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# SEMI E66-1103
# TEST METHOD FOR DETERMINING PARTICLE CONTRIBUTION BY MASS FLOW CONTROLLERS

This test method 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 July 27, 2003. Initially available at www.semi.org October 2003; to be published November 2003. Originally published September 1997.

## 1 Purpose

1.1 The purpose of this test is to measure particle contribution by mass flow controllers (MFCs) in high-purity gas systems.

## 2 Scope

2.1 This document describes a test method that yields statistically significant comparisons of particle contribution among mass flow controllers under test conditions.

**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 document is not intended as a method for monitoring in situ particulate performance once a particular MFC has been tested.

3.2 The test medium is limited to nitrogen. Actual performance under normal operating conditions may differ.

3.3 The accuracy of the data generated by this method is limited to the accuracy of the particle measuring instruments used.

3.4 This test method is intended for use by operators who understand the use of the apparatus at a level equivalent to one year of experience.

3.5 This test method should not be expected to yield comparable results from one test set up to another, due to the limitations of current particle counting technology.

3.6 Results may be compromised by the methods used to construct the apparatus.

## 4 Referenced Standards

4.1 *SEMI Standards*

SEMI E29 — Standard Terminology for the Calibration of Mass Flow Controllers and Mass Flow Meters

SEMI F1 — Specification for Leak Integrity of High-Purity Gas Piping Systems and Components

4.2 *ANSI Standards*[1]

ANSI B46.1 — Surface Texture (Surface Roughness, Waviness, and Lay)

4.3 *ISO Standards*[2]

ISO 14644-1 — Cleanrooms and associated controlled environments Part 1: Classification of air cleanliness.

ISO 14644-2 — Cleanrooms and associated controlled environments Part 2: Specifications for testing and monitoring to prove continued compliance with ISO 14644-1

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

## 5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *CNC* — condensation nucleus counter

5.1.2 *dof* — degrees of freedom

5.1.3 *DUT* — device under test

5.1.4 *FS* — full scale

5.1.5 *IKS* — isokinetic sampler

5.1.6 *kPa* — kiloPascal

5.1.7 *LPC* — laser particle counter

5.1.8 *ppm* — parts per million

5.1.9 *psia* — pounds per square inch absolute

5.1.10 *psid* — pounds per square inch differential

1 American National Standards Institute, Headquarters: 1819 L Street, NW, Washington, DC 20036, USA. Telephone: 202.293.8020; Fax: 202.293.9287, New York Office: 11 West 42nd Street, New York, NY 10036, USA. Telephone: 212.642.4900; Fax: 212.398.0023, Website: www.ansi.org

2 International Organization for Standardization

ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30 Website: www.iso.ch

5.1.11 *psig* — pounds per square inch gauge

5.1.12 *Ra* — roughness average per ANSI B46.1

5.1.13 *RH* — relative humidity per ANSI B46.1

5.1.14 *Rmax* — roughness maximum

5.1.15 *scfm* — standard cubic feet per meter

5.1.16 *SFC* — supply mass flow controller

5.1.17 *slpm* — standard liters per minute

5.1.18 *SPC* — statistical process control

5.2 *Definitions*

5.2.1 *background counts* — Counts contributed by the test apparatus (including counter electrical noise) with the spool piece in place of the test object.

5.2.2 *condensation nucleus counter (CNC)* — A light scattering instrument that detects particles in a gaseous stream by condensing supersaturated vapor on the particles.

5.2.3 *dynamic control mode test* — A test performed to determine particle contribution as a result of test flow variation within the normal range of MFC operation (i.e., 0 to 100% flow).

5.2.4 *impact or vibration test* — A test performed to determine particle contribution as a result of test flow variation within the normal range of MFC operation (i.e., 10 to 100% flow).

5.2.5 *normal statistical distribution* — Measurements that randomly fall about an average, within a range of ± 3 standard deviations.

5.2.6 *observation* — A 10-minute sample/data collection period.

5.2.7 *purge mode* — Control valve fully open.

5.2.8 *sample flow* — The volumetric flow drawn by the counter for particle detection.

5.2.9 *sampling time* — The time increment over which counts are recorded.

5.2.10 *spool piece* — A null component consisting of a straight piece of electropolished tubing and appropriate fittings used in place of the test component to establish the background.

5.2.11 *stable particle level* — Particle level that has been consistent, as described in Appendix 1, for at least eight consecutive readings.

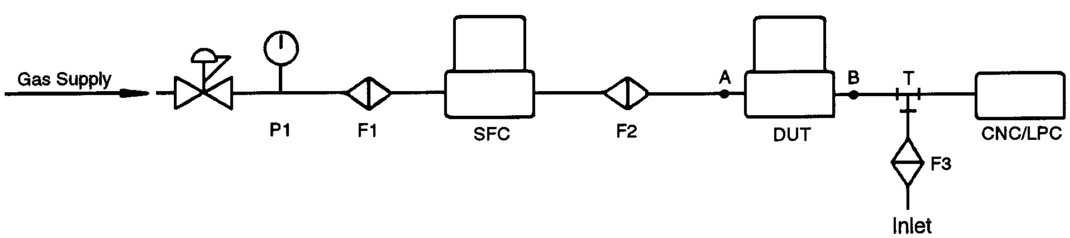
5.2.12 *standard reference conditions* — 101.32 kPa, 0.0°C (14.7 psia, 32°F) (see SEMI E29)

5.2.13 *statistical process control* — A method used by this standard for analyzing experimental data that follows a normal statistical distribution to determine if the test is stable.

5.2.14 *steady state control mode test* — A test performed to determine particle contribution during steady state test flow within the normal operating range of the MFC (i.e., 10 to 100% full scale).

5.2.15 *supply pressure* — Pressure immediately upstream of filter F1. (See Figures 1 and 2.)

5.2.16 *test flow* — Mass flow through the device under test.




Legend

P = Pressure Gauge
F = Filter
SFC = Supply Flow Controller
DUT = Device Under Test
CNC = Condensation Nucleus Controller
LPC = Laser Particle Counter
T = Piping Tee

Notes

(1) Inlet F3 facing down.
(2) Distance between DUT and center of tee to be kept at a minimum.
(3) All tubing to be 6.35 mm (1/4") OD.
(4) A, B are connection points.

**Figure 1**
**Test Set-Up when Test Flow < Sample Flow**

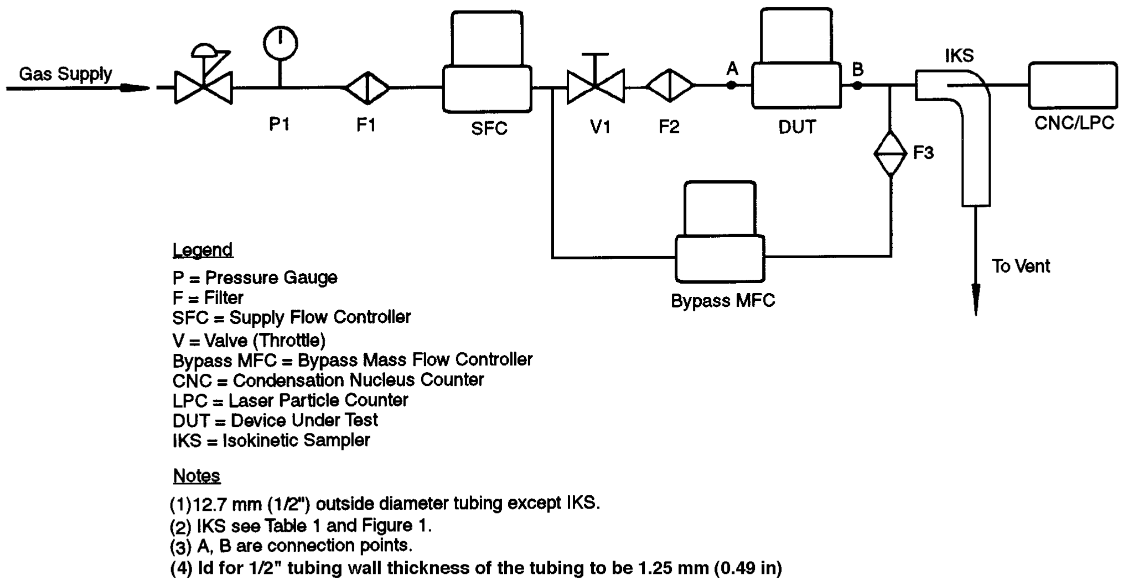



**Figure 2**
**Test Set-Up when Test Flow > Sample Flow**

## 6 Summary of Test Method

6.1 Background count is determined for steady state control, dynamic control, and impact tests. The steady state control mode test, dynamic control mode test, and impact test are run by counting particles for the time necessary to achieve a stable particle level. Background testing is performed again.

## 7 Significance and Use

7.1 The significance of this test method is that it defines a procedure for testing mass flow controllers intended for installation into a high-purity gas system. It is intended for use by manufacturers and end users.

## 8 Apparatus

8.1 *Test Gas* — Nitrogen of minimum dryness, with -40°C (-40°F) dew point at 790.57 kPa (100 psig) and with < 10 ppm of total hydrocarbons.

8.2 *Membrane Filters* — To provide filtered test gas, nine-log retentive to larger than 0.01 mm particles, with a pressure drop of less than 7.91 kPa (1 psid) at 283,170 sccm (10 scfm) for a 790.57 kPa (100 psig) inlet, and capable of achieving less than one particle[3] 0.01 mm per cubic foot of test gas under test conditions.

8.3 *Pressure Regulator* — Made of electropolished 316L stainless steel, with an internal surface finish of 0.18 mm (7 µin.) $R_a$ and 0.25 mm (10 µin.) Rmax, to maintain system test pressure.

8.4 *Pressure Gauge or Transducer* — Made of electropolished 316L stainless steel, with an internal surface finish of 0.18 mm (7 µin.) $R_a$ and 0.25 mm (10 µin.) Rmax, to monitor system test pressure.

8.5 *Throttle Valve* — Made of electropolished 316L stainless steel, with an internal surface finish of 0.18 mm (7 µin.) $R_a$ and 0.25 mm (10 µin.) Rmax, to proportion flow in test system.

8.6 *Tubing* — Made of electropolished 316L stainless steel, with an internal surface finish of 0.18 mm (7 µin.) Ra and 0.25 mm (10 µin.) Rmax.

8.7 *Supply Flow Controller (SFC)* — Metal-sealed, used to establish a flow rate through the spool piece in the absence of the DUT, with a settling time less than or equal to that of the DUT. More than one range SFC may be required to run all the tests.

8.8 *Sampler* — Constructed according to the drawing and design parameters shown in Figure 3 and Table 1, to collect gas from the stream exiting the test device, where the sample is near-isokinetic in design.

8.9 *Upstream Adapter* — To connect 12.7 mm (1/2 in.) tubing to the test device. For 12.7 mm (1/2 in.) test devices, the adapter is a simple face-seal connector. For 6.35 mm (1/4 in.) test devices, the adapter is a tapered cone between 6.35 mm and 12.7 mm (1/4 in. and 1/2 in.) face-seal connections.

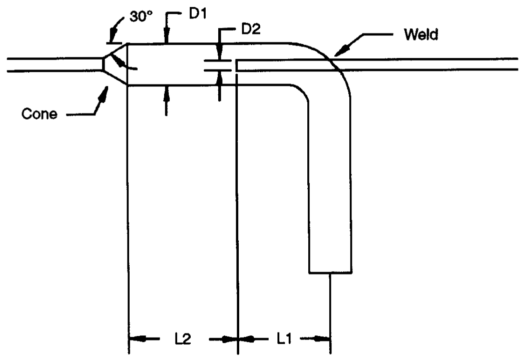



**Figure 3**
**Isokinetic Sampler Design**

**Table 1**

| *Maximum IKS Inlet Flow (liters/min.)* | *ID Probe $D_2$ (note)mm (inches)* | *ID Sampler $D_1$ - mm (inches)* | *Worst-Case Dilution* |
|---|---|---|---|
| 300 | 4.62 (0.180) | 68.58 (2.700) | 3:1 |
| 100 | 4.62 (0.180) | 39.62 (1.560) | 3:1 |
| 30 | 4.62 (0.180) | 21.44 (0.844) | 3:1 |
| 10 | 4.62 (0.180) | 11.99 (0.472) | 3:1 |
| 3 | 7.75 (0.305) | 12.57 (0.495) | 2:1 |

NOTE 1: For 300,000 to 10,000 cc/min. test flow:

- Constant sample velocity = 132 cm/sec.
- D2 = 4.57 mm (0.180 in.) ID standard 6.35 mm (1/4 in.) tubing (see Figure 3)
- For 1.41 l/min. CNC

NOTE 2: For 3,000 cc/min. test flow:

- Constant sample velocity = 49.9 cm/sec.
- $D_2$ = 7.75 mm (0.305 in.) ID standard 9.53 mm (3/8 in.) tubing (see Figure 3)
- For 1.41 l/min. CNC

8.10 *Downstream Adapter* — To connect 12.7 mm (1/2 in.) sampler tubing to the test device. For 12.7 mm (1/2 in.) test devices, the adapter is a simple face-seal connector. For 6.35 mm (1/4 in.) test devices, the adapter is a tapered cone between 6.35 mm and 12.7 mm (1/4 in. and 1/2 in.) face-seal connections.

8.11 *Spool Pieces* — Of the same inside diameter as the inside diameter fittings on the test piece and of a length representative of the DUT, to be installed in the system in place of the test device while obtaining background counts for the system.

8.12 *Fittings* — Face seal connectors or compression fittings, depending on test component end connections. The end connection fittings of each DUT being compared must be of the same type.

8.13 *Metal Gaskets* — New gaskets should be used for each new connection.

8.14 *Mechanical Shock Device* — To provide mechanical shock by impact to the test device. (See Figure 4.)

8.15 *Instrumentation* — Condensation nucleus counter (CNC) or laser particle counter (LPC) to collect particle count data.

8.16 *Isokinetic Sampler (IKS)* — A static device used to collect a representative sample that is not influenced by flow characteristics and/or particle size (see Figure 3). Other designs of isokinetic samplers are permitted as long as they collect a representative sample of the flow.

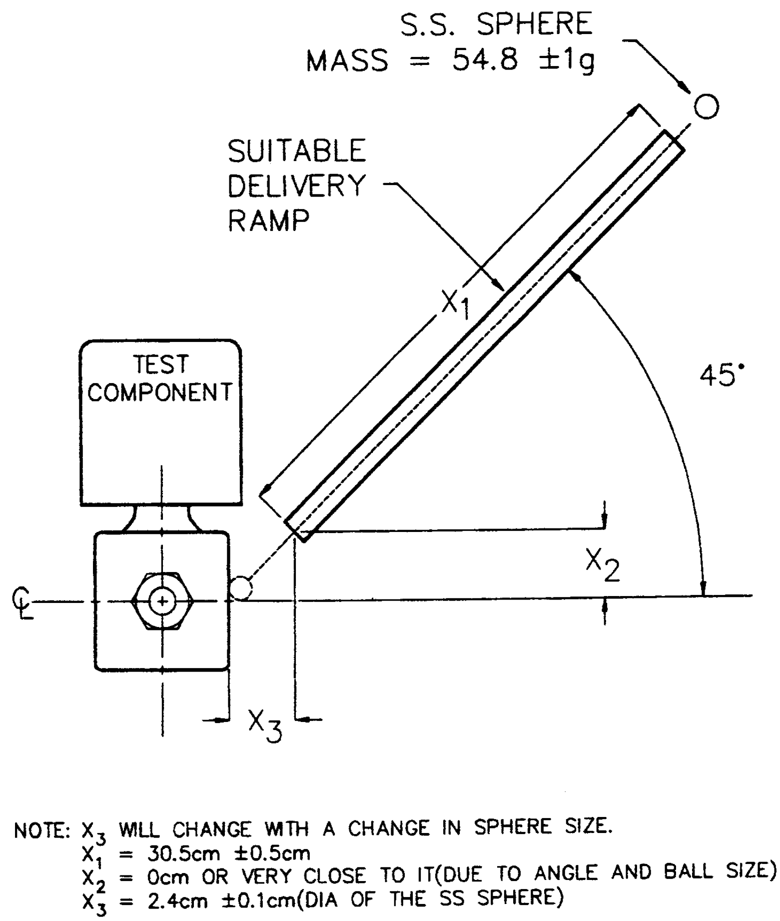



**Figure 4**
**Mechanical Shock Test Device**

NOTE: Position the delivery ramp so that the position of impact is at the midpoint of the axial centerline of the device under test.

## 9 Sampling, Test Specimens, and Test Units

9.1 MFCs regulate flows greater than or less than the flow requirements of particle counters; therefore, two different sampling techniques have been defined, isokinetic sampling and direct sampling.

9.1.1 *Direct Sampling* — The direct sampling method is used when the test flow is less than or equal to the sample flow. (See Figure 1.)

9.1.1.1 In this case, gas exiting the DUT is introduced directly into the CNC. A tee, equipped with a filtered branch, is inserted between the DUT and the CNC to provide make-up flow to the CNC. The volume and overall length of the tubing connecting the DUT to the tee assembly should be minimized.

9.1.2 *Isokinetic Sampling* — Isokinetic sampling is used when the test flow is greater than the sample flow. (See Figure 2.)

NOTE 1: An alternative size IKS may be substituted for the IKS described in Sections 9.1.2.1 through 9.1.2.7 as long as it collects a representative sample of particles that is not influenced by flow characteristics and/or particle size.

9.1.2.1 Select the appropriate IKS (see Figure 3) from Table 1 for the test flow. This is the smallest IKS that exceeds the flow of the DUT.

9.1.2.2 The average velocity of the gas through the sampling probe shall approximate the average velocity in the tubing in which the sampling probe is inserted. The sample flow used to calculate the sampling probe diameter is the total flow drawn by the counter.

9.1.2.3 The tip of the sampling probe is to have a 30_ taper on the outside diameter.

9.1.2.4 The pick-off point is to be centered within the flow stream.

9.1.2.5 The pick-off point is to be at a minimum distance of 15 diameters of the primary flow tube upstream or downstream from any connection.

9.1.2.6 Flow stability within the isokinetic sampler is maintained by the bypass MFC.

9.1.2.7 To determine the dimensions of the isokinetic sampler, as shown in Table 1, the following equations and conditions are used:

## 10 Preparation of Apparatus

10.1 *Setup and Schematic for Direct Sampling* — See Figure 1.

10.1.1 Install the spool piece between points A and B.

10.1.2 Set nominal supply pressure to 308.10 kPa (30 psig).

10.1.3 Cycle the supply MFC, switching between a low flow and maximum purge flow as quickly as is reasonably possible. Cycle every five seconds for at least 30 minutes. The maximum purge flow should be as high as possible and no less than twice the test rate. During this initial cleanup, the particle counter should be off-line.

10.1.4 Moisture from an inboard leak can cause particle counts on some particle counters. Test the system for leak integrity per SEMI F1 – Subsystems Inboard Leak Test.

10.2 *Setup and Schematic for Isokinetic Sampling* — See Figure 2.

10.2.1 Install the spool piece between points A and B.

10.2.2 Set nominal supply pressure to 308.10 kPa (30 psig).

10.2.3 Cycle the supply MFC, switching between a low flow and maximum purge flow as quickly as is reasonably possible. Cycle every five seconds for at least 30 minutes. The maximum purge flow should be as high as possible and no less than twice the test rate. During this initial cleanup, the particle counter should be off-line.

10.2.4 Moisture from an inboard leak can cause particle counts on some particle counters. Test the system for leak integrity per SEMI F1 – Subsystems Inboard Leak Test.

10.3 Select the appropriate isokinetic sampler based on the maximum test flow of the DUT, using Table 1 and Figure 3. The size of the sampler should be equal to or greater than the maximum test flow.

## 11 Calibration and Reference Standards

11.1 Calibrate instruments regularly according to the manufacturer's recommendations.

## 12 Test Procedure

The test apparatus is to be enclosed in a Class 100 environment (in accordance with ISO 14644). Test must be performed in the sequence described below. (See Figures 5 and 6.)

Measure DUT in purge mode to determine flow or use the value supplied by the manufacturer. This will determine which apparatus to use, direct sampling (Figure 1) or IKS (Figure 2). Both of the test apparatus may be required for testing a wide range of flow controllers.

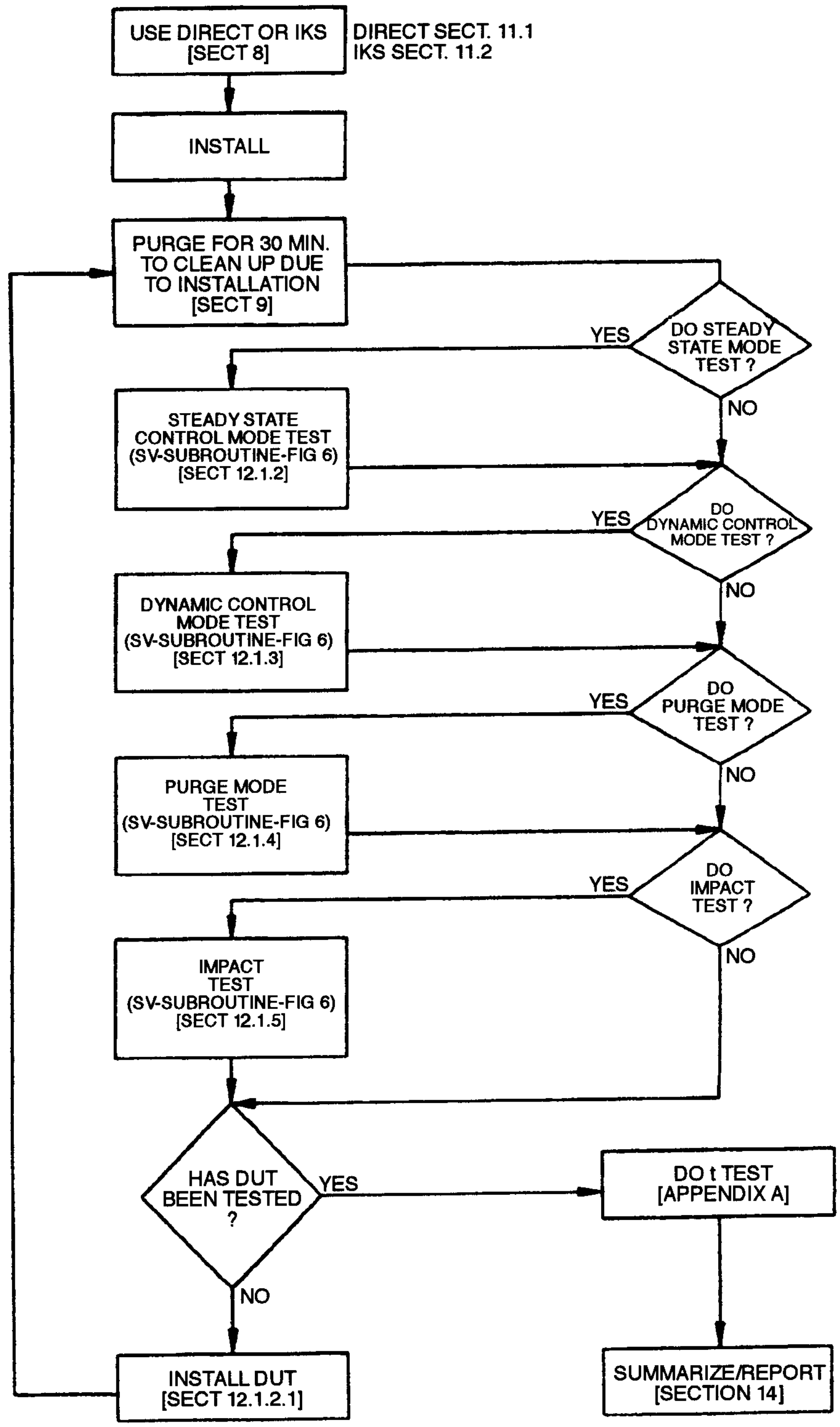
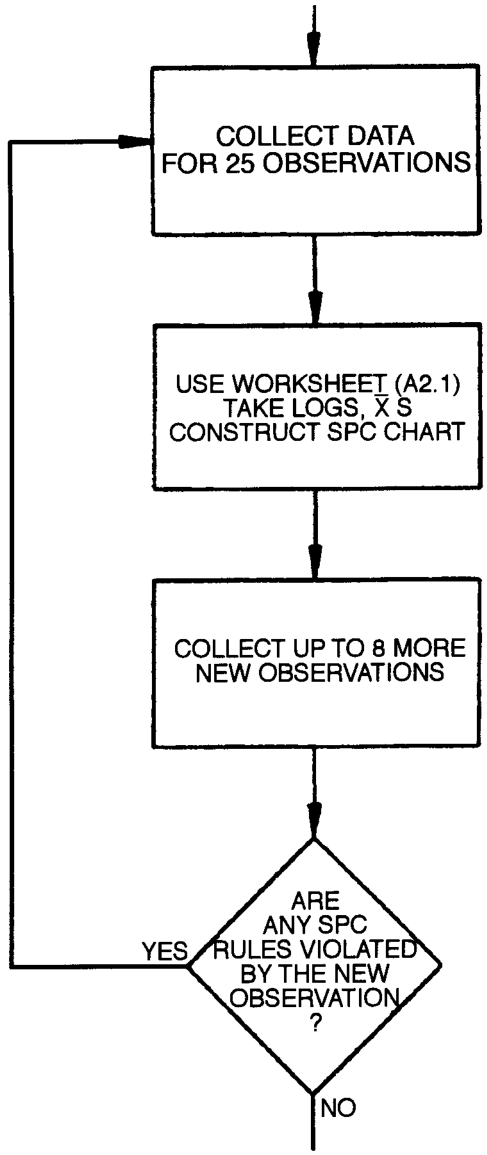



**Figure 5**
**Particle Test Flow Chart**




NOTES: 1. ONE OBSERVATION = 10 MINUTE DATA COLLECTION PERIOD
2. SEE TABLE A2.1 FOR WORKSHEET
3. SEE APPENDIX 1 AND 2 FOR SPC

**Figure 6**
**Statistical Validity Subroutine**

12.1 *Procedure for Direct Sampling* — See Figures 5 and 6.

12.1.1 *Background Count Determination* — Insert spool piece between points A and B (see Figure 1).

12.1.2 *Steady State Control Mode Background Test* — Set supply MFC (SFC) to the intended test flow value of the DUT. For this test, the 100% full scale value is recommended.

12.1.2.1 Count particles for the time necessary to achieve a stable particle level.

12.1.3 *Dynamic Control Mode Background Test* — Cycle the SFC from 10% to 100% of the DUT's rated flow. The cycle period is equal to two times the settling time of the DUT with the longest settling time. (This will ensure that all MFCs in a given test are tested at the same cycle time.)

12.1.3.1 Count particles for the time necessary to achieve a stable particle level.

12.1.4 *Purge Mode Background Test* — Set the SFC to 100% of the rated flow of the DUT.

12.1.4.1 Count particles for the time necessary to achieve a stable particle level.

12.1.5 *Impact Background Test (optional)* — Set the SFC to the intended flow value of the DUT. For this test, the 100% full scale (FS) value is recommended.

12.1.5.1 Maintain the test flow in the spool piece to achieve a constant particle level. Strike the spool piece once a minute (using the mechanical shock device) until a constant particle level is achieved. (See Figure 4.)

12.1.5.2 Count particles for the time necessary to achieve a stable particle level.

12.1.6 *Steady State Control Mode Test* — Set SFC to 10% setpoint of the DUT's rated flow.

12.1.6.1 Remove the spool piece by disconnecting the downstream fitting and then the upstream fitting. Immediately install the test component in a fully open position by connecting the upstream fitting and then the downstream fitting. Take extreme care to minimize contamination of the test apparatus during this operation.

12.1.6.2 Set the SFC in purge mode (emulates tubing).

12.1.6.3 Set the DUT to the desired flow. For this test, the 100% full scale value is recommended.

12.1.6.4 Count particles for the time necessary to achieve a stable particle level.

12.1.7 *Dynamic Control Mode Test* — Keep the SFC in purge mode (emulates tubing).

12.1.7.1 Cycle the DUT from 10% to 100% of the DUT's rated flow. The cycle period is equal to two times the settling time of the DUT with the longest settling time. (This will ensure that all MFCs in a given test are tested at the same cycle time.)

12.1.7.2 Count particles for the time necessary to achieve a stable particle level.

12.1.8 *Purge Mode Test* — Set SFC to 100% of the DUT's rated flow.

12.1.8.1 Operate DUT in the purge mode until a stable particle level is achieved.

12.1.9 *Impact Test (optional)* — This test is to immediately follow the purge mode test.

12.1.9.1 Keep the SFC set to 100% of the DUT's rate flow.

12.1.9.2 Operate the DUT in the purge mode until a stable particle level is achieved.

12.1.9.3 Strike the DUT once a minute until consistent particle transients are achieved using the mechanical shock device. (See Figure 4.)

12.1.10 *Background Test* — Repeat all background tests performed in Section 12.1.1.

12.1.10.1 *Procedure for Isokinetic Sampling* — Follow the procedures described in Section 12.1, with the following exceptions:

12.1.10.2 To establish the background, see Figure 2 and the example below. With the spool piece in place, the throttle valve V1 fully open, and the bypass MFC in purge mode, set the SFC to the maximum inlet flow of the IKS. Adjust V1 and monitor the flow through the bypass MFC until the difference between the SFC flow and the bypass MFC flow is equal to the intended test flow of the DUT. The throttle valve V1 should remain fully open for all other tests that use the test set-up in Figure 2.

| *Example* | *Given Test Flow:* | *Set SFC Flow:* | *Adjust V1 for Bypass MFC Flow:* |
|---|---|---|---|
| | 25 slpm | 30 slpm | 5 slpm |
| | 50 slpm | 100 slpm | 50 slpm |

12.1.10.3 During steady state and dynamic testing of the DUT, use the bypass MFC to make up the difference between the intended flow value of the DUT and the maximum inlet flow of the sampler selected from Table 1.

## 13 Data Analysis

13.1 Appendix 1 contains information on statistical process control charting. Appendix 2 contains information on performing the t-test, a statistical method of comparing the mean background particle count with the mean device particle count.

## 14 Data Presentation

14.1 The following test conditions are to be reported in the data presentation:

14.1.1 Date and time of test

14.1.2 Operator

14.1.3 Test flow rate (sccm)

14.1.4 Test pressure (kPa)

14.1.5 Ambient temperature (°C)

14.1.6 MFC orientation

14.1.7 MFC location in test bed if multiple station test set-up used.

14.1.8 Cleanroom or environment classification

14.1.9 MFC type, manufacturer, serial number, sample flow rate (sccm), model number, calibration date, and particle range

14.1.10 Test gas type and dew point (°C)

14.1.11 A schematic of the test apparatus, including manufacturers and model numbers of all test apparatus components

14.1.12 Calibration dates for the flow meters

14.2 Refer to Figure A1-2 as an example of a typical cleanup curve. Graph the static, dynamic, and impact portions of the test separately as counts/minute (measured by the counter) versus time. Include the appropriate background (measured with the spool piece in place) for each. Also graph the entire data set as counts per minute versus time. If different MFCs are to be compared, graph their entire data sets together.

14.3 Present the entire raw data set in tabular form (see Table A2-1).

## 15 Precision and Bias

15.1 The precision and bias of the data generated by this test method is limited to the precision and bias of the particle measuring instruments used.

## 16 Related Documents

16.1 *SEMI Standards*

SEMI F78 — Practice For Gas Tungsten Arc (GTA) Welding Of Fluid Distribution Systems In Semiconductor Manufacturing Applications

SEMI F81 — Specification For Visual Inspection And Acceptance Of Gas Tungsten Arc (GTA) Welds In Fluid Distribution Systems In Semiconductor Manufacturing Applications

16.2 *Manufacturer's Document*

16.2.1 *Manufacturers Operating Manual* — The appropriate particle counters manufacturer operating and maintenance manuals should be consulted when using this test method.

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

# APPENDIX 1
# STATISTICAL PROCESS CONTROL CHARTING

NOTE: This appendix was approved as an official part of SEMI E66 by full letter ballot procedure.

### A1-1

A1-1.1 The following rules should be used to interpret the statistical process control chart, Figure A1-1:

1. If one observation is outside UCL/LCL, the process is out of control.
2. If two consecutive observations are > halfway, the process is out of control.
3. If at least eight successive points are in control, the process is stable.

A1-1.2 It has been assumed that the data is approximately normal under log transform and that samples are independent.

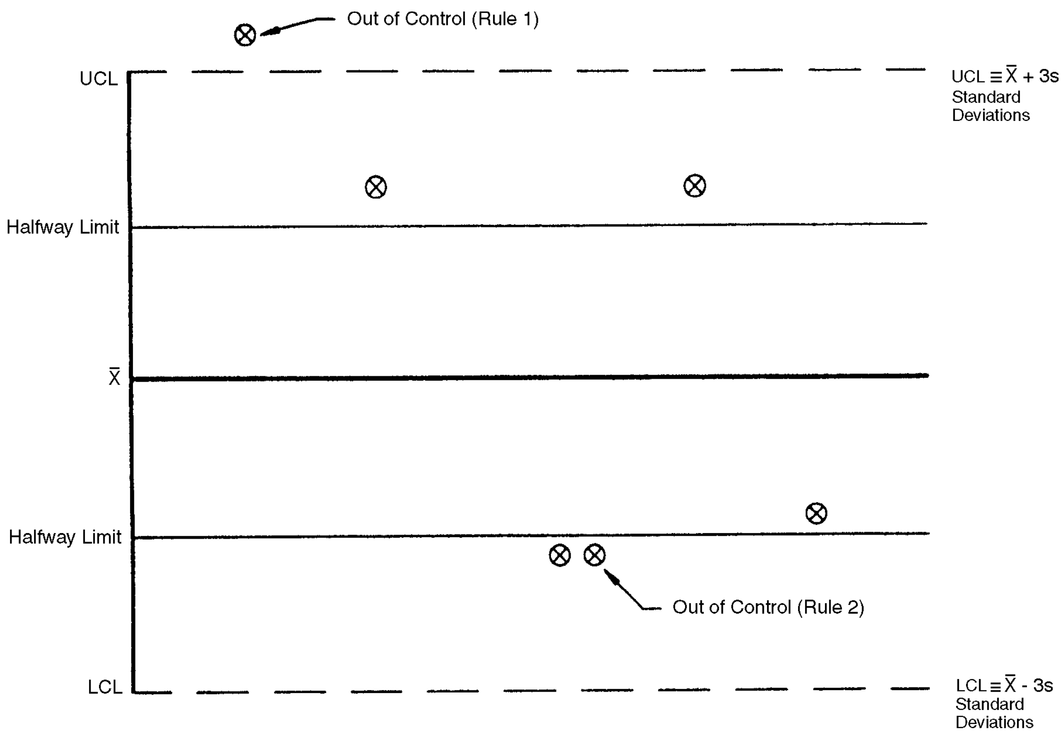



**Figure A1-1**
**Statistical Process Control Chart**

$$S = \sqrt{\frac{\sum_{1}^{n}(x_i - \bar{x})^2}{n-1}}$$

where $n$ = # of observations

A1-1.3 Figure A1-2 gives an overall picture of the data collection specified by Table A2-1 for both “BACKGROUND” and “DEVICE”. There are three phases of data collection:

1. Cleanup
2. Steady-state performance
3. Statistical process control (SPC)

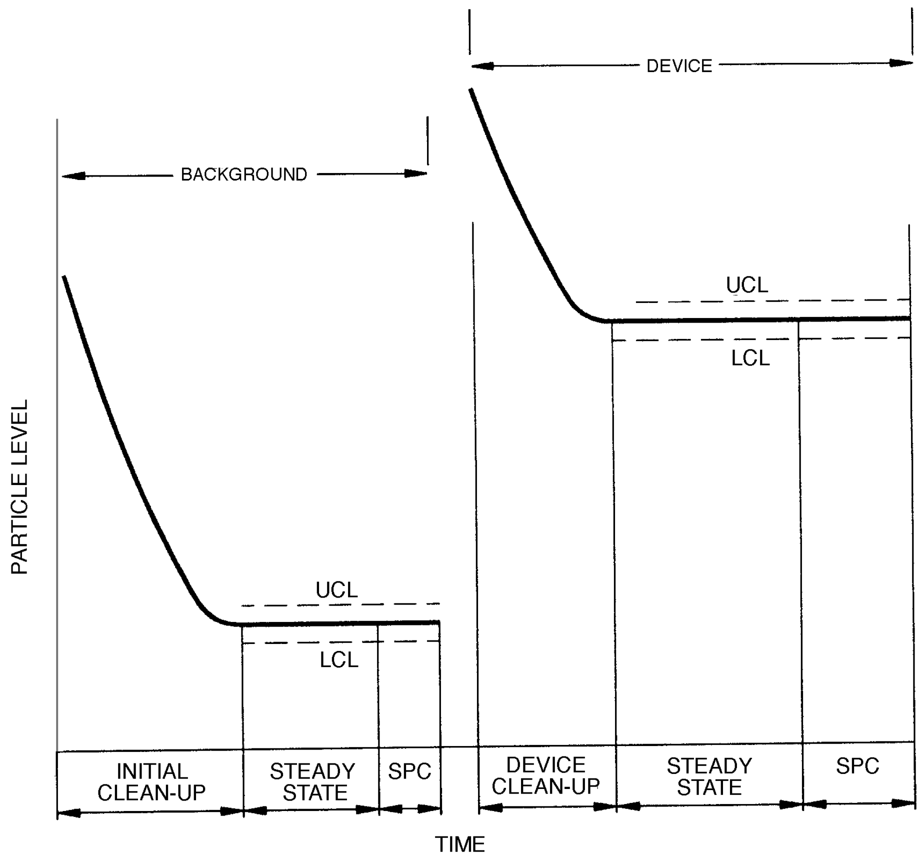



**Figure A1-2**
**Graphical Representation of Data Collection**

# APPENDIX 2
# t-TESTING; COMPARISON OF BACKGROUND MEAN AND DEVICE MEAN

NOTE: This appendix was approved as an official part of SEMI E66 by full letter ballot procedure.

## A2-1

A2-1.1 The background and DUT are expected to have low particle counts. Therefore, a statistical method is needed to determine if there is a difference between background and DUT particle counts. The t-test is a method of determining the actual statistical difference between the mean background particle count and the mean device particle count. It can be used to characterize the particle contribution by the MFC Record results in Table A2-1.

**Table A2-1 Test Worksheet**

| | # | *Observation* | *log Observation* | *Remarks* |
|---|---|---|---|---|
| Spool Cleanup | 1 ... Nx | | | All computations are in the logs of original observations. |
| Stable Level | | X1 ... X25 | | Compute $X_{1,\ S1,\ UCL,\ LCL.}$ |
| SPC | | X26 ... X334 | | Use all 8 values to recompute new values ($X_{1,S1}$). |
| Connect Device | | | | |
| Device Cleanup | | X34 ... X35 + n | | |
| Stable Level | | X34 + n + 1 ... X34 + n + 25 | | Compute $X_{2,\ S2,\ UCL,\ LCL}$. |
| SPC | | X34 + n + 26 ... X34 + n + 34 | | Use all 8 values to recompute new values ($X_{2,\ S2}$). |

NOTE: Use t-test to compare X’s. (See Appendix 2.)

A2-1.2 Calculate pooled standard deviation using the following equation:

$$S_{pooled} = \sqrt{\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2}}$$

where :

$S_1$ = background standard deviation

$S_2$ = device standard deviation

$n_1$ = background sample size

$n_2$ = device sample size

A2-1.3 Calculate the value of T (the t-test’s namesake) as follows:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{S_{pooled} \cdot \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

where :

1 = background mean

2 = device mean

A2-1.4 The degrees of freedom (dof) is $n_1 + n_2 - 2$. For example, if $n_1 = n_2 = 8$, then dof = 14.

### A2-2 Interpretation

A2-2.1 If $|t| > t_{.975}$, then the two means are significantly different at the 95% level. If $|t| > t_{.995}$, then the two means are significantly different at the 99% level (e.g., by "95% confidence," it is meant that the difference/no-difference decision based on the t-test will be correct 95% of the time).

$t_{.975} = 2.145$ (2-sided)

$t_{.995} = 2.977$ (2-sided)

NOTE:

- All readings are log particle counts, not particle counts.
- Since logs are used, zeros have to be replaced by positive values (e.g., 1/2).
- To determine t value for a particular confidence level and (dof), refer to any statistical reference book.

# SEMI E67-0304
# TEST METHOD FOR DETERMINING RELIABILITY OF MASS FLOW CONTROLLER

This test method 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 December 4, 2004. Initially available at www.semi.org February 2004; to be published March 2004. Originally published September 1997.

## 1 Purpose

1.1 This document describes a method to help determine the ability of an MFC to meet the manufacturer's published specifications over its life time. The results of the test will also be useful in the comparison of MFCs.

## 2 Scope

2.1 This procedure applies to MFCs used in semiconductor gas systems.

**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 procedure is to be used only in conjunction with another existing parametric test for mass flow controllers to obtain the reliability data for that particular parametric test.

3.2 New MFCs shall be used for reliability testing. An MFC that has been put through this test method may be tested for reliability again.

3.3 In addition to this procedure, the parametric test may also cycle the valve. These cycles should be ignored for determining the cumulative cycles that are described in the data table.

3.4 This test will not address root cause analysis of failures.

3.5 Read points have been selected for this test procedure so that the test will take approximately six months to complete. The read point schedule given is only a suggested schedule and if the user feels that a different read point schedule would better suit his needs, this test method can still be used to obtain reliability data.

## 4 Referenced Standards

4.1 *SEMI Standards*

SEMI E17 — Guideline for Mass Flow Controller Transient Characteristics Tests

SEMI E66 — Test Method for Determining Particle Contribution by Mass Flow Controllers

SEMI E69 — Test Method for Determining Reproducibility and Zero Drift for Thermal Mass Flow Controllers

SEMI F1 — Specification for Leak Integrity of High-Purity Gas Piping Systems and Components

4.2 *SEMASPECs*[1]

NOTE 1: The SEMASPECs noted here will be superceded by the comparable SEMI documents when available.

90120391B-STD — SEMATECH Test Method for the Determination of the Helium Leak Rate for Gas Distribution System Components

92071220B-STD — SEMATECH Guide to Provisional Test Methods for Mass Flow Controllers

4.3 *Other Document*

Nelson, Wayne, Applied Life Data Analysis, New York, NY Wiley, 1982 (see Annex)

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

## 5 Terminology

5.1 *Acronyms and Abbreviations*

5.1.1 *MFC* — Mass flow controller

5.1.2 *UHP* — Ultra-high purity

5.2 *Definitions*

5.2.1 *cycle* — a repeating sequence of setpoints applied to the MFC.

5.2.2 *hard failure* — a catastrophic mechanical failure or electrical failure that results in an inoperable MFC,

1 SEMATECH, 2706 Montopolis Drive, Austin, TX 78741, USA website: www.sematech.org.

or a deviation from a user-defined specification that results in a condition that makes the MFC inadequate for the user's process.

5.2.3 *parametric test* — the test method that determines the data for which reliability information is sought (e.g., accuracy test or particle test, SEMI E66).

5.2.4 *readpoint* — cumulative cycles applied to the MFC.

5.2.5 *reliability* — the probability that the equipment will perform its intended function, within stated conditions, for a specified period of time.

5.2.6 *soft failure* — failure that occurs when an MFC no longer meets the manufacturer' s specification for the parameter under test.

## 6 Summary of Test Method

6.1 The MFC is installed in a fixture capable of applying and recording a number of flow cycles. When the number of cycles specified in the readpoint schedule is reached, cycling is suspended, parametric tests are per-formed, and the cycling is resumed until either the next readpoint is reached, or the MFC experiences a hard failure. After the cycling is completed, the parametric test data is analyzed to determine the reliability of each parameter.

## 7 Significance and Use

7.1 This test provides an estimate of the reliability of a mass flow controller. The results of the test will also be useful in the comparison of MFCs. The data provided by this test can help end users determine the reliability of equipment that uses MFCs.

7.2 The following parameters and associated test methods should be tested with this test method to obtain reliability data:

| *Parameter* | *Test Method* |
|---|---|
| Particle Contribution | SEMI E66 |
| Reproducibility & Zero Drift | SEMI E69 |
| Helium Leak Rate | SEMASPEC 90120391B-STD |
| Step Response | SEMI E17 |

7.3 The following modifications to the preceding parametric test methods are suggested to abbreviate the time required to complete the reliability test:

7.3.1 *SEMI E66 (Particle Contribution)* — Abbreviate this test method to perform only the dynamic control mode test. Perform Sections 12.1.3 and 12.1.7, and eliminate Sections 12.1.2, 12.1.4, 12.1.5, 12.1.6, 12.1.8, 12.1.9, and 12.1.10. Refer to Sections 5.2.1 (Background), 5.2.3 (Dynamic), and Figure 5 (Particle Test Flow Chart).

7.3.2 *SEMI E69 (Reproducibility & Zero Drift)* — Omit Sections 12.1 and 12.2.

7.3.3 *SEMI F1 (Leak Integrity)* — The intent of the reliability test method is to detect the development of gross leaks in the DUT due to cycling of the DUT valve. The inboard component leak test portion of this standard should be performed.

7.3.4 *SEMI E17 (Step Response)* — No abbreviation is necessary for this test. However, perform this test with the modifications noted in the SEMATECH Guide to Provisional Test Methods for Mass Flow Controllers, SEMASPEC 92071220B-STD.

7.4 Change in the performance characteristics of the MFC, as measured by the above tests, may also be monitored and analyzed as indicative of drift.

## 8 Apparatus

8.1 In addition to the apparatus listed below, the user must also acquire any apparatus required to perform the parametric test for which reliability data is needed. (See documents cited in Section 7.2.)

8.1.1 Power supply

8.1.2 *NIST (or equivalent recognized standards agency)* — traceable flow calibration system

8.1.3 MFC control cables, as many as required in Section 8.1.4

8.1.4 Mass flow controllers for controlling test flows in addition to the DUT MFCs, as many as required for the test setup

8.1.5 Cycling fixture

## 9 Materials

9.1 In addition to the materials listed below, the user must also acquire any materials required to perform the parametric test for which reliability data is needed. (See documents cited in Section 7.2.) Since reliability data for leak integrity is being sought, helium cannot be used during the cycling procedure.

9.1.1 Source of nitrogen (99.999%)

## 10 Sampling, Test Specimens, and Test Units

10.1 Three MFCs are required for meaningful data analysis. However, 20 to 30 MFCs are a recommended minimum. A larger sample size provides a more precise estimate of reliability.

## 11 Preparation of Apparatus

11.1 The setup for the parameter under test is described in the document for that particular parameter (see Section 7.2).

## 12 Calibration and Reference Standards

12.1 Any required instrument calibration or use of reference standards must be done in accordance with the particular parametric test for which reliability data is needed.

## 13 Conditioning

13.1 Conditioning requirements are those of the particular parametric test for which reliability data is needed.

## 14 Procedure

14.1 Connect all MFCs under test in parallel.

14.2 Perform the parametric test before any cycling is done and note the resulting data on the data sheet (Table 1). This is the first readpoint (see Figure 1).

**Table 1 Data Sheet for Reliability Testing**

| *READPOINT (Cumulative cycles applied to the MFC)* | *FAILURE TYPE — SOFT OR HARD* | *SOFT FAILURE TYPE** |
|---|---|---|
| 0 (baseline) | | |
| 10,000 | | |
| 40,000 | | |
| 100,000 | | |
| 200,000 | | |
| 300,000 | | |
| 450,000 | | |
| 600,000 | | |
| 750,000 | | |
| 875,000 | | |
| 1,000,000 | | |

*Use the following soft failure types:

A = Accuracy/Repeatability

P = Particles

S = Step Response

L = Leakage

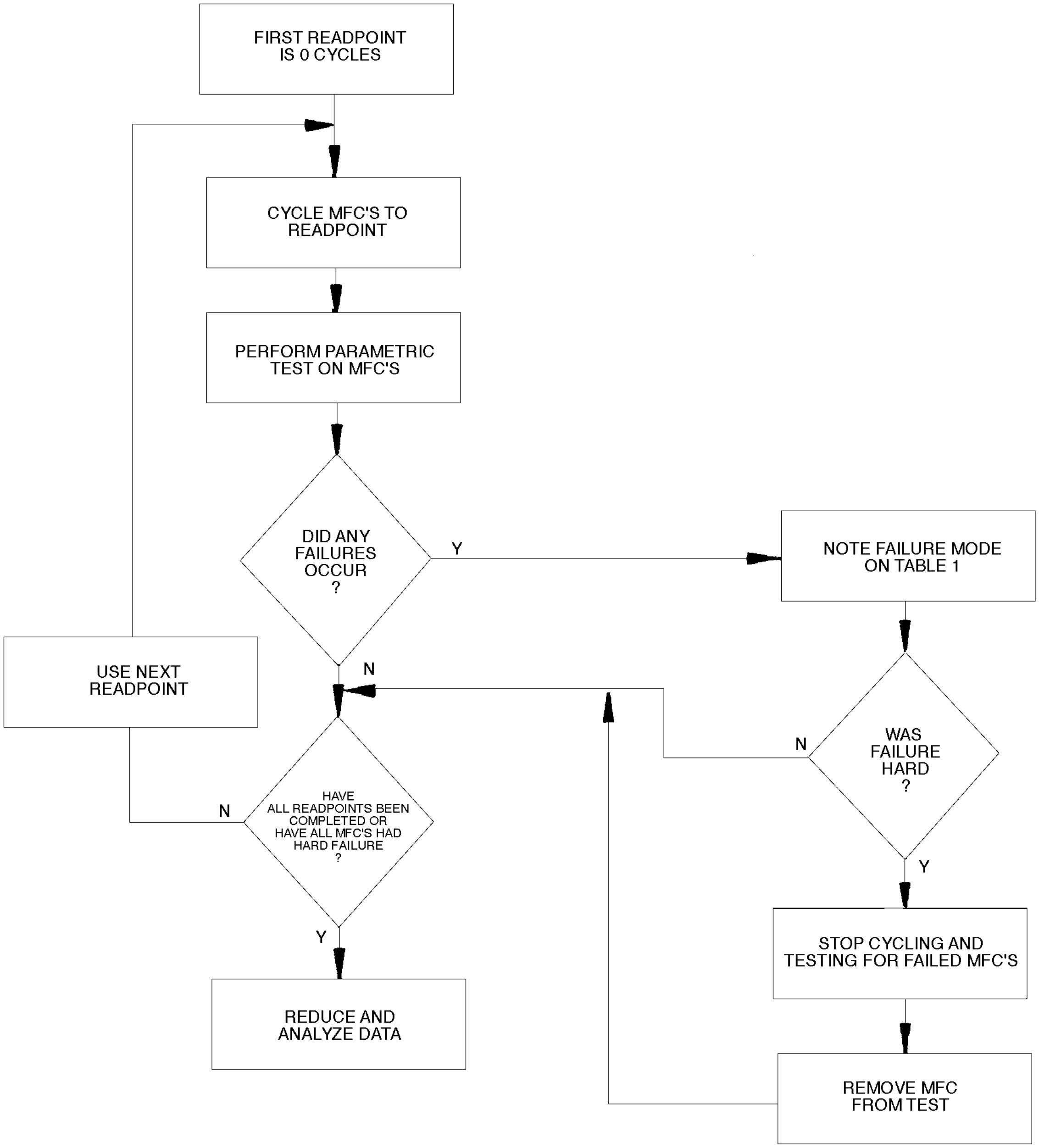



**Figure 1**
**Flowchart for Reliability Test Procedure**

NOTE: Do not count the cycles that occur during the parametric test.

14.3 Cycle the MFCs to the next readpoint in Table 1. Two types of cycles are applied to the MFC to simulate more realistically the MFC's field environment. Alternate between the two types of cycles as illustrated in Figure 2. Maintain each setpoint for a fixed period of time. Use one of the following times based upon the settling time of the slowest DUT. If the settling time is less than or equal to 1.25 seconds, use a time period of 2.5 seconds. If the settling time is less than or equal to 2.5 seconds and greater than 1.25 seconds, use a time period of 5 seconds. If the settling time is greater than 2.5 seconds, use a time period of twice the settling time.

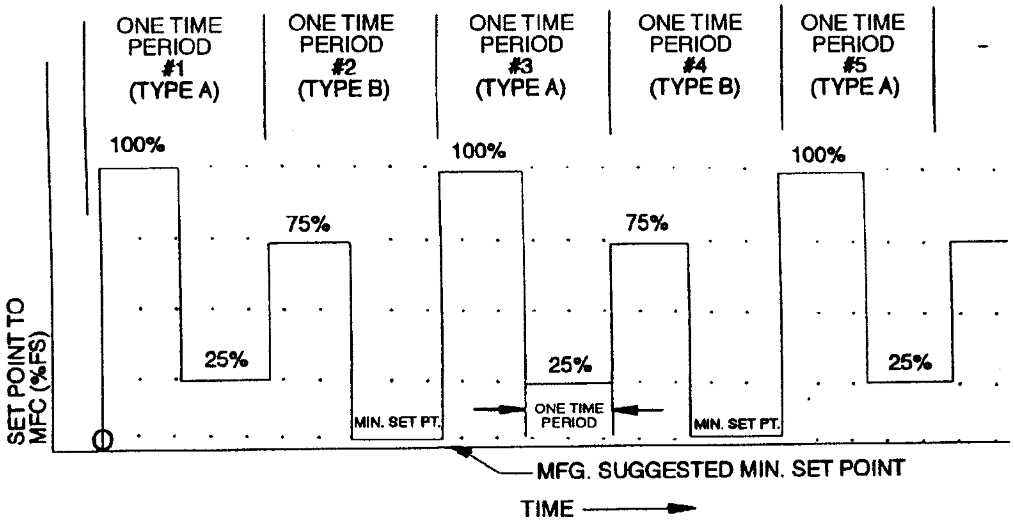



**Figure 2**
**Types of Cycles**

14.4 Discontinue cycling. Perform the parametric tests on all MFCs and record the results on the data sheet. If any MFC experiences a soft failure, record the data but do not stop the cycling procedure. However, if an MFC experiences a hard failure, record the data, discontinue testing this MFC, and take appropriate action to maintain system integrity.

NOTE 2: The test does not require mention of the cause for hard failure, as it is beyond the scope of this document.

14.5 The parametric tests should be performed in the following order: particle, accuracy, response, and leak.

14.6 Perform all of the parametric tests on a single MFC before proceeding to the next one. Record the order of the MFCs tested and the time since the test stand was idled.

14.7 If the readpoint is reached during a time when it is not possible to start the parametric testing, continue cycling until it is possible to begin. Record the number of cycles that occurred before beginning testing.

14.8 Average the particle count information over a 10-minute interval. Count particles for six 10-minute intervals. Record the data from only the last three 10-minute intervals.

14.9 Repeat Sections 14.4 through 14.8 until all the readpoints have been completed or until all MFCs have experienced hard failures.

## 15 Data Analysis

15.1 *Calculations* — See Appendix 1 for a discussion on reliability calculation.

15.2 *Interpretation of Results* — The readpoints included in Table 1 are approximately equidistant on a log scale, and as data is collected, the number of readpoints needed to show trends and estimate life will decrease significantly.

## 16 Data Presentation

16.1 Plot each performance measure over number of cycles to look for trends and shifts as a function of use (see Figure 3). This gives a picture of dynamic performance vs. use.

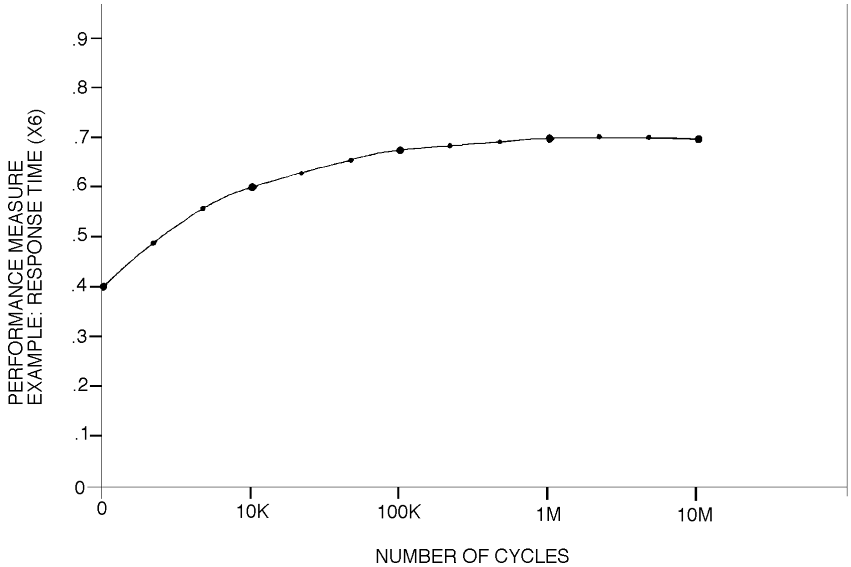



**Figure 3**
**Typical Performance Measure vs. Number of Cycles**

16.2 Record time to failure and plot failure times on lognormal or Weibull probability scales (see Figure 4). This plot gives an estimate of the useful life of an MFC (see Sections A1-1.1.4 – A1-1.1.5). Record data for the parameter tested in the data sheet given within the parametric test method.

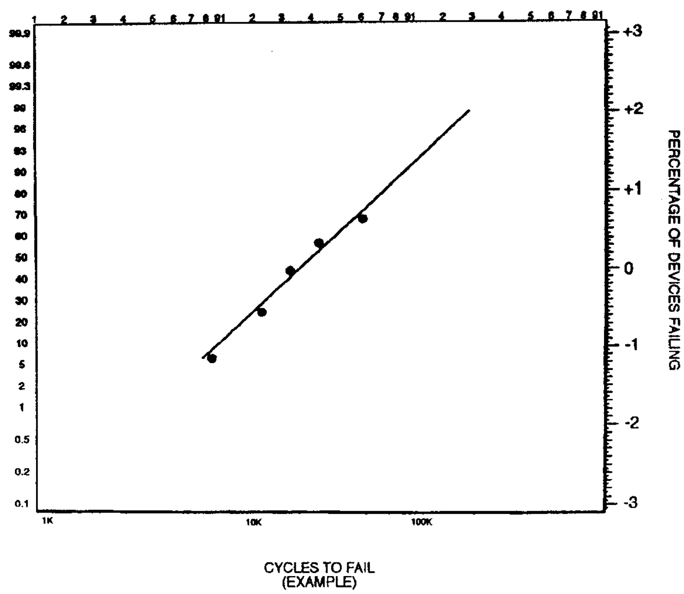



**Figure 4**
**Time to Fail vs. Failure Percentage**

16.3 Record data for the parameter tested in the data sheet given within the parametric test method.

16.4 The following test conditions are to be reported in the data presentation:

16.4.1 date and time of test

16.4.2 operator

16.4.3 test flow rate (SLM)

16.4.4 test pressure (kPa)

16.4.5 ambient temperature (° C)

16.4.6 MFC orientation

16.4.7 MFC location in test bed

16.4.8 cleanroom or environment classification

16.4.9 MFC type, manufacturer, serial number, lot number, and model number

16.4.10 LPC/CNC manufacturer, serial number, sample flow rate (SLM), model number, calibration date, particle range, and efficiency

16.4.11 test gas type and dew point (° C)

16.4.12 a schematic of the test apparatus, including manufacturers and model numbers of all test apparatus components

16.4.13 calibration dates for the flow meters

16.4.14 cycle time used for test

## 17 Precision and Bias

17.1 Precision and bias in this test are a function of the uncertainty of the measurement equipment used. The tester or end user is responsible for determining the precision and bias of a particular setup and test.

# APPENDIX 1
# RELIABILITY ANALYSIS

**NOTICE**: This appendix was approved as an official part of SEMI E67 by full letter ballot procedure.

NOTE 1: The method for reliability analysis provided herein is one of many possible methods which may be used. It is up to the user to determine if this method or another (e.g., Weibull) is to be used for determination of MFC reliability.

## A1-1 Reliability Analysis

A1-1.1 Almost all reliability studies of entities whose failure is unplanned, focus on the time until a small percentage has failed (time until 10% of the population has failed, for example). Focus is on the left tail of the time-to-failure probability distribution. Nelson's book, *Applied Life Data Analysis*, (Wiley, 1982) gives a simple method for estimating the time to 10% failure for a lognormal distribution (n = 2 to 10) from units put on test. Table A1 (from page 272 of Nelson's book) can be used as follows:

A1-1.1.1 Calculate the % failed from the following equation:

Plot % failed vs. # cycles to failure for each MFC that failed on lognormal probability paper (see Figure 4).

A1-1.1.2 Estimate the mean, **μ***, and the standard deviation, **σ***, from the plot with the following equations:

A1-1.1.3 Calculate a 90% lower confidence limit for the (log of) 10% failure percentile ($y_{10,\ lcl}$) from the following equations:

$$y^* = \mathrm{LOG}\,(y_{10,\ lcl}) = \mu^* + t^*\ [\delta = 0.10,\ P = 0.10,\ n = \#\ \text{tested},\ r = \#\ \text{failed}] \times \sigma^*$$

where $t^*$ is found from *Applied Life Data Analysis*, Table A1

$$y_{10,\ lcl} = 10^{y^*}$$

A1-1.1.4 Here is a sample set of data to illustrate the procedure.

| *i* | *Cycles to Failure* | *% Failed* |
|---|---|---|
| 1 | 6.3 K | 8.3 |
| 2 | 15.8 K | 25.0 |
| 3 | 25.1 K | 41.7 |
| 4 | 40 K | 58.3 |
| 5 | 63 K | 75.0 |
| 6 | did not fail | did not fail |

The % failed column was calculated from the equation in Section A1-1.1.1.

A1-1.1.5 See Figure 4 for a plot of this data.

A1-1.1.6 Use Figure 4 to calculate **μ*** and **σ***.

# of cycles to 50% failure = 3000 from graph

$\mu^*$ = LOG (# of cycles to 50% failure)

$\mu^*$ = LOG (30000)

$\mu^*$ = 4.477

# of cycles to 16% failure = 11000 from graph

$\sigma^* = \mu^* -$ LOG (# of cycles to 16% failure)

$\sigma^* = 4.477 -$ LOG (11000)

$\sigma^* = 4.477 - 4.041$

$\sigma^* = 0.436$

A1-1.1.7 From Table A1 (from page 272 of Nelson’s book), look up t*:

This data indicates, with a 90% confidence limit, that 10% of the devices will fail by 2443 cycles.

A1-1.1.8 Table A1 percentiles t* (d: 10, n, r) for limits for $y_{.10}$.

| *nφ* | *rφ* | *pÆ* 0.005 | *0.01* | *0.025* | *0.05* | *0.1* | *0.5* | *0.9* | *0.95* | *0.975* | *0.99* | *0.995* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 2 | -183.9 | -88.09 | -36.3 | -16.4 | -7.869 | -1.405 | -0.327 | -0.118 | 0.083 | 0.444 | 0.888 |
| 3 | 2 | -117.6 | -59.41 | -26.14 | -13.45 | -6.786 | -1.38 | -0.495 | -0.256 | -0.0715 | 0.898 | 2.072 |
| 3 | 2 | -17.6 | -12.28 | -7.761 | -5.497 | -3.691 | -1.326 | -0.473 | -0.305 | -0.154 | 0.047` | 0.172 |
| 4 | 2 | -113.5 | -56.59 | -21.5 | -11.55 | -5.934 | -1.348 | -0.537 | -0.28 | 0.236 | 1.864 | 4.305 |
| 4 | 3 | -15.58 | -11.52 | -7.112 | -5.071 | -3.503 | -1.313 | -0.558 | -0.399 | -0.252 | -0.0573 | 0.107 |
| 4 | 4 | -9.617 | -7.008 | -4.985 | -3.792 | -2.921 | -1.29 | -0.559 | -0.409 | -0.265 | -0.124 | -0.0141 |
| 5 | 2 | -112.9 | -48.61 | -18.13 | -9.49 | -4.988 | -1.322 | -0.567 | -0.182 | 0.519 | 2.436 | 5.585 |
| 5 | 3 | -13.33 | -9.911 | -6.294 | -4.598 | -3.208 | -1.306 | -0.622 | -0.463 | -0.285 | -0.00405 | 0.271 |
| 5 | 4 | -7.956 | -6.415 | -4.652 | -3.636 | -2.778 | -1.292 | -0.624 | -0.475 | 0.335 | -0.173 | -0.0587 |
| 5 | 5 | -5.565 | -4.871 | -3.892 | -3.184 | -2.585 | -1.287 | -0.622 | -0.472 | -0.344 | -0.202 | -0.109 |
| 6 | 2 | -76.15 | -37.64 | -17.14 | -8.573 | -4.669 | -1.313 | -0.57 | -0.0928 | 0.779 | 3.427 | 6.336 |
| 6 | 3 | -14.2 | -10.33 | -6.289 | -4.393 | -3.107 | -1.303 | -0667 | -0.503 | -0.323 | -0.0332 | 0.375 |
| 6 | 4 | -7.414 | -5.87 | -4.386 | -3.487 | -2.721 | -1.302 | -0.673 | -0.546 | -0.427 | -0.286 | -0.197 |
| 6 | 5 | -5.45 | -4.681 | -3.746 | -3.083 | -2.498 | -1.297 | -0.673 | -0.547 | -0.44 | -0.309 | -0.219 |
| 6 | 6 | -4.663 | -4.012 | -3.336 | -2.826 | -2.371 | -1.3 | -0.678 | -0.546 | -0.438 | -0.322 | -0.246 |
| 7 | 2 | -68.12 | -32.41 | -15.19 | -8.208 | -4.34 | -1.303 | -0.561 | -0.016 | 0.989 | 4.067 | 9.64 |
| 7 | 3 | -12.82 | -9.162 | -5.602 | -4.099 | -3.005 | -1.301 | -0.71 | -0.529 | 0.33 | -0.0654 | 0.292 |
| 7 | 4 | -7.571 | -5.812 | -4.171 | -3.346 | -2.622 | -1.298 | -0.722 | -0.587 | -0.464 | -0.289 | -0.12 |
| 7 | 5 | -5.523 | -4.604 | -3.705 | -3.034 | -2.417 | -1.295 | -0.723 | -0.595 | -0.495 | -0.361 | -0.243 |
| 7 | 6 | -4.636 | -4.112 | -3.351 | -2.791 | -2.32 | -1.288 | -0.722 | -0.597 | -0.501 | -0.381 | -0.294 |
| 7 | 7 | -4.282 | -3.693 | -3.041 | -2.641 | -2.228 | -1.285 | -0.725 | -0.595 | -0.501 | -0.376 | -0.287 |
| 8 | 2 | -63.58 | -29.95 | -13.34 | -6.948 | -3.728 | -1.293 | -0.472 | 0.226 | 1.645 | 6.157 | 14.5 |
| 8 | 3 | -10.54 | -7.628 | -4.967 | -3.637 | -2.756 | -1.297 | -0.732 | -0.549 | -0.309 | 0.13 | 0.54 |
| 8 | 4 | -6.59 | -5.172 | -3.937 | -3.119 | -2.484 | -1.286 | -0.752 | -0.609 | -0.468 | -0.266 | -0.11 |
| 8 | 5 | -5.363 | -4.296 | -3.443 | -2.885 | -2.361 | -1.287 | -0.757 | -0.629 | -0.507 | -0.358 | -0.242 |
| 8 | 6 | -4.515 | -3.855 | -3.22 | -2.756 | -2.282 | -1.287 | -0.758 | -0.633 | -0.514 | -0.386 | -0.306 |
| 8 | 7 | -4.086 | -3.583 | -3.019 | -2.602 | -2.205 | -1.284 | -0.755 | -0.632 | -0.514 | -0.399 | -0.336 |
| 8 | 8 | -3.781 | -3.414 | -2.851 | -2.485 | -2.162 | -1.29 | -0.757 | -0.63 | -0.514 | -0.404 | -0.338 |
| 9 | 2 | -56.28 | -30.29 | -11.44 | -6.353 | -3.55 | -1.314 | -0.465 | 0.353 | 2.089 | 6.581 | 11.57 |

| *nϕ* | *rϕ* | *pÆ* 0.005 | *0.01* | *0.025* | *0.05* | *0.1* | *0.5* | *0.9* | *0.95* | *0.975* | *0.99* | *0.995* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 3 | -11.84 | -8.048 | -5.062 | -3.693 | -2.704 | -1.312 | -0.739 | -0.551 | -0.304 | 0.209 | 0.744 |
| 9 | 4 | -6.562 | -5.165 | -3.775 | -3.043 | -2.457 | -1.31 | -0.772 | -0.64 | -0.505 | -0.3 | -0.167 |
| 9 | 5 | -5.034 | -4.316 | -3.446 | -2.851 | -2.318 | -1.307 | -0.777 | -0.66 | -0.548 | -0.427 | -0.326 |
| 9 | 6 | -4.437 | -3.901 | -3.21 | -2.714 | -2.232 | -1.305 | -0.779 | -0.663 | -0.566 | -0.444 | -0.365 |
| 9 | 7 | -4.103 | -3.651 | -3.08 | -2.605 | -2.177 | -1.303 | -0.78 | -0.665 | -0.57 | -0.457 | -0.373 |
| 9 | 8 | -3.813 | -3.408 | -2.878 | -2.49 | -2.135 | -1.3 | -0.776 | -0.665 | -0.572 | -0.459 | -0.381 |
| 9 | 9 | -3.624 | -3.228 | -2.752 | -2.413 | -2.067 | -1.298 | -0.78 | -0.666 | -0.571 | -0.458 | -0.396 |
| 10 | 2 | -60.81 | -27.39 | -10.07 | -5.683 | -3.326 | -1.299 | -0.34 | 0.77 | 2.744 | 7.973 | 15.67 |
| 10 | 3 | -9.675 | -6.99 | -4.618 | -3.42 | -2.572 | -1.301 | -0.758 | -0.532 | -0.255 | 0.306 | 1.018 |
| 10 | 4 | -6.389 | -5.028 | -3.792 | -2.993 | -2.353 | -1.297 | -0.798 | -0.657 | -0.528 | -0.332 | -0.134 |
| 10 | 5 | -5.258 | -4.324 | -3.357 | -2.749 | -2.257 | -1.297 | -0.801 | -0.684 | -0.581 | -0.426 | -0.315 |
| 10 | 6 | -4.559 | -3.701 | -3.029 | -2.569 | -2.182 | -1.294 | -0.802 | -0.689 | -0.59 | -0.488 | -0.405 |
| 10 | 7 | -3.838 | -3.43 | -2.853 | -2.497 | -2.121 | -1.293 | -0.803 | -0.689 | -0.593 | -0.497 | -0.428 |
| 10 | 8 | -3.706 | -3.173 | -2.752 | -2.401 | -2.091 | -1.292 | -0.803 | -0.688 | -0.598 | -0.502 | -0.431 |
| 10 | 9 | -3.458 | -3.118 | -2.636 | -2.353 | -2.046 | -1.288 | -0.804 | -0.689 | -0.598 | -0.502 | -0.438 |
| 10 | 10 | -3.297 | -2.996 | -2.561 | -2.284 | -2.02 | -1.29 | -0.804 | -0.693 | -0.598 | -0.501 | -0.437 |



**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 E68-0997 (Reapproved 1103)
# TEST METHOD FOR DETERMINING WARM-UP TIME OF MASS FLOW CONTROLLERS

This test method was technically reapproved 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 July 27, 2003. Initially available at www.semi.org October 2003; to be published November 2003. Originally published September 1997.

## 1 Purpose

1.1 The purpose of this method is to provide a standardized method for quantifying the warm-up time of an MFC.

NOTE 1: Warm-up times affect the initial performance of a mass flow controller (MFC). Warm-up time is necessary information in deciding if a process tool is ready to be put back into service. In addition, warm-up data will be useful in calibration labs.

## 2 Scope

2.1 The test conditions in this method are intended to simulate bench top warm-up, with an MFC that has been equalized to ambient conditions for 24 hours before the application of power.

**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 Conditions in the lab may be different from conditions found in the field and may influence test results. This test is intended to measure warm-up under a controlled condition.

3.2 The MFC is to be at ambient temperature before the beginning of the test.

3.3 Due to manufacturing variability, warm-up times may vary for the same model of MFC. This specification addresses a method for taking a single data point repetitively from the same MFC. Resulting data will show exactly how warm-up effects change the delivered flow of that particular MFC. To statistically quantify warm-up time for a particular model of MFC, multiple samples should be tested.

## 4 Referenced Documents

None.

## 5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *DUT* — Device under test

5.1.2 *FS* — Full scale

5.1.3 *MFC* — Mass flow controller

5.2 *Definitions*

5.2.1 *device under test* — the MFC being tested for warm-up time.

5.2.2 *indicated flow* — flow indicated by the MFC under test. Electrical output of the DUT.

5.2.3 *stability* — a condition that exhibits only natural, random variations in the absence of unnatural, assignable-cause variations. For the several purposes of this test, stability is defined as ± 10% of the accuracy of the DUT at full scale.

5.2.4 *steady state* — state at which the indicated flow is stable for a 15-minute time period.

5.2.5 *warm-up* — a process where the MFC goes from an unpowered condition to a condition where the output is within ± 1% full scale, of the final steady state output.

## 6 Summary of Test Method

6.1 The DUT is connected in series with shut-off valves on either side of the DUT. With no gas flow and the DUT powered, indicated flow is monitored until steady state is achieved. Power is briefly disconnected then reconnected and indicated flow is again monitored until steady state is achieved.

## 7 Significance and Use

7.1 Data generated by this method is used to estimate the amount of time an MFC should be powered up in a process tool before resuming production. When calibrating an MFC, the warm-up time can be used to estimate the waiting time before calibration. For power interruptions, the power interruption warm-up time may be used to determine the time required following a power interruption to resume production or calibration.

## 8 Apparatus

8.1 See Figure 1.

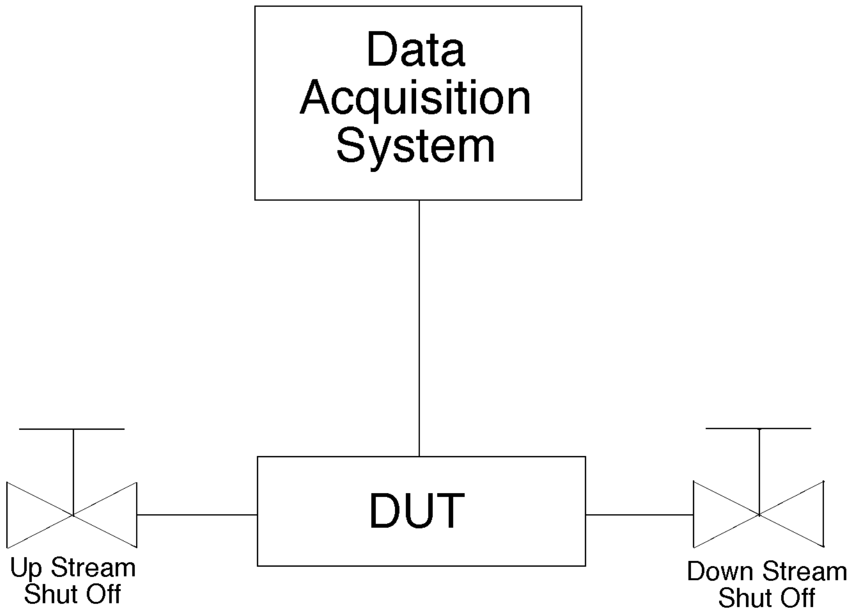


**Figure 1**
**Test Set Up**

8.2 *Time-Keeping Apparatus* — Capable of keeping accurate records within ± 10 seconds. Time-keeping requirements are not stringent, and almost any apparatus is acceptable.

8.3 *Data Acquisition System* — Having a resolution of one mV or better and a sample rate of one Hz.

## 9 Conditioning

9.1 Ambient temperature must be controlled and stable between 20° C and 25° C during testing for all tests. The DUT must be exposed to the ambient environment for 24 hours before the beginning of the test so that it is in equilibrium. The gas temperature must be measured and verified to be at equilibrium with both the DUT and with ambient temperature. Temperatures are in equilibrium if they are within 1° C of each other. Lab temperature may not change more than 1° C during test.

## 10 Procedure

10.1 Connect the DUT in series with the two shut-off valves, one upstream of the DUT and the other downstream. Electronically connect the DUT to a data acquisition system capable of recording indicated flow from the DUT. The test set-up should be set to give appropriate signals to the DUT so the DUT control valve will not dissipate power. For normally closed MFC's, the setpoint should be zero, and for normally open MFC's, the setpoint should be 100%. Suggested orientation of the DUT is horizontal (base down). If the DUT is positioned otherwise, the orientation should be reported in the test data (see Figure 1). Valves are to be opened in a downstream-to-upstream sequence and closed in reverse fashion. The data acquisition system must be warmed up as per the manufacturer's instructions.

10.2 Close shut-off valves.

10.3 In Table 1, record the time of day when power was applied to the DUT. Begin recording the indicated flow from the DUT at one sample per second.

**Table 1 Format for Data Presentation**

| Warm-up Time | Date:____________ | | |
|---|---|---|---|
| | ± 1% FS | Time to Achieve Steady State | Steady State Value |
| Cold Start | | | |
| Power Interruption | | | |

10.4 *Cold Start* — Apply power to the DUT and continue collecting data until the indicated flow achieves a steady state value.

10.5 *Power Interruption* — Continue to collect data while disconnecting power from the test unit for 120 ± 10 seconds. Reconnect power to the DUT and monitor indicated flow until steady state is again achieved.

## 11 Data Analysis

11.1 Graph the data collected from the six test scenarios as directed in Section 10.

11.2 The time required for the DUT to achieve a steady state value can be visually determined from the graph of each test scenario. This data can be used to predict the warm-up times required by an MFC experiencing a field condition similar to the test scenario.

## 12 Data Presentation

12.1 For the two tests in Section 10, plot DUT indicated flow vs. time as illustrated in Figures 2 and 3. Note the following on these graphs and in Table 1.

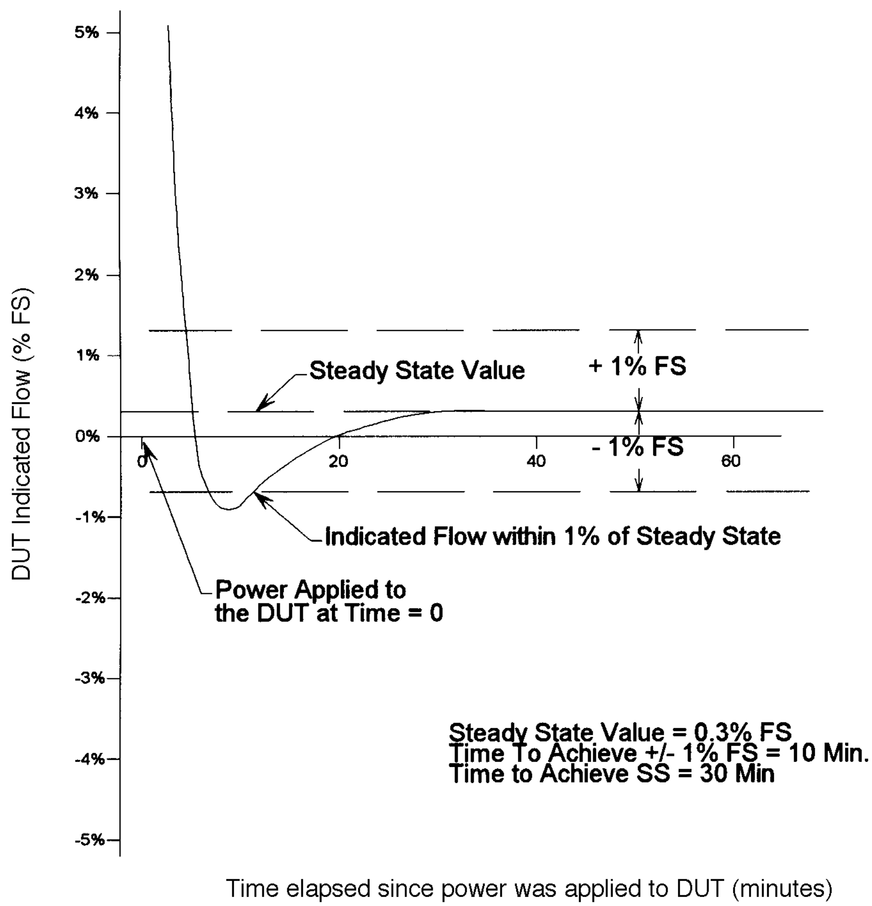


**Figure 2**
**Cold Start Warm-Up Time**

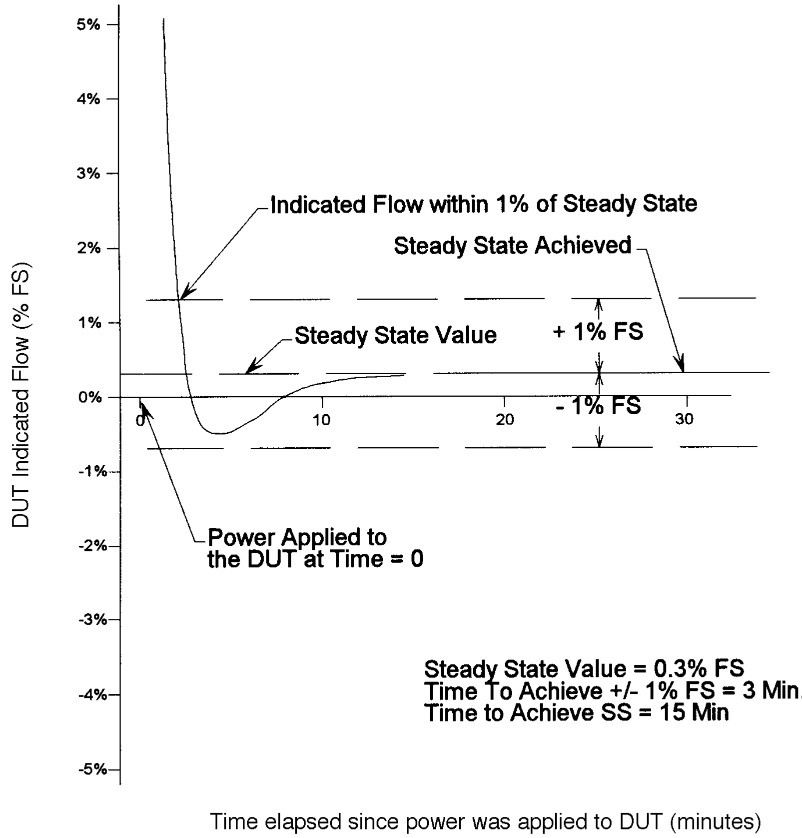


**Figure 3**
**Two-Minute Power Interruption Warm-Up Time**

12.1.1 Final steady-state value of the DUT.

12.1.2 Time to achieve a steady state value.

12.1.3 Use Table 1 to summarize warm-up times associated with each of the test scenarios.

## 13 Precision and Bias

13.1 Precision and bias in this test are a function of the uncertainty of the measurement equipment used. The tester or end user is responsible for determining the precision and bias of a particular setup and test.

# SEMI E69-0298 (Reapproved 1103)
# TEST METHOD FOR DETERMINING REPRODUCIBILITY AND ZERO DRIFT FOR THERMAL MASS FLOW CONTROLLERS

This test method 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 July 27, 2003. Initially available at www.semi.org October 2003; to be published November 2003. Originally published February 1998.

## 1 Purpose

1.1 The purpose of this document is to provide a standardized method to quantify the reproducibility and zero drift of a thermal mass flow controller.

1.2 The intent of this document is not to suggest any specific testing program but to specify the test method to be used when testing for parameters that are covered by this method. The user might use this document to check significant performance characteristics, such as reproducibility and zero drift, under a set of closely controlled test conditions.

1.3 The significance of the accuracy calculations in this method is to allow an MFC user to transfer a process from one manufacturing tool to another and to exchange MFCs within a single manufacturing tool while maintaining process control.

## 2 Scope

2.1 This document describes the conditions and procedures for testing the reproducibility and zero drift of thermal mass flow controllers (MFCs). Because of the generic nature of this document, not all test procedures apply to all types of MFCs.

2.2 This document 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 Limitations

3.1 It is not practical to evaluate performance under all possible combinations of operating conditions. This test procedure should be applied under laboratory conditions; its intent is to collect sufficient data to form a judgement of the field performance of the MFC being tested.

## 4 Referenced Standards

4.1 *SEMI Standard*

SEMI E28 — Guideline for Pressure Specifications of the Mass Flow Controller

4.2 *ANSI Standards*[1]

ANSI C39.5 — Safety Requirements for Electrical and Electronic Measuring and Controlling Instrumentation

ANSI C42.100 — Dictionary of Electrical and Electronics Terms

ANSI MC4.1 — Dynamic Response Testing of Process Control Instrumentation

4.3 *ASME Document*[2]

ASME MFC-1M — Glossary of Terms Used in the Measurement of Fluid Flow in Pipes

4.4 *IEC Standards*[3]

IEC 160 — Standard Atmospheric Conditions for Test Purposes

IEC 546 — Methods of Evaluating the Performance of Controllers with Analogue [sic] Signals for Use in Industrial Process Control

4.5 *ISA Documents*[4]

ISA S7.3 — Quality Standards for Instrument Air

ISA S51.1 — Process Instrumentation Terminology ANSI/ISA-1 979 (reaffirmed 1993)

1 American National Standards Institute, Headquarters: 1819 L Street, NW, Washington, DC 20036, USA. Telephone: 202.293.8020; Fax: 202.293.9287, New York Office: 11 West 42nd Street, New York, NY 10036, USA. Telephone: 212.642.4900; Fax: 212.398.0023, Website: www.ansi.org

2 American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990, USA. Telephone: 800.843.2763 (U.S./Canada), 95.800.843.2763 (Mexico), 973.882.1167 (outside North America), Website: www.asme.org

3 International Electrotechnical Commission, 3, rue de Varembé, Case Postale 131, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.919.02.11; Fax: 41.22.919.03.00, Website: www.iec.ch

4 Instrument Society of America, 67 Alexander Drive, Research Triangle Park, NC 27709. Telephone: 919.549.8411, Fax: 919.549.8288, Website: www.isa.org

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

## 5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *FS* — Full scale

5.1.2 *kPa* — Kilopascal

5.1.3 *MFC* — Mass flow controller

5.1.4 *NC* — Normally closed

5.1.5 *NO* — Normally open

5.1.6 *psia* — Pounds per square inch absolute

5.1.7 *sccm* — Standard cubic centimeters per minute

5.1.8 *slm* — Standard liters per minute

5.2 *Definitions*

5.2.1 *accuracy* — the closeness of agreement between an observed value and the true value; the total uncertainty of an observed value, including both precision and bias.

5.2.2 *accuracy curve* — the curve fitted through the average measured values over the specified range of the device under test (DUT).

5.2.3 *accuracy, device* — the total uncertainty over a specified range of the device. Device accuracy over a range is stated as the worst case accuracy taken over all tested setpoints in this range.

5.2.4 *bias* — the difference, at a setpoint, between the measured value and the sum of the setpoint value and the zero offset. The measured values of a flow standard include its total uncertainty.

5.2.5 *cardinal setpoint* — a specific setpoint to assess the accuracy of the device under test. For this test method, the cardinal setpoints are 10%, 50%, and 100% of full scale.

5.2.6 *deadband* — the range through which a setpoint may be varied, upon reversal of direction, without initiating an observable change in output signal.

5.2.7 *downscale reading* — a reading approached from a setpoint greater than the current setpoint and beyond the deadband.

5.2.8 *downscale value, average* — the sum of all downscale readings, in one cycle, at a single setpoint, divided by the number of these values.

5.2.9 *flow standard* — a device used to measure the actual mass flow through the DUT.

5.2.10 *linearity* — the closeness to which a curve approximates a straight line. It is measured as a non-linearity and expressed as a linearity.

5.2.11 *linearity, terminal-based* — the maximum absolute value of the deviation of the accuracy curve (average of upscale and downscale values) from a straight line through the upper and lower setpoint limits of the accuracy curve (see Figure 1).

5.2.12 *measured value* — the actual flow through a device under test, expressed in sccm or slm, as measured by a standard, preferably primary.

5.2.13 *measured value, average* — the sum of all readings (both upscale and downscale) for all cycles, at a single setpoint, divided by the number of these readings.

5.2.14 *operating conditions, normal* — the range of operating conditions within which a device is designed to operate and for which operating influences are stated [ISA S51.1].

5.2.15 *operating conditions, reference* — the range of operating conditions of a device within which operating influences are negligible [ISA S51.1].

5.2.16 *operating influence* — the change in a performance characteristic caused by a change in a specified operating condition from reference operating conditions, all other conditions being held within the limits of reference operating conditions [ISA S51.1].

5.2.17 *precision* — the closeness of agreement among the measured values at a setpoint. It is often expressed as a standard deviation.

5.2.18 *repeatability* — the closeness of agreement among a number of measured values at a setpoint, under the same operating conditions, operator, apparatus, laboratory, and short intervals of time. It is usually measured as a nonrepeatability and expressed as a repeatability in percent of reading [ISA S51.1].

5.2.19 *reproducibility* — the closeness of agreement among repeated measured values at a setpoint, within the specified reference operating conditions, made over a specified period of time, approached from both directions. It is usually measured as a non-reproducibility and expressed as a reproducibility in percent of average reading. Reproducibility includes hysteresis, deadband, long-term drift, and short-term reproducibility [ISA S51.1].

NOTE 1: Between repeated measurements, the input may vary over the range, and operating conditions may vary within normal operating conditions.

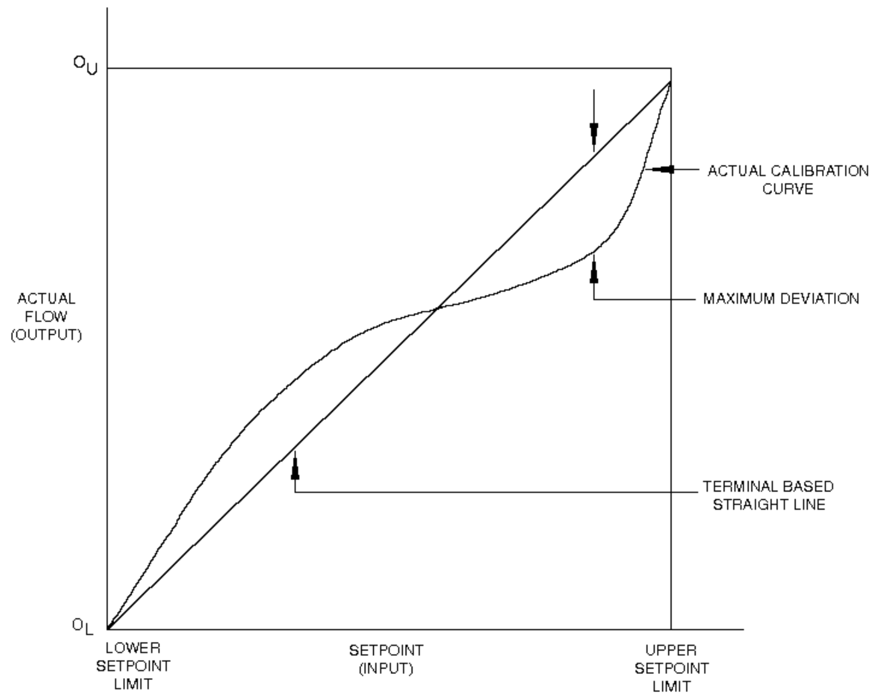


**Figure 2**
**Terminal-Based Linearity for Mass Flow Controller**

5.2.20 *reproducibility, short-term* — the closeness of agreement among a number of measured values at a setpoint, under the same operating conditions, operator, apparatus, laboratory, and short intervals of time, approached from both directions. The approach must be from beyond the deadband. It is usually measured as a nonreproducibility and expressed as a reproducibility in percent of reading. Short-term reproducibility includes repeatability, hysteresis, deadband, and shortterm drift.

5.2.21 *setpoint* — the input signal provided to achieve a desired flow, reported as sccm, slm, or percent-full scale.

5.2.22 *setpoint limit, lower* — the lowest setpoint at which the instrument is specified to operate.

5.2.23 *setpoint limit, upper* — the highest setpoint at which the instrument is specified to operate, usually full scale.

5.2.24 *span* — the full-scale range of the DUT.

5.2.25 *stability* — the ability of a condition to exhibit only natural, random variation in the absence of unnatural, assignable-cause variation.

5.2.26 *standard conditions* — 101.32 kPa, 0.0°C (14.7 psia, 32°F)

5.2.27 *uncertainty, total* — the range within which the true value of the measured quantity can be expected to fit; an indication of the variability associated with a measured value that takes into account the two major components of error — bias and the random error attributed to the imprecision of the measurement process.

5.2.28 *upscale reading* — a reading approached from a setpoint less than the current setpoint and beyond the deadband.

5.2.29 *upscale value, average* — the sum of all upscale readings, in one cycle, at a single setpoint, divided by the number of these values.

5.2.30 *zero drift* — the undesired change in electrical output, at a no-flow condition, over a specified time period, reported in sccm or slm.

5.2.31 *zero offset* — the deviation from zero, at a no-flow condition, reported in sccm or slm.

## 6 Summary of Test Method

6.1 Specific procedures are given for characterizing MFCs discharging to atmospheric pressure or into a vacuum using accepted reference standards to determine reproducibility and zero drift (see Figure 2).

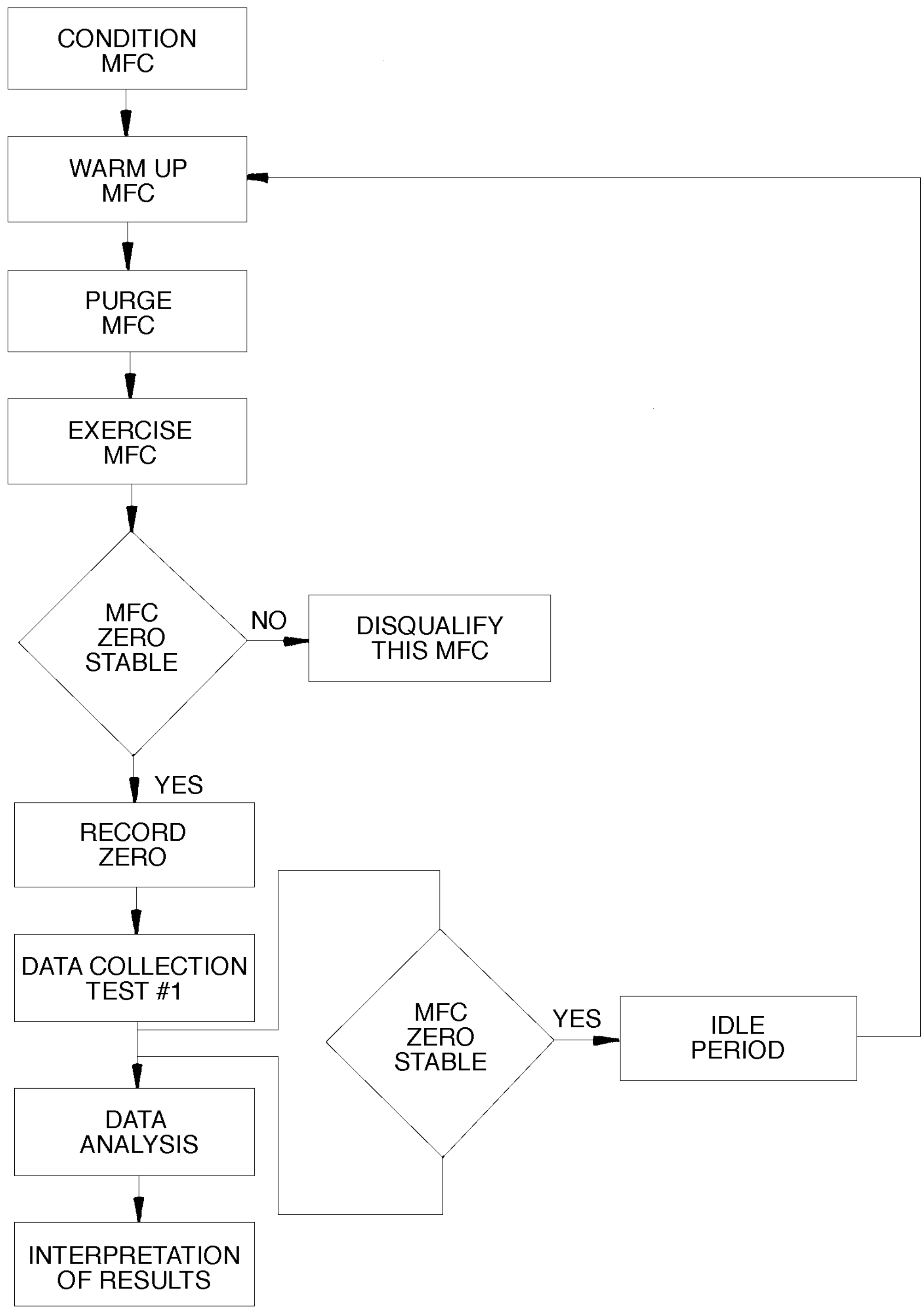


**Figure 3**
**Test Flowchart**

## 7 Interferences

7.1 The accuracy rating of the measuring equipment must include superior measurement capability compared with that of the DUT. In no instance should the accuracy rating of the measuring equipment be less than twice that of the DUT (e.g., if the accuracy of the DUT is ± 1 sccm, then the accuracy of the measuring device must be better than, or equal to, ± 1/2 sccm). The traceability of all the pertinent measuring instruments and devices should be realistically established and quantified.

7.1.1 In addition, take care when using test instruments with a specified accuracy expressed in percent of full scale. For example, if an instrument with a specified accuracy of ± 0.1% of full scale is used to measure the output of the DUT, but this output signal falls only within the lower third of the scale of the instrument, the effective accuracy over the range of the instrument being used may be ± 0.3%, which is unsuitable for many applications.

7.1.2 Use special precautions to ensure that minimum effects result from pneumatic noise in flow lines. Monitor pressure both upstream and downstream of the MFC to ensure that pneumatic noise is minimized.

7.1.3 The DUT should be installed so that the inlet flow can be fully developed, pulsation-free, for the specific conditions. This can be achieved by plumbing a straight length of tubing 40–50 diameters long upstream and another straight length 5 diameters long downstream of the DUT. (For additional information about inlet effects, refer to ASME MFC-1M.)

7.1.4 At regular calibration intervals, verify electrical signals directly at the MFC connector to ensure that there are no unacceptable line losses in the cables.

## 8 Apparatus

8.1 back pressure regulator

8.2 digital voltmeter

8.3 flow standard

8.4 heat exchanger

8.5 power supply

8.6 pressure transducer

8.7 setpoint generator

8.8 temperature probe

## 9 Precautions

9.1 *Technical Precautions*

9.1.1 Many analog-to-digital converter cards do not differentiate between measurements of less than zero and zero. It may be necessary to use a digital voltmeter to record measurements below zero volts. Some MFCs do not differentiate between measurements of less than zero and zero. This may bias the results.

9.1.2 The manufacturer's specifications and instructions for installation and operation must be applied during all testing.

9.1.3 All electrical measurements should be read on devices with at least 4.5 digits of resolution. These devices must have valid calibration certifications.

9.1.4 The mounting position of the device must be in accordance with the manufacturer's specifications. No external mechanical constraints beyond the manufacturer's recommended mounting position shall be permitted.

## 10 Preparation of Apparatus

10.1 Figure 3 is a representation of a recommended generic testing apparatus. The flow standard is shown downstream of the device under test (DUT). It may be placed upstream of the DUT if the flow standard cannot be exposed to a low pressure environment. In this case, the user should be aware of possible back pressure effects on the flow standard.

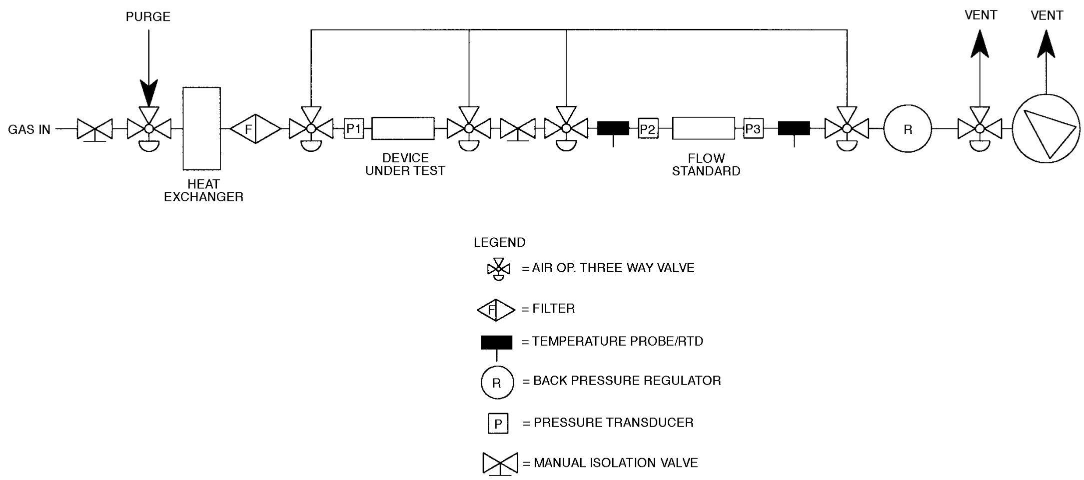


**Figure 3**
**Mass Flow Controller Test Fixture**

## 11 Calibration Standardization

11.1 All measurement devices must have valid calibration certificates.

## 12 Conditioning

12.1 Place the MFC to be tested in the testing environment. Apply power to the MFC for the 24 hours prior to initiating warm-up as defined by the manufacturer. The valve should be in its "off" position (closed for an NC valve, open for an NO valve).

12.2 Following the conditioning period, install and warm up the device according to manufacturer's specifications.

12.3 Purge the MFC with nitrogen or argon following the warm up period.

12.4 Allow the test gas to flow through the DUT for a minimum of 10 minutes at 100% of flow.

12.5 Apply a 100% full-scale setpoint to the DUT and wait for the flow to stabilize for 10 seconds. Apply the lower setpoint limit to the DUT and wait for the flow to stabilize for 10 seconds. Repeat this cycle two more times. This process exercises the device before initiating the test.

12.6 *Test Conditions*

12.6.1 The reference operating conditions shall be as follows if the downstream pressure is atmospheric:

| | |
|---|---|
| Ambient temperature | 23 ± 2°C |
| Gas temperature | Same as actual ambient |
| Ambient pressure | 101.3 kPa (+ 4.7 or − 15.3 kPa) |
| Gas pressure $P_1$, Inlet | 274 ± 34 kPa |
| Gas pressure $P_3$, Outlet | 101.3 kPa (+ 4.7 kPa or − 15.3 kPa) |
| Relative humidity | 40% ± 10%, noncondensing |
| Magnetic field | ≤ 50 µT |
| Electromagnetic field | < 100 µV/m |
| Vibration | < 0.5 m/s |
| Shock | ≤ 3 g |

12.6.2 The reference operating conditions shall be as follows if the downstream pressure is at vacuum:

| | |
|---|---|
| Ambient temperature | 23 ± 2°C |
| Gas temperature | Same as actual ambient |
| Ambient pressure | 101.3 kPa (+ 4.7 or − 15.3 kPa) |
| Gas pressure $P_1$, Inlet | 172 ± 34 kPa |
| Gas pressure $P_3$, Outlet | < 0.13 kPa |
| Relative humidity | 40% ± 10%, noncondensing |
| Magnetic field | ≤ 50 µT |
| Electromagnetic field | < 100 µV/m |
| Vibration | < 0.5 m/s |
| Shock | ≤ 3 g |

12.7 *Power Supply Conditions*

12.7.1 The reference power supply conditions used shall be the reference values specified by the manufacturer. For those instances when a range of values is specified rather than a reference value, the midpoint of the range shall be taken to be the reference value.

12.7.2 The reference power supply must be sufficiently rated for the DUT. In addition, the following supply conditions and tolerances shall apply:

| | |
|---|---|
| DC supply reference voltage | ± 0.1% of operating voltage |
| Noise and ripple of DC supply | ≤ 0.1% rms |

## 13 Procedure

13.1 *Zero Offset*

13.1.1 Close the gas shut-off valve upstream of the device under test and apply a 100% setpoint to the DUT to equilibrate the pressure across the MFC. Wait for the flow to stabilize at a value near zero, then close the downstream shut-off valve. Deactivate the MFC's control valve (open for (NO) valves, closed for (NC) valves), and disable the MFC to auto zero if an auto-zero disable option is available. After the electrical output signal has stabilized for at least three minutes, record the MFC zero offset on Table 1. (Consult the manufacturer's specifications for the stabilization time and report this time on Table 2.)

**Table 1 Data Tabulation**

| *Week #___________* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Date______________* | *Technician________________________* | | | | | | *MFC_______________* | | | | |
| *Input %* | *Set Point (sccm)* | *Indicated Flow (sccm)* | | | | | *Actual Flow (sccm)* | | | | |
| 0 | | | | | | | 0 | 0 | 0 | 0 | 0 |
| 50 | | | | | | | | | | | |
| 100 | | | | | | | | | | | |
| 50 | | | | | | | | | | | |
| 10 | | | | | | | | | | | |
| 5 | Wait 10 minutes | Record no data | | | | | | | | | |
| 10 | | | | | | | | | | | |
| 50 | | | | | | | | | | | |
| 100 | | | | | | | | | | | |
| 50 | | | | | | | | | | | |
| 10 | | | | | | | | | | | |
| 5 | Wait 10 minutes | Record no data | | | | | | | | | |
| 10 | | | | | | | | | | | |
| 50 | | | | | | | | | | | |
| 100 | | | | | | | | | | | |
| 50 | | | | | | | | | | | |
| 10 | | | | | | | | | | | |
| 5 | Wait 10 minutes | Record no data | | | | | | | | | |
| 10 | | | | | | | | | | | |

**Table 2 Test Data Cover Sheet**

| | | | |
|---|---|---|---|
| *MFC* | | | |
| Manufacturer__________ | Model__________ | Serial Number__________ | Attitude__________ |
| Nameplate Gas__________ | Seal Type__________ | Valve Seat Matl.__________ | Full Scale Range__________ |
| | | | |
| *Environment* | | | |
| Ambient Temp. (°C)_________ | Ambient Press. (kPa)________ | Humidity (%)__________ | |
| Test Gas__________ | Inlet Gas Pres. (kPa)_________ | Outlet Gas Press.__________ | Gas Temp. (°C)__________ |
| *Test Facility* | | | |
| Name__________ | City/State__________ | Telephone (    )__________ | Fax (    )__________ |
| Standard Used__________ | Standard Accuracy__________ | Facility Bias__________ | Certification Date__________ |
| Other Equipment__________ | Accuracy__________ | Certification Date__________ | |
| Other Equipment__________ | Accuracy__________ | Certification Date__________ | |
| Other Equipment__________ | Accuracy__________ | Certification Date__________ | |
| Other Equipment__________ | Accuracy__________ | Certification Date__________ | |
| Comments or Special Instructions: | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | Technician__________ |
| | | | Date__________ |

13.1.2 Use the cardinal setpoints and any other setpoints of specific interest. These setpoints will be used to determine the reproducibility of the MFC. The setpoint increments should exceed the expected deadband of the DUT.

13.1.3 At each setpoint under test, maintain the input signal until the output of the DUT becomes stabilized at its apparent final value. Observe and record the output values in Table 1 for each input value.

13.1.4 Record five readings at each setpoint during testing.

NOTE 2: If the data points show a trend in one direction, either up or down, the DUT is not stable enough for the test to proceed to the next setpoint. Record another five readings at this setpoint. If the results continue to show a trend, repeat the measurements at the previous setpoint. If the results are not satisfactory at this setpoint, stop the test for this MFC. If the results are not satisfactory, halt the test and verify the performance of the testing apparatus.

13.1.5 At each point under test, maintain the input signal until the output of the device under test becomes stabilized at its apparent final value. Observe and record the output values for each input value.

13.2 *Reproducibility and Zero Drift Test*

13.2.1 Apply a 50% setpoint to the MFC and record data.

13.2.2 Move the setpoint to 100% and record data.

13.2.3 Move the setpoint to 50% and record data.

13.2.4 Move the setpoint to 10% and record data.

13.2.5 After recording data at 10%, apply a 5% setpoint for 10 minutes, but do not record any data at this setpoint.

13.2.6 Move the setpoint back up to 10% and record data.

13.3 Repeat Sections 13.2.1–13.2.6, for a total of three times, until at least six sets of data have been collected at each setpoint (with the exception of 100%).

13.4 Repeat Sections 13.1.1–13.3 weekly for a period of at least 12 weeks. During the idle time, the MFC should be continuously powered, with any exceptions so noted. Gas flow is not required during the idle time, but any gas flow shall be recorded. Finally, record all details about the conditions of the MFC during the idle time.

## 14 Data Analysis

14.1 *Calculations*

14.1.1 Determine the precision at a setpoint by calculating the standard deviation of all the measured values (both upscale and downscale) for that setpoint. Perform this calculation at each setpoint:

$$P = \sqrt{\frac{\sum\left(\sum (V_i - A_a)^2\right)_j}{n_j}}$$

P = Precision

$V_i$ = The i th reading at a setpoint for a given cycle

$A_a$ = Average measured value

$n_j$ = Number of readings at a setpoint for a given cycle

14.1.2 Determine the short-term reproducibilty at a setpoint by dividing the precision of the setpoint by the average setpoint. This is expressed as a percentage of setpoint. Perform this calculation at each point:

$$SRS\% = \frac{P}{S_a} \times 100$$

14.1.3 The long term reproducibility at a setpoint is the greatest absolute weekly reproducibility at a setpoint.

14.1.4 Determine the precision over the test period at a setpoint by calculating the standard deviation of all the measured values (both upscale and downscale) for that setpoint. Perform this calculation at each setpoint:

$$P_L = \sqrt{\frac{\sum\left(\sum\left(\sum (V_i - A_a)^2\right)_j\right)_w}{\sum\left(\sum n_j\right)_w}}$$

$P_L$ = Precision over the test period

$V_i$ = The $i^{th}$ reading at a setpoint for a given cycle

$A_a$ = Average measured

$n_j$ = Number of readings at a setpoint for a given cycle

w = Number of weeks

14.1.5 Determine the reproducibility at a setpoint by dividing the precision over the test period at this setpoint by the average setpoint. This is expressed as a percentage of setpoint. Perform this calculation at each setpoint:

$$RS\% = \frac{P_L}{S_a} \times 100$$

14.1.6 The overall reproducibility of the DUT is the maximum value calculated in Section 14.1.4:

$$\pm RD\% = RS_{max}$$

*RD* = Reproducibility of the device

14.1.7 Calculate zero drift by subtracting the minimum zero value from the maximum zero value and dividing by two. This number is reported as ± sccm or slm over the specified time period.

## 15 Data Presentation

15.1 Plot the average measured value of each setpoint (10%, 50%, 100%) for each measurement period on a graph, with the *x*-axis representing time, and the *y*-axis showing the actual flow output in sccm or slm.

15.2 Plot the measured value at zero for each measurement period on a graph, with the *x*-axis representing time and the *y*-axis showing flow output signal in sccm or slm.

15.3 *Reproducibility* — Report a single number, as calculated above, as a percentage of reading stated, with the time period of the test.

15.4 *Zero Drift* — Report a single number, as calculated above, stated with the time period of the test.

## 16 Related Documents

16.1 *SEMI Standard*

SEMI E67 — Test Method for Determining Reliability of Mass Flow Controller (Refer to this standard if reliability data is needed for some of the parameters tested in this method.)

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

**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 E70-1103
# GUIDE FOR TOOL ACCOMMODATION PROCESS

This guide was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on September 3, 2003. Initially available at www.semi.org September 2003; to be published November 2003. Originally published June 1998.

## 1 Purpose

1.1 This document will provide an overview of the various elements of Tool Accommodation, a methodology by which semiconductor processing equipment is installed in a cost-effective and timely manner. This addition to the SEMI Tool Accommodation Standards set describes the process by which the referenced SEMI documents can be effectively used to achieve tool installation cost and schedule goals.

## 2 Scope

2.1 This overview document will provide process development, facilities, manufacturing, and sales engineers (as well as purchasing agents and managers) with a basic understanding of the various elements in a Tool Accommodation methodology. This process emphasizes quality, completeness, timeliness, and cost-effectiveness as key elements of successfully installing semiconductor processing equipment into wafer fabrication facilities. By describing a generic process flow, this document identifies a road map for using published standards that comprehend all the procedures involved in tool accommodation from procurement through acceptance. As a common ground for communication and comparison, terms and definitions are also included.

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

## 3 Referenced Standards

3.1 *SEMI Standards*

SEMI E6 — Guide for Semiconductor Equipment Installation Documentation

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

SEMI E45 — Test Method for the Determination of Inorganic Contamination from Minienvironments Using Vapor Phase Decomposition-Total Reflection X-Ray Spectroscopy (VPD-TXRF), VPD-Atomic Absorption Spectroscopy (VPD-AAS), or VPD/Inductively Coupled Plasma-Mass Spectrometry (VPD/ICP-MS

SEMI E49 — Guide for Standard Performance, Practices, and Sub-Assembly for High Purity Piping Systems and Final Assembly for Semiconductor Manufacturing Equipment

SEMI E49.1 — Guide for Tool Final Assembly, Packaging and Delivery

SEMI E49.2 — Guide for High Purity Deionized Water and Chemical Distribution Systems in Semiconductor Manufacturing Equipment

SEMI E49.3 — Guide for Ultrahigh Purity Deionized Water and Chemical Distribution Systems in Semiconductor Manufacturing Equipment

SEMI E49.4 — Guide for High Purity Solvent Distribution Systems in Semiconductor Manufacturing Equipment

SEMI E49.5 — Guide for Ultrahigh Purity Solvent Distribution Systems in Semiconductor Manufacturing Equipment

SEMI E49.6 — Guide for Subsystem Assembly and Testing Procedures - Stainless Steel Systems

SEMI E49.7 — Purity Guide for the Design and Manufacture of Ultrapure Water and Liquid Chemical Systems in Semiconductor Process Equipment

SEMI E49.8 — Guide for High Purity and Ultrahigh Purity Gas Distribution Systems in Semiconductor Manufacturing Equipment

SEMI E51 — Guide for Typical Facilities Services and Termination Matrix

SEMI S4 — Safety Guideline for the Segregation/Separation of Gas Cylinders Contained in Cabinets

3.2 *ISO Standards*[1]

ISO 14644-1 — Cleanrooms and associated controlled environments Part 1: Classification of air cleanliness.

1 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30, Website: www.iso.ch

ISO 14644-2 — Cleanrooms and associated controlled environments Part 2: Specifications for testing and monitoring to prove continued compliance with ISO 14644-1.

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

## 4 Summary of Referenced Standards

4.1 *SEMI E6* — Guide for Semiconductor Equipment Installation Documentation

4.1.1 Purpose of SEMI E6 is to communicate from supplier to user the facilities requirements of semiconductor equipment.

4.1.2 Benefits of SEMI E6 include assurance of effective communication of process tool installation requirements.

4.1.3 *Roles and Responsibilities for SEMI E6* — Tool supplier submits information requested in SEMI E6, facilities interface specification. Equipment engineer, facilities engineer, and installation manager use tool requirements information provided by supplier to prepare facility and efficiently install the tool.

**Table 1 SEMI Tool Accommodation Standards**

| | *Facility Services* | *Process Tool* | *Process Tool Subsystems (internal distribution system for)* | | | |
|---|---|---|---|---|---|---|
| *Guideline for* | | | General | Water & Chemical | Solvent | Gas |
| Facility Services Matrix defines utilities available for tool | SEMI E51 | | | | | |
| Facilities Interface Specification defines tool requirements of facilities | | SEMI E6 | | | | |
| Subsystem terms and references | | | SEMI E49 | | | |
| High purity (HP) subsystem requirements | | | | SEMI E49.2 | SEMI E49.4 | SEMI E49.8 |
| Ultrahigh purity (UHP) subsystem requirements | | | | SEMI E49.3 | SEMI E49.5 | SEMI E49.8 |
| Subsystem assembly and testing | | | | SEMI E49.7 | SEMI E49.6 | SEMI E49.6 |
| Tool packaging and delivery | | SEMI E49.1 | | | | |

4.2 *SEMI E49* — Guide for Standard Performance, Practices, and Sub-Assembly for High Purity Piping Systems and Final Assembly for Semiconductor Manufacturing Equipment

4.2.1 Purpose of SEMI E49 is to specify requirements for process distribution systems located inside of, and provided with, semiconductor processing tools. (SEMI E49 acts as a reference document for the series of SEMI E49 standards, SEMI E49.1 through SEMI E49.8. See Table 1, SEMI Tool Accommodation Standards for an explanation of the ten documents included in the SEMI E49 series.)

4.2.2 Benefits of the SEMI E49 series include assurance of compatibility in purity and performance between the tool and facility distribution systems.

4.2.3 *Roles and Responsibilities for SEMI E49 Series* — Facilities engineer and installation manager submit appropriate SEMI E49 requirements, either HP or UHP. Tool supplier uses information provided to ensure distribution system compatibility.

4.3 *SEMI E51* — Guide for Typical Facilities Services and Termination Matrix

4.3.1 Purpose of SEMI E51 is to communicate from customer to supplier factory facilities available at the utility point of connection (UPOC) for a semiconductor tool.

4.3.2 Benefits of SEMI E51 include assurance of cost-effective and timely tool installation with minimum retrofit to customer site.

4.3.3 *Roles and Responsibilities for SEMI E51* — Facilities engineer and installation manager submit utility specifications requested in SEMI E51 matrixes, either typical or site-specific. Tool supplier uses information provided about facility to assist in configuration of the process tool.

## 5 Terminology

5.1 *Definitions*

5.1.1 *acceleration cost* — additional costs incurred to complete the project sooner than the original scheduled baseline plan.

5.1.2 *as-built drawings* — documentation describing the actual configuration and dimensions at the end of construction.

5.1.3 *base build* — installation of base building, services, and equipment to establish functional environmental controls and utilities to support production equipment installation.

5.1.4 *bidding* — obtaining sealed quotes for a defined scope of work.

5.1.5 *burdened/unburdened* — identification of costs included or excluded from contractual labor rates.

5.1.6 *capital equipment* — equipment that is depreciated according to tax guidelines for durable goods. Generally has a value greater than $ 1,000.00 and a useful life greater than 5 years.

5.1.7 *change order* — a document defining a formal change in drawings, specifications, and/or scope of work.

5.1.8 *cleanroom* — confined area in which the humidity, temperature, particulate matter, and contamination are precisely controlled within specified parameters. Cleanroom classes are defined in ISO 14644.

5.1.9 *conditioned power* — electrical power that is manipulated to maintain specified tolerances.

5.1.10 *construction* — the set of activities that transforms plans and specifications into functional systems capable of performing to specification.

5.1.11 *construction consumable* — any material used up during construction.

5.1.12 *construction management* — the set of activities that define, direct, monitor, and report construction activities such as workmanship, adherence to design, cost, and schedule conformance.

5.1.13 *contingency* — a reserve of funds, time, and/or material that is allocated to maintain schedule and budget. A reserve for scope changes, unforeseen site conditions, change in material prices, or unanticipated events.

5.1.14 *contract award* — notification to the successful bidder and subsequent signing of contract documents.

5.1.15 *contractor* — a licensed company hired to accomplish a contractually specified scope of work.

5.1.16 *cost of ownership (COO)* — the total lifetime cost associated with acquisition, installation, and operation of fabrication equipment [SEMI E35].

5.1.17 *cycle time, gross installation* — total time to install and commission process equipment, typically starting from dock date to release for vendor startup.

5.1.18 *cycle time, net installation* — actual time devoted to construction activities related to tool hookup from dock date to ready for inspection.

5.1.19 *damage* — destruction or unintentional alteration resulting in a liability.

5.1.20 *dedicated truck* — exclusive drayage of a shipment.

5.1.21 *design build* — a contract method whereby the contractor assumes responsibility for design generation and construction to accomplish a specified performance criteria.

5.1.22 *design start* — a milestone event that designates the initial conversion of equipment specifications and design concepts into engineering plans and specifications.

5.1.23 *detailing* — generation of dimensioned shop fabrication plans based on process and instrumentation drawings (P&ID), field surveys, and configuration verifications.

5.1.24 *direct/indirect cost* — direct costs are the cost of anything physically associated with the installation, removal, or modification of equipment. Indirect costs cannot be associated with a specific piece of equipment. Profit, overhead, and administrative costs are typically considered indirect.

5.1.25 *distribution system* — the collection of subsystems and components used in a semiconductor manufacturing facility to control and deliver process chemicals from source to point of use for wafer manufacturing processes.

5.1.26 *dock date* — the date when the fab equipment, including all ancillary components, is on-site at the loading dock.

5.1.27 *emergency power* — electrical power supplied by alternate sources or backup systems, like generators that come on line when the main utility power supply fails.

5.1.28 *equipment engineering* — a group that focuses primarily upon the electrical, electronic, and mechanical characteristics of production equipment. Depending upon the site and the fab area, Equipment Engineering may be a distinct organization, or the equipment engineering responsibilities may be handled by other groups, such as Process Engineering or Manufacturing Engineering. Equipment Engineering is typically responsible for selection and physical configuration of production equipment.

5.2 *facilities interface specification* — Documentation provided by a tool supplier that contains the tool requirements for utilities and installation as defined in SEMI E6. So-called equipment data sheets are one section of this document that also includes requirements for safety, facilities services, shipping and receiving, install, startup, acceptance, and training.

5.2.1 *fast track* — a scheduling method that eliminates float and maximizes parallel activities, thereby reducing overall project duration. Selective use of overtime is typically used to reduce the duration of critical path activities.

5.2.2 *field change order* — a document defining a formal change in drawings, specifications, and/or scope of work generated after contract award by on-site personnel to incorporate conditions identified during construction.

5.2.3 *field fabrication* — assembly and/or modification of components on the job site to accommodate site-specific conditions.

5.2.4 *float* — unallocated time created when tasks are completed ahead of schedule or a task's duration is less than the allotted amount.

5.2.5 *free on board (FOB)* — goods placed on a truck or other means of transportation at a point specified by the seller without charge to the buyer, but with all further transportation at the buyer's expense.

5.2.6 *gas cabinet* — a metal enclosure that is intended to provide local exhaust ventilation, protection for the gas cylinder from fire from without the cabinet, and protection for the surroundings from fire from within [SEMI S4].

5.2.7 *gas interface box (GIB)* — an enclosure located between the tool mainframe and facility services containing components for pressure regulation and filtration. Functions to consolidate all gas requirements to single points of connection. Provides location and ability to pre-facilitate tool hookups in advance of tool delivery.

5.2.8 *grounding* — electrical wiring system to provide earth ground.

5.2.9 *hookup* — the set of activities and organization required to accept incoming process equipment, move it into place, connect the equipment to all facilities, and test the connections. The connection of all necessary facilities and interconnects required to make the equipment package fully operational. The hookup activity is complete when all of the following are met.

- The equipment positioning and bolting down is complete.
- The final equipment utility connections and interconnects are complete, tested, and certified.
- The process piping certification is complete. The wall system, including bulkheads as required, is complete.
- The final decontamination is complete.
- Government inspections have been conducted as required.

5.2.10 *inertia base* — a structural unit using mass damping to attenuate vibration for production equipment.

5.2.11 *interconnect* — connections between tool mainframe and peripheral tool subsystem equipment [SEMI E6].

5.2.12 *issue for construction (IFC)* — a milestone event that identifies when drawings and specifications are released to subcontractors for construction.

5.2.13 *labor rate* — the contractually stipulated cost of labor.

5.2.14 *laterals/sublaterals* — intermediate facility service distribution lines that run between mains and equipment-specific isolation valves.

5.2.15 *layout fixed* — the milestone date when the physical layout of equipment and components is fixed and all stockholders complete approval sign-off.

5.2.16 *local abatement* — treatment of emissions at the point of generation at the tool.

5.2.17 *long lead materials* — material requiring early ordering due to availability or long manufacturing time.

5.2.18 *mains/submains* — central distribution lines from a facility services source to which laterals are connected. Individual equipment is not connected directly to mains.

5.2.19 *minienvironment* — a localized environment created by an enclosure to isolate the product from contamination and people [SEMI E45].

5.2.20 *mobilization* — initial assignment of resources to a project resulting in measurable work being accomplished.

5.2.21 *move-in* — the movement of the process equipment from the loading dock into the fab area, and into the final taped position. The piece of equipment is defined as the main body of the equipment and all its subsystems, assemblies, and components, excluding the hookup. If major subsystems such as pumps or chillers are missing, move-in will not be considered complete until they arrive.

5.2.22 *move-in date* — milestone date indicating completion of step when processing equipment is moved into designated location in fab.

5.2.23 *not-to-exceed (NTE)* — an agreement to guarantee that the charges for a service or services will not be greater than a specified amount.

5.2.24 *on-the-job training (OJT)* — the instruction of personnel in the operation or maintenance, or both, of equipment done during the course of normal work functions. On-the-job training typically does not interrupt operation or maintenance activities and, therefore, can be included in any equipment state without special categorization [SEMI E10].

5.2.25 *overtime* — time spent in excess of normal working hours.

5.2.26 *owner buys* — material purchased by the owner and consigned to subcontractors for use in construction.

5.2.27 *pedestal* — structural support element upon which equipment or raised floor rests.

5.2.28 *permits* — legal governmental documents granting permission for specific construction activities.

5.2.29 *prefacilitation* — a stage in the equipment installation process that follows base build and precedes tool hookup. Prefacilitation brings the various facilities services close to the new equipment location, including new facilities services and structural modifications required to prepare the facility to accept the equipment. Also known as rough-in, this step is performed as a time-saving operation. The activity requires the following conditions to be met:

- The raised floor is in (if required).
- The ceiling is in.
- The seismic or isolation frame is in.
- All utilities are within 1.8 meters (6 feet) of the equipment or terminated in a utility box.
- The floor is taped with the equipment location.

5.2.30 *prepurchase* — purchase of materials and equipment in advance of total scope definition to accommodate long lead times.

5.2.31 *process and instrumentation drawing (P&ID)* — a diagram using graphic engineering symbols to represent the components, flows, and functions that make up a process delivery system.

5.2.32 *project management* — the set of activities that design, define, direct, monitor, and report on factory building construction.

5.2.33 *protocol* — description of procedures, materials, and practices used to define a methodology for accomplishing a specific task. Typically refers to material and personnel handling to maintain cleanroom integrity.

5.2.34 *punch list* — a list of corrective actions required to fulfill contractual obligations.

5.2.35 *purchase order (P.O.)* — a document used by a buyer to acquire a product or service that usually contains the terms and conditions (including price) governing the sale.

5.2.36 *qualification* — certification of compliance with contractual stipulations before release to manufacturing production use.

5.2.37 *quality assurance/quality control (QA/QC)* — activities performed to ensure compliance with contractually stipulated conditions.

5.2.38 *raised floor* — the removable floor system installed above the actual building floor within cleanroom environments to control air flow and allow access for utility routing and connection.

5.2.39 *request for information (RFI)* — documentation from contractor to request clarification.

5.2.40 *request for proposal (RFP)* — documentation from purchasing agent to vendor to request a proposal to provide product and/or services.

5.2.41 *request for quote (RFQ)* — documentation from purchasing agent to vendor to request a firm price to provide product and/or services.

5.2.42 *seismic bracing* — structural reinforcement to minimize damage due to earthquakes.

5.2.43 *shifts* — duration of routine work day, typically an 8, 10, or 12 hour as required to accrue a minimum of 40 equivalent hours (or local equivalent) within a 7-day (one week) period.

5.2.44 *single line drop* — a hookup strategy where a piece of processing equipment has only one point of connection per facility service. All manifolding for an individual service is handled with in the tool.

5.2.45 *site-specific facilities services and termination matrix* — a compilation of service types, quality, and capacity available for use at utility point of connection for a tool (see SEMI E51).

5.2.46 *slurry system* — a distribution system to convey abrasive slurries for use in chemical mechanical polishing (CMP) systems.

5.2.47 *source inspection* — inspection at the equipment manufacturer's factory to confirm configuration details, review modifications, and confirm installation designs prior to shipment of equipment.

5.2.48 *specialty gas* — non-bulk process gases typically stored in cylinders and used to supply one or more process tools through specialized manifolds.

5.2.49 *subfab* — the area within the cleanroom boundaries directly below the production level.

5.2.50 *submittal* — a written presentation for signed acceptance of a proposal in response to a request for services.

5.2.51 *support equipment* — ancillary equipment not part of the main chassis.

5.2.52 *time and materials (T&M)* — a contracting method whereby cost is determined by the actual requirements of the project as opposed to an estimate and a fixed cost system.

5.2.53 *tool* — any piece of semiconductor fabrication or inspection equipment designed to process wafers. Often used synonymously with equipment in the silicon wafer processing industry.

5.2.54 *tool accommodation* — a methodology by which semiconductor processing equipment is installed in a cost-effective and timely manner.

5.2.55 *turnkey* — delivery of a fully functional and tested system.

5.2.56 *utility point of connection (UPOC)/tool point of connection (TPOC)* — UPOC is a fitting typically located at a valve on a lateral to provide service for a tool, the facilities end/termination of the hookup. TPOC is a fitting typically at a valve on a processing tool (either external or internal), the tool end/termination of the hookup.

5.2.57 *uninterruptable power supply (UPS)* — a power supply that provides an uninterrupted or continuous supply of electrical power even during a failure in the main utility power supply.

5.2.58 *union labor* — a group of trained craftpersons that are represented by a single bargaining organization. A labor bargaining unit.

5.2.59 *value engineering* — a set of reviews to determine minimum requirements at a minimum cost.

5.2.60 *valve manifold box (VMB)/valve manifold panel (VMP)* — a metal enclosure and/or panel including distribution valves and components required to distribute gases or liquids to multiple points of use from a single source.

## 6 Roles and Responsibilities

6.1 Definition and responsibility assignment are critical to a successful project. Communications mechanisms must be established as early as possible. SEMI E6 provides a template for establishing a format for administrative interface. Using this format for establishing interfaces will improve communication and avoid cost and schedule impacts that might arise from equipment or facilities modifications during the procurement cycle. (See Figure 1.)

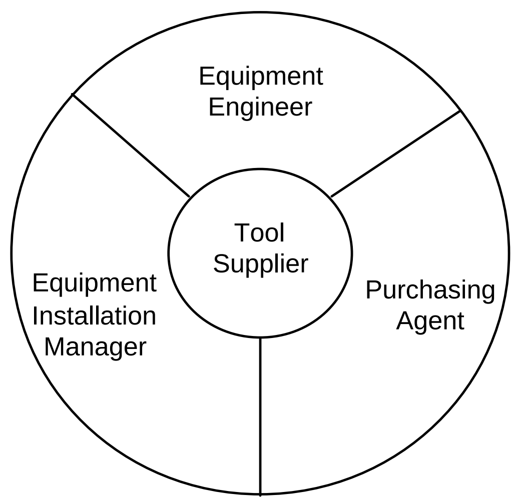


**Figure 1**
**Information Exchange Relationships**

## 7 Process

7.1 The following 15 steps describe a generic process flow for using published tool accommodation standards to achieve cost and schedule goals in a cycle of procurement through acceptance for a particular process tool. (See Figure 2.)

7.1.1 *Process Requirement Defined by Customer* — Process parameters are defined and documented by the process engineer and equipment engineer. Specific performance targets are established that are consistent with production requirements and cost of ownership expectations.

7.1.2 *Process Tool Location Identified by Customer* — Physical location is determined by collaboration between production, industrial, and facilities engineering. The location is typically selected to optimize production flow within the facility while minimizing accommodation costs and production interruptions. A layout document of record is generated and approved by all affected parties.

7.1.3 *Customer Generates Facilities Services Matrix* — Equipment and facilities engineering establish site-specific parameters by using the SEMI E51 format to define the available utilities and physical environment within which the production tool will have to function. Local jurisdictional and code requirement will be comprehended by site specific parameters.

7.1.4 *Customer Specifies Internal Tool Piping and Distribution System Requirements* — Site-specific exceptions to SEMI E49 through SEMI E49.8 are identified and reviewed with equipment suppliers to determine the most cost- and schedule-efficient configuration.

7.1.5 *Customer Issues Formal Request for Quote* — A formal request for quotation (RFQ) is generated by the customer's procurement department soliciting quotations from qualified manufacturers. SEMI E49 and SEMI E51 data are included with request for quotation.

7.1.6 *Supplier Submits Quote Including the Facilities Interface Specification in SEMI E6 Format* — A "Statement of Conformance" to specified standards is normally required for a quotation to be considered valid. Exceptions to performance specifications must be thoroughly documented and resolved. Multiple re-quotation is sometimes required to establish a contractually valid agreement.

7.1.7 *Contractual Terms Finalized and Order is Placed by Customer* — Terms and conditions of the purchase agreement based upon the finalized quotation are negotiated and approved by all stakeholders.

7.1.8 *Supplier Manufactures Equipment* — Equipment is manufactured per purchasing agreement. To prevent errors and omissions during installation, change orders are documented, approved prior to implementation, and copies are distributed per administrative interfaces as defined in SEMI E6.

7.1.9 *Installation Detailed and Prefacilitation Performed by Customer* — Installation design documentation is generated, approved, and distributed to subcontractors for pricing. Long lead-time hookup materials are identified and prepurchased. Prefacilitation is performed to insure accurate and quick hookup of tool on arrival.

7.1.10 *Customer Source Inspects Equipment* — Source inspection is the final validation of all designs and capabilities of the specific tool. Functionality testing is performed and documented. Physical configuration is confirmed. Modifications to configurations are documented so that installation pricing can be adjusted accordingly.

7.1.11 *Supplier Ships Equipment to Customer* — Equipment is packaged per SEMI E49.1 and shipped as defined in SEMI E6. Equipment is shipped per purchase order stipulations. Customs clearance is obtained as required.

7.1.12 *Customer Verifies Equipment Matches Supplier Provided Facilities Interface Specification* — Upon arrival at the customer site, verification of compliance to purchase order is determined. Verification of physical dimensions, point of connections, and interface cabling and tubing is performed.

7.1.13 *Equipment Hookup by Customer* — Mechanical, electrical, process piping, and life safety system hookups are done, and all functional testing is completed. Equipment is ready for vendor startup and commissioning. Final payment to hookup contractor is authorized, and upon payment, construction liens are released. As-built drawings showing newly installed tool are updated and submitted to owner for inclusion in permanent records.

7.1.14 *Equipment Is Qualified and Customer Verifies Contract Completion* — Equipment startup is complete and functional testing to verify compliance to purchase agreement is complete and documented. Final payment to equipment vendor is released.

7.1.15 *Actual Cost and Schedules Are Reviewed* — Final accounting is performed to determine actual costs associated with the project. Actual duration of all activities is compared to original schedule to determine areas for improvement. Estimating models for future installations are updated to reflect new information.

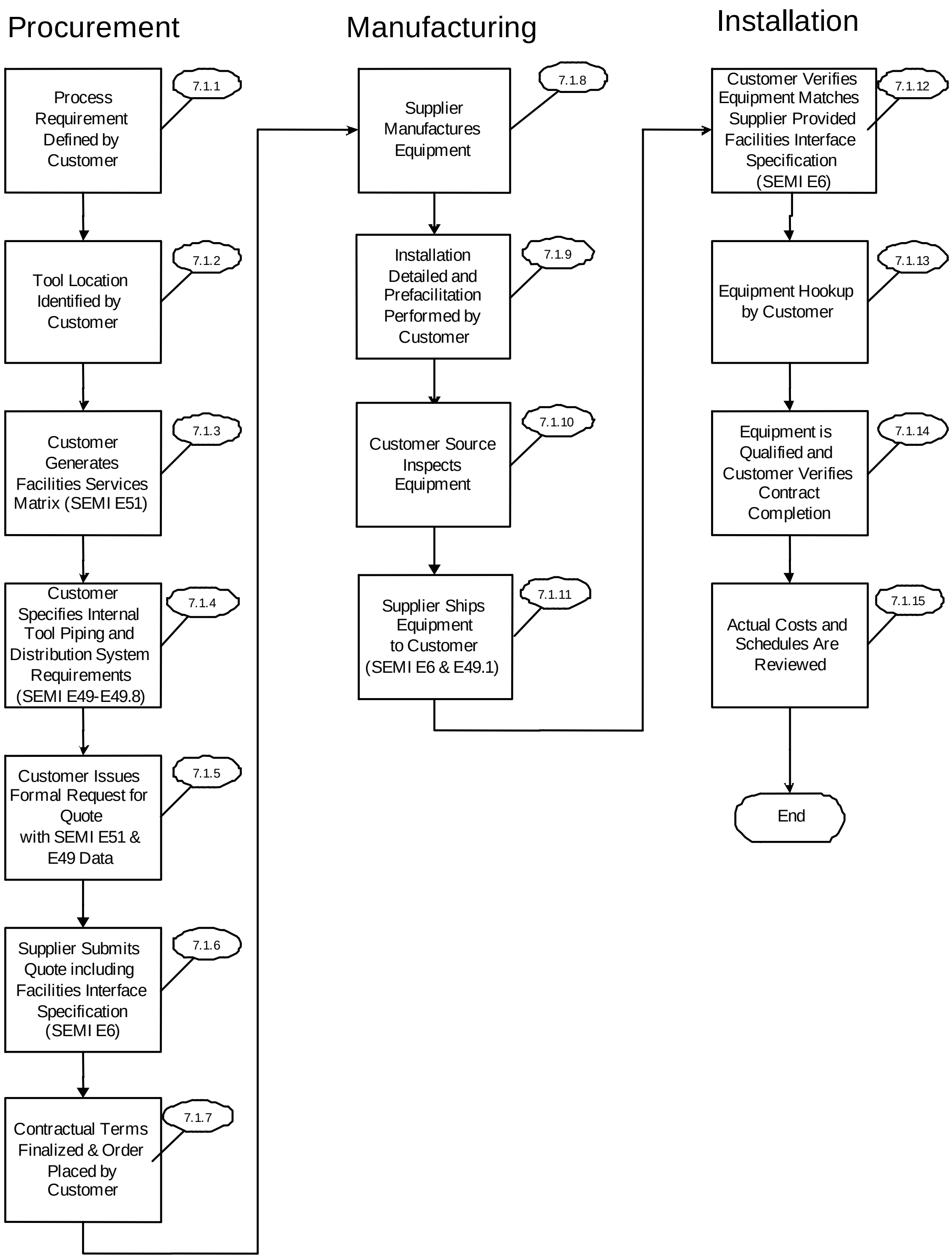


**Figure 2**
**Tool Accommodation Process Flow Chart**

# SEMI E72-0600 (Reapproved 0305)
# SPECIFICATION AND GUIDE FOR 300 mm EQUIPMENT FOOTPRINT, HEIGHT, AND WEIGHT

This specification 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 December 10, 2004. Initially available at www.semi.org February 2005; to be published March 2005. Originally published in 1998, previously published June 2000.

## 1 Purpose

1.1 Currently, device manufacturers cannot easily plan or retrofit their fabs, because equipment volumes are not predictable. Similarly, equipment suppliers cannot predict fab designs, because there are too many configurations. In general, fab space is not used efficiently, and there seems to be a trade-off between space efficiency and maintainability. This standard is a guide for equipment design and a specification for maximum limits on equipment volume and weight.

## 2 Scope

2.1 This standard specifies limits on the footprint, height, and weight of equipment for 300 mm fabs. Separate limits are given for the parts of the equipment in the main fab and in the sub-fab. Separate limits are also given for the equipment after it is installed and for the components of the equipment as it is moved into the fab. The actual footprint may vary by equipment type.

2.2 This standard is intended to set an appropriate level of specification that places minimal limits on supplier innovation while ensuring opportunities for users to be globally (though possibly not locally) efficient with equipment volumes.

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

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

## 3 Referenced Standards

3.1 *SEMI Standards*

SEMI E15 — Specification for Tool Load Port

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

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

## 4 Terminology

4.1 *Definitions*

4.1.1 *cost footprint* — the area ($A$) of the smallest horizontal rectangle that contains all of the shadow footprint and half of the easement space around the equipment (for use as the floor space metric in Cost of Ownership calculations). As shown in Figure 1, this is computed as

$$A = [Wt + ½ (Ws – Wt)] × [Dt + ½ (Ds – Dt)]$$

$$= ¼ (Wt + Ws) × (Dt + Ds)$$

Where $W$ represents width and $D$ represents depth

4.1.2 *depth* — the horizontal dimension perpendicular to the load face plane.

4.1.3 *easement space* — the floor space that must remain clear to the rear and sides of the equipment (but not in front of the load face plane). This includes safety aisles, ergonomic maintenance access space, component removal space, and room for doors to swing out (see Figure 1).

4.1.4 *load face plane* — the furthest physical vertical boundary plane from the cassette centroid or carrier centroid on the side (or sides) of the tool where loading of the tool is intended (as defined in SEMI E15).

4.1.5 *shadow footprint* — the area of the floor space directly under every part of the equipment during its operation (see Figure 1). This includes any temporary projections from the equipment during loading or processing (such as carriers that stick out from the equipment or equipment load ports that protrude only when the equipment is being loaded).

4.1.6 *width* — the horizontal dimension parallel to the load face plane.

## 5 Requirements and Recommendations

NOTE 1: The dimensions cited in the following sections are specified in Table 1.

5.1 *Sub-Fab vs. Main Fab Footprint*

5.1.1 *Requirements* — Both the cost footprint and the shadow footprint of the remote parts of any equipment in the sub-fab must be less than or equal to the cost footprint and the shadow footprint (respectively) of the parts of that equipment in the main fab (the cleanroom including both bays and chases, if any). Furthermore, the remote parts of the equipment in the sub-fab must be capable of being installed so that the rectangle defining the cost footprint in the sub-fab is entirely underneath the rectangle defining the cost footprint in the main fab. In some fab designs (such as slab on grade), there is no sub-fab (or basement). In such cases, these requirements apply to the remote parts of the equipment in whichever equipment support area contains the same remote parts of the equipment as a sub-fab. Also, some fabs have multiple sub-fab levels. In such cases, these requirements apply to the remote parts of the equipment in all sub-fab levels.

5.1.2 *Recommendations* — Since the sub-fab is likely to have more columns than the main fab, it is recommended that the remote parts of the equipment in the sub-fab come in modules that can be arranged to accommodate a variety of layouts.

5.2 *Equipment Height*

5.2.1 *Requirements* — The maximum height of any equipment (other than a stocker) must be less than or equal to *H* in the main fab and *Hs* in the sub-fab. Any connections for utilities and required overhead mainten-ance access must also be included within these limits. These limits also apply during installation, so if a part of the equipment must be rotated up into place, the diagonal measurement must be less than these limits.

5.2.2 *Recommendations* — Thus, equipment suppliers are advised to not plan on ceilings higher than these limits.

5.3 *Floor Loading*

5.3.1 *Requirements* — The maximum mass of any equipment in the main fab divided by its shadow footprint must be less than or equal to *M* (except when support pedestals are used). Furthermore, the maximum weight on any 0.6 m by 0.6 m (2 ft. by 2 ft.) floor tile (in any installation configuration) must be less than or equal to *Mt.* These limits also apply when the equipment is being moved into the fab and installed, unless spreader plates are used.

5.3.2 *Recommendations* — It is recommended that seismic loading also be considered when designing equipment weight distribution.

5.4 *Move-In-Size*

5.4.1 *Requirements* — To clarify the size of the doors and hallways needed in the fab, this paragraph specifies the size of the equipment's components after it has been uncrated, while it is being moved into the fab, and before it is installed. All parts of the equipment destined for the main fab must come in packages that are no taller than *Z* and that are smaller than *X* by *Y* in two orthogonal horizontal dimensions. All parts of the equipment destined for the sub-fab must come in packages that are no taller than *Zs* and that are smaller than *Xs* by *Ys* in two orthogonal