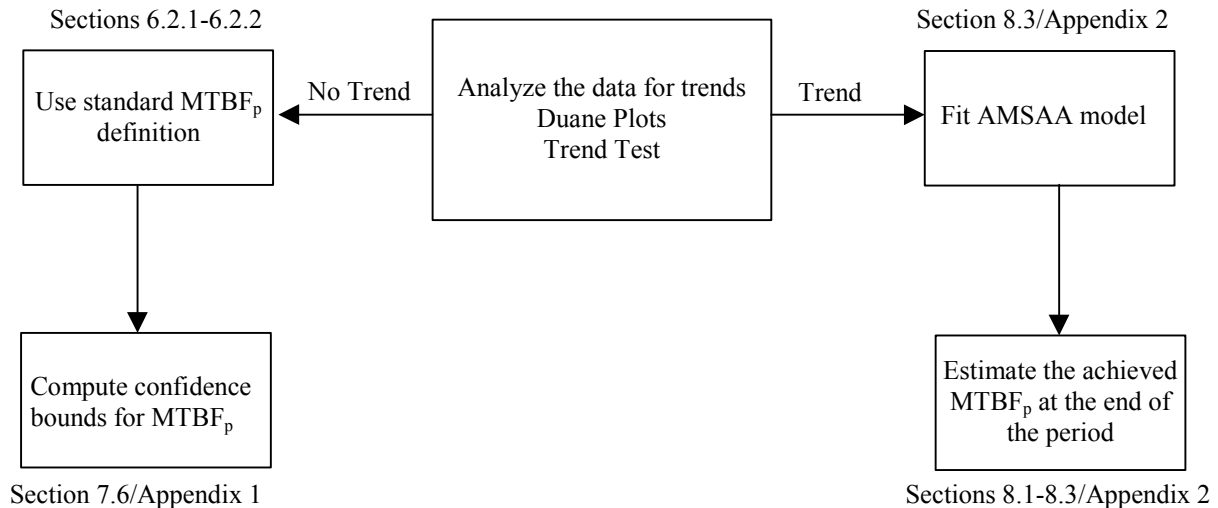
Figure A2-1
Duane Plot of CUM MTBF$_p$ vs. Time

Figure A2-2
Flow Chart for Reliability Data Analysis

RELATED INFORMATION 1
MULTI-PATH CLUSTER TOOL RAM METRICS

NOTICE: This related information is not an official part of SEMI E10 and was derived from work done by the SEMI NA Cluster Tool RAM Metrics Task Force. This related information was approved for publication by full letter ballot on October 15, 2003.

R1-1 Introduction

R1-1.1 This related information presents tracking requirements and standard metrics for evaluating multi-path cluster tool reliability, availability, and maintainability (RAM) performance. The metrics in the main body of SEMI E10 apply to non-cluster or single-path cluster tools and individual modules in a straightforward manner. While these entities are either entirely "up" (i.e., in one of the SEMI E10 uptime states) or entirely "down" (i.e., in one of the SEMI E10 downtime states), multi-path cluster tools may still be capable of processing with some modules in an unscheduled downtime state. Furthermore, the effect of module unscheduled downtime on multi-path cluster tool performance depends on the specific multi-path cluster tool configuration and the combination of modules in an unscheduled downtime state at each point in time.

R1-1.2 Because module performance provides a sufficient lowest common denominator for evaluating multi-path cluster tool performance, all metrics in this related information are calculated as functions of module-level data only. Specific module tracking requirements are presented. The metrics, Total Failure Rate (TFR) and Cluster-Tool Mean Time to Repair ($MTTR_{CT}$), provide simple evaluations of aggregate module reliability and maintainability.

R1-1.3 Other metrics are based on the specific combinations of modules and process paths, defined here as process flows.

R1-1.3.1 A *process path* is a specific set of modules for which each module is unique and has no alternative modules.

R1-1.3.2 A *process flow* is a defined set of modules that is used to achieve a process, where any multi-path cluster tool may have one or more such process flows. A process flow may include alternative modules at one or more steps of the process. A process flow may therefore contain one or many process paths.

R1-1.4 A method of temporal mapping, defined in this related information, is used to generate a history of process flow and multi-path cluster tool states from individual module states. Multi-path cluster tool availability is then evaluated as the aggregate process flow availability. Multi-path cluster tool reliability is evaluated as the expected, or mean, productive time between all process flows being in unscheduled downtime.

R1-2 Module Tracking Requirements

R1-2.1 Multi-path cluster tool metrics require the tracking of SEMI E10 state data from all of the modules that impact the RAM or productivity of a multi-path cluster tool or its process flows. This set of modules includes processing and non-processing modules.

R1-2.1.1 *processing module* — an indivisible production entity within an equipment system, e.g., a processing chamber or station within a cluster tool. (SEMI E79)

R1-2.1.2 *non-processing module* — an equipment entity that supports the movement or conditioning of units through the system, such as, robotic handler, load/unload lock, pre-aligner.

R1-2.2 Multi-path cluster tool metrics require tracking at the module level of at least productive states, unscheduled downtime states, scheduled downtime states, and other *neutral* states that are not in the first three categories. Tracking of these states at the level of the multi-path cluster tool as a whole is insufficient for accurate evaluation of performance. Specific requirements for tracking these states at the module level, as well as requirements for handling the other SEMI E10 states, are presented here.

R1-2.2.1 Productive state shall be tracked for each module. For process modules, the productive time shall include time for active loading and unloading of the process module. Waiting times or inactive times, including waiting for load, waiting for unload, and process suspend times shall be specifically excluded from productive time. Times for heating, cooling, purging, cleaning, etc., that are specified as part of process recipes shall be tracked as productive time. However, similar times that are not specified as part of process recipes shall be specifically excluded from productive time.

NOTE 1: Productive state events may be derived from SEMI E58 (ARAMS) state change data or the SEMI E116 (EPT) module BUSY state events where the module or whole multi-path cluster tool is known to be in a "manufacturing" state and the SEMI E116 task type is either "Process" or "Support."

R1-2.2.2 Unscheduled downtime state shall be tracked for each module. Tracking of unscheduled downtime state for the multi-path cluster tool as a whole is not sufficient. A module cannot be in productive and unscheduled downtime states at the same time. Each contiguous instance of unscheduled downtime state for a module is a module failure. Subsequent substate events within the same instance of unscheduled downtime state shall not to be counted as additional failures.

R1-2.2.3 Scheduled downtime state shall be tracked for each module. Tracking of scheduled downtime state for the multi-path cluster tool as a whole is not sufficient. A module cannot be in productive and scheduled downtime states at the same time. Instances of scheduled downtime shall not to be counted as failures.

R1-2.2.4 Time in standby and engineering states shall not be considered as either productive time, scheduled downtime, or unscheduled downtime at the module level. For the purpose of tracking multi-path cluster tool states and calculating multi-path cluster tool and process flow metrics, modules in these states are considered as being in a *neutral* state.

R1-2.2.5 Non-scheduled time that is tracked for the multi-path cluster tool as a whole is omitted from operations time in calculating multi-path cluster tool and process flow RAM metrics, as it is with the other SEMI E10 metrics from the main body of the specification. Non-scheduled time that is allocated to some modules but not other modules, if any, shall be handled differently, as follows.

R1-2.2.5.1 For new modules under installation that have not yet been used for their intended function, those modules shall be considered as non-existent in the cluster-tool configuration.

R1-2.2.5.2 For installed modules that have been used, non-scheduled time state shall be treated as a *neutral* state.

R1-2.3 To calculate these metrics, an observation period shall be defined and agreed upon by the user and/or the supplier. Section A1-1.3 provides some guidance on establishing the observation period time needed to demonstrate a desired $MTBF_p$ at a given confidence level.

R1-2.3.1 *observation period time* — elapsed calendar time (e.g., weeks, months, quarters) observing and tracking tool performance. No allowance is made for the number of modules in a cluster tool.

R1-3 Total Failure Rate and Cluster-Tool Mean Time to Repair

R1-3.1 *Total Failure Rate (TFR)* — total count of module-level failure onsets, tracked according to the requirements in Section R1-2, divided by the observation period time. This metric characterizes the frequency of repairs where failures on separate modules are presumed to require independent repair actions. TFR is an indicator of reliability and maintainability. TFR is defined as:

$$TFR = \frac{\sum_{all\ modules} count\ of\ module\ failure\ onset\ events}{observation\ period\ time}$$

NOTE 2: For different multi-path cluster tools with comparable module failure rates, a multi-path cluster tool with fewer modules is expected to have better performance according to this metric than one with more modules. However, the multi-path cluster tool with more modules may have a better aggregate intended process flow uptime ($Uptime_{CT\text{-}IPF}$), as defined in Section R1-7.3.

R1-3.2 *Cluster-Tool Mean Time to Repair ($MTTR_{CT}$)* — mean time to correct a module-level failure and return the module to a condition where it can perform its intended function; the sum of all repair time on all modules (elapsed module time, not necessarily total work-hours) incurred during a specified observation period time (including equipment and process test time, but not including maintenance delay downtime), divided by the total number of failure onset events during that period.

$$MTTR_{CT} = \frac{\sum_{all\ modules} repair\ time}{\sum_{all\ modules} count\ of\ module\ failure\ onset\ events}$$

NOTE 3: This is the same equation as MTTR for non-cluster and single-path cluster tools. However, because a multi-path cluster-tool may have repairs occurring simultaneously, the sum of repair time is not constrained to the duration of the observation period.

R1-3.3 For any module, a failure onset event is the first chronological event of a contiguous instance of unscheduled downtime. To ensure that over multiple observation periods, neither failure onset events nor repair time is ever double-counted, the following rules shall be followed.

R1-3.3.1 Failure onset events that occur during the observation period are counted in TFR and $MTTR_{CT}$ regardless of when those failures are resolved.

R1-3.3.2 Failure onset events that occur before the observation period are not counted in TFR and $MTTR_{CT}$, even if those failures are not resolved until during or after the observation period.

R1-3.3.3 For a failure whose onset occurs outside of the observation period, the portion of its repair time that occurs within the observation period is still counted in $MTTR_{CT}$.

NOTE 4: These metrics also may be calculated for any multi-module tool even if that tool is not a multi-path cluster tool. For a system failure that arises from multiple module failures, the additional severity of this case and the independence of module repair efforts are reflected in this metric. For standard evaluation of a non-multi-path cluster tool, however, the tool is considered to be either entirely in the unscheduled downtime state or not in the unscheduled downtime state.

R1-3.4 These metrics are not compatible with approaches based on renewal cycle models where uptime and downtime are assumed to be mutually exclusive. As such, subsequent module failures may occur even while failures are already in progress on other modules. Other renewal cycle results (e.g., the limiting probability of finding the system "up" (or "down") when approaching the system at random) similarly may not apply.

R1-4 Temporal Mapping

R1-4.1 Temporal mapping provides an output state history as a function of constituent input state histories. For each event when at least one of the modules changes state, the states of the process flows and/or cluster tool may change. For the metrics in this related information, cluster-tool and process-flow state histories are generated as functions of module state histories on an event-by-event basis in temporal, or chronological, order. The metrics themselves are calculated as functions of these output state histories. For reference, this technique may be regarded as generating a type of convolution of constituent state models.

R1-4.2 Figure R1-1 presents an example of temporal mapping. The constituent input states for two modules, M1 and M2, are shown over the observation period t = 0 to t = 10. An output state is mapped temporally as a function of the module states, where if either module is "down" or both modules are "down," the output state is "down." Note that transition events for the output state history are the union set of the transition events for the constituent input state histories.

R1-4.3 In a near-real-time tracking system, temporal mapping may be performed as each event is generated and received by the tracking system. Temporal mapping also may be performed afterwards as a batch process. Regardless, the logical process is the same. Depending on the mapping to be performed, a different logic function is applied at each input state transition event to derive an output state value as a function of the constituent input state values. Two specific temporal mapping functions are used in metrics in this related information:

R1-4.3.1 Process flow "up/scheduled downtime/ unscheduled downtime" states from module "up/scheduled downtime/unscheduled downtime" states as a function of supplier-defined and/or user-defined process flows.

R1-4.3.2 Multi-path cluster tool "productive/neutral/ unscheduled downtime" as a standard function, presented herein, of module "productive/not-productive" states and process-flow "up/scheduled downtime/unscheduled downtime" states.

NOTE 5: While it may be theoretically possible to model the desired output states using Harel notation and modeling concepts, output state complexity may be confounded by the combinatorial nature of multi-path cluster tools and their process flows. For this application, the temporal mapping approach is much more straightforward.
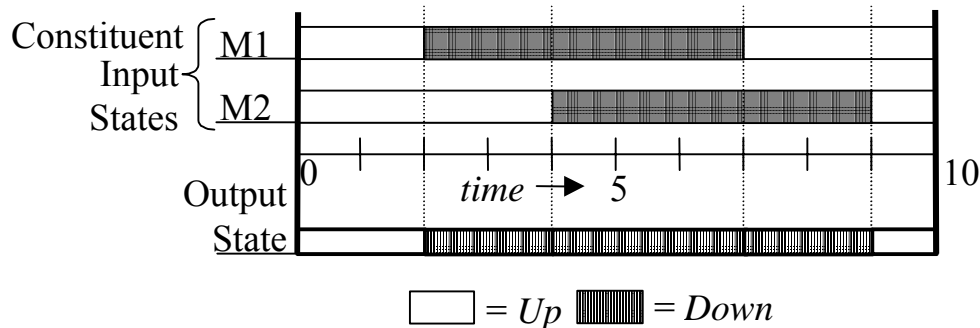

Figure R1-1
An Example Of Temporal Mapping

R1-5 Modeling Process Flows

R1-5.1 In order to evaluate multi-path cluster tool availability and reliability, the set of process flows shall be defined for the multi-path cluster tool. It is important to differentiate between all the process flows that are theoretically possible on a given multi-path cluster tool configuration and those intended process flows (IPF) that are actually intended for operational use (i.e., performing its intended function). For meaningful agreement between any two parties on the metrics presented in this related information, first there shall be documented agreement on the set of IPFs used for evaluation, so that any analyst with the module state histories can calculate the same values for the metrics. First, the general case of "up/down" states for an IPF is presented, and then later the distinction between unscheduled downtime and total (i.e., scheduled and unscheduled) downtime for an IPF is presented.

R1-5.2 An IPF "up/down" state is modeled as a network flow through the modules that make up that IPF. If there is "connectivity" through the IPF network, then the IPF is "up;" otherwise it is "down." The modules in an IPF network have series and parallel relationships that determine the connectivity through the network. Mathematically, each module and each IPF has a state value equal to 1 when the state is "up" and 0 when the state is "down." For example,

$$M_i = \begin{cases} 1, \text{ if module } i \text{ is up} \\ 0, \text{ if module } i \text{ is down} \end{cases}$$

R1-5.3 The general process steps within an IPF have a mutually serial relationship (i.e., if connectivity is not possible through any single step, then connectivity is not possible through the network). This is illustrated in Figure R1-2. The IPF state value for serial constituents is calculated as the product of the constituent state values (e.g., IPF = $\Pi_{i=1 \text{ to } 4}$ Si = S1 × S2 × S3 × S4).
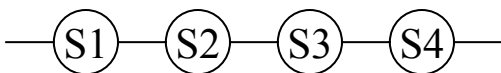

Figure R1-2
Serial Process Steps Within An IPF

R1-5.4 At any general process step, S_x, the set of alternative modules, Ai (if any are present), have a mutually parallel relationship (i.e., if any one of the alternative modules is up, then connectivity through that step is still possible). This is illustrated in Figure R1-3. The state value through this step is calculated as:

$$\text{IPF} = 1 - \Pi_{i=1 \text{ to } 3} (1 - Ai)$$
$$= 1 - [(1 - A1) \times (1 - A2) \times (1 - A3)]$$

If any alternative module is "up," the expression in the square brackets evaluates to zero, and the IPF state value evaluates to 1, or "up." If all of the alternative modules are "down," the expression in the square brackets evaluates to 1, and the IPF state value evaluates to 0, or "down."
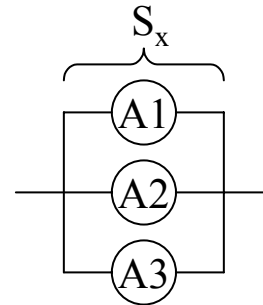

Figure R1-3
Parallel Alternative Modules At A Process Step

NOTE 6: In general network modeling, it is possible to have complicated multi-constituent structures in parallel with other multi-constituent structures. At the time of this writing, the need for such structures in evaluating multi-path cluster tool RAM is not anticipated. Therefore, this exposition is limited to serial relationships amongst the process steps and single-constituent parallel relationships for alternatives within any one step. To model multi-path cluster tool systems that exceed these limitations, the modeler is encouraged to consult any text on the modeling of coherent systems for reliability.

R1-5.5 For almost all systems, there will be a subset of modules that will appear in every IPF regardless of any process differentiation, called the *key group*. The key group includes support modules (e.g., transport, load locks), common process modules that are used by every IPF, and the platform itself. A key group may include alternative modules such as multiple load locks or multiple cooling stations. The key group's relationship to all IPFs is such that if the key group is down, all IPFs are down. Therefore, the key group has a serial relationship to each IPF. By modeling a key group and leveraging it in calculations, substantial redundant calculations are avoided. Furthermore, understanding which modules belong to the key group also helps in understanding and improving overall system reliability.

R1-5.6 Two examples are now presented to illustrate how to model IPFs, including modeling of the key group and of IPF state functions.

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R1-5.6.1 *Example 1* — This example, shown in Figure R1-4, is of a multi-path cluster tool with seven modules. L1 and L2 are load lock modules that are used to load units into the tool. A single transport arm, T, performs all point-to-point transportation. The first process module visited by any unit is either PM1 or PM2, after which every unit visits PM3. Lastly, L3 is a load lock that is used to unload units from the multi-path cluster tool.

R1-5.6.1.1 The key group, K, as shown in Figure R1-5, is made up of the three load locks and the transport, which are the common support modules for this multi-path cluster tool used by any unit. Since all modules visit PM3 regardless of any IPF distinction, PM3 also is included in the key group in order to simplify calculation. Any other system-level failure issues may be allocated to the abstract platform module, P.
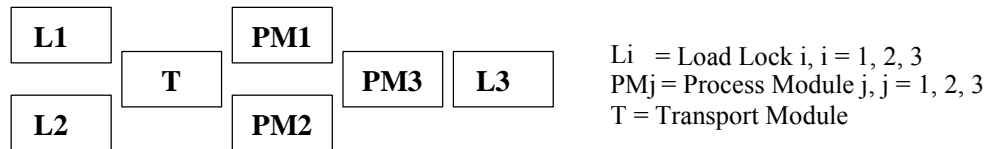
Figure R1-4
Multi-Path Cluster Tool Modules, Example 1

Li = Load Lock i, i = 1, 2, 3
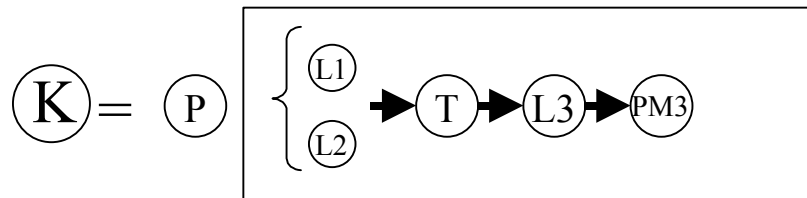PMj = Process Module j, j = 1, 2, 3
T = Transport Module

Figure R1-5
Key Group, Example 1

R1-5.6.1.2 The state value function for the key group is $K = P \times [1 - (1 - L1) \times (1 - L2)] \times T \times L3 \times PM3$. For reference, the equivalent truth table for this logic is shown in Table R1-1:

Table R1-1 Truth Table for Key Group, Example 1

P	L1	L2	T	L3	PM3	K
1	1	1	1	1	1	1
1	1	0	1	1	1	1
1	0	1	1	1	1	1
else						0

R1-5.6.1.3 IPF1 is a general IPF that uses the key group and either process module PM1 or PM2, as shown in Figure R1-6.
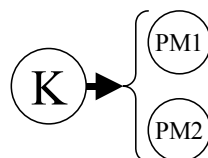

Figure R1-6
IPF1, Example 1

R1-5.6.1.4 The state value function for IPF1 = $K \times [1 - (1 - PM1) \times (1 - PM2)]$. The equivalent truth table is shown in Table R1-2:

Table R1-2 Truth Table for the State Function, Example 1

K	PM1	PM2	IPF1
1	1	1	1
1	1	0	1
1	0	1	1
else			0

R1-5.6.1.5 IPF2 represents a process engineering issue where PM2 is not sufficiently matched in performance to PM1. Therefore for certain processes, all units are restricted to go through PM1 only as shown in Figure R1-7.
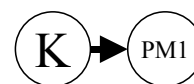

Figure R1-7
IPF2, Example 1

R1-5.6.1.6 The state value function for IPF1 = K × PM1. The equivalent truth table is trivial and is therefore not shown.

R1-5.6.2 *Example 2* — This example, as shown in Figure R1-8, is of a more complicated coat/develop system that has 56 total modules, including four load locks (L1-L4), four common transport robots (R1-R4), four coat stations, four develop stations, and four arrays of heat/chill plates with ten modules in each array.

R1-5.6.2.1 The key group, K, contains the platform, the four load locks, and the four transport robots, as shown in Figure R1-9. There are no process modules that are used in every IPF, therefore no process modules appear in K.
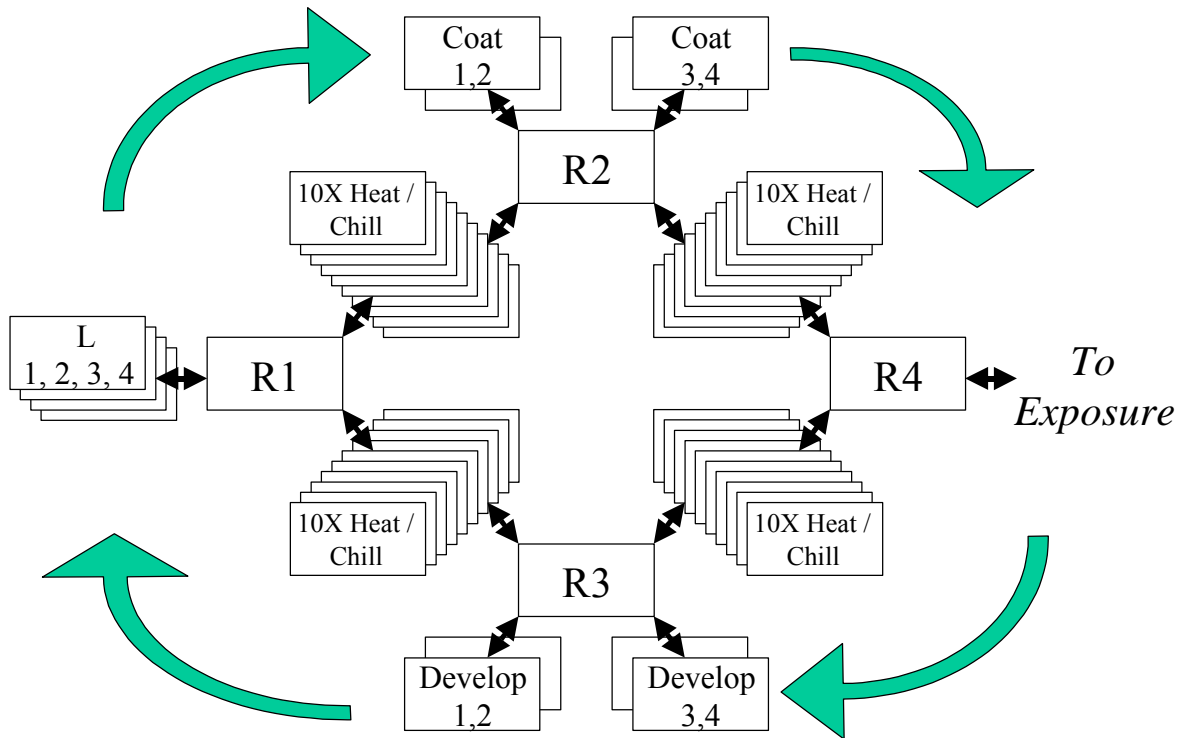
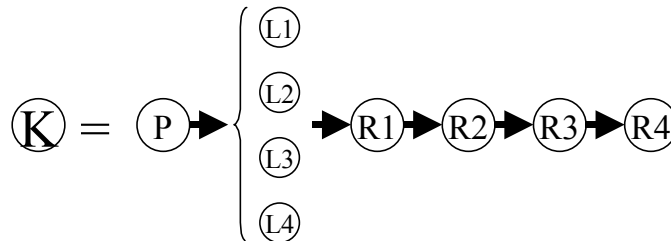**Figure R1-8**
Modules For A Coat/Develop System

Figure R1-9
Key Group Modules, Example 2

R1-5.6.2.2 The state value function for the key group is $K = P \times [1 - \Pi_{i=1\ to\ 4} (1 - Li)] \times \Pi_{j=1\ to\ 4} Rj$, which can be expanded to:

$$K = P \times [1 - (1 - L1) \times (1 - L2) \times (1 - L3) \times (1 - L4)] \times R1 \times R2 \times R3 \times R4$$

R1-5.6.2.3 The equivalent truth table is shown in Table R1-3:

Table R1-3 Truth Table for State Function, Example 2

P	*L1*	*L2*	*L3*	*L4*	*R1*	*R2*	*R3*	*R4*	*K*
0	any	any	any	any	any	any	any	any	0
1	0	0	0	0	any	any	any	any	0
any	any	any	any	any	0	any	any	any	0
any	any	any	any	any	any	0	any	any	0
any	any	any	any	any	any	any	0	any	0
any	any	any	any	any	any	any	any	0	0
else									1

NOTE 7: This truth table emphasizes the subsets that bring the key group "down," which are called *minimum cut sets*, rather than the subsets that keep the key group "up," called *minimum path sets*.

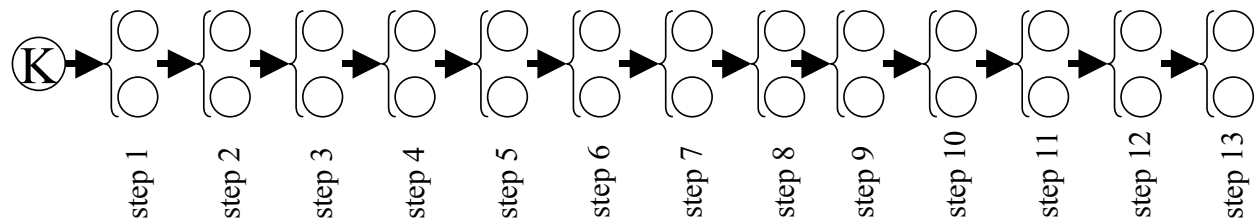R1-5.6.2.4 IPF1 has 13 steps and each step has two alternative modules, as shown in Figure R1-10.

Figure R1-10
Module Configuration For IPF1, Example 2

R1-5.6.2.5 The state value function for IPF1 $= K \times \Pi_{i=1\ to\ 13}[1 - (1 - PM_{i,1}) \times (1 - PM_{i,2})]$. The equivalent truth table is highly redundant and is therefore omitted.

R1-5.6.2.6 IPF2 has the same 13 steps as IPF1. However due to process matching issues, all units are restricted to a single process module at steps 1, 5, 9, and 13, as shown in Figure R1-11.
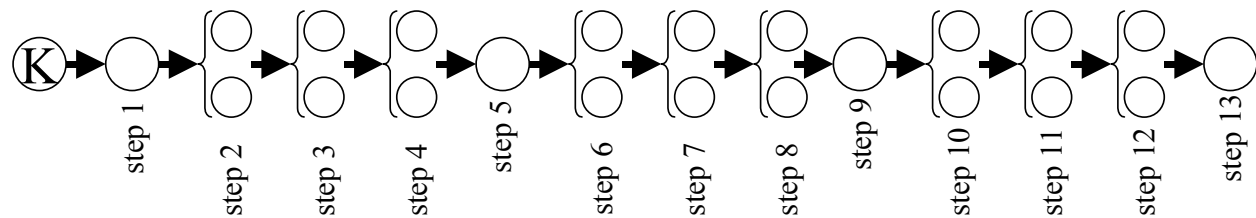

Figure R1-11
Module Configuration For IPF2, Example 2

R1-5.6.2.7 The state value function for IPF2 $= K \times PM_{1,1} \times PM_{5,1} \times PM_{9,1} \times PM_{13,1} \times \Pi_{i=\{2\text{-}4,\ 6\text{-}8,\ 10\text{-}12\}} [1 - (1 - PM_{i,1}) \times (1 - PM_{i,2})]$

R1-5.6.2.8 The coat/develop system is likely to have several more IPFs defined essentially in the same manner as IPF1 and IPF2, shown above.

R1-5.7 *Unscheduled Downtime versus Total Downtime* — In order to make a distinction between unscheduled downtime and total downtime for an IPF, the IPF function discussed thus far shall be executed twice: once to determine an unscheduled downtime state and a second time to determine a general downtime state.

R1-5.7.1 The first time the function is executed, each module variable is set to zero if the module is in an unscheduled downtime state and set to one otherwise. If the function evaluates to 0, the IPF is in an unscheduled downtime state. Each contiguous instance of process-flow unscheduled downtime is a process-flow failure. If the function evaluates to 1, the IPF may be in either a general downtime state or an up state.

$$M_{i\text{-}UD} = \begin{cases} 0, \text{ if module } i \text{ is in an unscheduled down state} \\ \\ 1, \text{ otherwise} \end{cases}$$

R1-5.7.2 The second time the function is executed, each module variable is set to zero if the module is in either a scheduled downtime state <u>OR</u> an unscheduled downtime state and set to one otherwise. If the function evaluates to 0, the IPF is in a general downtime state. If the function evaluates to 1, the IPF is a neutral state.

$$M_{i\text{-}GD} = \begin{cases} 0, \text{ if module } i \text{ is in scheduled down state} \\ OR \text{ an unscheduled down state} \\ \\ 1, \text{ otherwise} \end{cases}$$

R1-5.7.3 To summarize, if IPF(M_{UD}) = 0, the process-flow state is *unscheduled downtime (UD)*. Otherwise, if IPF(M_{GD}) = 0 the process-flow state is *general downtime (GD)*, and if IPF(M_{GD}) = 1, the IPF state is *uptime*.

NOTE 8: The process-flow state for an IPF that has at least one module in an unscheduled downtime state may be either (1) unscheduled downtime, (2) general downtime, or (3) neutral. Condition (1) occurs when the unscheduled downtime module is serial within the IPF. Condition (2) occurs when the unscheduled downtime module is not serial within the IPF, but a module (or set of modules) that is serial within the IPF is in a scheduled downtime state. Condition (3) occurs when none of the downtime modules are serial within the IPF regardless of being in a scheduled or unscheduled state.

R1-6 Determining Multi-Path Cluster Tool States

R1-6.1 The temporal mapping rules for determining multi-path cluster tool "productive/unscheduled downtime/neutral" states from module "productive/not-productive" states and IPF "up/downtime/unscheduled" states is as follows:

R1-6.1.1 If any module is in the "productive" state, then the cluster tool is in the "productive" state.

R1-6.1.2 Otherwise, if all of the IPFs are in the "unscheduled downtime" state, then the multi-path cluster tool is in the "unscheduled downtime" state.

R1-6.1.3 Otherwise, the multi-path cluster tool is in the "neutral" state.

R1-6.2 Each contiguous instance of a multi-path cluster tool unscheduled downtime state is a multi-path cluster tool failure.

NOTE 9: This logic is similar to the relationship between module states and the equipment states in SEMI E116, where the SEMI E116 "busy" state is analogous to the multi-path cluster tool "productive state," the SEMI E116 "blocked" state is analogous to the "unscheduled downtime" state, and the SEMI E116 "idle" state is analogous to the "neutral" state. However, the actual relationship between these two sets of states is neither trivial, nor direct.

NOTE 10: Productive time may not be easily allocated to IPFs in the general case. It is expected that some modules will belong to more than one IPF and that it will be prohibitive to ascertain the specific flow for each module from moment to moment. Hence, metrics that depend on productive time may not be calculated for IPFs.

NOTE 11: For the metrics presented in this document, it is not necessary to calculate downtime states other than unscheduled downtime at the multi-path cluster tool level. The effect of states other than productive and unscheduled downtime on the multi-path cluster tool is evaluated as the aggregate effect of such states on the IPFs.

R1-6.3 *Example 3* — A simplified example with a discrete timeline is shown in Figure R1-12. In this example there are three modules (i.e., M1, M2, M3) and three IPFs (i.e., IPF1, IPF2, IPF3). IPF1 uses all three modules, whereas IPF2 does not use M3, and IPF3 does not use M2. The state value functions for the IPFs are IPF1 = M1 × M2 × M3, IPF2 = M1 × M2, and IPF3 = M1 × M3, respectively. Temporal mapping of the IPFs and the multi-path cluster tool is described in Table R1-4.

NOTE 12: The condition between time t = 4 and t = 5, where the multi-path cluster tool is productive but all of its IPFs are down, is expected only as a transient condition in actual practice. Once the productive module finishes its task in progress, the multi-path cluster tool would be expected to go down. However, while the module is productive, it also is accruing theoretical processing time used in the SEMI E79 metric, rate efficiency. The allocation of this transient condition to productive time is necessary in order to guarantee that rate efficiency evaluated over any interval is never greater than 100%.
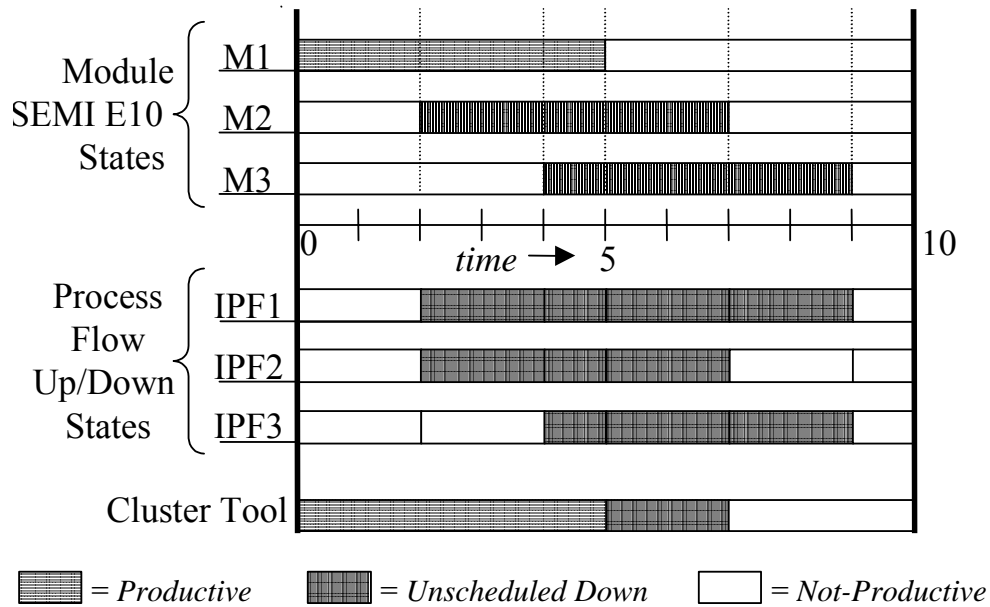

= *Productive*   = *Unscheduled Down*   = *Not-Productive*

Figure R1-12
Mapping Cluster-Tool States, Example 3

Table R1-4 Temporal Mapping of Example 3

Time	Module Events	IPF Events	Cluster Tool State
t = 0	M1 is productive.	All IPFs are up.	Productive
t = 2	M2 goes down. M1 is still productive.	IPF1 and IPF2 go to unscheduled downtime.	Productive
t = 4	M3 goes down. M1 is still productive.	All IPFs are in unscheduled downtime.	Productive
t = 5	M1 exits productive state. No modules are productive.	All IPFs are still in unscheduled downtime.	Unscheduled Downtime
t = 7	M2 come back up. M3 transitions into scheduled downtime.	IPF2 is up. At least one IPF is up. IPF1 and IPF3 are down, but not in unscheduled downtime	Neutral
t = 9	M3 comes back up. All modules are up.	All IPFs are up.	Neutral

R1-7 Intended Process-Flow and Multi-Path Cluster-Tool Metrics

R1-7.1 Once the IPF and multi-path cluster tool state histories have been prepared, evaluation of metrics may be performed in a similar manner to that used for evaluating non-cluster or single-path cluster tools or modules. The metrics are defined below with sample calculations based on Example 3 from Section R1-6.

NOTE 13: The multi-path cluster tool metrics presented here reflect the reliability of the multi-path cluster tool against total failure rather than partial failure. It is recognized that these metrics proposed here will reflect more favorably on systems with higher levels of redundancy at each process step. The cost or "trade-off" of this redundancy may be evaluated using other metrics from SEMI E10, SEMI E79, SEMI E35, or from non-standard evaluations. It also is recognized that these metrics will not reflect the partial loss of throughput for an IPF that is "up," but some of its alternative modules are "down." Once again the analyst is encouraged to consult other metrics from SEMI E10, SEMI E79, or from non-standard evaluations.

R1-7.2 *Multi-Path Cluster Tool Reliability*

R1-7.2.1 *Multi-Path Cluster Tool Mean Productive Time Between Failure (MTBF$_{p-CT}$)* — mean productive time between failure where productive time occurs when at least one module is in the productive state, and a failure occurs when there are no available IPFs through the multi-path cluster tool due to module-level unscheduled downtime.

$$MTBF_{p\text{-}CT} = \frac{Multi\text{–}Path\ Cluster\ Tool\ Productive\ Time}{Number\ of\ Multi\text{–}Path\ Cluster\ Tool\ Failures}$$

$$= \frac{5\ hours}{1\ failure}$$

$$= 5\ hours$$

R1-7.2.2 *Multi-Path Cluster Tool Failure Time (MFT$_{CT}$)* — mean time when there are no available IPFs through the multi-path cluster tool due to module-level unscheduled downtime.

$$MFT_{CT} = \frac{Multi\text{–}Path\ Cluster\ Tool\ Unscheduled\ Downtime}{Number\ of\ Multi\text{–}Path\ Cluster\ Tool\ Failures}$$

$$= \frac{2\ hours}{1\ failure}$$

$$= 2\ hours$$

NOTE 14: Since multi-path cluster tool productive time and multi-path cluster tool unscheduled downtime are mutually exclusive; they may be compatible with approaches based on renewal cycle models. Other renewal cycle results (e.g., the limiting probability of finding the cluster-tool productive or failed when approaching it at random) similarly may apply, as determined by the analyst.

R1-7.3 *Multi-Path Cluster Tool Availability*

R1-7.3.1 *Multi-Path Cluster Tool Aggregate IPF Uptime (Uptime$_{CT-IPF}$)* — availability of the multi-path cluster tool as a function of module "up/downtime/unscheduled downtime" states and is evaluated as the aggregate uptimes of all IPFs.

$$Uptime_{CT\text{-}IPF} = \frac{\sum_{all\ IPFs} IPF\ Uptime}{\sum_{all\ IPFs} IPF\ Operations\ Time} \times 100$$

$$= \frac{3 + 5 + 5}{10 + 10 + 10} \times 100$$

$$= \frac{13}{30} \times 100$$

$$\approx 43.3\%$$

NOTE 15: For reference, the value of the aggregate availability efficiency metric from SEMI E79 for the same example is 20/30 or 66.7%. This difference clearly demonstrates that depending on which combination of modules is "down," the effect on the multi-path cluster tool's availability may be substantially different than the aggregate module availability.

NOTICE: SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI E10-0304^E © SEMI 1986, 2004

SEMI E12-0303
STANDARD FOR STANDARD PRESSURE, TEMPERATURE, DENSITY, AND FLOW UNITS USED IN MASS FLOW METERS AND MASS FLOW CONTROLLERS

This standard was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on October 25, 2002. Initially available at www.semi.org December 2002; to be published March 2003. Originally published in 1986, previously published in 1996.

1 Purpose

1.1 In the past, confusion has existed in the values of standard temperature and standard pressure when gas flow is expressed in "standard" volumetric units. To eliminate this confusion, the Mass Flow Controllers Committee has established this standard.

2 Scope

2.1 This standard provides a common basis for communication between manufacturers and users.

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 Standard

3.1 *ASTM Standard*[1]

E 380-89a — Standard Practice for Use of the International System of Units (the Modernized Metric System)

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

4 Terminology

None.

5 Standard Temperature

5.1 Standard temperature is defined as 273.15 K (0.0° C).

6 Standard Pressure

6.1 Standard pressure is defined as 101,325 pascals (1 atm, 760 Torr).

7 Standard Density

7.1 The standard density is defined as Mw/22,413.6 grams per standard cubic centimeter (g/scc), where Mw is the molecular weight of the gas in grams per mole (g/mol), and 22,413.6 is the standard molar volume in cubic centimeters (scc/mol) (i.e., the volume of one mole of a perfect gas at standard temperature and standard pressure).

8 Standard Flow Rate

8.1 Standard flow rate is the volumetric flow rate of the gas at the standard density defined in Section 7.1.

9 Units

9.1 Units for standard flow rate may be expressed as standard cubic centimeters per minute (sccm), standard liters per minute (slm), standard cubic decimeters per minute (scdm), or as standard cubic meters per minute (scmm).

$$1 \text{ sccm} = 1 \times 10^{-3} * \text{slm}$$

$$= 1 \times 10^{-3} * \text{scdm}$$

$$= 1 \times 10^{-6} * \text{scmm}$$

NOTE 1: Units in this document have been editorially changed to sccm, slm, scdm, and scmm in line with international standards which require all units to be expressed in SI terms. While neither "minute" nor "liter" is a primary SI unit, each is acceptable under the system, and eliminating the use of these units in this standard would seriously diminish its acceptability.

10 Background

10.1 In the absence of this specification, there has been confusion in the definition of standard conditions. "Standard" temperature in particular has been variously defined as 59° F, 68° F, 70° F, 20° C, 22° C, etc. to reflect "normal" test conditions. The scientific community has

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[1] American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555 Website: www.astm.org

generally accepted 0° C, as has the semiconductor industry, in its definition of sccm. Standard pressure has almost universally been accepted as one atmosphere, except for rounding errors in different units.

10.2 Further confusion has existed in the definition of standard density when extended to vapors. For perfect gases (most light gases are nearly perfect), the standard density can be defined as the density of the gas at standard temperature and pressure. Since one gram mole of a perfect gas occupies 22,414 cubic centimeters at standard pressure and standard temperature, it follows that a flow rate of 22,414 sccm of any perfect gas is one mole per minute.

10.3 By defining standard density as in Section 7.1, the correlation between sccm and moles/minute is retained, even for vapors. If standard density were defined as the actual density of the vapor at standard temperature and pressure, then the correlation with moles per minute would differ by the vapor's compressibility factor (Z). This is not an acceptable alternative because the compressibility of many vapors is not accurately known, and, in fact, does not exist for those materials that are liquid at standard temperature and pressure.

11 Implications for Calibration

11.1 Since the standard flow units are defined at a standard density, they represent units of mass flow rather than volumetric flow.

11.2 Gravimetric calibration readings in grams per minute (g/min) can be converted to standard cubic centimeters per minute (sccm) by dividing by the standard density (g/scc) as defined in Section 7.1.

11.3 Rate-of-rise (ROR) data will generally have negligible compressibility error when operated over a low absolute pressure range. If compressibility errors are significant, they will cause the rate of pressure rise to be reduced and become pressure-dependent as the pressure increases. In this case, the pressure range must be reduced, or correction made, for compressibility.

11.4 Volumetric flow data must be corrected from actual density of the real gas at the test conditions to the standard density. The actual density can be approximated for near-perfect gases by ratios of absolute pressure and temperature to the standard density. For vapors, the actual density at the test conditions must be known from other data.

SEMI E15-0698^{E2} (Reapproved 0703)
SPECIFICATION FOR TOOL LOAD PORT

This standard was technically reapproved by the Global Physical Insterfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition approved by the North American Regional Standards Committee on March 12, 2003. Initially available at www.semi.org May 2003; to be published July 2003. Originally published in 1990; previously published March 2003.

^E This specification was editorially modified in November 2004 to correct an editorial error. Changes were made to Table 1.

1 Purpose

1.1 This standard is intended to unify the interface between process/inspection tools and automated wafer carrier transport systems while maintaining compatibility with human transport.

2 Scope

2.1 This specification deals with the mechanical interface (load port) for wafer carrier transfer between wafer carrier material transport systems, including humans, and wafer fabrication/inspection equipment (tools). The concept defines the placement and orientation of a wafer carrier on a tool to allow reasonable interfacing with mechanized material movement systems without compromising human access to perform the material exchange function.

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 Impact

3.1 Compliance with this specification requires the placement of load ports on tools to specific heights, orientations, and load depths. Restrictions are also placed on clearances to obstructions which may be adjacent to such ports.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E1 — Specification for 3 inch, 100 mm, 125 mm, and 150 mm Plastic and Metal Wafer Carriers

SEMI E19 — Standard Mechanical Interface (SMIF)

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

5 Terminology

5.1 *Definitions*

5.1.1 *box* — A protective portable carrier for a cassette and/or substrate(s).

5.1.2 *cassette* — An open structure that holds one or more substrates.

5.1.3 *cassette centroid* — A datum representing the theoretical center of a stack of wafers in a cassette formed by the pocket centerline and the "center" pocket as defined by the location associated with dividing dimension B3 by two (see SEMI E1, Figure 1).

5.1.4 *cassette envelope* — A rectangular volume with vertical sides which completely contains a cassette, even if the cassette is tilted (see Figure 1).

5.1.5 *enclosed load port* — A load port with overhead clearance obstructed by the tool.

5.1.6 *global orientation* — The general orientation of a wafer carrier in a tool; may be vertical or horizontal.

5.1.7 *load depth* — The horizontal distance from the load face plane to cassette centroid or carrier centroid (see Figures 2 and 3 (D)).

5.1.8 *load face plane* — The furthest physical vertical boundary plane from cassette centroid or carrier centroid on the side (or sides) of the tool where loading of the tool is intended (see Figures 2 and 3).

5.1.9 *load height* — The distance from the bottom of the cassette or carrier to the floor at the load face plane (see Figure 3 (H)).

5.1.10 *load port* — The interface location on a tool where wafer carriers are delivered. It is possible that wafers are not removed from, or inserted into, the carrier at this location.

5.1.11 *open load port* — A load port with overhead clearance unobstructed by the tool.

5.1.12 *pod* — A box having a Standard Mechanical Interface (SMIF) per SEMI E19.

5.1.13 *spacing* — The minimum spacing between centroids (see Figure 2, S).

5.1.14 *tool* — Any piece of semiconductor fabrication or inspection equipment designed to process wafers delivered in wafer carriers.

5.1.15 *tilt* — A small angle of offset from the normal horizontal or vertical orientation of a cassette or wafer carrier designed to preferentially align or keep wafers in their intended place within the carrier/cassette (see Figure 1, T).

5.1.16 *wafer carrier* — Any cassette, box, pod, or boat that contains wafers.

5.1.17 *wafer carrier centroid* — A datum representing the theoretical location of the center of a stack of wafers in the carrier.

5.1.18 *wafer carrier envelope* — A rectangular volume with vertical sides which completely contains a carrier, even if the carrier is tilted (see Figure 1).

5.2 *Description of Terms Specific to this Standard*

5.2.1 *carrier* — Wafer carrier.

6 Ordering Information

6.1 The following items require communication between the tool supplier and user and shall be included in any request for quotation, quotation, or purchase order:

6.1.1 If the tool has multiple load ports, provide the spacing, S, between carrier centroids (see Section 7.8).

6.1.2 Specify what carrier (e.g., SEMI standard cassette, pod) is to be accommodated by the load port.

6.1.3 Specify whether the load port is open or enclosed.

6.1.4 Specify whether the wafer orientation is horizontal (per Section 7.3.1) or vertical (per Section 7.3.2).

7 Requirements

7.1 The dimensions for the placement of a wafer carrier on the load port of a tool are given in Table 1.

7.2 The standard is based upon the concept that any wafer carrier can be used. Dimensions are usually specified as clearances to wafer carrier envelopes (see envelope concept in Figure 1).

7.3 The global orientation of the cassette or wafer carrier is constrained to be parallel or perpendicular to the load face plane. Allowable cassette orientations are:

7.3.1 For wafers horizontal, the opening of the cassette must be opposite the load face plane, and the front surface of the wafer must face up (see Figure 4);

7.3.2 For wafers vertical, the opening of the cassette must face up, and the front surface of the wafer must face the load face plane (see Figure 5).

7.3.3 This requirement also applies to cassettes in pods.

7.4 The maximum tilt is 10 degrees.

7.5 The load height is specified as follows (see Figure 3):

7.5.1 Dimension H is 900 mm (~35.4 in.), fully adjustable over ± 10 mm (~0.4 in.).

7.6 The maximum height above H of an obstruction between the load face plane and the carrier envelope (such as for an alignment device or identification tag reader) is 50 mm (~2 in.) (see Dimension H1 in Figure 3).

7.7 Clearances (C1, C2, and C3) are defined with respect to the largest carrier envelope required. For cassettes, envelopes are defined using cassette dimensions from SEMI E1. For pods or other wafer carriers, envelopes are defined using the carrier standard (if any) or the carrier manufacturer's specifications (see Figure 1 for concept and Figures 2 and 3 for use).

7.8 Dimension S specifies the recommended minimum spacing between cassette/wafer carrier centroids. In any case, if S violates clearance C1 in any application, then C1 prevails (see Figure 2).

7.9 Tools with enclosed load ports shall have a minimum vertical clearance, C3, above the cassette or carrier at the load port. Open load ports shall have a vertical clearance above the load port which is unrestricted by the tool.

Table 1 Dimension Requirements, mm (inches)

Dimension	Application	Value, mm (in.)	Notes
C1	minimum	75 (3)	
C2	minimum	30 (1.2)	
C3	minimum	225 (9)	See Note 1
D	maximum	250 (9.8)	

Dimension	Application	Value, mm (in.)	Notes
H	range	900 (35.4) ± 10 (.4)	See Note 2
H1	maximum	50 (2.0)	
S	≤ 150 mm carriers 200 mm carriers	350 (13.8) 400 (15.7)	See Section 7.8.
T	maximum	10 degrees	

NOTE 1: Applies to tools with enclosed port; otherwise, clearance above the port must be unrestricted by the tool (see Section 5.8).

NOTE 2: Fully adjustable over ± 10 mm (~0.4 in.) range.

Table 2 Dimension Definitions

Dimension	Description
C1	Minimum side clearance between one carrier envelope and another, or to vertical obstruction.
C2	Minimum rear clearance from carrier envelope to vertical obstruction.
C3	Minimum clearance above carrier envelope to horizontal obstruction on the tool.
D	Maximum load depth to carrier centroid.
H	Allowable load height to bottom of carrier envelope.
H1	Maximum height of horizontal obstruction above load height between load face plane and carrier envelope.
S	Recommended minimum spacing between carrier centroids.
T	Maximum cassette or wafer carrier tilt.
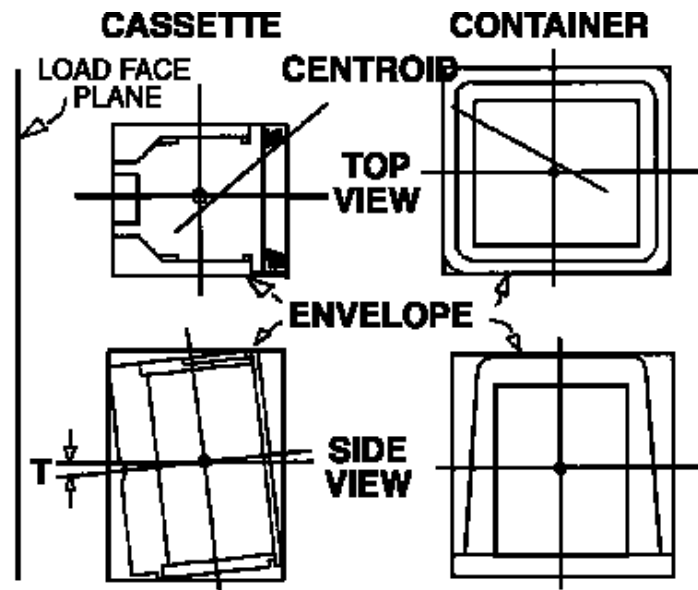
Envelope is formed by planes which are parallel or perpendicular to load face plane independent of tilt (T).

Figure 1
Envelope Concept

SEMI E15-0698^{E2} © SEMI 1990, 2003
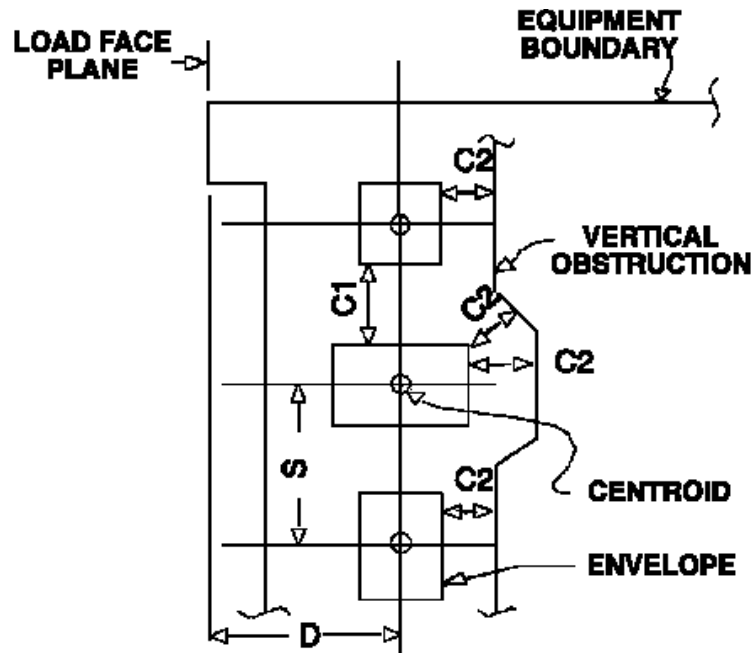
Envelope must be parallel to load face plane.

Figure 2
Load Port Requirements, Plan View
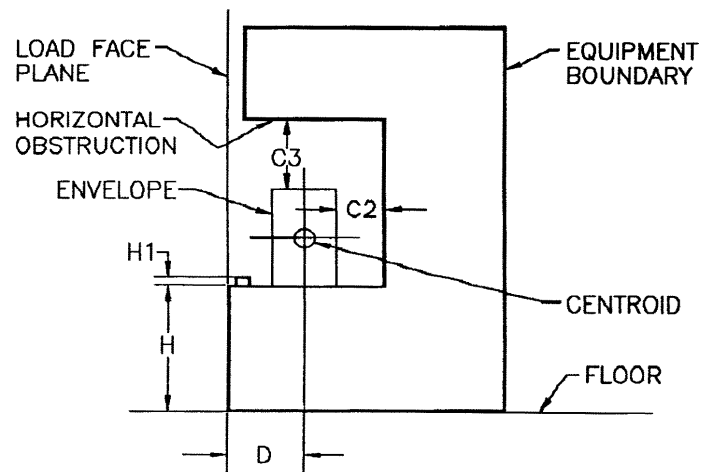
Figure 3
Load Port Requirements, Elevation View
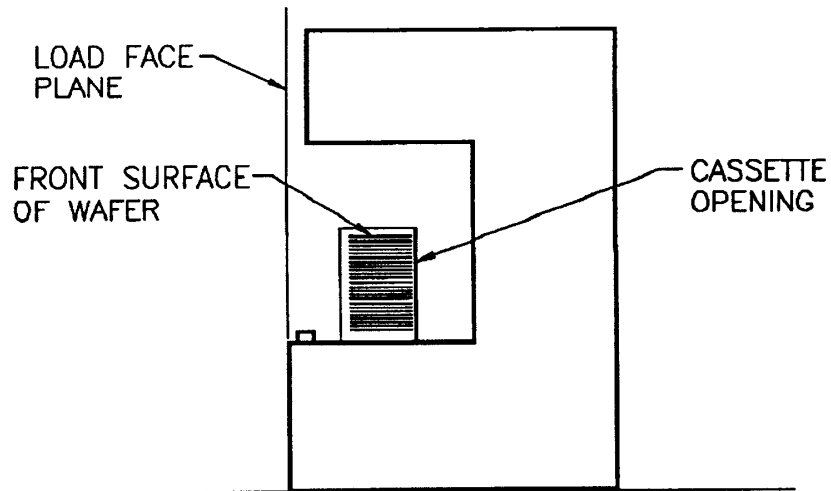
Figure 4
Wafer and Cassette Orientation, Wafers Horizontal

Figure 5
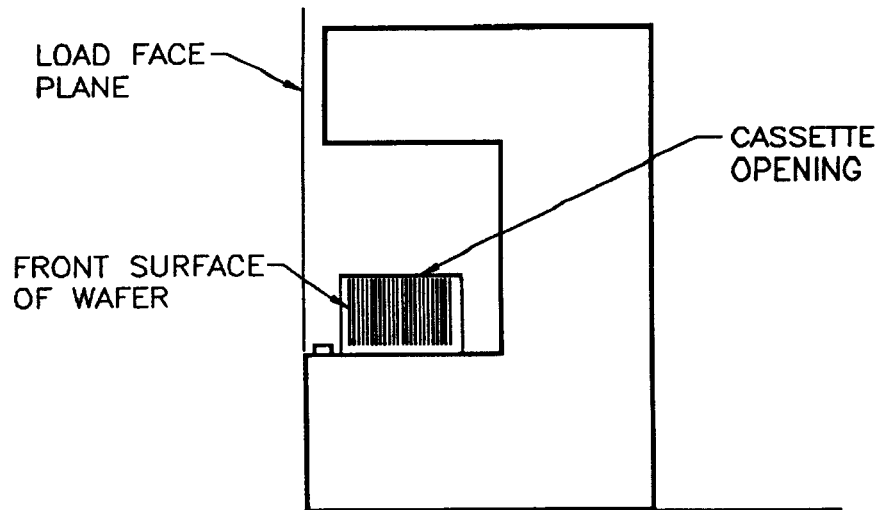**Wafer and Cassette Orientation, Wafers Vertical**

8 Related Documents

8.1 *SEMI Documents*

SEMI E47 — Specification for 150 mm/200 mm Pod Handles

SEMI E48 — Specification for SMIF Indexer Volume Requirement

SEMI S8 — Safety Guidelines for Ergonomics Engineering of Semiconductor Manufacturing Equipment

SEMI T4 — Specification for 150 mm and 200 mm Pod Identification Dimensions

SEMI Compilation of Terms

APPENDIX 1
APPLICATION NOTES

NOTICE: This appendix was approved as an official part of SEMI E15 by full letter ballot procedure.

A1-1   Material transport automation can come in a number of forms, including AGV's (automated guided vehicles) and tracks (conveyers), which operate anywhere from tool loading level to ceiling level. Wafers may be transported in cassettes or in carriers (such as cassettes in pods). Automation provides flexibility with regard to the range of interface coordinates it can accommodate. On the other hand, it is clear that humans will continue to load carriers on tools in many fabs. SEMI E15 is an attempt to satisfy all of these needs, including continued human compatibility. In fact, compatibility of automation and human ergonomics has been considered of primary importance in the rewrite of this standard.

A1-2   The increased value for C1, of 75 mm, over the previous value in this standard is determined by the ergonomic requirement to accommodate a 95th percentile human male hand carrying a pod by its handles. Limitation of the load port height to 900 mm was, again, driven by ergonomic considerations, as the previously allowed value of up to 1300 mm was clearly "user unfriendly."

A1-3   Equipment suppliers must consider the dimension, S, in order to ensure that their tool will be compatible with automation systems and pods. This fact applies to tools with more than one load port per tool. In order to enable space for two pods on side-by-side load ports, the dimension, S, must be greater than or equal to 350 mm for tools processing 150 mm or smaller wafers, and 400 mm for 200 mm wafer tools. The dimension, S, is defined as the distance between wafer carrier centroids. Driving factors for S are that the size of a pod is larger than a cassette and that ergonomic guidelines suggest a clearance of at least 75 mm between the box and an adjacent object in order to provide space for the human hands to grasp and pick up the box by its handles.

A1-4   A global horizontal placement tolerance of 15 mm of the carrier centroid should be allowed by the alignment means of the load port. (That is, a misalignment by up to $\pm$ 7.5 mm in both the x and y directions of the carrier centroid will still allow the alignment means to guide the carrier to its correct final location on the load port). The misplacement dimension is made large to be consistent with the tactile/visual capabilities of humans and the placement accuracy of AGV's. This requires that the load port provide some alignment aid to bring the carrier centroid to within the final registration tolerance (generally 0.5 mm) required by the automated wafer handling of the tool. Standards for this registration tolerance will generally be found in the SMIF documents.

A1-5   The standard purposely does not address vacuum load locks. Since minimization of volume is usually a design requirement for a vacuum load lock, the minimum clearances (C1 – C3) of this standard are not compatible with optimum load lock design. It is not intended that vacuum load locks would be the load port of a tool in which vacuum processing is performed. Simple solutions exist today for transportation of a cassette, or of individual wafers, from a SEMI E15-compatible load port to a vacuum load lock. Open load ports are intended to be specified for use with overhead transport systems for automation.

A1-6   It is not easy to formulate a standard which allows compatibility with such a wide range of requirements. Nor is it easy to design equipment compatible with a number of different standards affecting the same hardware. SEMI E15 covers a wide range of applications without causing undue compromise in any particular implementation, while remembering that most of our fabs will continue to use human transport in the immediate future. We hope this short discussion of key issues aids in your understanding of the intent and details of the standard.

SEMI E16-90 (Reapproved 1104)
GUIDELINE FOR DETERMINING AND DESCRIBING MASS FLOW CONTROLLER LEAK RATES

1 Purpose

1.1 The purpose of this guideline is to establish a uniform, worldwide means for describing and measuring leak rates of mass flow controllers. The leak integrity of a gas delivery system is important to maintaining product quality and performance. This guideline is intended to prevent confusion and misunderstanding between manufacturers and users. In particular, it distinguishes between mechanical and diffusion leak rates.

2 Scope

2.1 This guideline contains definitions of terms and procedures for determining the Leak Rates of mass flow controllers as used in the semiconductor industry.

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 Terminology

3.1 *Definitions*

3.1.1 *leak* — a path or paths in a sealed system which will pass helium when a partial pressure differential exists. A partial pressure differential can exist for helium even though a total gas pressure differential may not exist. There are two major leak mechanisms, a mechanical passage or a material through which gas can diffuse or permeate. In a real system, a leak may have both mechanisms operating in parallel.

3.1.1.1 A mechanical leak may be a physical crack, pit, scratch or other imperfection in a sealing surface, or contamination or debris on the seals. A diffusion or permeation leak is caused by the movement of helium through gaskets, O-rings, polymers, or other materials through which helium can diffuse.

3.1.2 *measured leak rate* — the leak rate of a given system measured under specified conditions and employing a specified test gas (helium). For the purposes of comparison with rates determined by other methods of testing, measured leak rates must be converted to equivalent standard leak rates.

3.1.3 *sensitivity (minimum detectable leak rate)* — the smallest standard leak rate that an instrument, method or system is capable of measuring under specified conditions.

3.1.3.1 For the purposes of this document, the Measured Leak Rate shall be corrected to Standard Leak Rate by multiplying by the ratio of 101.32 kPa to the absolute value of the pressurizing helium unless otherwise called for by the MFC specifications.

$$\frac{\text{Measure Leak Rate} \times 101.32 \text{ kPa}}{\text{He Actual Pressure}} = \text{Standard Leak Rate}$$

3.1.4 *standard leak rate* — the quantity of helium at 25°C and 101.3 kPa (760 Torr) flowing through a leak when the high pressure side is at 101.32 kPa and the low pressure side is below 100 Pa (approximately 1 Torr). Standard Leak Rate shall be expressed in the following units:

Pa-m^3/s (He) = "Pascal cubic meters per second, helium"

or, alternatively,

atm-cc/s (He) = "atmospheric cubic centimeters per second, helium"

3.1.4.1 The "mass spectrometer helium leak detector" is generally used for leak rate testing of high and medium level vacuum apparatus. Units of sccs, Torr-L/s, and m bar-L/s, have been used in the past but are not encouraged. Reference materials include MIL STD-202E, C-1.

NOTE 1: The Pascal (1Pa = 1 N/m^2) is defined as the pressure unit of the international unit system SI. Therefore, the SI units above are preferred. Atm-cc/s is acceptable, as it is widely used in the semiconductor industry.

4 Testing

4.1 *General Requirements*

4.1.1 *Leak Detector* — The leak detector shall be of the helium mass spectrometer type. It shall have sensitivity at least equal to or smaller than the specified leak rating of the mass flow controller to be tested. If

the actual leak rate is to be reported, the sensitivity shall be five times smaller than the leak to be measured. If the sensitivity is not five times smaller, the actual leak rate may be reported if the sensitivity of the detector is also reported.

4.1.2 Helium must have access to all primary seals.

4.1.3 Connections between the MFC and the leak detector must be leak-tight.

4.1.4 The ambient temperature of the MFC should be $25° \pm 5°C$ unless otherwise specified. If another test temperature is used, it must be recorded during the test.

4.2 *Test Procedures* — There are two basic setups which may be used to measure the leak rate from the external environment to the internal gas passages of the MFC or from the internal passages to the external environment. Results for either test method may be reported. The method used must be reported as well. A third test, the through-the-valve setup, is intended to measure the quality of the valve seat shutoff.

4.2.1 *Internally-Pressurized Leak Test* — The purpose of this test set-up is to simulate operation of the MFC under conditions where the internal pressure is above ambient. The recommended internal pressure is 300 kPa absolute (30 psig) of helium (see Figure 1).
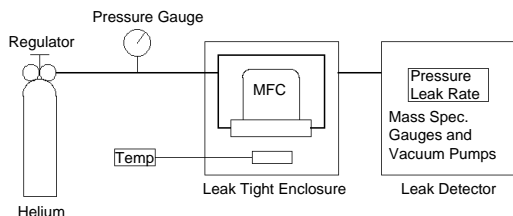

Figure 1
Internally-Pressurized Leak Test

4.2.2 *Externally-Pressurized Leak Test* — The purpose of this test is to simulate operation of the MFC under conditions where the internal pressure is at vacuum. The external pressure should be equal to atmospheric pressure. The internal pressure should be less than 100 kPa (see Figure 2).
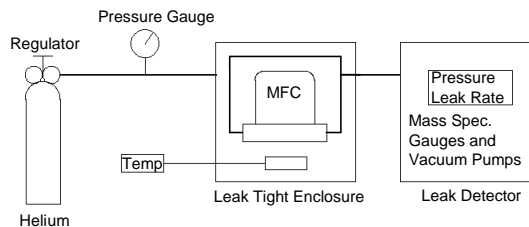

Figure 2
Externally-Pressurized Leak Test

4.2.3 *Control Valve Seat Leak Test* — The purpose of this test is to determine the leakage through the control valve under simulated operation in the closed control mode. The MFC should be electrically energized for normal operation and placed in the closed position as specified for the operation of the MFC. The input pressure to the MFC should be 100 kPa $\pm$ 20%. The outlet should be connected directly to the helium leak detector, and pressure should be as low as possible using good leak detector practice (see Figure 3).
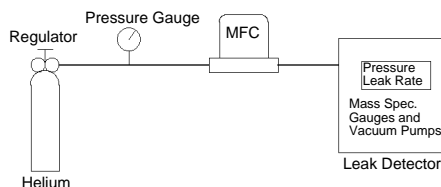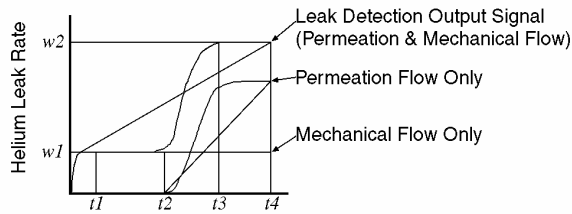

Figure 3
Control Valve Seat Leak Test

4.2.3.1 In the case of MFCs which are not designed for positive shutoff at the control valve, alternative methods may be employed if documented and reported.

4.3 *Reporting Results* — The example shown in Figure 4 is a plot of leak detector output value vs. time for a representative elastomer-sealed MFC. This curve is the sum of mechanical and permeation leak components.

NOTE 2: All times are from application of helium, starting with a leak detection system pumped down to base reading.

Interval	Rate	Example
t1 Initial System Response		Less than 10 seconds
t2 Leak Prior to Onset of Permeation	*w1*	10 seconds to 1 minute
t3 Increasing Permeation		1 minute to 30 minutes
t4 Total Saturation	*w2*	Beyond 30 minutes

Figure 4
Leak Detector Output Value vs. Time

4.3.1 The actual shape of these curves and time intervals is dependent on the design of the MFC under test, the elastomer used, if any, and the characteristics of the leak detection system. These time intervals must be determined using sound engineering judgment following qualification testing of the specific MFC model and test set-up. Once determined, it is recommended that receiving inspection consist of measuring for leak rate value *w1* at the end of interval *t2*.

4.3.2 Following qualification testing, report typical values for *t1* through *t4* and *w1* and *w2*. *w1* is primarily the mechanical portion of the leak, and *w2* is mechanical plus permeation. In the case where *w2* is significantly greater than *w1*, *w2* is primarily permeation. In the case of a gross mechanical leak, *w1* could greatly exceed, and thereby mask, *w2*.

NOTE 3: This test must be performed with elastomers that are devoid of helium. Such elastomers have either not been previously exposed to helium or have been degassed following exposure. Once this test has been performed, the elastomers must be purged of helium by the passage of time and/or baking.

4.3.3 In good leak testing practice, the background level should be verified before the application of helium to ensure that the elastomers are in a helium degassed state and that the leak detecting system is in proper operation.

NOTICE: SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature, respecting any materials or equipment mentioned herein. These standards are subject to change without notice.

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SEMI E17-0600
GUIDELINE FOR MASS FLOW CONTROLLER TRANSIENT CHARACTERISTICS TESTS

1 Scope

1.1 This guideline is intended to establish a common basis for communication between users and suppliers of semiconductor equipment. It provides terminology and methodology aimed at eliminating confusion regarding what previously has been referred to as MFC "response time." The conditions and procedures are given for determining and expressing the transient characteristics of a mass flow controller (MFC) to a step change in set point. This guideline applies to mass flow controllers for gases used in semiconductor fabrication equipment.

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

2 Definitions (Figures 1 and 2)

2.1 *Actual Flow* — For the purpose of this standard, the output value of the master reference standard.

2.2 *Dead Time* — The interval of time between the set point step change and the start of the resulting observable response.

2.3 *Final Steady State Value* — The average value of the actual flow, after the effects of the input transient have expired to a value equal to or below the intrinsic drift and noise.

2.4 *Settling Time* — The time between the set point step change and when the actual flow remains within the specified band.

2.5 *Step Response Time* — The time between the setpoint step change and when the actual flow first enters the specified band.

2.6 *Transient Overshoot* — The maximum change in actual flow minus the steady state change in actual flow, expressed as a percentage of the set point step change.

2.7 *Transient Undershoot* — The maximum amount that the actual flow passes the final steady state value, in the opposite direction of overshoot, expressed as a percentage of the set point step change.

2.8 *Set Point* — The electrical input signal to the MFC which sets the desired value of the controlled flow.

2.9 *Specified Band* — The region between ± 2% of the final steady state value or ± 0.5% of full scale, whichever is greater.

3 Test Setup

3.1 The purpose of the flow system is to furnish the mass flow controller under test with a constant pressure supply of suitable gas. It must also provide a means of determining the gas flow rate through the mass flow controller that responds to changes in gas flow significantly faster than the device under test. The recommended flow system for testing the speed of response of MFCs is shown in Figure 3a.

3.2 The flow system shall have straight tubing or pipe connecting the MFC to the master reference standard. The inside diameter of the interconnecting tubing or pipe shall be of sufficient size to preclude any pressure drop that would affect the performance of the MFC.

3.3 The pneumatic time constant, Tau, should be minimized. (See Section 3.7.)

Tau =	$(V*DPm) / (Qm*Pa)$

Where:

V =	Internal volume of the flow system between the MFC under test and the master reference standard, including tubing, fittings and the side of the master reference standard that is connected to the MFC under test.
Qm =	Maximum volumetric flow expected during the test.
DPm =	Pressure drop of the master reference standard at flow Qm.
Pa =	The absolute pressure present at the outlet of the master reference standard at final steady state value.

3.4 The source of the test gas shall be capable of delivering an essentially constant upstream pressure to the mass flow controller under test during the transient characterization. A maximum variation of ± 2% from

the median absolute pressure is considered adequate for most mass flow controllers.

3.5 Nitrogen is the recommended gas for the standard test shown in Figure 3a. The inlet pressure is 25 psig (1.75 kg/cm^{2}G). Outlet pressure is the prevailing atmospheric pressure. The temperature of the gas entering the flow controller and the temperature surrounding the flow controller shall be the same. Neither shall vary during the test so as to have a significant effect.

3.5.1 The preceding conditions are recommendations. Deviations may be made to more accurately reproduce the conditions that the MFC will experience in use, such as the variation shown in Figure 3b. Any deviation from the above gas and pressure conditions and/or test setup must be noted with the test results.

3.6 The master reference standard is used to provide a representation of the instantaneous actual flow. It is customary to refer to the output of the master reference standard as the actual flow. It shall have an accuracy of ± 5% of reading (including linearity), or better, over the flow range for which results will be reported. The pressure drop across the master reference standard at the test flow shall be small enough to not effect the response of the MFC under test.

3.6.1 Typical master reference standards are Hot-Wire flow meters (or similar immersible thermal flow sensors), laminar flow elements with a differential pressure transducer, and Rate of Rise (RoR) systems.

3.7 The measuring system response time is the sum of the pneumatic time constant, master reference response time and the recording system response time. The measuring system response time shall be less than 1/5 of any reported transient characteristic. If the measuring system response time is greater than 1/5 of a specific transient characteristic, that characteristic may be reported if the measuring system response time is also reported.

3.8 The test setup shall provide a step change in the setpoint to the mass flow controller, along with a time-zero cue to the data acquisition system. The step change transient time shall be less than 1% of the step response time of the MFC under test.

3.9 The test setup is recommended for MFC full scale flow rates above 10 sccm. In those cases where the flow rate is below 10 sccm and the pneumatic time constant is not less than 1/5 of the step response time of the MFC the pneumatic time constant shall be reported.

3.10 The MFC shall be electrically energized for the supplier recommended "warm up" time prior to the start of the test.
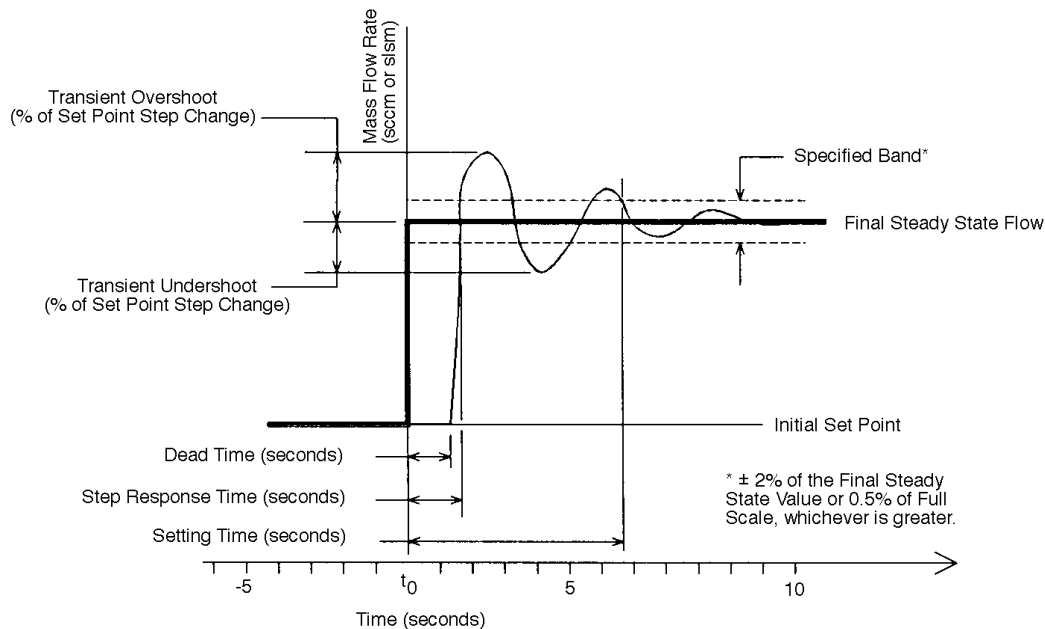

Figure 1
Definitions of MFC Transient Characteristics Terminology in the Case
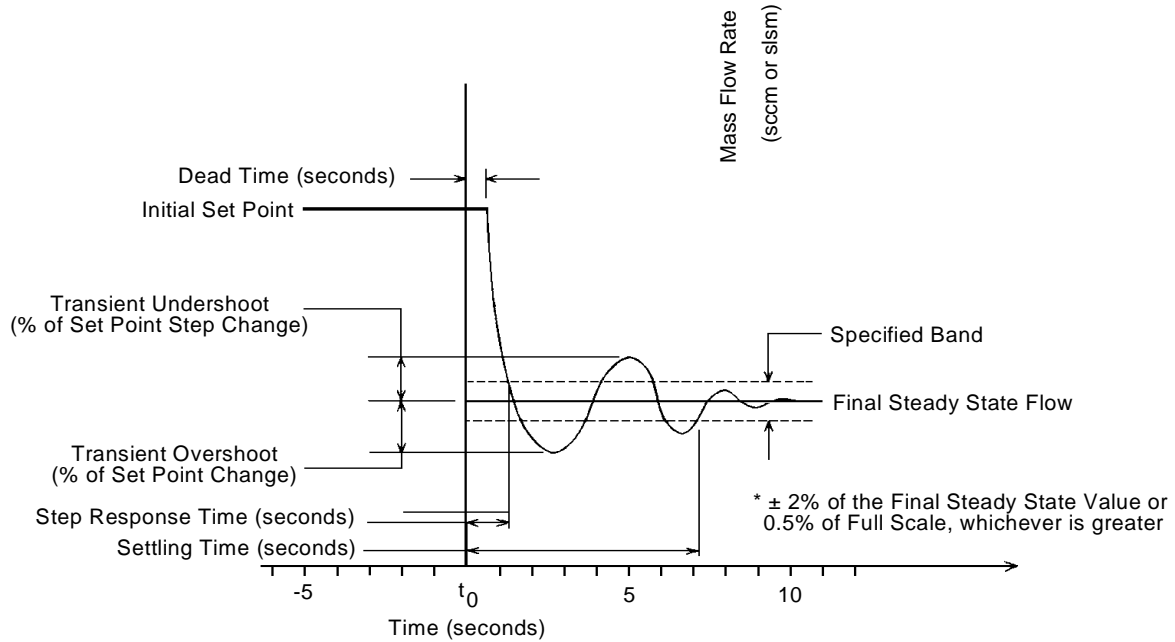**Where the Final Set Point Is Higher than the Initial Set Point**

Figure 2
Definitions of MFC Transient Characteristics Terminology in the Case
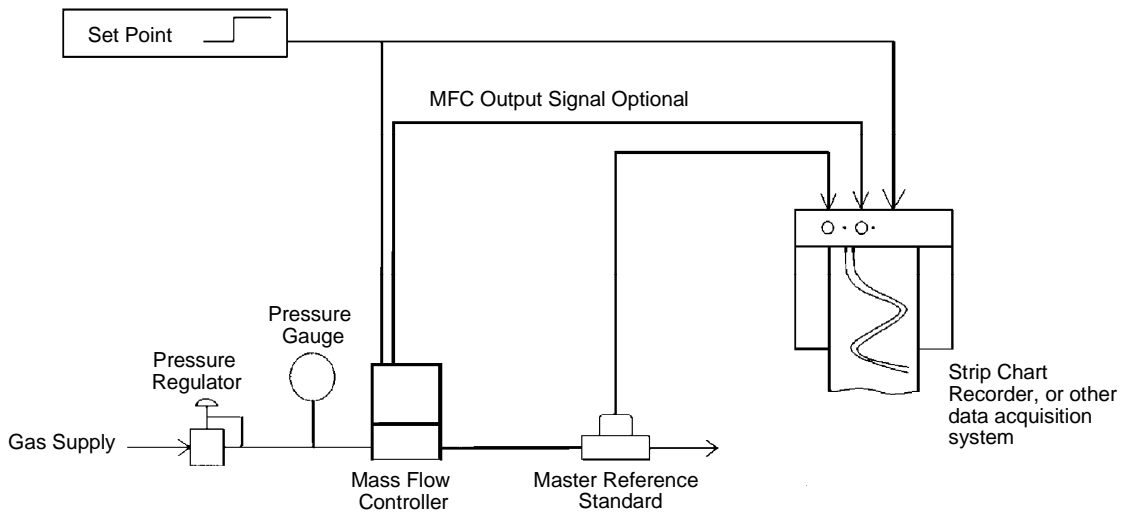**Where the Final Set Point Is Lower than the Initial Set Point**

Figure 3a
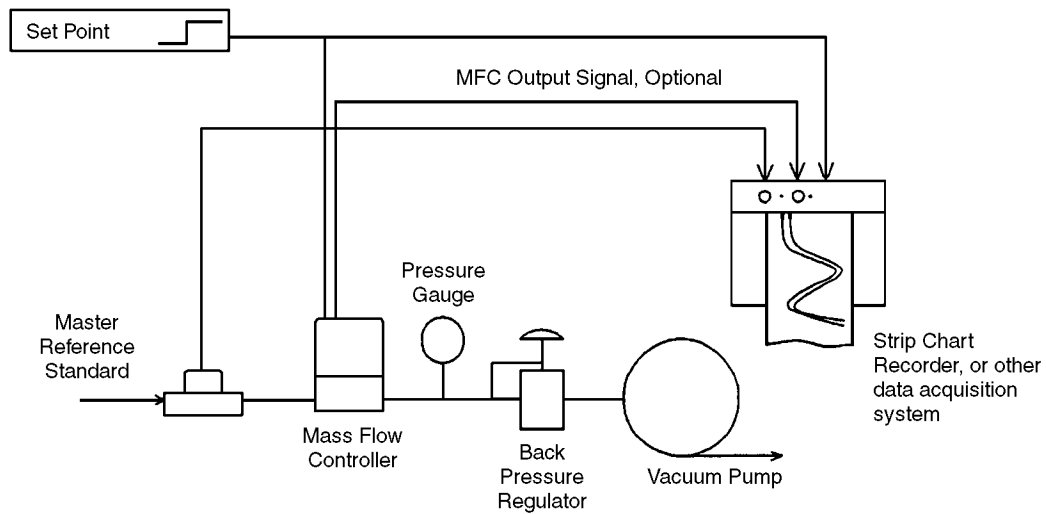**MFC Transient Characteristics Test Setup with Outlet at Atmospheric Pressure**

SEMI E17-0600 © SEMI 1991, 2000

Figure 3b
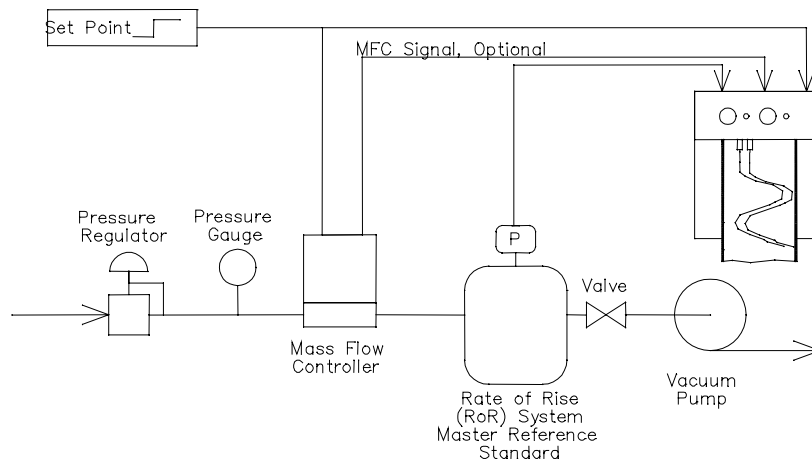**MFC Transient Characteristics Test Setup with Outlet at Vacuum**

Figure 3c
VFC Transient Characteristics Test Setup with Rate of Rise (RoR) System

4 Test Procedure

4.1 Evaluate the transient characteristics from "OFF" to a flowing condition at final set point by a transition in set point voltage only.

4.1.1 Apply a set point voltage sufficient to close the control valve following the manufacturer's recommendation. This may be a voltage other than zero, either positive or negative. Allow the output of the mass flow controller and the actual flow, if any, to stabilize.

4.1.2 Apply the final set point value as shown in Table 1.

4.2 Evaluate the transient characteristics from "OFF" to a flowing condition at final set point by using an auxiliary input to an MFC designed for the purpose.

4.2.1 Establish an "OFF" condition following the manufacturer's recommendation. The setpoint should be applied as shown in Table 1. Allow the output of the mass flow controller and the actual flow, if any, to stabilize.

4.2.2 Change the state of the auxiliary input to achieve control.

4.3 Evaluate the testing transient characteristics between two non-zero set point controlled flows.

4.3.1 Adjust the command to the "initial set point" in Table 1, and allow the actual flow (as measured by the master reference standard) to stabilize.

4.3.2 Apply final set point as shown in Table 1.

4.4 Refer to Figures 3 and 4 to determine the dead time, step response time, settling time, overshoot, and undershoot. Record the results in Table 1.

5 Test Results

5.1 Transient characteristics test results shall be presented as follows:

(1) "OFF" means the MFC set point is zero or the lowest value permitted.

(2) The control valve leak rate at shut-off shall be recorded.

(3) Other initial and final set points may be tested and reported.

(4) The transient characteristics of the MFC electrical output signal shall also be recorded during the above testing for purposes such as comparison with the actual flow.

Table 1

Initial Set Point (% of Full Scale)	OFF (1)	OFF (1)	25	75	OTHER (3)
Final Set Point (% of Full Scale)	100	25	75	25	OTHER(3)
Dead Time (Seconds)					
Step Response Time (Seconds)					
Settling Time (Seconds)					
Transient Overshoot (Percent of set point step change)					
Transient Undershoot (Percent of set point step change)					

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SEMI E18-91 (Reapproved 1104)
GUIDELINE FOR TEMPERATURE SPECIFICATIONS OF THE MASS FLOW CONTROLLER

1 Purpose

1.1 The purpose of this guideline is to establish a uniform, worldwide means to describe the temperature parameters which are characteristic of mass flow controllers. It is intended to prevent confusion and misunderstanding between manufacturers and users.

2 Scope

2.1 This guideline contains definitions of terms which describe the effects of temperature upon mass flow controllers as used in the semiconductor industry.

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 Standard*

SEMI E12 — Standard for Standard Pressure, Temperature, Density, and Flow Units Used in Mass Flow Meters and Mass Flow Controllers

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

4 Terminology

4.1 *Definitions* (see Figure 1)

4.1.1 *ambient temperature* — the temperature of the medium surrounding the device.

NOTE 1: The ambient temperature assumes that the instrument is not exposed to significant radiant energy sources.

4.1.2 *calibration temperature* — the ambient temperature at which the mass flow controller was calibrated.

4.1.2.1 Description Form: ___°C

CAUTION — Calibration Temperature is not to be confused with Gas Temperature or Standard Temperature.

4.1.3 *gas temperature* — the actual temperature of the flowing gas at the primary flow standard.

4.1.4 *maximum baking temperature* — the highest temperature to which the Mass Flow Controller or its components in contact with the gas can be heated in accordance with a specified baking procedure. The specified baking process will not impair the performance characteristics per the manufacturers specifications. ("Baking" is a process whereby a device is heated to accelerate the removal of adsorbed gases and/or other volatile material).

4.1.4.1 Description Form: MAX. ___°C

4.1.5 *normal operating temperature* — the temperature range within which the influence of ambient temperature on the performance is stated.

4.1.5.1 Description Form: ___°C – ___°C

4.1.6 *operating temperature limits* — operation is permitted within this range but performance is not specified beyond the Normal Operating Temperature. If the instrument is operated outside these limits damage may occur.

4.1.6.1 Description Form: ___°C – ___°C

4.1.7 *reference operating temperature* — the range within which accuracy statements apply without requiring correction for Temperature Effects (see Section 4.1.10).

4.1.7.1 Description Form: ___°C – ___°C

4.1.8 *standard temperature* — the temperature to which a volumetric flow rate (measured at the Gas Temperature) is referenced through the ideal gas law ($PV = nRT$). SEMI E12 defines Standard Temperature as 0.0°C.

CAUTION — Standard Temperature is not the same as the Gas Temperature or Calibration Temperature.

4.1.9 *storage temperature limits* — the temperature limits to which the mass flow controller may be subjected in an unpowered condition. No permanent impairment shall take place, however minor adjustments may be needed to restore performance to normal.
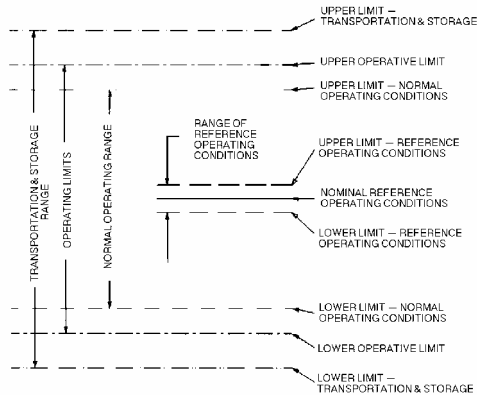
4.1.9.1 Description form: ___°C – ___°C

Figure 1

4.1.10 *temperature effects* — See Figure 2.

NOTE 2: This section requires that Gas Temperature be the same as Ambient Temperature.

4.1.10.1 *span effect* — the change in span due to a change in ambient temperature from one normal operating temperature to a second normal operating temperature. All other conditions must be held within the limits of reference operating conditions.

4.1.10.1.1 The effect of temperature change on span may be expressed as a coefficient calculated as the ratio of percent of reading change in output to the corresponding change in temperature. The change in ambient temperature should be specified. This coefficient is defined as the "temperature coefficient of span."

Example: Temperature coefficient of span may be expressed as:

$$\frac{1\% \text{ of reading}}{40°C - 20°C} = 0.05\% \text{ of reading/}°C$$

NOTE 3: If the relation between temperature and change in output is linear, one coefficient will suffice.

4.1.10.1.2 If the temperature influence is non-linear a different method of expression may be used. Two examples:

1. The percent of span change in output will not exceed a specified value for any value of temperature within a specified temperature range.

Example: "± 1.0% of reading maximum error over 10°C to 50°C"

2. It may be desirable to state a series of coefficients for successive increments of temperature within a specified temperature range.
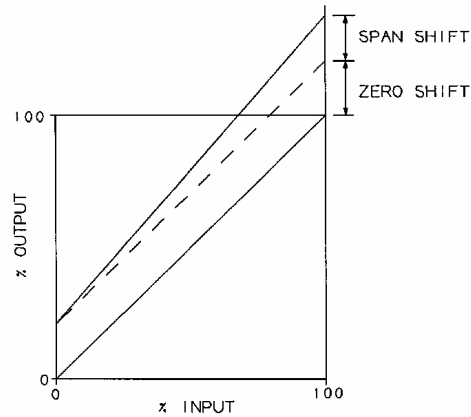

Figure 2
Span and Zero Shift

4.1.10.2 *total effect* — the change in output, including zero and span, due to a change in Ambient Temperature from one normal operating temperature to a second normal operating temperature. All other conditions must be held within the limits of reference operating conditions.

4.1.10.3 *zero effect* — the change in zero due to a change in ambient temperature from one normal operating temperature to a second normal operating temperature. All other conditions must be held within the limits of reference operating conditions.

4.1.10.3.1 The effect of temperature change on zero may be expressed as a coefficient calculated as the ratio of full scale percent change in output to the corresponding change in temperature. The change in ambient temperature should be specified. This coefficient is defined as the "temperature coefficient of zero."

Example: Temperature coefficient of zero may be expressed as:

$$\frac{2\% \text{ of Full Scale}}{40°C - 20°C} = 0.1\% \text{ of Full Scale/}°C$$

NOTE 4: If the relation between temperature and change in output is linear, one coefficient will suffice.

4.1.10.3.2 If the temperature influence is non-linear a different method of expression may be used. Two examples:

1. The percent of full scale change in output will not exceed a specified value for any value of temperature within a specified temperature range.

Example: "± 1.5% of full scale maximum error over 10°C to 50°C"

2. It may be desirable to state a series of coefficients for successive increments of temperature within a specified temperature range.

4.1.11 *units* — degrees Celsius (C) is used as the temperature unit.

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SEMI E19-0697 (Reapproved 0702)
STANDARD MECHANICAL INTERFACE (SMIF)

NOTE: This standard has been purposely restricted to 100 mm (4 in.), 125 mm (5 in.), and 150 mm (6 in.) versions of the SMIF port. This has been done to establish a base for SMIF port standardization. Aspects of the 200 mm (8 in.) version have been negotiated by interested parties and published as SEMI E19.4.

1 Purpose

1.1 A standard interface is required for containers intended to control the transport environment of cassettes containing wafers or disks. The interface must address the proper container orientation for material transfer and maintain continuity between the container and equipment environment in order to control particulate matter.

2 Scope

2.1 This specification describes one approach to interfacing a clean cassette transport box to a clean environmental housing on a piece of semiconductor processing equipment or to other clean environments. The system concept involves mating a door on a cassette container to a door on an equipment canopy and transferring the cassette into, and out of, the equipment without exposing the cassette and wafers to outside contamination.

2.2 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 Impact

3.1 The incorporation of this standard requires equipment designers to include the features of the interface into the tool design. Spacing between open cassette ports is inadequate for incorporation of this interface. Designers are directed to the recommendations made in SEMI E15 in this regard.

4 Limitations

4.1 This standard is specific to the size of the designated wafer and references the appropriate SEMI cassette and wafer diameter. A single numerical suffix is assigned to this base standard number or each wafer diameter. This specification focuses on applications in which the interface port is positioned horizontally. The standard is focused exclusively on the box-to-canopy interface. Other considerations of box and equipment design are purposely excluded.

NOTE 1: Hewlett-Packard has stated that it is seeking patent coverage for this design and is offering non-exclusive licenses on an equal basis to any company. Companies intending to manufacture products to this standard should be aware of Hewlett-Packard's position.

NOTE 2: The user's attention is called to the possibility that compliance with this standard may require use of an invention covered by patent rights. By publication of this standard, Semiconductor Equipment and Materials International (SEMI) takes no position with respect to the validity of any patent rights asserted in connection with any item mentioned in this document. Users of this document are expressly advised that determination of any such patent rights and the risk of infringement of such rights are entirely their own responsibility.

5 Referenced Standards

5.1 *SEMI Standards*

SEMI E1 — Specification for 3 inch, 100 mm, 125 mm, and 150 mm Plastic and Metal Wafer Carriers

SEMI E15 — Specification for Tool Load Port

6 Terminology

(See Figure 1 for a pictorial depiction of most terms.)

6.1 *Definitions*

6.1.1 *box* — an environmentally controlled enclosure for a cassette containing wafers or disks. For purposes of this standard, a box has features that conform to the specified interface. A box includes a box door and box latches. (A box is also referred to as a *container*.)

6.1.2 *box door* — a removable bottom for the box that contains a means (such as registration holes) for properly positioning the wafer cassette.

6.1.3 *box latches* — mechanical latches that hold the box door in position until activated by the latch pins. Upon activation, a portion of each box latch engages a latch cavity and smaller, thereby locking the box to the port plate.

6.1.4 *guide rail* — a component of a port plate that provides coarse location for placing the box on the port assembly.

6.1.5 *latch cavities* — spaces located in the port assembly guide rails that accommodate the box latches in the open position of the box door.

6.1.6 *latch pins* — pins that engage the box latches and accomplish the lock/unlock functions. Latch pins are on the port plate.

6.1.7 *port* — a port assembly appropriately sized for the wafers or disks that are to be transferred. Three port sizes are specified for the purposes of this standard: 100 mm (4 in.) for 100 mm (4 in.) wafer cassettes, 125 mm (5 in.) for 125 mm (5 in.) wafer cassettes, and 150 mm (6 in.) for 150 mm (6 in.) wafer cassettes.

6.1.8 *port assembly* — an assembly of the port plate and port door that includes the guide rails, registration pins, latch pins, and latch cavities.

6.1.9 *port door* — a door for the port plate opening that provides a mating surface for the bottom of the box door when the box is in place on the port plate. The port door contains the registration pins.

6.1.10 *port plate* — a horizontal mating surface for the base of the box that provides a seal surface to the bottom surface of the box perimeter. The port plate contains the guide rails and the latch pins.

6.1.11 *registration holes* — holes in the bottom of the box door that fit over registration pins in the top of the port door when the box is placed on the port door.

6.1.12 *registration pins* — pins that provide fixed position and orientation between the port door and box door and assist in final positioning of the box on the port assembly. The registration pins fit into the registration holes in the bottom of the box door.

7 Requirements

7.1 *Cassette Sizes* — The requirements and dimensions for the design of mechanical interface standard ports and boxes are given in this section. All dimensions of the interface between box and port are specified in reference to the port. Different sets of port dimensions are standardized to accommodate the following three cassette sizes:

100 mm (4 in.)	per SEMI E1.2
125 mm (5 in.)	per SEMI E1.3 and E.4
150 mm (6 in.)	per SEMI E1.5

7.2 *Port Design Requirements* — The general design of the port is shown in Figures 2 and 3. Specific dimensions for the different cassette sizes are given in SEMI E19.1, SEMI E19.2, and SEMI E19.3. Design requirements for the interface components are provided in Sections 7.2.1 through 7.2.5. The general design of the port is shown in Figures 2 and 3. Specific dimensions for the different cassette sizes are given in SEMI E19.1, SEMI E19.2, and SEMI E19.3. Design requirements for the interface components are provided in Sections 7.2.1 through 7.2.5.

7.2.1 *Port Door* — Dimensions A1 through A3 specify the port door top view. The gap between port door and port plate is not specified, but should be kept to a minimum distance to restrict particle movement.

7.2.2 *Guide Rails* — The inside distance of the guide rails on the four sides of the port is specified (B1 and B2). The guide rail can be continuous or in sections. If connected at the corners, the inside radius shall not exceed B9. The maximum height of the rail is given by B5. The guide rails include cavities. Two cavities are provided for the 100 mm (4 in.) port size or four cavities for the the 125 mm (5 in.) and 150 mm (6 in.) port sizes.

7.2.3 *Latch Pins* — The 100 mm (4 in.) port requires two latch pins (C5), located on the port center line at a distance specified by C1 in the unactivated position. The 125 mm (5 in.) and 150 mm (6 in.) ports require four latch pins, positioned by C1 and C3. The displacement to move the latch pins from the unactivated (box door closed) to the activated (box door unlatched) position is specified by the linear dimension C2 . The minimum available force per pin to unlatch and latch the box door is specified by F1 and F2. The latch pins can move in a linear or circular motion as long as the position of the activated pins falls within the target area dimensioned by C8.

7.2.4 *Registration Pins* — The three registration pins on the port door are located asymmetrically, and spaced by dimensions D1 through D4. The size of the pins is specified by D5 through D7.

7.2.5 *The Box* — The bottom surfaces of the box body and box door shall conform to the specified port dimensions. The upper part of the box body and top surface of the box door must fit and hold in place the wafer cassette specified by SEMI E1, for 100 mm (4 in.), 125 mm (5 in.), and 150 mm (6 in.) cassettes. Although the box dimensions are not explicitly specified by this standard, the following requirements apply:

7.2.5.1 The bottom surface of the box door at its perimeter shall match the dimensions of the port door top (A1 through A3). The tolerances shall be chosen so that the box door does not extend over the port door in any instance, even when the port door is built to its minimal acceptable dimensions and potential variance

between registration pins and holes is considered. This is to ensure interference free passage of the box door through the port opening.

7.2.5.2 The base of the box body shall fit freely but with close tolerance between the guide rails (B1, B2, and B9), which not only hold the box in place while the port is open, but also provide proper alignment for the closure of the box at the end of the open/shut cycle.

7.2.5.3 The bottom surface of the box requires three registration holes to engage with the registration pins on the port. The registration pins shall be positioned in the door bottom so that the registration pins prevent seating of the box with the port in the event that the box is improperly rotated by 180 degrees from the correct orientation. The correct orientation is illustrated in Figure 2.

7.2.5.4 The perimeter of the bottom surface of the box body shall be continuous (except possibly at the latch locations) and shall be positioned against the port surface. This positioning assures the activation of an optional limit switch placed in an unspecified location along the port perimeter for the sensing of proper box placement.

7.2.5.5 Each box door latch requires a hole to engage its corresponding port latch pin. The hole shall be elongated to provide a target area for the activated pin (box door open) as shown by dimension C8. A

protrusion from each latch shall engage with its corresponding cavity in the guide rail to prevent the removal of the box while the port is open.

7.2.5.6 The center of the cassette crossbar shall coincide with the center of the box door, with the cassette orientated as shown in Figure 2. The top surface of the box door requires registration bars that hold the cassette in place. The horizontal cassette movement is limited by the tolerances G2. The vertical position of the cassette while located on the box door is specified by the distance G1 between the top of the port surface and the bottom surface of the cassette.

7.2.5.7 The external top of the box shall not exceed the top of the cassette by more than two inches. This is to prevent possible interference between the box and the equipment.

8 References

The following articles describe the standard mechanical interface concept:

8.1 "The Challenge to Control Contamination: A Novel Technique for the IC Process," *The Journal of Environmental Sciences* (May/June 1984) , page 23.

8.2 "SMIF, A Technology for Wafer Cassette Transfer in VLSI Manufacturing," *Solid State Technology* (July 1984), page 111.
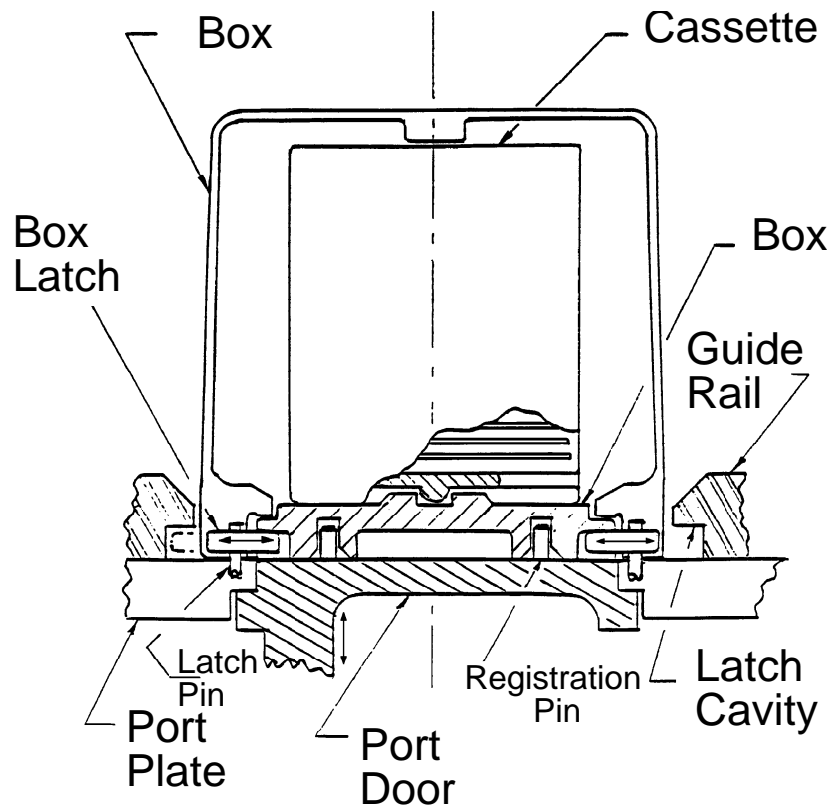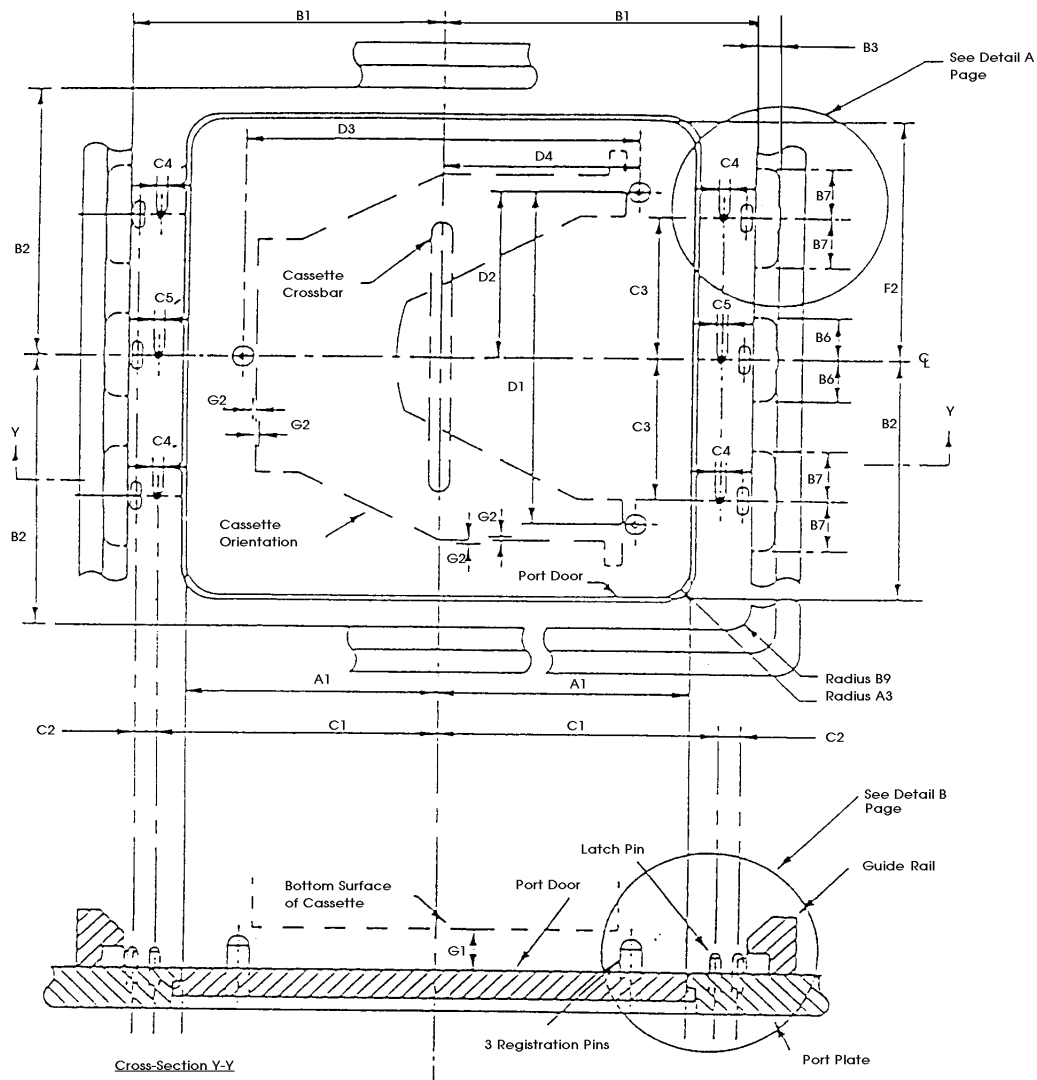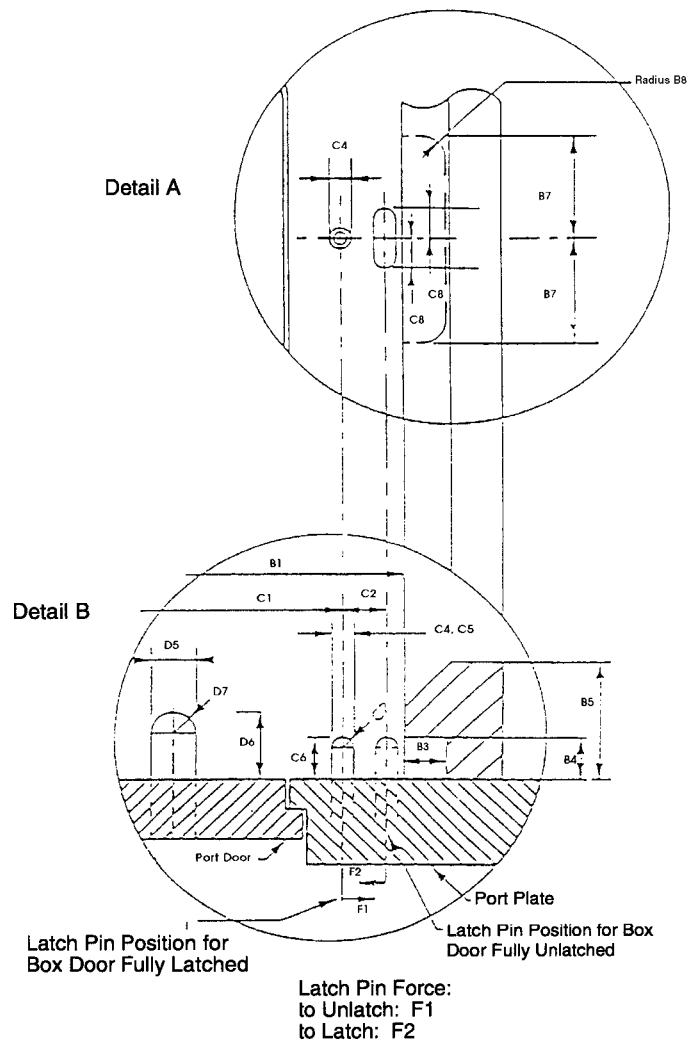
Figure 1
Port Terminology

Figure 2

Figure 3

NOTICE: SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI E19.1-0697 (Reapproved 0702)
PORT STANDARD FOR MECHANICAL INTERFACE OF WAFER CASSETTE TRANSFER, 100 mm (4 inch) PORT

This standard was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition approved by the North American Regional Standards Committee on March 17, 2002. Initially available at www.semi.org June 2002, to be published July 2002. Originally published in 1991; previously published June 1997.

The complete specification for this interface includes all general requirements of SEMI E19.

Table 1   Port Dimensions for 100 mm (4 in.) Wafer Cassette

Port Door	A1	73.02 mm ± 0.13 mm	(2.875 in. ± 0.005 in.)
	A2	73.02 mm ± 0.13 mm	(2.875 in. ± 0.005 in.)
	A3	9.53 mm ± 0.25 mm	(0.375 in. ± 0.010 in.)
Guide Rails	B1	90.17 mm ± 0.13 mm	(3.550 in. ± 0.005 in.)
	B2	82.55 mm ± 0.13 mm	(3.250 in. ± 0.005 in.)
	B3	6.35 mm ± 0.25 mm	(0.250 in. ± 0.010 in.)
	B4	6.35 mm ± 0.25 mm	(0.250 in. ± 0.010 in.)
	B5	17.78 mm (0.700 in.)	maximum
	B6	12.70 mm (0.500 in.)	minimum
	B7		
	B8	3.18 mm ± 0.25 mm	minimum
	B9	6.35 mm (0.250 in.)	maximum radius
Latch Pins	C1	81.25 mm ± 0.13 mm	(3.200 in. ± 0.005 in.)
	C2	6.35 mm ± 0.13 mm	(0.250 in. ± 0.005 in.)
	C3		
	C4		
	C5	3.18 mm ± 0.05 mm	(0.125 in. ± 0.002 in.)
	C6	6.35 mm ± 0.25 mm	(0.250 in. ± 0.010 in.)
	C7	Full spherical radius	
	C8	4.44 mm (0.175 in.)	minimum
Registration Pins	D1	101.60 mm ± 0.13 mm	(4.000 in. ± 0.005 in.)
	D2	50.80 mm ± 0.13 mm	(2.000 in. ± 0.005 in.)
	D3	114.30 mm ± 0.13 mm	(4.500 in. ± 0.005 in.)
	D4	57.15 mm ± 0.13 mm	(2.250 in. ± 0.005 in.)
	D5	6.35 mm ± 0.08 mm	(0.250 in. ± 0.003 in.)
	D6	10.16 mm ± 0.25 mm	(0.400 in. ± 0.010 in.)
	D7	Full spherical radius	
Latch Pin Force each	F1	1.36 kg (3 lb)	minimum
	F2	1.36 kg (3 lb)	minimum
Position of Cassette	G1	12.70 mm ± 0.25 mm	(0.500 in. ± 0.010 in.)
	G2	0.50 mm (0.020 in.)	maximum

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels,

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SEMI E19.2-0697 (Reapproved 0702)
PORT STANDARD FOR MECHANICAL INTERFACE OF WAFER CASSETTE TRANSFER, 125 mm (5 inch) PORT

This standard was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition approved by the North American Regional Standards Committee on March 17, 2002. Initially available at www.semi.org June 2002, to be published July 2002. Originally published in 1991; previously published June 1997.

The complete specification for this interface includes all general requirements of SEMI E19.

Table 1   Port Dimensions for 125 mm (5 in.) Wafer Cassette

Port Door	A1	85.72 mm ± 0.13 mm	(3.375 in. ± 0.005 in.)
	A2	85.72 mm ± 0.13 mm	(3.375 in. ± 0.005 in.)
	A3	9.53 mm ± 0.25 mm	(0.375 in. ± 0.010 in.)
Guide Rails	B1	102.87 mm ± 0.13 mm	(4.050 in. ± 0.005 in.)
	B2	95.25 mm ± 0.13 mm	(3.750 in. ± 0.005 in.)
	B3	6.35 mm ± 0.25 mm	(0.250 in. ± 0.010 in.)
	B4	6.35 mm ± 0.25 mm	(0.250 in. ± 0.010 in.)
	B5	17.78 mm (0.700 in.)	maximum
	B6		
	B7	12.70 mm (0.500 in.)	minimum
	B8	3.18 mm ± 0.25 mm	(0.125 in. ± 0.010 in.)
	B9	6.35 mm (0.250 in.)	maximum radius
Latch Pins	C1	93.98 mm ± 0.13 mm	(3.700 in. ± 0.005 in.)
	C2	6.35 mm ± 0.13 mm	(0.250 in. ± 0.005 in.)
	C3	63.50 mm ± 0.13 mm	(2.500 in. ± 0.005 in.)
	C4	3.18 mm ± 0.05 mm	(0.125 in. ± 0.002 in.) diameter
	C5		
	C6	6.35 mm ± 0.25 mm	(0.250 in. ± 0.010 in.)
	C7	Full spherical radius	
	C8	4.44 mm (0.175 in.)	minimum
Registration Pins	D1	127.20 mm ± 0.13 mm	(5.000 in. ± 0.005 in.)
	D2	63.50 mm ± 0.13 mm	(2.500 in. ± 0.005 in.)
	D3	139.70 mm ± 0.13 mm	(5.500 in. ± 0.005 in.)
	D4	69.85 mm ± 0.13 mm	(2.750 in. ± 0.005 in.)
	D5	6.35 mm ± 0.08 mm	(0.250 in. ± 0.003 in.)
	D6	10.16 mm ± 0.25 mm	(0.400 in. ± 0.010 in.)
	D7	Full spherical radius	
Latch Pin Force each	F1	1.36 kg (3 lb)	minimum
	F2	1.36 kg (3 lb)	minimum
Position of Cassette	G1	12.70 mm ± 0.25 mm	(0.500 in. ± 0.010 in.)
	G2	0.50 mm (0.020 in.)	maximum

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels,

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SEMI E19.3-0697 (Reapproved 0702)
PORT STANDARD FOR MECHANICAL INTERFACE OF WAFER CASSETTE TRANSFER, 150 mm (6 inch) PORT

This standard was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carrier Committee. Current edition approved by the North American Regional Standards Committee on March 17, 2002. Initially available at www.semi.org June 2002, to be published July 2002. Originally published in 1991; previously published June 1997.

The complete specification for this interface includes all general requirements of SEMI E19.

Table 1   Port Dimensions for 150 mm (6 in.) Wafer Cassette

Port Door	A1	98.48 mm $\pm$ 0.13 mm	(3.875 in. $\pm$ 0.005 in.)
	A2	98.48 mm $\pm$ 0.13 mm	(3.875 in. $\pm$ 0.005 in.)
	A3	9.53 mm $\pm$ 0.25 mm	(0.375 in. $\pm$ 0.010 in.)
Guide Rails	B1	115.57 mm $\pm$ 0.13 mm	(4.550 in. $\pm$ 0.005 in.)
	B2	107.95 mm $\pm$ 0.13 mm	(4.250 in. $\pm$ 0.005 in.)
	B3	6.35 mm $\pm$ 0.25 mm	(0.250 in. $\pm$ 0.010 in.)
	B4	6.35 mm $\pm$ 0.25 mm	(0.250 in. $\pm$ 0.010 in.)
	B5	17.78 mm (0.700 in.)	maximum
	B6		
	B7	12.70 mm (0.500 in.)	minimum
	B8	3.18 mm $\pm$ 0.25 mm	(0.125 in. $\pm$ 0.010 in.)
	B9	6.35 mm (0.250 in.)	maximum radius
Latch Pins	C1	106.68 mm $\pm$ 0.13 mm	(4.200 in. $\pm$ 0.005 in.)
	C2	6.35 mm $\pm$ 0.13 mm	(0.250 in. $\pm$ 0.005 in.)
	C3	63.50 mm $\pm$ 0.13 mm	(2.500 in. $\pm$ 0.005 in.)
	C4	3.18 mm $\pm$ 0.05 mm	(0.125 in. $\pm$ 0.002 in.) diameter
	C5		
	C6	6.35 mm $\pm$ 0.25 mm	(0.250 in. $\pm$ 0.010 in.)
	C7	Full spherical radius	
	C8	4.44 mm (0.175 in.)	minimum
Registration	D1	152.40 mm $\pm$ 0.13 mm	(6.000 in. $\pm$ 0.005 in.)
	D2	76.20 mm $\pm$ 0.13 mm	(3.000 in. $\pm$ 0.005 in.)
	D3	165.10 mm $\pm$ 0.13 mm	(6.500 in. $\pm$ 0.005 in.)
	D4	82.55 mm $\pm$ 0.13 mm	(3.250 in. $\pm$ 0.005 in.)
	D5	6.35 mm $\pm$ 0.08 mm	(0.250 in. $\pm$ 0.003 in.)
	D6	10.16 mm $\pm$ 0.25 mm	(0.400 in. $\pm$ 0.010 in.)
	D7	Full spherical radius	
Latch Pin Force each	F1	1.36 kg (3 lb)	minimum
	F2	1.36 kg (3 lb)	minimum
Position of Cassette	G1	12.70 mm $\pm$ 0.25 mm	(0.500 in. $\pm$ 0.010 in.)
	G2	0.50 mm (0.020 in.)	maximum

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SEMI E19.4-0998^E (Reapproved 0703)
200 mm STANDARD MECHANICAL INTERFACE (SMIF)

1 Purpose

1.1 A standard interface is required for containers intended to control the transport environment of cassettes containing substrates. The interface must address the proper container orientation for material transfer and maintain continuity between the container and equipment environment in order to control particulate matter.

2 Scope

2.1 This specification describes one approach to interfacing a clean cassette transport box to a clean environmental housing on a piece of semiconductor processing equipment or to other clean environments. The system concept involves mating a door on a cassette container to a door on an equipment enclosure and transferring the cassette into, and out of, the equipment without exposing the cassette and substrates to outside contamination.

2.2 The incorporation of this standard may require equipment designers to include the features of the interface into the tool design. Spacing between open cassette ports must be considered when incorporating this interface. Designers are directed to the specifications and recommendations made in SEMI E15 in this regard.

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 is specific to 200 mm wafers. This specification focuses on applications in which the interface port is positioned horizontally. The standard is focused exclusively on the box-to-canopy interface. Other considerations of box and equipment design are purposely excluded.

NOTE 1: Hewlett Packard has patent coverage for this concept and is offering non-exclusive licenses on an equal basis to any company. Companies intending to manufacture products to this standard should be aware of Hewlett Packard's position.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E15 — Specification for Tool Load Port

SEMI E19 — Standard Mechanical Interface (SMIF)

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

5 Terminology

5.1 (See Figure 1 for a pictorial depiction of most terms.)

5.2 *Definitions*

5.2.1 *box* — a protective portable container for a cassette and/or substrate(s).

5.2.2 *cassette* — an open structure that holds one or more substrates (wafers, masks, etc.).

5.2.3 *guide rail* — a component of a port plate that provides coarse location for placing the pod on the port assembly.

5.2.4 *hold-down latch* — a mechanism for locking the pod to the port plate.

5.2.5 *latch pins* — pins that engage the pod door latch and accomplish the pod door lock/unlock functions. Latch pins are carried by the port door.

5.2.6 *pod* — a box having a Standard Mechanical Interface per SEMI E19.

5.2.7 *pod door* — a removable bottom for the pod that contains a means for properly positioning the cassette.

5.2.8 *pod latch* — a mechanical latch that holds the pod door to the pod until activated by the latch mechanism pins. Upon activation, the pod door is released from the pod.

5.2.9 *pod latch holes* — holes near the center of the pod door bottom which accept the latch pins.

5.2.10 *port assembly* — an assembly of the port plate and port door that includes the guide rails, registration pins, latch pins, and pod hold-down latches.

5.2.11 *port door* — a door for the port plate opening that provides a mating surface for the bottom of the pod door when the pod is in place on the port plate. The port door contains the registration pins and the pod door latch pins.

5.2.12 *port plate* — a horizontal mating surface for the base of the pod that provides a seal surface for the bottom surface of the pod perimeter. The port plate contains the guide rails and the pod hold-down latches.

5.2.13 *registration holes* — holes in the bottom of the pod door that fit over registration pins in the top of the port door when the pod is placed on the port door.

5.2.14 *registration pins* — pins that provide fixed position and orientation between the port door and pod door and assist in the final positioning of the pod on the port assembly. The registration pins fit into the registration holes in the bottom of the pod door.

6 Requirements

NOTE 2: The requirements and dimensions for the design of mechanical interface standard ports and pods are given in this section. See Table 1 for 200 mm (8 inch) Port Dimensions.

6.1 *Cassette Sizes* — All specifications are related to 200 mm wafers held in an appropriate cassette. It is understood that smaller diameter wafers and other substrates may be contained in pods which are compatible with this standard.

6.2 *Port Design Requirements* — The general design of the port is shown in Figures 2 and 3. Design requirements for the interface components are provided in Sections 6.2.1 through 6.2.5.

6.2.1 *Port Door* — Dimensions A1 through A3 specify the port door top view. The gap between port door and port plate is not specified, but should be kept to a minimum distance to restrict particle movement.

6.2.2 *Pod Guide* — The inside distance of the corner guides of the port is specified by B1 and B2. The length of the corner is specified by B12. The corner guides may be connected by guide rails if desired.

6.2.3 *Latch Pins* — Two latch pins are located around the port door center. For location of the pins, see C1, C2, and C3.

6.2.4 *Registration Pins* — The three registration pins on the port door are located asymmetrically, and spaced by dimensions D1 through D4. The size of the pins is specified by D5 through D7.

6.2.5 *Pod* — The bottom surfaces of the pod body and pod door shall conform to the specified port dimensions. The upper part of the pod body and top surface of the pod door must fit and hold in place the cassette for 200 mm (8 inch) wafers. Although the pod dimensions are not explicitly specified by this standard, the following requirements apply:

6.2.5.1 The bottom surfaces of the pod door at its perimeter shall match the dimensions of the port door top (A1 through A3). The tolerances shall be chosen so that the pod door does not extend over the port door in any instance, even when the port door is built to its minimal acceptable dimensions and potential variance between registration pins and holes is considered. This is to ensure an interference-free passage of the pod door through the port opening.

6.2.5.2 The base of the pod body shall fit freely but with close tolerance between the guide rails (B1, B2, and B9), which not only hold the pod in place while the port is open, but also provide proper alignment for closure of the pod at the end of the open/shut cycle.

6.2.5.3 The bottom surface of the pod requires three registration holes to engage with the registration pins on the port. The registration pins shall be positioned in the door bottom so that the registration pins prevent seating of the pod with the port in the event that the pod is improperly rotated by 180 degrees from the correct orientation. The correct orientation is illustrated in Figure 2.

6.2.5.4 The perimeter of the bottom surface of the pod body shall be continuous and shall be positioned against the port surface. This positioning assures the activation of an optional limit switch, placed in an unspecified location along the port perimeter, for the sensing of proper pod placement.

6.2.5.5 The center of the cassette crossbar shall coincide with the center of the pod door, with the cassette oriented as shown in Figure 2. The top surface of the pod door requires the registration bars that hold the cassette in place. The horizontal cassette movement is limited by the tolerances G2. The vertical position of the cassette while located on the pod door is specified by the distance G1 between the top of the port surface and the bottom surface of the cassette.

6.2.5.6 A pod hold-down latch is required. The available latch area is specified by dimension B11 in Figure 2. Latch detail dimensions are specified in Figure 3.

6.2.5.7 The pod latch holes have a dimension of I1 perpendicular to the plane connecting both holes.

6.2.5.8 Positions for latches are identified in Figure 2 by positions 1, 2, 3, and 4. The following options for hold-down latch positions are defined by this specification:

Option A	Positions 1 and 2
Option B	Positions 3 and 4
Option C	Positions 1, 2, 3, and 4

7 References

The following articles describe the standard mechanical interface concept:

"The Challenge to Control Contamination: A Novel Technique for the IC Process," The Journal of Environmental Sciences (May/June 1984), page 23.

"SMIF, A Technology for Wafer Cassette Transfer in VLSI Manufacturing," Solid State Technology (July 1984), page 111.

The complete specification for this interface includes all general requirements of SEMI E19.

Table 1 Port Dimensions for 200 mm (8 inch) Wafer Cassette

Feature	Dimension Label	Metric	English
Port Door	A1	135.84 mm $\pm$ 0.13 mm	(5.348 in. $\pm$ 0.005 in.)
	A2	131.06 mm $\pm$ 0.13 mm	(5.160 in. $\pm$ 0.005 in.)
	A3	13.08 mm $\pm$ 0.25 mm	(0.515 in. radius $\pm$ 0.010 in.)
	A4	0.38 mm $\pm$ 0.13 mm	(0.015 in. $\pm$ 0.005 in.)
Guide Rails	B1	146.48 mm $\pm$ 0.13 mm	(5.767 in. $\pm$ 0.005 in.)
	B2	141.71 mm $\pm$ 0.13 mm	(5.579 in. $\pm$ 0.005 in.)
	B3		
	B4		
	B5	29.97 mm maximum	(1.18 in. maximum)
	B6		
	B7	16 mm minimum	(0.630 in. minimum)
	B8	45° maximum	(45° maximum)
	B9	22.22 mm radius maximum	(0.875 in. radius maximum)
	B10		
	B11	50.8 mm maximum	(2.00 in. maximum)
	B12	26.9 mm minimum	(1.06 in. minimum)
Latch Pins	C1	16° $\pm$ 0° 30'	(16° $\pm$ 0° 30')
	C2	86° $\pm$ 0° 30'	(86° $\pm$ 0° 30')
	C3	26.72 mm $\pm$ 0.05 mm	(1.052 in. diameter $\pm$ 0.002 in.)
	C4	3.175 mm $\pm$ 0.025 mm	(0.125 in. diameter $\pm$ 0.001 in.)
	C5		
	C6	9.14 mm $\pm$ 0.25 mm	(0.360 in. $\pm$ 0.010 in.)
	C7	Full Spherical Radius	Full Spherical Radius
	C8		
Registration Pins	D1	183.39 mm $\pm$ 0.25 mm	(7.22 in. $\pm$ 0.010 in.)
	D2	91.69 mm $\pm$ 0.13 mm	(3.610 in. $\pm$ 0.005 in.)
	D3	231.78 mm $\pm$ 0.25 mm	(9.125 in. $\pm$ 0.010 in.)
	D4	116.59 mm $\pm$ 0.13 mm	(4.590 in. $\pm$ 0.005 in.)

Feature	Dimension Label	Metric	English
	D5	6.35 mm ± 0.025 mm	(0.250 in. diameter ± 0.001 in.)
	D6	16.26 mm ± 0.25 mm	(0.640 in. ± 0.010 in.)
	D7	Full Spherical Radius	Full Spherical Radius
Latch Pin	F1	0.8 Nm minimum	(7 in. lbf. minimum)
Force (Torque)		1.7 Nm maximum	(15 in. lbf. maximum)
Position of Cassette	G1	20.70 mm ± 0.25 mm	(0.815 in. ± 0.010 in.)
	G2	H-Bar Centered ± 0.51 mm	(H-Bar Centered ± 0.020 in.)
Pod Latch Holes	I1	3.4 mm ± 0.1 mm	(0.135 in. ± 0.004 in.)
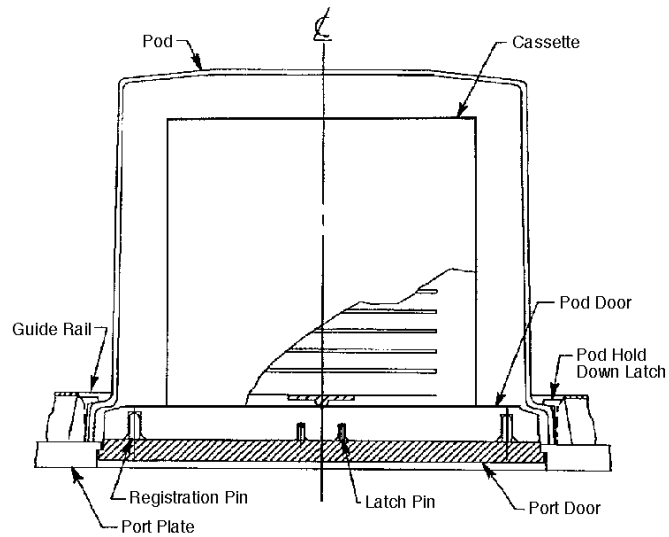
Figure 1
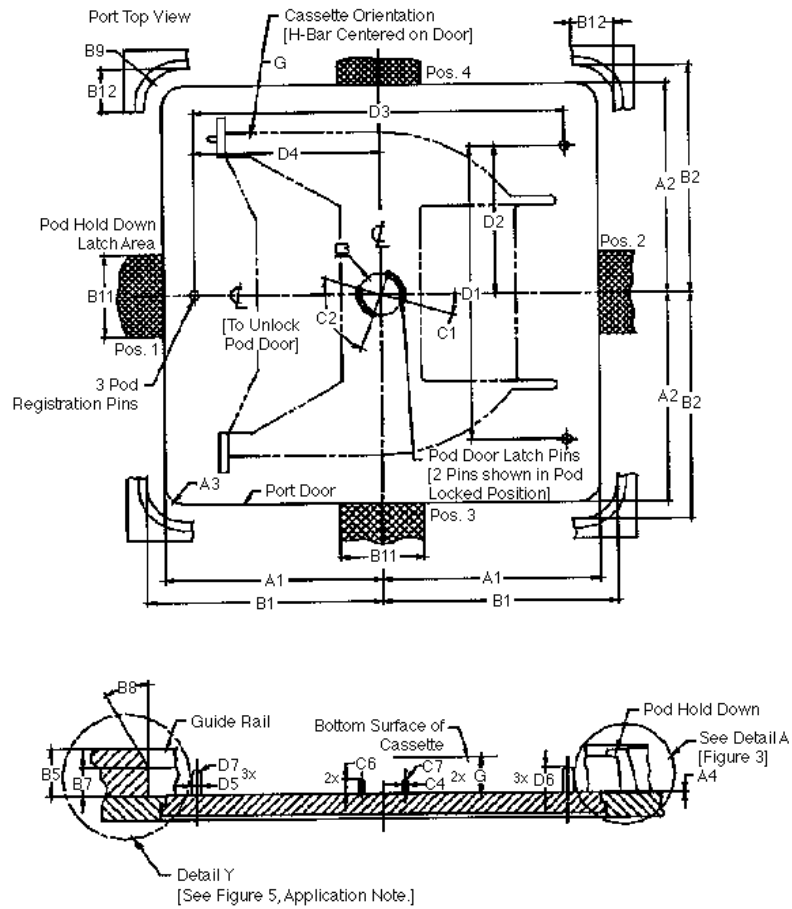**Port Terminology**
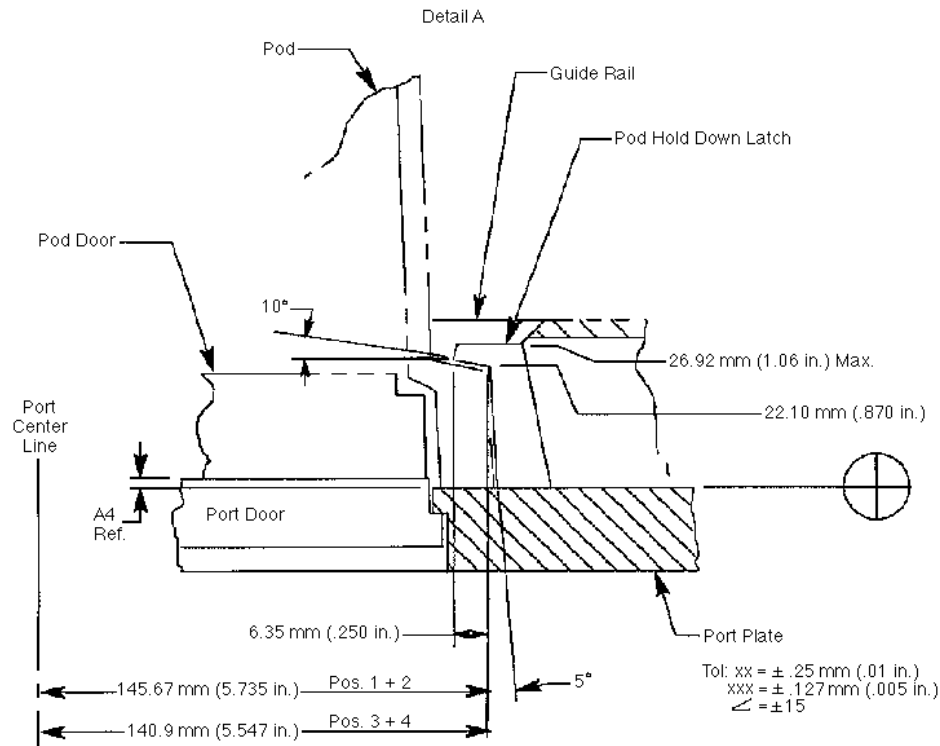
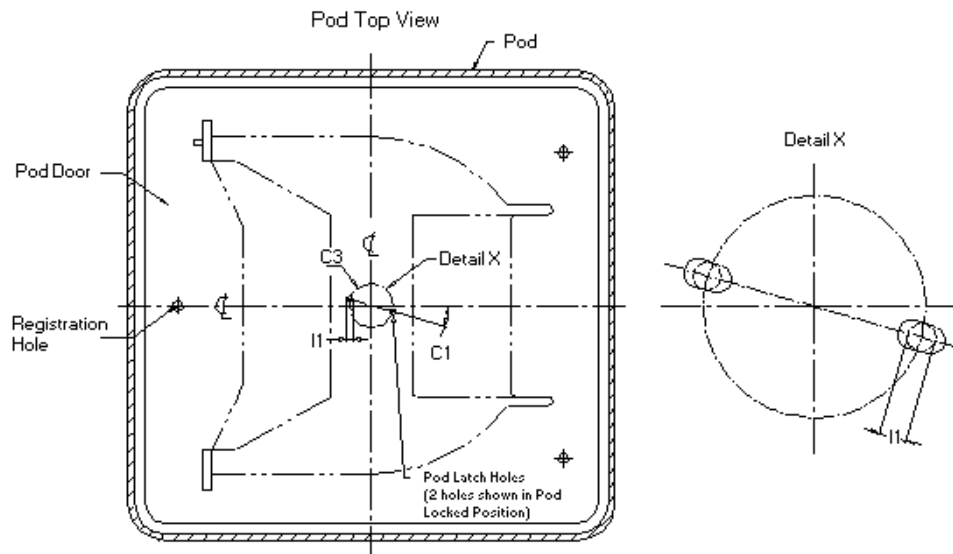**Figure 2**
Port Dimensions

Figure 3
Dimensions of Pod Hold Down Latches

Figure 4
Dimensions of Pod Latch Hole