other related standards.

3.4 This standard is intended to be a performance specification, it is not intended to address design issues related to safety which are covered elsewhere in the SEMI Standards (see SEMI S2).

NOTE 1: Safety related systems may require ride-through capability for conditions up to and including full power failure. Further, if hazards could result from voltage sags greater than those allowable in Table 1, provisions should be made to negate or eliminate such hazards.

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

4 Referenced Standards

4.1 *SEMI Standards*

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

SEMI E51 — Guide for Typical Facilities Services and Termination Matrix

SEMI F42 — Test Method for Semiconductor Processing Equipment Voltage Sag Immunity

SEMI S2 — Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment

4.2 *IEEE Standards* [1]

IEEE 446 — IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (IEEE Orange Book)

IEEE 1100 — IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment (IEEE Emerald Book)

IEEE 1250 — IEEE Guide for Service to Equipment Sensitive to Momentary Voltage Disturbances

NOTE 2: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *assist* — an unplanned interruption that occurs during an equipment cycle where all three of the following conditions apply:

- The interrupted equipment cycle is resumed through external intervention (e.g., by an operator or user, either human or host computer).
- There is no replacement of a part, other than specified consumables.
- There is no further variation from specification of equipment operation [SEMI E10].

5.2 *failure* — any unplanned interruption or variance from the specifications of equipment operation other than assists [SEMI E10].

5.3 *interrupt* — any assist or failure [SEMI E10].

5.4 *ride-through capability* — the ability of equipment to withstand momentary interruptions or sags [IEEE 1250]. Also known as voltage sag immunity.

5.5 *voltage sag* — an rms reduction in the ac voltage at power frequency for durations from half-cycle to a few seconds [IEEE 1250]. Also known as voltage dip.

6 Ordering Information

6.1 Semiconductor manufacturers may use this standard when procuring processing equipment to specify equipment ride-through requirements capability to the equipment supplier. This document may also be used by semiconductor processing equipment suppliers to specify ride-through requirements to component and module suppliers.

6.2 Orders for equipment in accordance with this standard shall include:

a) This specification number and date of issue.

b) Requirements for qualification testing per SEMI F42.

c) Any certification showing passage of qualification tests required to be provided (optional).

d) Any test results required to be included in reports to be provided (optional).

7 Requirements

7.1 Semiconductor processing, metrology, and automated test equipment must be designed and built to conform to the voltage sag ride-through capability shown in Figure 1. Equipment must continue to operate without interrupt (see Terminology) during conditions identified in the area above the defined line.

7.2 The requirements defined in this specification apply to two phase (phase-to-phase) and single phase (phase-to-neutral) voltage incidents.

7.3 The performance curve is defined by values shown in Table 1—voltage sag duration and percent deviation from equipment nominal voltage.

NOTE 3: For recommendations on equipment ride-through capability below 0.05 seconds (50 milliseconds) and above 1.0 seconds, see Related Information at the end of this document.

1 The Institute of Electrical and Electronic Engineers, Inc., 345 East 47th Street, New York, NY 10017-2394, USA

8 Test Methods

8.1 Qualification tests are conducted on samples of production articles, not each item produced. Qualification testing of equipment to requirements in this specification should be performed per SEMI F42.

9 Related Documents

9.1 *SEMI Standard*

SEMI S9 — Electrical Test Methods for Semiconductor Manufacturing Equipment

9.2 *CENELEC Standard* [2]

EN 50082-2 — Electromagnetic Compatibility — Generic Immunity Standard, Part 2: Industrial Environments

9.3 *IEC Standard* [3]

IEC 61000-4-11 — Electromagnetic Compatibility (EMC) — Part 4: Testing and Measuring Techniques — Section 11: Voltage Dips, Short Interruptions and Voltage Variations Immunity Tests

9.4 *IEEE Standard*[1]

IEEE 1346 — Electric Power System Compatibility with Electronic Process Equipment

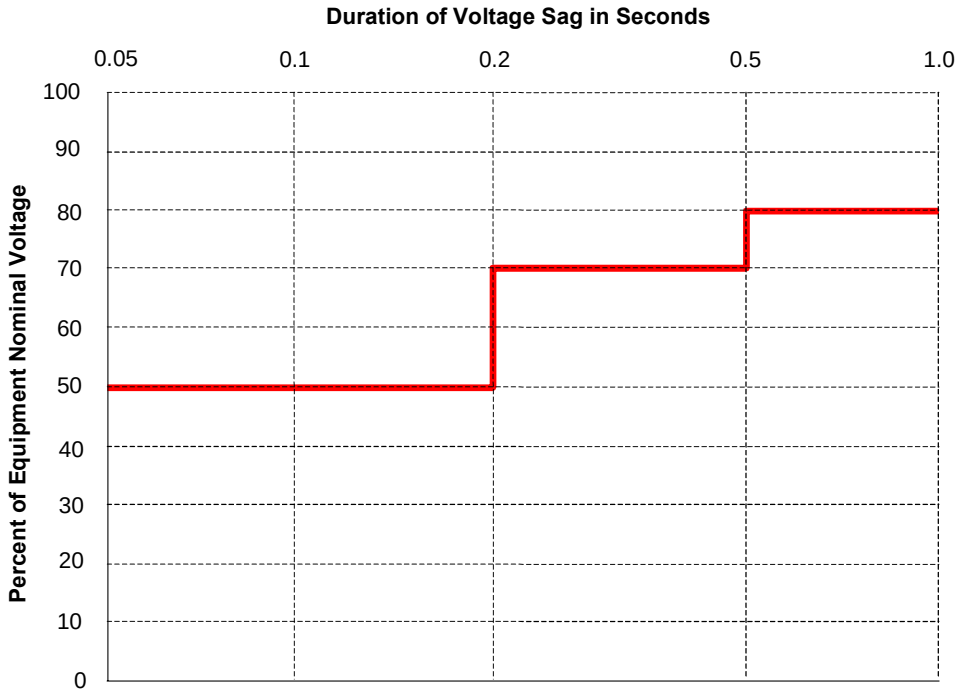
NOTE 4: As listed or revised, all documents cited shall be the latest publications of adopted standards.

2 European Committee for Electrotechnical Standardization, Rue de Stassart, 35, B – 1050, Brussels

3 International Electrotechnical Commission, 3, rue de Varembé, P.O. Box 131, 1211 Geneva 20, Switzerland

Table 1 Voltage Sag Duration and Percent Deviation from Equipment Nominal Voltage

VOLTAGE SAG DURATION				*VOLTAGE SAG*
Seconds (s)	*Milliseconds (ms)*	*Cycles at 60 hz*	*Cycles at 50 hz*	*Percent (%) of Equipment Nominal Voltage*
< 0.05 s	< 50 ms	< 3 cycles	< 2.5 cycles	Not specified
0.05 to 0.2 s	50 to 200 ms	3 to 12 cycles	2.5 to 10 cycles	50%
0.2 to 0.5 s	200 to 500 ms	12 to 30 cycles	10 to 25 cycles	70%
0.5 to 1.0 s	500 to 1000 ms	30 to 60 cycles	25 to 50 cycles	80%
> 1.0 s	> 1000 ms	> 60 cycles	> 50 cycles	Not specified



NOTE: Equipment must continue to operate without interrupt during voltage sags above the line.

Figure 1
Required Semiconductor Equipment Voltage Sag Ride-Through Capability Curve

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.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

RELATED INFORMATION 1
RELATIONSHIP TO OTHER ELECTRICAL STANDARDS

NOTE: This related information is not an official part of SEMI F47 and is not intended to modify or supersede the official standard. It has been derived from the work of the originating task force. Determination of the suitability of the material is solely the responsibility of the user.

R1-1 Basis for this Industry-Specific Semiconductor Standard

R1-1.1 The Information Technology Industry Council (ITIC) "CBEMA-curve," contained in IEEE 446, IEEE 1100, and SEMI E51, was used as a starting point in establishing recommended ride-through limits. The following curve (see Figure R1-1) was developed to define voltage sag ride-through for use with semiconductor processing equipment. Primarily due to testing limitations, only the portion between 0.05 seconds (50 milliseconds) and 1.0 seconds was selected for inclusion in the specification. As future test equipment, methods, and data are developed the specified duration limits may be expanded. Recommended voltage sag ride-through capability limits from zero to 100 seconds are included here for reference (see Figure R1-1). While not currently included in this SEMI specification the wider range should be considered when designing equipment and selecting components.

R1-1.2 Over voltage conditions also covered in the ITIC CBEMA-curve contained in IEEE 446, IEEE 1100, and SEMI E51, are not considered in the scope of this industry-specific specification primarily due to the extremely low number of semiconductor equipment interruptions caused by over voltage events. While not in the scope of this specification, over voltage conditions should not be ignored and use of existing equipment protection techniques should be continued (see SEMI E51 or IEEE 446 for generic equipment over voltage ride-through specifications).

R1-2 Relationship to Generic Electrical Standards

R1-2.1 This SEMI standard is intended to be coordinated with related SEMI, IEC and IEEE standards. The relationship of this SEMI specification to many other standards that address equipment immunity, test methods, and safety was considered in development of this specification. For example, the emerging IEC Generic Immunity standard for industrial environments currently published by CENELEC as EN 50082-2 recommends a generic equipment immunity limit for Europe. When published by IEC, this standard will provide a generic equipment voltage sag immunity limit. Another example is the US National Fire Protection Association on Industrial Machinery (NFPA 79), which sets a generic equipment voltage sag immunity limit for the United States.

R1-2.2 These emerging generic limits were considered in the establishment of ride-through limits for semiconductor equipment. However, most generic equipment limits are less stringent than the existing CBEMA-curve currently referenced in SEMI E51. For most installations meeting the CBEMA limits (a specification which was developed for computer business equipment) still results in an unacceptable number of semiconductor equipment interrupts. Therefore, the requirements in this international standard were developed to better suit the semiconductor industry. While more stringent, this industry-specific specification is not in conflict with known generic equipment regulations from other regions or generic equipment standards from other organizations.

R1-2.3 Another published IEC standard defines a generic immunity test method for voltage sags (dips), IEC 61000-4-11. This standard does not provide limits but does provide a voltage sag test method for single-phase equipment rated less than 16 amps. It has been considered in defining voltage sag ride-through parameters and it may provide an interim voltage sag immunity test method. As noted in this document, a test method for three-phase equipment greater than 16 amps is being developed for use with semiconductor equipment.

R1-2.4 The generic type standards developed for industrial or consumer equipment by organizations like IEC, ITIC, and IEEE provide a foundation for industry-specific standards like those published by SEMI Standards. In acknowledgement of this tiered approach to standardization there are provisions for recognizing industry-specific or product-type standards by organizations like IEC. Typically, product-type standards when developed by industry-specific organizations take precedent over the broader based generic industrial standards.

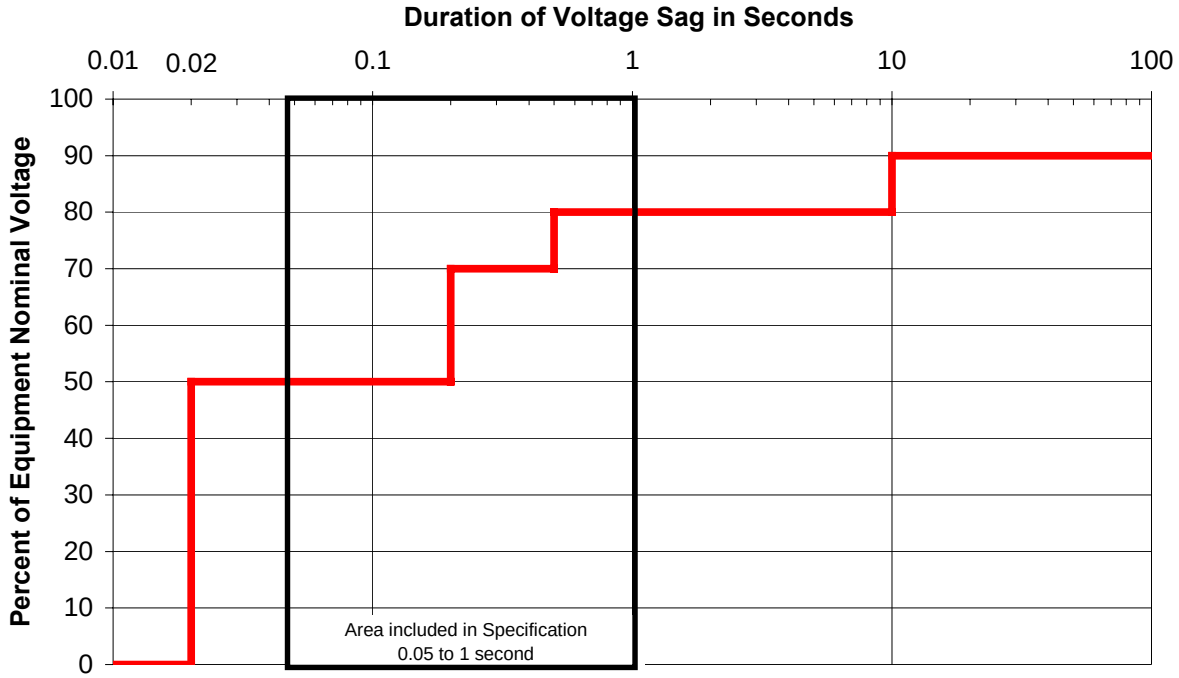


Figure R1-1
Recommended Semiconductor Equipment Voltage Sag Ride-Through Capability Curve from 0 to 100 Seconds

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.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI F48-0600
TEST METHOD FOR DETERMINING TRACE METALS IN POLYMER MATERIALS

This test method 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 March 2, 2000. Initially available on www.semi.org April 2000; to be published June 2000.

1 Purpose

1.1 This method provides a procedure for determining the nonvolatile trace inorganic impurities in bulk polymeric materials.

2 Scope

2.1 Following digestion by dry ashing (DDA) or digestion in closed vessel (DCV) preparation techniques, samples previously obtained and cleaned according to SEMI F40 are analyzed for trace inorganics using inductively coupled plasma-mass spectrometry (ICP–MS), graphite furnace atomic absorption spectroscopy (GFAAS), and/or inductively coupled plasma-atomic emission spectroscopy (ICP–AES).

2.2 Materials for analysis include, but are not limited to:

- Raw polymer materials (resins), such as pellets of perfluoroalkoxy (PFA), polyvinylidene fluoride (PVDF), ethylenechlorotrifluoroethylene (ECTFE), polyetheretherketone (PEEK), polypropylene (PP), polyethylene (PE), acetal resin, polyvinyl chloride (PVC), Perfluoromethylether-based Perfluoro-alkoxy (MFA) and powders of polytetrafluoro-ethylene (PTFE).
- Polymer components of tubing, piping, fittings, valves, regulators, filter housings, filter cartridges, O–rings and gaskets used in ultrapure water (UPW) and liquid chemical distribution systems (LCDS). See Section 3.8 for further information.
- Ion-exchange resins
- Polymer products used in the manufacturing of semiconductor devices, such as wafer carriers and wands, as well as accessories internal to wet equipment (e.g., drums in spin rinse dryers, tanks in quick dump rinsers). See Section 3.8 for further information.

2.3 The DDA sections of this document refer to an ashing technique, whereby the sample is placed into a platinum or quartz crucible and thermally decomposed. Thermal decomposition in muffle furnace or microwave muffle furnace may also be used. Additionally, oxygen plasma may be used separately or in conjunction with these techniques.

2.4 The DCV sections of this document refer to closed vessel microwave acid decomposition at elevated temperature and pressure. Alternatively closed vessel thermal conduction heating may also be applied.

2.5 ICP–MS, GFAAS, and ICP–AES are all appropriate methods for inorganic analysis. ICP–MS is the preferred method because it is more sensitive and efficient. Alternate procedures may be used if they meet the same analytical performance criteria. Each laboratory is responsible for verifying the validity of each method within its own operation.

2.6 This method is applicable for the elements found in Table 1:

Table 1 List of Applicable Elements (See NOTE 1.)

Aluminum	Magnesium
Barium	Manganese
Calcium	Nickel
Chromium	Potassium
Cobalt	Sodium
Copper	Strontium
Iron	Tin
Lead	Titanium
Lithium	Zinc
Molybdenum	Zirconium

NOTE 1: See Limitations, Section 3.3.

2.7 This method may be used for other materials, or other nonvolatile elements, if the end-user wishes and performance is demonstrated for the analyte of interest, in the matrices of interest, at the concentration levels of interest.

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

3 Limitations

3.1 The accuracy of the method is limited by the detection limits of the instruments and by the sample preparation procedure.

3.2 This procedure anticipates analysis levels in the ppm (mass/mass) range. Impurities less than 0.1 ppm may not be detected by this method.

3.3 When extending the method to other elements recovery should be evaluated during validation. Poor recovery rates are often found for volatile elements such as boron (B), arsenic (As), antimony (Sb), mercury (Hg), gold (Au), and tungsten (W) because of the relatively high temperature sample preparation method and poor stability of some elements in aqueous solution. Elements forming volatile halogenides can be affected due to the in-situ production of hydrogen halogenides when halogenated polymers are ashed.

3.4 This is a bulk analysis technique. For leachable testing or surface analysis refer to the Related Documents (Section 16) of this method.

3.5 Due to the rapid advances in digestion technology, consult the manufacturer's recommended instructions for guidance when conducting analyses using the DCV sections of this document.

3.6 DCV techniques can generate gaseous digestion reaction products, very reactive, or volatile materials at high pressures. Spontaneous venting which can occur during sample heating may cause venting of the vessels with potential loss of sample and analytes. Sample sizes greater than 0.25 g may accentuate this event.

3.7 In the use of the DCV technique, TiO2, alumina, and other oxides may not be totally dissolved. Sequestering of target analyte elements may occur.

3.8 Although this method allows the sampling of small pieces of polymer that are mechnically removed from a larger item, obtaining such samples in a clean manner may be difficult. Multiple sampling, separation and preparation techniques might be necessary to establish confidence in the results.

3.9 This document is not intended to supersede international, national or local codes, regulations, and laws. Each should be consulted to ensure that the method meets regulatory requirements in each location.

4 Referenced Standards

4.1 *SEMI Standard*

SEMI F40 — Practice for Preparing Liquid Chemical Distribution Components for Chemical Testing

4.2 *ASTM Standard*[1]

ASTM D4375 — Standard Practice for Basic Definitions, Notation, and Symbology for Statistics in Committee D19 on Water

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *Acronyms and Abbreviations*

5.1.1 *AAS/GFAAS* — atomic absorption spectroscopy/ graphite furnace atomic absorption spectroscopy

5.1.2 *amu* — atomic mass unit

5.1.3 *DCV* — digestion in closed vessel

5.1.4 *DDA* — digestion by dry ashing

5.1.5 *GFAAS* — graphite furnace atomic absorption spectroscopy

5.1.6 *ICP–AES* — inductively coupled plasma–atomic emission spectroscopy

5.1.7 *ICP–MS* — inductively coupled plasma–mass spectrometry

5.1.8 *ppb* — parts per billion by mass (ng/g)

5.1.9 *ppm* — parts per million by mass (µg/g)

5.1.10 *UPW* — ultrapure water (see Section 9.4)

6 Summary of Test Method

6.1 Samples previously prepared using SEMI F40 are ashed or digested under pressure within a digestion device, and trace inorganics in the residue are dissolved into acid and UPW. The sample is then analyzed by ICP–MS, GFAAS, and/or ICP–AES to determine the inorganic content of the material. This method applies only to nonvolatile metals (i.e., alkali metals, alkaline earths, and transition metals).

6.2 Data from different tests can be compared to determine the inorganic content in different materials and in the same material from different manufacturers.

7 Significance and Use

7.1 Determining the metallic contamination concentration in bulk polymer materials used in either distribution systems for process fluids or products in direct contact with the wafer is important criterion for deciding the suitability of a material. For example, ultrapure water contaminated by distribution system components may adversely affect microelectronic and other processes.

7.2 This method measures the total amount of impurities in the bulk of the material. These impurities will not necessarily leach into a process fluid stream.

1 American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103

8 Apparatus

8.1 *Muffle Furnace* — With temperature control ranging up to a minimum of 700°C and equipped with a means to regulate air circulation.

8.2 Microwave Muffle Furnace

8.3 *Crucibles* — Made of either platinum or quartz and with a 30 mL capacity.

8.4 ICP–MS

8.5 GFAAS

8.6 *ICP–AES* — Either simultaneous or sequential reading type.

8.7 Chemical Fume Hood

8.8 Propane Torch or Appropriate Heating Source with a minimum temperature of 650°C.

8.9 Device for digestions under a pressure of at least 30 bar (435 psi), with temperature control. This can be a laboratory microwave-based system or a system based on other heating sources.

8.9.1 In the case of microwave digestion devices: Laboratory microwave digestion systems should be used that possess appropriate temperature control of chemical reactions. Closed microwave systems must have controlled pressure relief.

8.9.2 Digestion vessels of appropriate internal volume should be used and construction should be of appropriate chemically inert materials. If the vessel is pressurized, it should be capable of withstanding a minimum pressure of 30 atm (30 bar or 435 psi), with controlled pressure relief of reagents and digestion products.

NOTE 2: Only microwave manufacturer's approved vessels for that device should be used.

8.9.3 In case of a laboratory microwave digestion device: Oscillating turntable to insure homogeneous distribution of microwave radiation to all vessels.

8.9.4 Filter paper, qualitative or equivalent.

8.9.5 Filter funnel, polypropylene, polyethylene or equivalent.

8.10 Volumetric flasks, 20 mL or 50 mL capacity or equivalent.

8.11 Analytical balance, of appropriate capacity, with a ± 0.0001 g or appropriate precision for the weighing of the sample. Optionally, the vessel with sample and reagents may be weighed, with an appropriate precision balance, before and after microwave processing to evaluate the seal integrity in some vessel types.

9 Materials

9.1 Argon Gas 99.99% pure or better.

9.2 *Standards and Reference Materials*

9.2.1 For preparation of multi-element standard solutions, use NIST[2], NIST-traceable, or other appropriate international standards as stock solutions.

9.2.2 From these stock solutions, multi-element working standard solutions must be prepared daily by pipeting the appropriate volumes of the trace metal standards and diluting to the desired concentrations.

NOTE 3: Prepare these working standards using the same amount of acid as used for the sample.

9.2.3 For validation purposes, use appropriate international reference materials that match the sample matrix as close as possible.

9.3 All reagents should be of appropriate purity or high purity (acids for example, should be sub-boiling distilled where possible) to minimize the blank levels due to elemental contamination. If the purity of a reagent is questionable, analyze the reagent to determine the level of impurities. The reagent blank must be less than the minimum detection limit in order to be used.

9.3.1 Ultrapure Hydrochloric Acid less than 1 ppb for each trace metal.

9.3.2 Ultrapure Nitric Acid less than 1 ppb for each trace metal.

9.4 *Ultrapure Water*

9.4.1 For purposes of this test, references to water shall be understood to mean ultrapure water as defined by maximum individual metal and anion impurity levels of 0.1 ppb or less, nonvolatile residue levels of 0.1 ppm or less, resistivity of 18 megohm-cm or greater, and reactive silica impurity of less than 1.0 ppb.

10 Precautions

10.1 *Safety Precautions*

10.1.1 This test method may involve hazardous materials, operations, and equipment. This test method does not purport to address the safety considerations associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and to determine the applicability of regulatory limitations before using this method.

2 National Institute of Standards and Technology, 100 Bureau Dr., Gaithersburg, MD, 20899-001 USA, (301) 975-6478, <www.nist.gov>

10.1.2 Care must be taken in the handling and use of the acids to avoid acid burns or contamination of the acid. Acid should be neutralized before disposal.

10.1.3 Care must be taken when using the propane torch to avoid burns. The torch should not be used near flammable materials or solvents.

10.1.4 Care must be taken when using the muffle furnace to avoid burns.

10.1.5 When ashing fluoropolymeric materials, the ashing must be performed in a fume hood. When heated, fluoropolymer materials outgas hydrofluoric acid fumes and may also emit fluoropolymeric particles which, if inhaled, can cause a condition known as "polymer fume fever." If hot fluoropolymer fumes are inhaled, remove the individual to a well-ventilated area and seek medical attention.

10.1.6 The outer layers of vessels used in the DCV technique are frequently not as acid or reagent resistant as the liner material. To retain the performance and safety required these outer layers must be neither chemically degraded nor physically damaged. Routine examination of the vessel materials may be required to ensure their safe use.

10.1.7 Only DCV containers with pressure relief or control mechanisms or containers with suitably inert polymeric or quartz liners and pressure relief mechanisms are considered acceptable for use with this process.

NOTE 4: Only microwave manufacturer's approved vessels for that device should be used.

10.1.8 Use of laboratory microwave systems is required for this method. Users are advised not to use domestic (kitchen) type microwave ovens or cookware. Nor should inappropriately sealed containers without pressure relief for microwave acid digestions be used. See Section 16.3.1 for additional information on safety issues concerning the use of laboratory microwave systems.

10.1.9 Toxic nitrogen oxide(s), hydrogen fluoride, and toxic chlorine (from the addition of hydrochloric acid) fumes are usually produced during digestion. Therefore, all steps involving open or the opening of digestion vessels must be performed in a properly operating fume ventilation system.

10.1.10 The analyst should wear appropriate protective clothing, such as gloves and face protection, and must not at any time permit a solution containing hydrofluoric acid to come in contact with skin or lungs.

10.2 *Technical Precautions – Digestion by Dry Ashing (DDA)*

10.2.1 Flaming and ashing temperatures must be controlled so that they do not exceed 650°C to minimize metal loss due to volatilization. If the crucible becomes excessively hot for longer than about one minute during flaming, it may have overheated. When testing the method for recovery rates, it will become apparent that the sample has been overheated from the low recovery of metals.

10.2.2 One method of cleaning the crucibles and covers is to flame them with a propane torch or other appropriate heating source until they are sufficiently hot, allow them to cool, rinse in dilute ultrapure nitric acid, and then rinse in ultrapure water.

10.2.3 When ashing a sample, take care that all of the ash residue remains in the crucible.

10.2.4 Several factors concerning selection of crucible materials should be considered when performing the DDA technique. For example, the crucible itself can contribute elevated levels of its own composition into samples at trace levels. Temperature restrictions are another factor to consider in the selection of the crucible material. Corrosion of the crucible during the decomposition of the sample should also be considered. For example, in the ashing of fluorinated materials, platinum is preferred over quartz glass that could be etched by the liberated hydrogen fluoride.

10.3 *Technical Precautions – Digestion in Closed Vessel (DCV)*

10.3.1 Trace analysis requires a thorough cleaning. One method of cleaning the vessels is to leach with hot (1:1) hydrochloric acid (greater than 80 C, but less than boiling) for a minimum of two hours followed with hot (1:1) nitric acid (greater than 80 C, but less than boiling) for a minimum of two hours and rinsed with reagent water and dried in a clean environment.

10.4 *Other Technical Precautions*

10.4.1 When switching between high concentration samples and low concentration samples, all crucibles or digestion vessels should be cleaned according to the corresponding and recommended cleaning procedure. This cleaning procedure should also be used whenever the prior use of the digestion vessels is unknown or cross contamination from vessels is suspected.

10.4.2 Trace metallic levels of reagent blanks must be significantly lower than those in the sample in order to obtain accurate results for the analyte of interest.

10.4.3 Perform sample preparation in a clean environment and under a fume hood to minimize contamination.

11 Sampling

11.1 *Sampling of Test Specimens*

11.1.1 Test specimens shall be representative of the polymer material being tested and shall be free of embedded particles and extraneous surface contamination when visually inspected.

11.1.2 Two samples of each material shall be prepared per SEMI F40. This test is performed in duplicate. More samples may be analyzed if desired.

NOTE 5: The samples are cleaned and weighed according to SEMI F40. The sample preparation described in this document begins with either the ashing (DDA) or digestion under pressure (DCV) of the polymer material.

11.2 *Sample Preparation – Digestion by Dry Ashing (DDA)*

NOTE 6: Digestion by ashing using an oxygen plasma asher differs considerably from the described procedures that refer to ashing in open crucibles. Specific instructions are available from the instrument manufacturers.

11.2.1 Clean the digestion container and cover using appropriate methods for the vessel materials and procedures being employed.

11.2.2 Place the sample into a cleaned crucible. For at least two additional samples, add the recovery spike as discussed in Section 12.

11.2.3 Use a propane torch or other appropriate heating source to carefully flame the outside of the crucible until the polymer inside the crucible is completely charred. Do not flame exceedingly, i.e., do not allow a platinum crucible, for example, to become red hot, as excessive heat will allow some metals to volatilize.

NOTE 7: This step must be carried out in a well-ventilated fume hood.

11.2.4 Prepare at least three procedural blanks by flaming three or more empty crucibles using the method discussed in Section 11.2.3. The results from these blanks will be used to determine the metallic contribution from the crucibles themselves, from the reagents and from the test procedure. These procedural blanks should be treated like any other sample. Crucibles should be rotated in and out of service so that the same crucibles are not always used for blanks.

11.2.5 Place the charred sample crucibles and blank crucibles in a muffle furnace, cover the crucibles with the cleaned covers, and continue to char at 500 to 650°C until all the carbon is removed (usually over a period of 6–18 hrs). The removal of all carbon is indicated by the absence of black material in the sample.

NOTE 8: Some oxides (such as SnO_2) are black and may confound this determination. If a sample is still black after 18 hours, assume that it is an oxide and continue with the procedure.

11.2.6 Allow the crucibles to cool.

11.2.7 Add the appropriate amount (1–2 mL) of concentrated ultrapure hydrochloric acid to each crucible.

11.2.8 Evaporate the hydrochloric acid to dryness in a chemical hood at less than 100°C if necessary to permit instrumental compatibility.

NOTE 9: The presence of chloride in the sample can result in interferences for the determination of arsenic and vanadium by ICP-MS.

11.2.9 Continue preparing the sample as described in Section 11.4.

11.3 *Sample Preparation – Digestion in Closed Vessel (DCV)*

11.3.1 Clean the digestion container and cover using appropriate methods for the vessel materials and procedures being employed.

11.3.2 Place the sample into a cleaned digestion container. For at least two additional samples, add the recovery spike as discussed in Section 12.

11.3.3 Add the reagents needed for the digestion.

11.3.4 Prepare at least three procedural blanks by adding the same amount of all reagents, but no sample, to three or more additional containers. The results from these blanks will be used to determine the metallic contribution from the containers themselves, from the reagents and from the test procedure. These procedural blanks should be treated like any other sample. Containers should be rotated in and out of service so that the same containers are not always used for blanks.

11.3.5 The analyst should be aware of the potential for a vigorous reaction. If a vigorous reaction occurs upon the initial addition of reagent or the sample is suspected of containing easily oxidizable materials, allow the sample to predigest in the uncapped digestion vessel. Heat may be added in this step for safety considerations (for example the rapid release of carbon dioxide from easily oxidized polymeric material). Once the initial reaction has ceased, the sample may continue through the digestion procedure.

11.3.6 Seal the vessel according to the manufacturer's directions.

11.3.7 Properly place the vessel in the digestion system according to the manufacturer's recommended specifications and connect appropriate temperature and pressure sensors to vessels according to manufacturer's specifications.

11.3.8 Set the parameters of the digestion device to manufacturer's recommendations.

NOTE 10: If the pressure exceeds the pressure limits of the vessel, the pressure will be reduced by the relief mechanism of the vessel.

NOTE 11: Pressure control for a specific matrix is applicable if instrument conditions are established using temperature control. Because each matrix will have a different reaction profile, performance using temperature control must be developed for every specific matrix type prior to use of the pressure control system.

11.3.9 At the end of the digestion program, allow the vessels to cool for an appropriate period of time before removing them from the system. When the vessels have cooled to near room temperature, determine if the microwave vessels have maintained a seal throughout the digestion. Due to the wide variability of vessel designs, a single procedure is not appropriate. The use of a spiked control sample is appropriate to ensure that analyte loss has not occurred due to vessel venting. For vessels with burst disks, a careful visual inspection of the disk may identify compromised sample digestions.

11.3.10 Complete the preparation of the sample by carefully uncapping and venting each vessel in a fume hood. Vent the vessels using the procedure recommended by the vessel manufacturer. Transfer the sample to an appropriate acid cleaned container.

11.3.11 If the digested sample contains particulates, which may clog nebulizers or interfere with injection of the sample into the instrument, the sample may be centrifuged, allowed to settle, or filtered.

11.3.11.1 If necessary, centrifugation at 2,000–3,000 rpm for 10 minutes is usually sufficient to clear the supernatant.

11.3.11.2 *Settling* — If undissolved material remains such as TiO, or other refractory oxides, allow the sample to stand until the supernatant is clear. Allowing a sample to stand overnight will usually accomplish this.

11.3.11.3 *Filtering* — If necessary, the filtering apparatus must be thoroughly cleaned and pre-rinsed with dilute (approximately 10% V/V) nitric acid. Filter the sample through qualitative filter paper into a second acid-cleaned container.

11.3.12 Continue preparing the sample as described in Section 11.4.

11.4 *Preparation of the Sample for Analysis*

11.4.1 If the sample was obtained from the DDA method, add 0.5 mL concentrated nitric acid to each crucible.

11.4.2 For samples obtained from the DCV method, transfer or decant the sample into volumetric ware.

11.4.3 Dilute either obtained sample to a required volume with ultrapure water (usually 20 mL). Alternatively, a gravimetric dilution of the samples is also appropriate. The samples are now ready for analysis. See Related Documents, Section 16 for applicable trace inorganics test methods.

12 Recovery Preparation and Percentage Recovery Rate Determination

12.1 Metal recovery percentage must be determined for all instruments by the individual laboratory. This is accomplished via spiking a crucible or digestion vessel containing a polymer sample with a known concentration of metals. Then, determining the percentage of each metal recovered after the decomposition process or acid digestion. The following provides the recommended method for spiking:

12.1.1 Add a known volume of a standard to a crucible or digestion container containing a polymer sample.

12.1.2 *For DDA* — Gently evaporate the standard solution to dryness.

12.1.3 Digest the dried standard and dried polymer using the same procedure as for the samples. Typical recovery rates are 70–110% for the alkali, alkaline earths, and most transition metals.

13 Data Analysis

13.1 *Calculations*

13.1.1 The concentration of trace metals in the solution must be calculated to determine the concentration in µg/g (ppm) of the polymeric material using the following equation:

polymer concentration (µg/g) =

= solution concentration (µg/L) × solution volume (L) / mass of the polymer(g)

13.1.2 Since the procedural blank does not contain a weighed sample, the results must be transformed to solid concentrations (in µg/g) by using the average weight of the samples (see Section 11.1.2 and corresponding NOTE).

14 Data Presentation

NOTE 12: Use the Report Form provided in Section 17 of this document.

14.1 *Sample Information*

14.1.1 Provide the date(s) of the test, the person and/or company requesting the analysis, the method in which the sample was obtained (e.g., if it was separated from a

larger component and delivered to the laboratory), operator and laboratory performing the test, type of material (e.g., PFA pellets, injection molded PVDF valve, perfluoroelastomer O-ring), material supplier, material model and lot number(s), date sample was obtained and if the sample is a prototype or production material.

14.2 *Methods*

14.2.1 Provide the method of cleaning the sample as well as indicating if the sample arrived pre-cleaned from the requester or if it was cleaned in the laboratory performing the test.

14.2.2 Check the applicable box for the type of digestion. Complete as well the information regarding the conditions.

14.3 *Results*

14.3.1 Use Table 1, Trace Metals in Bulk Polymer Worksheet in Section 17.3 to report the results of the analysis along with detection limits and recovery rates for all elements required in the samples.

NOTE 13: For this document, the detection limit is defined as the concentration equivalent to three standard deviations of the results of the procedural blanks (see Section 13.1.2).

NOTE 14: The procedural blanks should be averaged and then subtracted from each sample (see Columns 3 and 4 of Table 1).

NOTE 15: If multiple samples of the same polymer material are evaluated, an average and standard deviation must be reported.

15 Precision and Bias

15.1 Expected variations in the blank are due to environmental and instrument variation.

15.2 Expected variation in the samples is 20–30% and is due to environmental, instrumental, and ashing or digestion variations.

15.3 This test does not give an indication of the variations found in the polymer sample material.

15.3.1 Analyze multiple samples of the same polymer material to determine the variation.

15.3.2 Refer to ASTM D4375 for information regarding sample populations to determine differences between materials.

16 Related Documents

16.1 *References Pertaining to ICP–MS*

Dams, R. F. J., Goossens, J., Moens, L. "Spectral and Non-Spectral Interferences in Inductively Coupled Plasma Mass Spectrometry" Microchim. Acta 119 (1995):277-286.

Evans, E. H., Giglio, J. J., "Interferences in Inductively Coupled Plasma Mass Spectrometry" J Anal. Atom. Spectrom. 8 (1993):1-18.

Jarvis, K. E., Gray, A. L., Houk, R. S. "Handbook of Inductively Coupled Plasma mass Spectrometry" Blackie, Glasgow 1992 (USA: Chapman and Hall, New York).

Shao, Y. and G. Horlick. "Recognition of Mass Spectral Interferences in Inductively Coupled Plasma–Mass Spectrometry." *Applied Spectroscopy* 45 (1991):143.

16.2 *References Pertaining to ICP–AES*

Garbarino, J.R., B.E. Jones, G.P. Stein, W.T. Belser, and H.E. Taylor. "Statistical Evaluation of an ICP–AES Method for Routine Water Quality Testing." *Applied Spectroscopy* 39 (1985):535.

Winge, R.K., V.S.Fassel, R.N. Kniseley, E. De Kalb, and W.J. Haas Jr. "ICP as an Analytical Source." *Spectrochimica Acta* 32B (1977):327

16.3 *References Pertaining to Microwave Digestion*

Kingston, H. M. Skip and Haswell, Steve, Eds., Microwave Enhanced Chemistry: Fundamentals, Sample Preparation, and Applications, ACS Professional Reference Book Series, American Chemical Society, Washington, DC, 1997.

16.4 *U.S. EPA Documents*[3]

U.S. EPA Method 3052 — Microwave Assisted Acid Digestion of Siliceous and Organically Based Matrices

U.S. EPA RCRA SW-846 — Chapter 3, sections on clean chemistry and microwave decomposition.

16.5 *SEMATECH Documents*[4]

SEMASPEC #92010956B–STD — SEMATECH Provisional Test Method for Analyzing the Plastic Surface Composition and Chemical Bonding of Components of UPW Distribution Systems (ESCA Method)

SEMASPEC #92010936B–STD — SEMATECH Provisional Test Method for the Determination of Leachable Trace Inorganics from UPW Distribution System Components

3 Environmental Protection Agency, 401 M St., SW, Washington, DC 20460, USA

4 SEMATECH, 2706 Montopolis Dr., Austin TX 78741

17 Report Form

17.1 Sample Information Test Date(s): _____

17.1.1 Person/Company Requesting Analysis: _____

17.1.2 Method of Obtaining Sample: _____

17.1.3 Operator and Laboratory Performing Test: _____

17.1.4 Sample Material: _____ Sample Supplier: _____

17.1.5 Model/Lot Number: _____ Date of Sample: _____

17.1.6 Circle one: Pre-Production Material or Final Production Material

17.2 *Methods*

17.2.1 Sample Cleaning Technique (SEMI F40 or other): _____

17.2.2 Digestion Technique (check one)

☐ Dry Ashing
Type of Crucible: _____
Temperature of Ashing: _____°C
Time of Ashing: _____ hours

☐ Closed Vessel
Vessel Material: _____
Reaction Conditions: _____
_____

17.3 *Results*

Table 1 Trace Metals in Bulk Polymer Worksheet

Element	*Detection Limit (µg/g)*	*Procedural Blank (µg/g)*	*Result with Blank Subtraction (µg/g)*	*% Recovery*
Aluminum				
Barium				
Calcium				
Chromium				
Cobalt				
Copper				
Iron				
Lead				
Lithium				
Molybdenum				
Magnesium				
Manganese				
Nickel				
Potassium				
Sodium				
Strontium				
Tin				
Titanium				
Zinc				
Zirconium				

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SEMI F49-0200
GUIDE FOR SEMICONDUCTOR FACTORY SYSTEMS VOLTAGE SAG IMMUNITY

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 December 15, 1999. Initially available on www.semi.org February 2000; to be published February 2000.

1 Purpose

1.1 A guide defining a systems approach to power conditioning is needed for semiconductor and flat panel display (FPD) facilities. Semiconductor and FPD factories require high levels of power quality due to the sensitivity of equipment and process controls. Semiconductor and FPD processing equipment is especially vulnerable to voltage sags. The facility electrical system distributes power to process equipment, support equipment, and facility infrastructure equipment. Facility electrical distribution systems should be designed to integrate the voltage sag susceptibility of all the equipment with the power quality supplied by the utility. Installing effective and efficient facilities power conditioning requires identification of appropriate conditioning technologies and properly applying the conditioning equipment.

1.2 Utilizing recommendations in this guide should result in effective power conditioning of the facility electrical distribution system such that the process equipment, associated support equipment and facilities infrastructure equipment function within acceptable ranges.

2 Scope

2.1 This guide is intended for facilities engineers, equipment engineers, and facilities managers who specify compatibility requirements for equipment and utility services, and in particular for electrical power requirements such as those found in SEMI E51.

2.2 This document provides recommendations for implementing a systems approach to identification and resolution of voltage sag events that disturb the performance of semiconductor process equipment. A program recommending facilities electrical distribution system monitoring and control strategies for both the direct and indirect effect of voltage sags on wafer processing is outlined as follows:

- Reasons for monitoring and conditioning (see Section 7.1).
- Facilities electrical distribution system power monitoring and conditioning (see Section 7.2).
- Quantifying process equipment performance (see Section 7.3).
- Quantifying support equipment and facilities infrastructure equipment performance (see Section 7.4).
- Utility power monitoring strategies (see Section 7.5).
- Measurement and modeling strategies (see Section 7.6).
- Power enhancing and conditioning strategies for use in the facilities electrical distribution system (see Section 7.7).

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

3 Limitations

3.1 This guide addresses power quality monitoring and conditioning solutions primarily within the facilities electrical distribution system. Process equipment and utility performance are covered in other related standards.

3.2 This guide does not address the impact of voltage sags on equipment beyond the effect to the electrical components. Effects on interdependent equipment interlocks are not examined in detail in this document.

3.3 This guide is not intended to address design or materials issues related to safety which are addressed elsewhere in the SEMI guidelines (see SEMI S2).

3.4 This document is not intended to supersede international, national or local codes, regulations and laws. Each should be consulted to ensure that the equipment meets regulatory requirements in each location.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI S2 — Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment

SEMI E51 — Guide for Typical Facilities Services and Termination Matrix

4.2 *IEEE Standards*[1]

IEEE 1100 — IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment

IEEE 1159 — IEEE Recommended Practice on Monitoring Electrical Power Quality

IEEE 1346 — IEEE Recommended Practice for Evaluating Electric Power System Compatibility with Electronic Process Equipment

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *facilities infrastructure equipment* — component, modules, and systems used to transport materials like chemicals, power, water, effluent, and exhaust in semiconductor factories.

5.2 *process equipment* — fabrication equipment, inspection equipment, and cassette stage equipment used in semiconductor manufacturing.

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

5.4 *voltage sag* — an rms reduction in the ac voltage, at power frequency, for durations from half-cycle to a few seconds.

6 Impact

6.1 The primary goal of this guide is mitigation of the effects of utility voltage sags on semiconductor processing equipment, support equipment, and facilities infrastructure equipment. A voltage sag event adversely affecting only one of these pieces of equipment can cause processing equipment to malfunction. Both the direct and indirect effect of voltage sags on process equipment should be managed. Voltage sags can effect process equipment directly through the electrical power points of connection. Voltage sags can also indirectly effect process equipment through fluctuations in air, gas, liquid, and other utility streams caused when voltage sags effect support equipment and facility infrastructure equipment.

6.2 Examples of processing equipment, support equipment, and facilities infrastructure equipment are listed below. The interaction of these three types of equipment is shown in Figure 1.

6.2.1 *Process Equipment*

- Etch (dry & wet)
- Film deposition (CVD & PVD)
- Thermal
- Surface prep and clean
- Photolithography (exposure & coater/developer)
- Chemical Mechanical Polishing
- Ion Implant
- Metrology
- Automated test

6.2.2 *Support Equipment*

- Vacuum system (roughing, turbo, and cryogenic pumps)
- RF generator
- Residual gas analyzer (RGA)
- Water heater
- Chiller
- Photolithography stepper laser light source power supplies
- Photolithography coat/developer temperature/ humidity controllers
- Emission control (burn boxes)

1 The Institute of Electrical and Electronic Engineers, Inc. (IEEE), 345 East 47th Street, New York, NY 10017-2394, USA

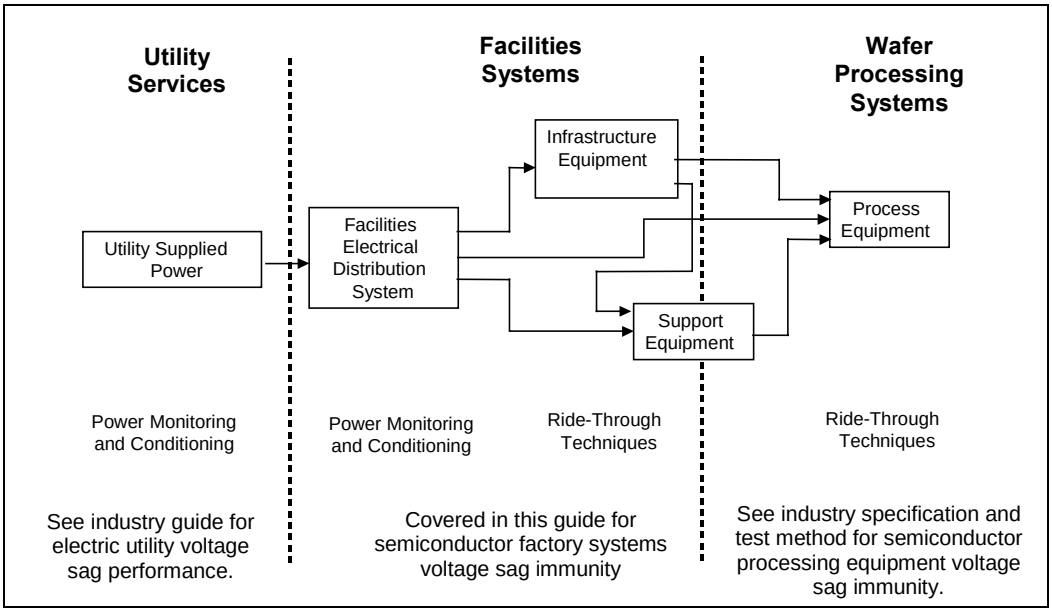

Figure 1
Power Quality Interfaces
(See Related Documents section.)

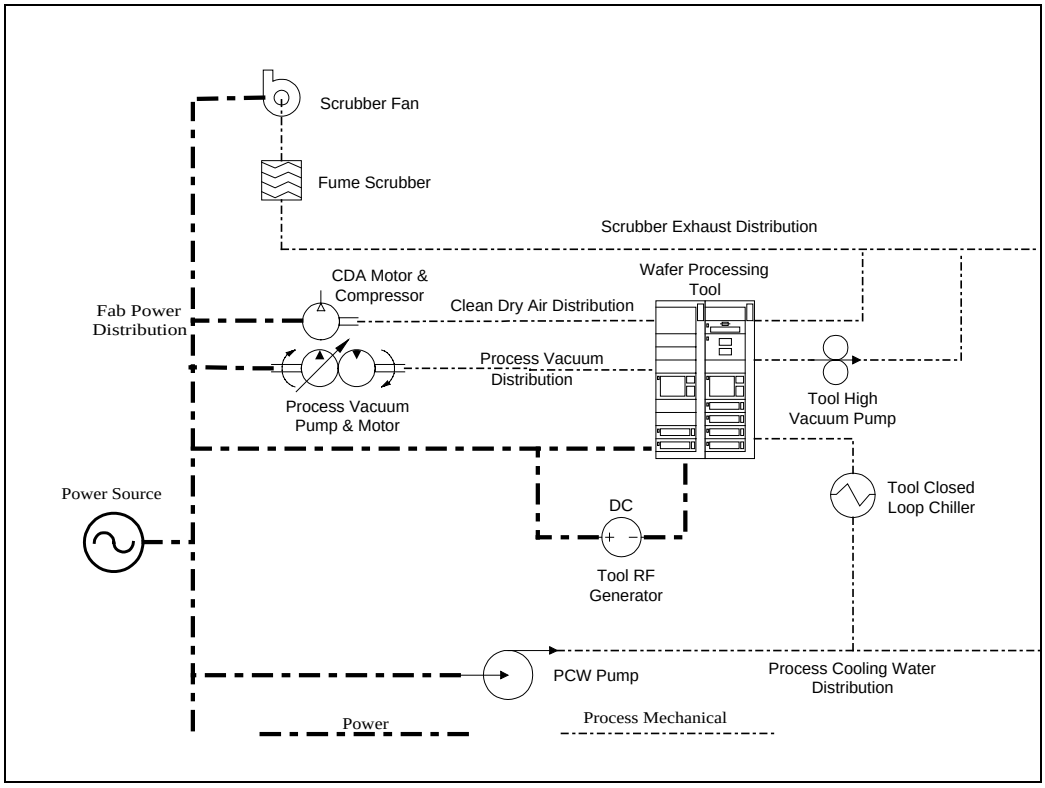

Figure 2
Typical Interconnection of Facility Infrastructure Equipment with Process and Support Equipment

6.2.3 *Facilities Infrastructure Equipment*

- Exhaust systems (scrubbers and VOC exhaust fans and controls)
- Process cooling water system (pumps and controls)
- Air compressors (and controls)
- Vacuum system (pumps and controls)
- Bulk and specialty gas distribution systems (pumps and controls)
- Liquid chemical distribution systems (pumps and controls)
- Power distribution systems

7 Power Monitoring and Conditioning Recommendations

7.1 *Reasons for Monitoring and Conditioning*

7.1.1 Semiconductor manufacturing facility electrical distribution systems should be designed to transport power to process equipment, support equipment, and other facilities infrastructure equipment without degradation to the electrical power quality. The system should recognize electrical power that does not meet specification and provide proper power conditioning so as not to impact wafer processing.

7.1.2 Power monitoring is used to measure electrical system power quality performance for the following reasons.

a) Monitoring data can be compared to equipment voltage sag specifications to identify problems.

b) Selection and control of power conditioning devices are dependent upon monitoring measurements.

7.1.3 Power conditioning is implemented to correct for gaps in equipment voltage sag susceptibility and point of connection electrical power performance. Power conditioning is occasionally implemented where the risk of unacceptable equipment performance is high, where equipment performance tolerance is outside specifications, and where equipment interruption is costly.

7.2 *Monitoring and Conditioning Program*

7.2.1 Quantify the process equipment, support equipment, and facilities infrastructure equipment voltage sag susceptibility using industry standard specifications and test methods. (See Sections 7.3 and 7.4.)

7.2.2 Set-up monitors for utility power quality (see Section 7.5).

7.2.3 Measure and/or model the impact of the facility electrical distribution system on the utility power delivered to the process equipment (see Section 7.6).

7.2.4 Model and evaluate cost/benefit of power conditioning solutions where there are gaps or high risks. Select and implement identified power conditioning solutions into the facilities electrical distribution system. (See Section 7.7.)

7.2.5 Maintain the installed power conditioning equipment and monitor the power either continuously or periodically to assure performance and evaluate results.

7.3 *Process Equipment Performance*

7.3.1 Facility design specifications should include requirements for processing equipment voltage sag immunity (see industry specification for semiconductor processing equipment voltage sag immunity). (See Related Documents section.)

7.3.2 Variability in process equipment manufacturing and supplied utility power quality preclude interruption free manufacturing. This variation comes from multiple sources:

a) Verification of representative samples of equipment does not guarantee 100% of the equipment will meet the same requirements.

b) Factors such as location, load changes, capacity, weather, and transmission/ distribution equipment, limit how well utility power quality can be controlled.

c) The tests, themselves, are not variation free; the test equipment, calibration processes, and the test personnel can introduce further variability.

7.3.3 The risk of manufacturing interruptions can be considerably reduced through two approaches.

a) Create a margin between allowable voltage sag for the supplied utility power and process equipment voltage sag immunity.

b) Provide added protection from interruptions due to voltage sag events by enhancing the power quality in the facilities distribution system. (This approach is covered in this document, see Scope and the middle segment of Figure 1.)

7.4 *Support and Facilities Infrastructure Equipment Performance*

7.4.1 The effects that support equipment and facilities infrastructure equipment have on process equipment should be considered.

7.4.2 Process and support equipment typically contain flow, temperature, or pressure sensors. If facility infrastructure equipment malfunctions due to a voltage sag event, the diminished flow of a required fluid or gas will cause the support or process equipment to alarm, malfunction, or stop.

7.4.3 A typical interconnection of facility infrastructure equipment with process and support equipment is illustrated in Figure 2. The various support and facilities infrastructure systems that can have an indirect effect on process equipment performance when subjected to voltage sag events are listed below:

- Process cooling water,
- Scrubbed exhaust,
- Volatile organic compound (VOC) exhaust,
- Gas cabinets and gas monitoring system controllers,
- Compressed dry air,
- Process vacuum,
- Automated wafer transport systems,
- Computer integrated manufacturing (CIM) systems,
- Gas leak detection systems,
- Exhaust abatement systems, and
- Bulk chemical delivery system.

7.4.4 Since the supplied utility power quality effects all the equipment within the factory, performance requirements for support equipment and facilities infrastructure equipment should be specified using the same standards used for processing equipment. Applying the same voltage sag susceptibility specifications for semiconductor processing equipment (see industry specification for semiconductor processing equipment voltage sag immunity) to the support equipment and the facilities infrastructure equipment has the following benefits: (See Related Documents section.)

a) Use of the same specification for all equipment allows for consistency when monitoring and conditioning for the effects of voltage sag events.

b) The same performance verification test methods as those used for processing equipment can be applied to the support equipment and facilities infrastructure equipment.

7.4.5 Where it is inefficient to have support and/or facilities infrastructure equipment supplied to meet the same specifications as process equipment, the facility electrical distribution system may be required to compensate for any specification gap.

7.5 *Monitoring Strategies*

7.5.1 Use power disturbance monitors and/or digital fault recorders to monitor voltage to detect compliance (see IEEE 1159). Monitor current to identify disturbance sources and assist in solutions.

7.5.2 Locate continuous monitoring at the electrical utility service, all major facility electrical distribution centers, and all critical equipment electrical points of connection. Perform periodic monitoring for at least one location of each equipment type in order to characterize the electrical environment under normal conditions (i.e., to create a baseline). Additional monitoring should be performed when experiencing unexplained operational problems. A comparison of baseline data to monitored data for equipment experiencing problems is recommended for evaluating the power supplied to the equipment.

7.5.3 Provide time synchronization for multiple monitors to allow for the correlation of a single voltage sag event between all monitors.

7.5.4 In order to understand the impact, correlate monitored voltage sag events with known wafer processing effects within the process equipment.

7.6 *Measuring and Modeling Strategies*

7.6.1 A single voltage sag event originating outside the factory will vary in magnitude and duration when measured at differing locations throughout the facility. This is largely due to differing lengths and type of distribution conductors feeding equipment located throughout the facility. In addition, the electrical interactions of the reactive and non-linear elements of equipment effect the voltage sag measurements.

7.6.2 Voltage sag events that originate within the facility electrical distribution system will vary in magnitude and duration when measured at differing locations throughout the facility. These voltage sag events are usually a result of a current flow increase and the associated voltage drop across the conductors between the source and load. The location along the current flow path greatly effects the voltage sag measured.

7.6.3 Computer design tools should be used to model the electrical distribution system in order to calculate anticipated voltage sags for utility or site originated faults. If limitations exist such that voltage sag monitors are not located at every piece of equipment, then event measurements can be adjusted from modeling information to determine voltage sag values at other locations.

7.6.4 As a means for measuring effectiveness in a business environment, it would be useful to statistically model the effect of voltage sag events on the manufacturing processes. The variations mentioned in Section 7.3.2, above, preclude a deterministic approach to how well a wafer fabrication process will perform for a given voltage sag event. A statistical correlation model would aid in estimating the correlation between voltage sags and manufacturing cost, and can be used to validate the effectiveness of power enhancement and conditioning programs.

7.6.5 *Example of Voltage Sag Event Modeling*

7.6.5.1 A voltage sag event originating on the electrical utility system often exhibits different characteristics when measured at different locations on facility electrical distribution systems. The variance in voltage sag characteristics can create different effects on similar equipment. Variances can usually be explained by examining 1) the characteristics of voltage sag at the utility interfaces, 2) the type and connection configuration of voltage transformations, and 3) the voltage levels and corresponding phase relationships at the terminals of infrastructure, support, and process equipment within the facility.

7.6.5.2 The types of faults that can occur on a utility system are:

- Line to line to line,
- Line to line to line to ground,
- Line to line,
- Line to line to ground, and
- Line to ground.

7.6.5.3 The utility network can be modeled to predict the voltage sag characteristics due to various types of faults at the electrical interfaces between a semiconductor manufacturing facility and utility. The most common utility system fault type is a single line to ground fault. An example of the translation of a voltage sag resulting from a line to ground voltage sag event is provided in the following sections.

7.6.5.4 Typical voltage transformations from the utility interface to utilization voltage levels are illustrated in Figure 3. Under normal conditions, the three phase voltages are all approximately equal and displaced 120º from each other. During a voltage sag event due to an unbalanced fault, this relationship changes. Delta-wye transformers between the origin of the fault and the equipment being studied will further affect the phase and magnitude relationships. The degree to which voltage phase shift and magnitude changes occur at each transformation throughout the facility distribution system should be considered when examining impacts on individual equipment.

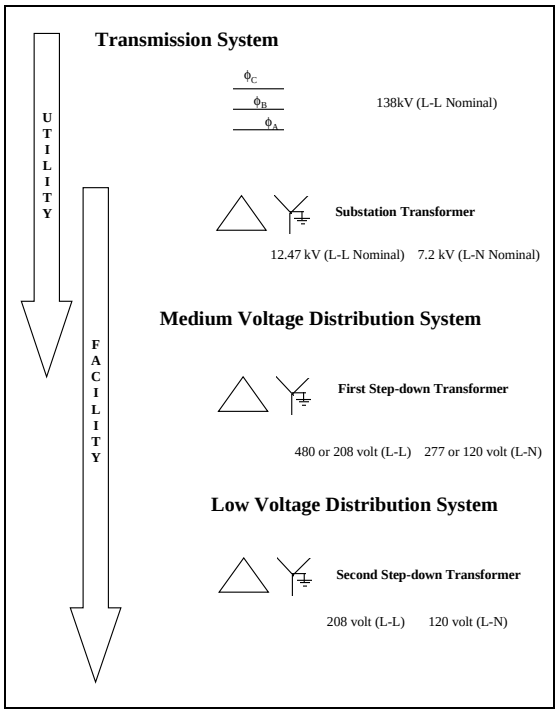

Figure 3
Typical Semiconductor Factory Voltage Transformations

7.6.5.5 Figure 4 illustrates the variations in magnitude of a voltage sag event within a facility during a single line to ground fault on a utility transmission line. This example illustrates a worst case situation, where a single-phase fault occurs at a substation transformer primary-side terminal. (See Related Documents section.)

7.6.5.6 Many devices in process, support, and facilities infrastructure equipment are not connected to all three phases. Because the voltage sag response of these devices may dictate the sag response for the entire equipment assembly, understanding device connection configuration and sag response characteristics is of critical importance. Sag depth and duration, the point on the wave at which the sag begins, and the corresponding phase relationships are all known to be

factors in determining the sag response of many common devices.

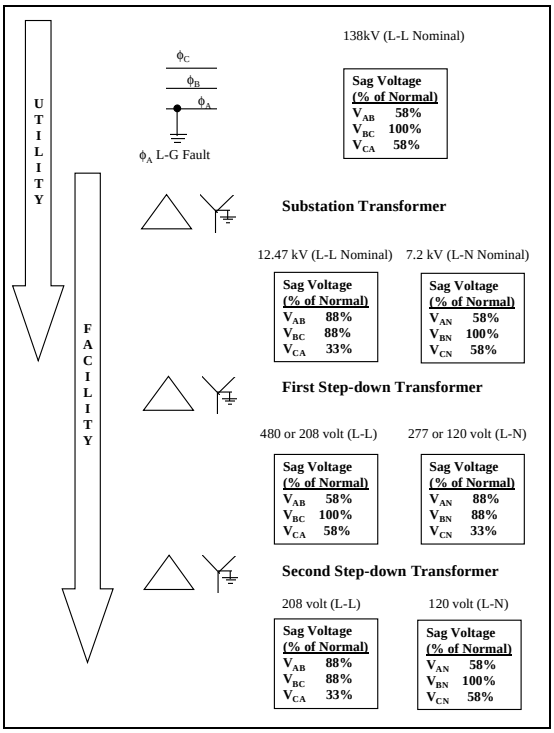

Figure 4
Example of Voltage Sag Levels during a Single Line to Ground Fault

7.6.5.7 Figure 4 illustrates the importance of phase relationships in the sag response of a 120-volt control circuit emergency off (EMO) relay which is connected to phase A (or phase B) in a 208-volt facility distribution system derived with only one low voltage transformation. In this example the voltage sags to only 88% of nominal on these phases, but drops to 33% of nominal on phase C. The industry specification for semiconductor processing equipment voltage sag immunity does not specify that equipment ride-through a sag to 33% of nominal voltage.

7.6.5.8 If two low voltage transformations were used to derive the 208-volt facility system (see Figure 4), phase B voltage would be unaffected during the utility voltage sag, but phases A and C would sag to 58% of nominal. Industry standards typically require equipment to ride-through a sag of this depth. However, a tolerance designed into the facility system may be necessary to provide adequate system protection.

7.7 *Power Enhancing and Conditioning Strategies*

7.7.1 While it is desirable to reduce and eliminate battery storage devices provided by equipment suppliers with individual pieces of process equipment, battery storage devices may be appropriate as a centralized or distributed part of a facilities distribution system (when evaluated in a systems approach to power enhancement and conditioning).

7.7.2 Facility power systems enhancements should be examined on a case-by-case approach to determine the appropriate measure of power conditioning to be applied. In general, the following types of equipment are frequently used to mitigate the effects of utility voltage sag events in semiconductor factories.

- Constant voltage transformers (typically applied on control systems)
- Diesel engine based uninterruptible power supplies (UPS)
- Magnetic synthesizers
- Motor-generators
- Rotary UPS
- Static UPS
- Static transfer switches with alternate power systems

7.7.3 Other power enhancement techniques and equipment available for use in facilities electrical distribution systems include but are not limited to the following:

- Capacitors for voltage regulation,
- Filters for power conditioning,
- High resistance grounding,
- Isolation of electrical circuit from other loads,
- Power line conditioners,
- Primary and secondary selective rather than radial distribution systems,
- Super-conducting magnetic energy storage systems,
- Transformer load tap changers, and
- Voltage regulators.

7.7.4 Power enhancement and conditioning equipment can be applied at selected equipment components, selected distribution circuits, or selected distribution buses. For power conditioning equipment application guidelines see IEEE 1100 and 1346.

8 Related Documents

8.1 *SEMI Standards*

Under development.

8.2 *CENELEC Standard* [2]

EN 50082-2 — Electromagnetic compatibility - Generic immunity standard, Part 2. Industrial environments.

8.3 *IEC Standard*[3]

IEC 61000-4-11 — Electromagnetic Compatibility (EMC) - Part 4: Testing and Measuring Techniques - Section 11: Voltage Dips, Short Interruptions and Voltage Variations Immunity Tests

8.4 *IEEE Standards*[1]

IEEE Std 493 — IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems

IEEE Std 1250 — IEEE Guide for Service to Equipment Sensitive to Momentary Voltage Disturbances

NOTE 2: As listed or revised, all documents cited shall be the latest publications of adopted standards.

2 European Committee for Electrotechnical Standardization (CENELC), Rue de Stassart, 35, B - 1050 Brussels

3 International Electrotechnical Commission (IEC), 3 rue de Varembé, PO Box 131, 1211 Geneva 20, Switzerland

SEMI F50-0200
GUIDE FOR ELECTRIC UTILITY VOLTAGE SAG PERFORMANCE FOR SEMICONDUCTOR FACTORIES

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 December 15, 1999. Initially available on www.semi.org February 2000; to be published February 2000.

1 Purpose

1.1 This guide provides a framework for semiconductor and flat panel display (FPD) manufacturers and their electric utility service providers to minimize the effect of voltage sag events on semiconductor processing. In particular, this guide focuses on electric utility power quality performance goals that are complementary to voltage sag immunity levels for semiconductor processing equipment and facilities infrastructure equipment (see Figure 1). Recommendations for measuring and evaluating voltage sag performance, evaluating utility system enhancements, and implementation of a continuous improvement process are included since no electric utility industry standards exist.

1.2 Utility systems are designed, constructed, and operated to meet utility industry regulations and requirements. One important requirement for semiconductor factories is power system reliability. Utilities measure reliability in minutes of voltage outages per customer per year. Semiconductor factories require a high level of power system reliability, any service outage is usually unacceptable. A second important requirement is power quality. Power quality relates to disturbed voltage waveforms, not outages. When utilities implement measures to increase power system reliability, power quality can be adversely affected. The structured approach defined in this guide can achieve high levels of power quality without sacrificing power reliability.

1.3 The intent of this guide is to help semiconductor manufacturers achieve both high levels of power reliability and power quality from energy utility providers. By becoming familiar with the cause and effect relationships of voltage sag events on the utility's side of the electric meter, semiconductor manufacturers and electric utilities can work together to pursue efficient solutions for improved voltage sag ride-through in semiconductor factories.

2 Scope

2.1 The scope of this guide extends beyond a discussion of typical electric utility reliability and quality improvement techniques to developing a continuous improvement process for electric utility voltage sag performance (depicted graphically in Figure 2). Factors in this process include the following:

- Define desired performance criteria by setting goals for voltage sag event duration and magnitude (see Section 6.1).
- Measure performance for both proposed and existing semiconductor factory sites (see Section 6.2).
- Summarize voltage sag event data and identify the impact on semiconductor processing and facilities infrastructure equipment (see Section 6.3).
- Recommend improvements that include consideration of cost, benefit, and risk. Improvements can include corrective action to eliminate system faults, changes to service configurations, and power enhancements (see Section 6.4).
- Select and implement improvements. Establish a continuous improvement process (see Section 6.5).

2.2 For the purposes of this document, the term Electric Utility refers to energy service providers (that sell energy to semiconductor manufacturers) and/or electric transmission and distribution providers (that deliver energy through their power lines).

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

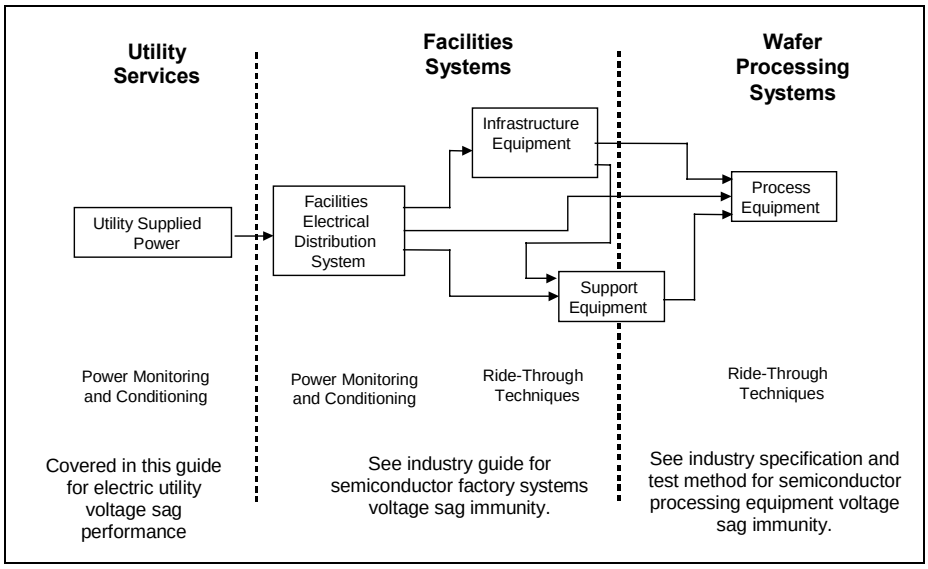

Figure 1
Power Quality Interfaces
(See Related Documents section.)

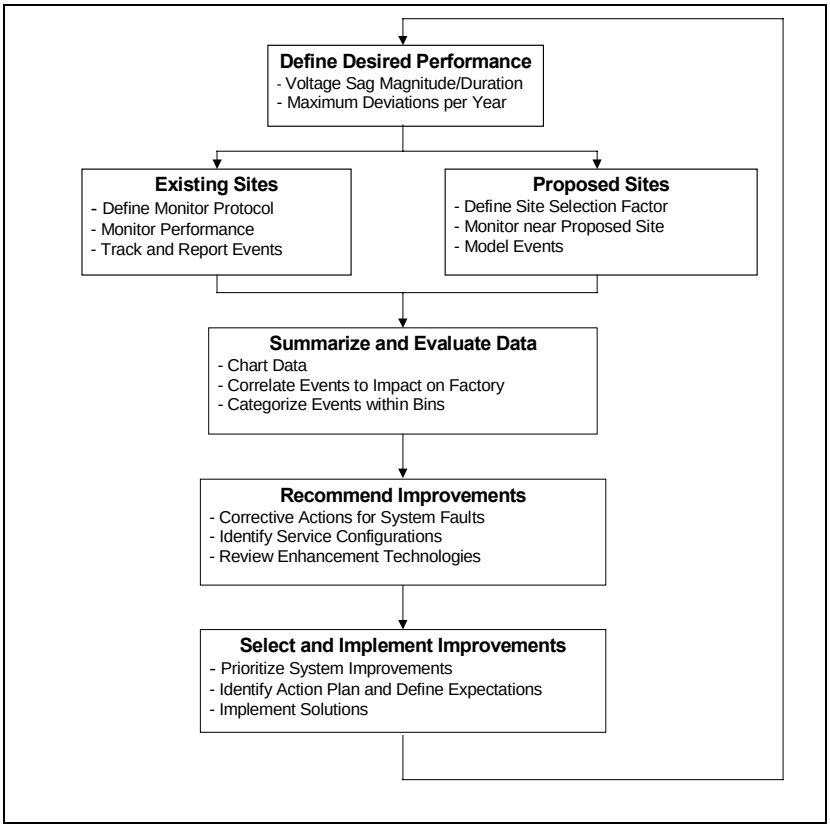

Figure 2
Continuous Improvement Process

3 Limitations

3.1 This guide addresses electric utility power quality monitoring and enhancement techniques primarily related to semiconductor factory energy utility providers. Process equipment and factory systems are covered in other related standards.

3.2 This standard is not intended to address design or materials issues related to safety which are addressed elsewhere in the SEMI guidelines (see SEMI S2).

3.3 This document is not intended to supersede international, national or local codes, regulations and laws. Each should be consulted to ensure that the equipment meets regulatory requirements in each location.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI S2 — Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment

4.2 *IEEE Standards*[1]

IEEE 1159 — IEEE Recommended Practice for Monitoring Electric Power Quality

IEEE 1250 — IEEE Guide for Service to Equipment Sensitive to Momentary Voltage Disturbances

IEEE 1346 — IEEE Recommended Practice for Evaluating Electric Power System Compatibility with Electronic Process Equipment

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *electric utility* — the company identified as the contractual provider of electrical power and energy to the customer point of delivery. Also known as the electric service provider.

5.2 *voltage sag* — an rms reduction in the ac voltage at power frequency for durations from half-cycle to a few seconds (see IEEE 1250). Also known as voltage dip.

6 Electric Utility Voltage Sag Performance Recommendations

6.1 *Define Voltage Sag Performance*

6.1.1 Defining a goal for acceptable voltage sag duration and magnitude is useful in establishing a benchmark or reference point for monitoring improvement. Events can be identified and categorized within the realm of the electric utility or the semiconductor manufacturer. Industry specifications for semiconductor processing equipment voltage sag immunity (which define the level of voltage sag immunity required for semiconductor processing equipment) are recommended as a performance goal. Using this goal for the performance of electric utility services will provide consistency with semiconductor processing equipment capabilities. (See Related Documents section.)

6.1.2 The goal for the maximum number of deviations from specified performance per year is zero. However, it is useful to recognize that utility generation, transmission, and distribution systems are subject to environmental and regulatory conditions that may negatively influence the ability to provide zero deviations on a continuous basis.

6.1.2.1 Document regulatory and environmental requirements that will limit the electric utility's choices when implementing improvements, such as rate structures or rights-of-way.

6.2 *Measure Performance*

6.2.1 *Measuring Performance at Proposed Semiconductor Factory Sites*

6.2.1.1 Factory site selection teams should consider the importance of power and power quality when evaluating potential sites. To insure that power quality considerations are properly factored into the site selection process, a selection factor should be assigned to power quality and reliability criteria.

6.2.1.2 Utility electrical service configurations should be considered when measuring and comparing reliability and power quality performance at different locations. The load profile for the proposed factory is used to determine the standard utility electrical service configuration. Usually, larger factories (> 10 MW) exceed allowable loading for lower voltage distribution systems (< 69 kV), therefore a high voltage service is the typical configuration for larger semiconductor factories. Selection of the highest available service voltage is preferred for reliability due to two factors. First, the area of exposure is greater for lower voltages since they include both higher and lower voltage system distribution lines and equipment. Second, higher voltage systems can provide energy to lower voltage system faults with little or no impact to high voltage system voltages, whereas, lower voltage systems are greatly impacted by faults not buffered by transformers.

6.2.1.3 The preferred method for comparing power quality and reliability from different locations involves creating a summary of the number of voltage sag events

1 The Institute of Electrical and Electronic Engineers, Inc., 345 East 47th Street, New York, NY 10017-2394, USA

that fall into different magnitude-duration categories. Data from different categories should be adjusted by weighting factors to enable valid comparison. See IEEE 1346 for suggested voltage sag event category and weighting factors.

6.2.1.4 Model events.

6.2.1.4.1 If actual disturbance data is not available, modeling results based on simulation of actual electrical faults should be calculated and reviewed. These studies called area of vulnerability analysis determine transmission lines and equipment where faults can adversely impact a semiconductor factory.

NOTE 2: As monitoring data is later collected, the modeling results should be validated.

6.2.1.5 Monitor events near proposed site(s).

6.2.1.5.1 Define monitoring protocol per the method outlined in Section 6.2.2.2.

6.2.1.5.2 Upon establishing an appropriate electrical service configuration, reliability and power quality information relative to that service configuration should be requested from the electric utility. Depending upon utility rate structures, semiconductor manufacturers may be required to pay separately for this analysis. Where available, the information provided should include actual disturbance data from other selected sites collected in accordance with IEEE 1159. Strive for data on sites that have similar electrical service configurations and are located electrically close to the proposed site (e.g., ideally, from the same transmission or distribution line).

6.2.2 *Measuring Performance at Existing Semiconductor Factory Sites*

6.2.2.1 Preparation for monitoring.

6.2.2.1.1 Review existing industry typical voltage sag performance data for utility point-of-service.

6.2.2.1.2 Review existing site voltage sag performance data, usually taken at a variety of locations within the factory.

6.2.2.1.3 Review existing utility voltage sag performance data for the area around the factory site, usually a 20–30 mile radius of the service area is sufficient.

6.2.2.1.4 Review existing utility area of vulnerability modeling studies for power flow and system power quality.

6.2.2.1.5 Document the existing utility and manufacturing site electrical design and operating procedures.

6.2.2.2 Define the monitoring protocol.

6.2.2.2.1 Define where measurement devices will be located, how many to be installed, who will operate and maintain them, and what are the standards for calibration.

6.2.2.2.2 Define sensitivity settings. Usually magnitude triggers are set as tightly as possible (95% of nominal voltage). This will generate a large amount of data that will verify trends and maximize comparison opportunities between cause and effect. After several evaluation cycles magnitude triggers can be moved closer to the criteria (90% of nominal voltage), in order to focus improvement efforts on the more significant sags.

6.2.2.3 Monitor the voltage sag performance.

6.2.2.3.1 Location of monitor(s) should be such that the utility point-of-service to the factory is represented by the recorded data. Data recorded remote from the utility point-of-service will be effected by other utility or factory system components. Remote data should be adjusted to represent a utility point-of-service equivalent.

6.2.2.4 Track and report events.

6.2.2.4.1 Define the reporting format for all events and who will receive the reports. (Example: Reports to contain magnitude, duration, time/date stamp and impact on process, if known. All events are summarized and reported monthly. All out-of-specification events only are reported same day as event. All reports distributed to both factory and utility representatives.)

6.3 *Summarize Data and Evaluate Impact*

6.3.1 Summarizing monitoring data.

6.3.1.1 Figure 3 shows how monitoring data can be graphically reported using charts representing magnitude and duration.

6.3.1.2 Monitored and measuring power quality performance provides the semiconductor manufacturer and their electric utility with empirical data on which to base voltage sag performance and improvement decisions.

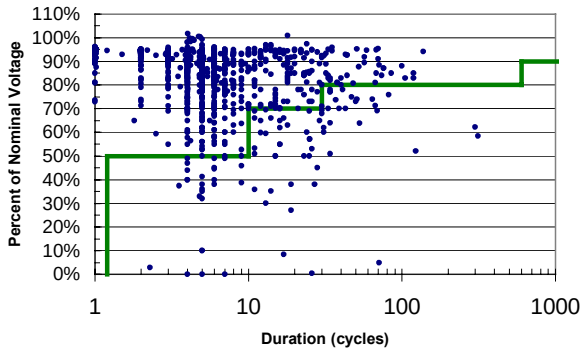

Figure 3
Example of Chart Summarizing Monitoring Data

6.3.2 Correlate data to impact on factory.

6.3.2.1 For new sites, categorize voltage sag events within magnitude/duration bins.

6.3.2.2 When evaluating new sites that are located in different electrical utility service areas it is beneficial to normalize the voltage sag data prior to comparison. The use of magnitude/duration bins to place historical or predicted event data creates discrete blocks of like kind events. The impact on factories, causes of events, and potential improvements may be evaluated on each individual bin or groups of bins. Increasing the number of magnitude/duration bins used in the data comparison refines the accuracy, but also increases the effort needed to translate events into discrete data bins. (See IEEE 1346 and Related Information 2.)

6.3.2.3 For existing sites, define categories of event impact on manufacturing process. For example:

- In Spec Event/No known impact
- In Spec Event/Minor impact
- In Spec Event/Major impact
- Out of Spec Event/No known impact
- Out of Spec Event/Minor impact
- Out of Spec Event/Major impact

6.3.2.3.1 The boundary between major and minor impact is often cost or number of wafer moves lost converted to an equivalent cost.

6.4 *Recommend Improvements*

6.4.1 Analyze costs, benefits, and risks.

6.4.1.1 The improvement recommendation process should include the equivalent of identifying the costs related to the disturbances, the costs related to improvements, and the effectiveness of improvements. The risks should be identified for taking no action, the possibility that events will occur during the implementation of improvements, and that events will occur as a result of unknown factors resulting from the installation of improvements. Improvements can include corrective action to eliminate system faults, changes to service configurations, and power enhancements.

6.4.2 Corrective action to eliminate system faults.

6.4.2.1 The key to influencing an electric utility's voltage sag performance is mutual understanding of measurement and improvement processes. Voltage sags on utility electric systems are created because of faults (short circuits) caused by a variety of events, including lightning, trees contacting power lines, equipment failure, and vehicles striking power poles. In order to reduce the number of voltage sag events, it is important to understand the specific cause of each fault. Semiconductor manufacturers should request that electric utilities share disturbance investigation reports and statistics. If data is not available, or tracking fault causes is not a focus (many utilities track only outage causes) then a fault tracking system should be established.

6.4.2.2 Many times, the initially identified fault cause (for example lightning) has a more specific cause (for example a contaminated insulator), with an even more specific root cause (for example salt contamination on coastal power lines in dry weather seasons). Identifying this root cause helps to establish the appropriate corrective action (for example, improved insulator cleaning practices to include weather considerations on coastal lines). Semiconductor manufacturers and their electric utilities should work together to ensure voltage sag event root cause identification processes exists.

6.4.2.3 Analysis steps for electric utilities to identify the root cause of system faults include the following:

Step 1 Locate the fault and identify what initiated the fault.

Step 2 Investigate the underlying causes of the fault to discover the root cause.

Step 3 Track faults and root causes in a database.

Step 4 Identify corrective actions.

6.4.2.4 Some of the more obvious corrective actions include additional animal guards on exposed electrical devices to reduce the effects from inadvertent touch. Additional patrols and early removal of birds nests, sources of nesting material, reduction in potential roosting and nesting sites, sealing any possible entry to electrical equipment against wildlife intrusion, and designs using larger phase spacing and higher Basic

Impulse Insulation Levels (BIL) are just some of the ways that events can be eliminated.

6.4.3 *Service Configurations*

6.4.3.1 Determine the factors that are fixed for the purposes of improvement development and evaluation. Some examples include, but are not limited to, physical location of site, utility system configuration beyond the immediate vicinity of the site, and electric rate structures.

6.4.3.2 Once the electrical reliability and power quality needs of a semiconductor factory are identified and the reliability and power quality of the electrical network in the area has been characterized, electric utility service configuration can be considered. The electric utility and the semiconductor manufacturer should jointly develop a plan that balances reliability and power quality. This plan should consider the following service configuration options.

6.4.3.3 High voltage service configurations.

6.4.3.3.1 Utility electrical service configurations have a significant effect on the levels of power quality and reliability. Semiconductor manufacturing facilities can typically derive the highest service quality and reliability from electrical service provided at the highest voltage level. By bringing service to the semiconductor factory from the highest available voltage system, semiconductor facilities can eliminate their exposure to electrical disturbances on lower voltage systems. Seldom are disturbances that result from events originating in lower voltage systems transferred into the higher voltage systems to any significant degree. Utility industry studies have indicated approximately 60–75% fewer voltage sag events (below 70% of nominal) on the high voltage systems.

6.4.3.3.2 For plants with loads greater than 10 MW, the highest voltage available is usually service at a voltage between 69 kV and 345 kV. Voltages above this range, while widely used by utilities, are not usually economical to adapt to loads less than 60 MW and may require lengthy regulatory approvals. If new overhead power lines are required, environmental and public issues associated with locating the lines may reduce access to higher voltage lines.

6.4.3.4 Redundancy.

6.4.3.4.1 All on-site facilities and internal factory distribution should have at least N+1 component redundancy. Where N is the number of components required to operate for maximum loading conditions and +1 indicates a single additional component that will operate to maintain the system capability in the event that one of the original components is out-of-service. If the plant is to be operated with no annual shutdowns for maintenance, then the system should be designed with enough redundancy to maintain every component in the plant without dropping service to any load. This requires at least a dual feed system that originates with two or more utility sources and continues throughout the semiconductor factory with appropriate transfer schemes to keep the loads energized at all times and to transfer loads without interruptions.

6.4.3.4.2 The most reliable service is one where there are multiple sources connected in a network to the semiconductor factory. This allows for adequate power supply, even if one of the sources fails. If a network is not available, a dual feed system can be configured to provide an immediate transfer to the backup system in the case of primary source failure, reducing outage time to near zero. Additionally, if the two sources are independent, a static transfer switch may increase quality to a level higher than that of a network. If only one source is available to a semiconductor factory with a load of less than five megawatts, an alternative is on site generation combined with a voltage sag ride-through system.

6.4.3.5 Minimize exposure.

6.4.3.5.1 When choosing source configurations, it is important to consider exposure at the semiconductor factory site. The more line length the factory is connected to, the more exposure there is.

a) It might not be desirable to have three lines serving the plant if one is a long line that is prone to failures. As a rule of thumb, more than three lines connected in a network may reduce quality without adding significantly to reliability.

b) If service is taken from a distribution class circuit, then consider purchasing a so-called express or dedicated feeder from the utility to isolate the plant from neighboring facilities.

c) Review the line routes with the utility and consider changes to reduce exposures, such as: where the poles are vulnerable to being struck by vehicles, or where trees are growing close to the transmission lines.

6.4.4 *Power Enhancements Technologies*

6.4.4.1 All disturbances will not be eliminated from the utility grid. In order to achieve the next step in plant protection, it may be necessary to implement some type of custom power option. Custom power is so called because it is thought to be a custom solution tailored to the needs of the process and the unique situation of the site. Custom power options usually involve some type of power enhancement and conditioning system. These power electronics systems are most often connected between the semiconductor

factory and the electric utility at the point of common coupling (also known as the electrical service point). Many custom power options include some energy storage to ride through the disturbance, but they are usually designed to carry the factory through only momentary interruptions. In fact, for large factories (>10 MW) some available ride-through systems only operate to boost the voltage during sags and will not carry the factory site through even short outages. The trade-off is cost versus protection. The systems should be economically evaluated as well as matched technically to the needs of the site.

6.4.4.2 Electric utility provided custom power options should be balanced against factory system voltage sag immunity covered in industry guide for factory systems voltage sag immunity.

6.5 *Select and Implement Improvements*

6.5.1 Both the electric utility and the semiconductor manufacturer should agree criteria methodology for prioritizing improvements. The following are examples of prioritization criteria.

- Expected frequency of disturbances.
- Impact of fault on electric utility and semiconductor processing.
- Relative cost of system improvement.
- Ability of action to reduce effects.

6.5.2 Select improvement to be implemented, identify the schedules for installation, and define the new system performance expectations.

6.5.3 Implement selected improvements.

6.5.4 With identified fault tracking and root cause analysis processes electric utilities will be in a position to communicate the cause of events, their corrective actions, and the impact of improvements. Results will be both immediate and long-term, but to ensure that the continuous improvement process remains successful, the impacts of improvements should be tracked. The results of this tracking should provide feedback to the continuous improvement process as a whole.

7 Related Documents

7.1 *SEMI Standards*

SEMI F42 — Test Method for Semiconductor Processing Equipment Voltage Sag Immunity

SEMI F47 — Provisional Specification for Semiconductor Processing Equipment Voltage Sag Immunity

SEMI F49 — Guide for Semiconductor Factory Systems Voltage Sag Immunity

SEMI E51 — Guide for Typical Facilities Services and Termination Matrix

7.2 *IEEE Standards*[1]

IEEE 141 — IEEE Recommended Practice for Electric Power Distribution for Industrial Plants

IEEE 446 — IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications

IEEE 493 — IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems

IEEE 1100 — IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment

IEEE 1250 — IEEE Guide for Service to Equipment Sensitive to Momentary Voltage Disturbances

NOTE 3: As listed or revised, all documents cited shall be the latest publications of adopted standards.

RELATED INFORMATION 1
VOLTAGE SAG PERFORMANCE AT SEMICONDUCTOR FACTORY SITES

NOTE: This related information is not an official part of SEMI F50 and was derived from the work of the originating task force. This related information was approved for publication by full letter ballot procedures on December 15, 1999. Determination of the suitability of the material is solely the responsibility of the user.

R1-1 Typical Electric Utility System Performance

R1-1.1 Although most large semiconductor sites are served from dedicated substations, data collected from utility (medium-voltage) distribution circuits can be useful in establishing a baseline for electric utility system performance. As part of the EPRI*[2] Distribution Power Quality (DPQ) study, data was collected for a two-year period from approximately 300 different BMI PQNode monitors. These monitors were located on 100 different feeders at 24 geographically dispersed utilities. The power quality database created in conjunction with this study is probably the most extensive in existence. The data derived from this study provides a statistically based assessment of the level of power quality on electric utility distribution circuits (voltage range from 4.16kV to 34.5kV).

R1-1.2 Almost every category of power quality data was collected in the DPQ study, however, only voltage sag and interruption data is assumed to be pertinent to this activity. In the DPQ study, a voltage sag event was initiated when the rms voltage dropped below 95% of nominal for one cycle (data analysis was performed only for events with magnitudes less than or equal to 90%). An interruption event was initiated when the voltage dropped below 10% of nominal for 120 seconds. Although waveforms were captured for most sag and interruption events, almost all of the data analysis was performed on the basis of minimum voltage magnitude (as a percentage on nominal) and maximum duration during the event.

R1-1.3 *DPQ Key Results*

- The average interruption rate per site, per month was approximately 0.5.
- The average sag rate per site, per month was approximately 4 (10% < V < = 90%).
- The ratio of voltage sags to interruptions was approximately 10:1.
- Almost all voltage sag events have only a single component.
- Most voltage sags had duration of less than 10 cycles.

R1-1.4 The Figure R1-1 represents a summary of the voltage sag and interruption data in a contour format. The contour lines on the graph represent the expected number of disturbance events that are more severe (longer or deeper) than the duration and magnitude grid.

R1-2 Semiconductor Factory Site Disturbance Data

R1-2.1 The DPQ study provides a baseline of the power quality that exists on typical utility distribution systems. However, only one of the semiconductor manufacturing sites from which data was collected is served from a typical utility distribution system. Fourteen of the fifteen semiconductor sites surveyed were served from dedicated substations owned by either the customer or the utility. A comparison between DPQ and semiconductor site data (for large facilities) indicates that application of DPQ data would yield a more restrictive tool tolerance standard. It is recommended, therefore, that data from semiconductor sites be utilized to develop an initial curve and that the curve be validated against DPQ data.

R1-2.2 Voltage sag and interruption data was accumulated for 14 different semiconductor manufacturing sites geographically dispersed throughout the United States. One additional site was located outside of the United States. Data represented in this report was provided by semiconductor manufacturing companies.

R1-2.3 All of the data collected was in the form of magnitude and duration point values. Although the validity of characterizing the electrical system performance is this manner has been questioned, it remains the most common data format for disturbance data.

R1-2.4 The coverage of the disturbance data is typically represented as the product of number of years (or months) monitored and the number of monitors present. In this report, the unit for data coverage is Monitor-Years. One Monitor-Year of data is the quantity of data derived by one monitor for a one-year period. The data for semiconductor sites covers 30.5

2 Electric Power Research Institute, Inc., 3412 Hillview Ave., Palo Alto, CA 94304-1395, USA

Monitor-Years. The minimum coverage for a site was 0.8 Monitor-Years (one monitor for 10 months). The site with the maximum coverage had eight Monitor-Years of data. The average for all sites was approximately 1.9 Monitor-Years.

R1-2.5 Shown below is a scatter graph of all of the 1076 disturbances that were reported. The graph represents the magnitudes and duration for all voltage sags and interruptions at all sites. The magnitude value is the minimum voltage level during the sag represented as a percent of the nominal voltage. Also shown on the graph is the pertinent portion of the Information Technology Industry Council (ITIC) "CBEMA-curve," contained in IEEE Standards 446 and 1100.

R1-2.6 The total number of events on or below the CBEMA curve was 166. Thirteen of the fifteen semiconductor sites averaged at least one event below the CBEMA each year. The average number of events below CBEMA, per site, each year was approximately 5.4. If the semiconductor manufacturers employed the new CBEMA curve for a tolerance standard, most would have experienced a significant number of equipment interruptions.

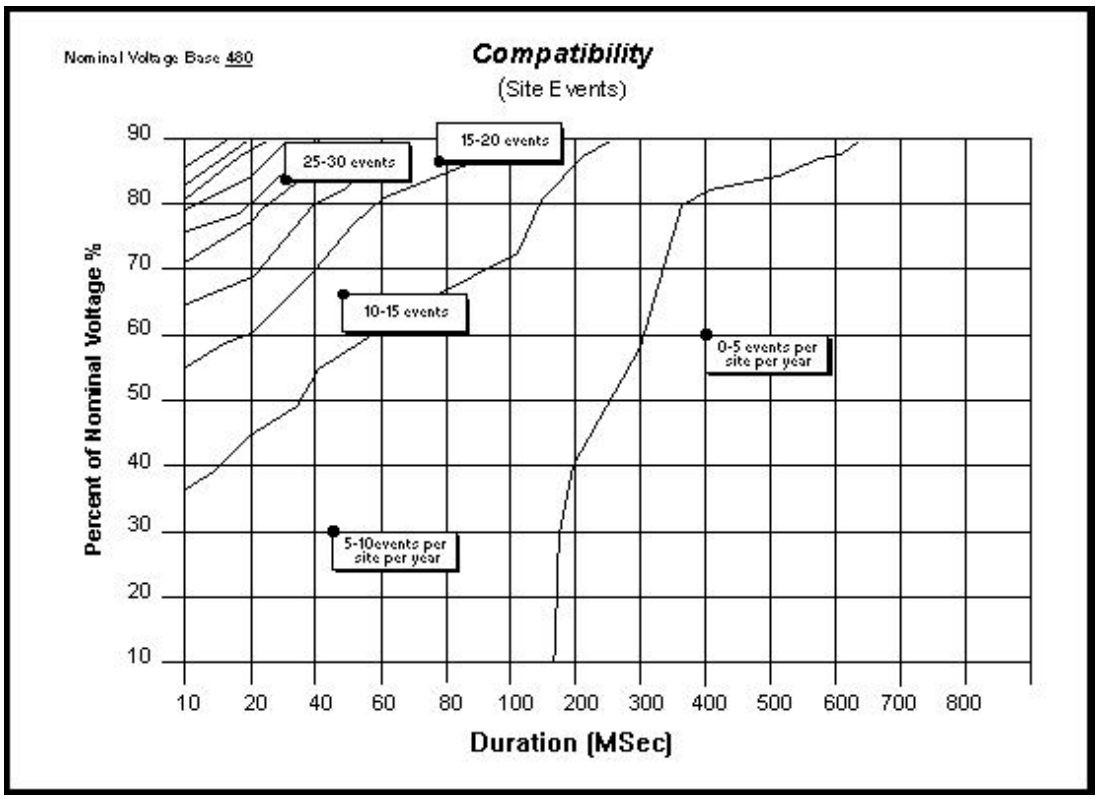

Figure R1-1
Typical Electric Utility System Performance

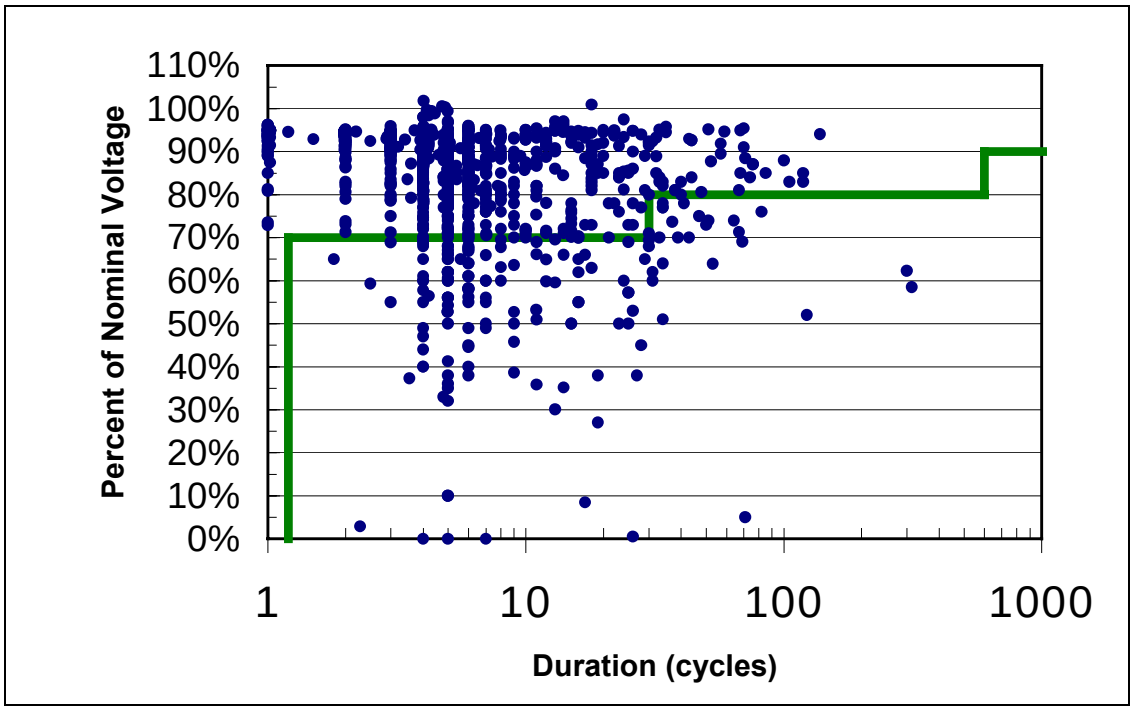

Figure R1-2
Semiconductor Factory Site Disturbance Data

RELATED INFORMATION 2
EXAMPLE OF MEASURED PERFORMANCE DATA REPORTED IN MAGNITUDE AND DURATION BINS

NOTE: This related information is not an official part of SEMI F50 and was derived from the work of the originating task force. This related information was approved for publication by full letter ballot procedures on December 15, 1999. Determination of the suitability of the material is solely the responsibility of the user.

NOTE: This related information section is reprinted from IEEE 1346. The IEEE disclaims any responsibility or liability resulting from the placement and use in the described manner. Information is reprinted with the permission of the IEEE.

R2-1 Excerpt from IEEE 1346 – Annex D Constructing Coordination Charts [3]

R2-1.1 The use of bins to count the number of voltage sag events on a utility service is developed in IEEE 1346[4] as a step within a procedure for developing number of sags per year contour graphs. The bin tables are themselves useful as a tool for comparison of voltage sag performance of electrical systems. The paragraphs and tables below have been included to explain the use of bins in the standardization of historical or predicted events.

R2-1.2 Table R2-1 shows a grid of nine sag magnitude ranges in rows and five sag duration ranges in columns. The combination of nine rows and five columns produce a total of 45 magnitude/duration bins. Each measured or predicted sag will have a magnitude and duration that fits in only one of the 45 bins. The magnitude bin is a range of sag voltages expressed as a percentage of nominal. The time bin is a range of sag durations expressed as seconds. Each sag will have associated with it one magnitude and one time bin. The number in each table entry will correspond to the number of sags that have magnitudes and times in the same bins. Interruptions would go into the lower row of bins according to the duration. The number bins may vary depending on coordination needs for a particular case. However, this selection of 45 bins is reasonably convenient.

R2-1.3 For this example, assume each of the 45 bins contains one sag event. This means there are 45 sags per year and the characteristics of each sag fits in a unique bin. The 15 bins in the lower-right corner have bold italic highlighting to promote understanding as this example continues.

R2-1.4 Table R1-2 shows the cumulative number of sag events that are worse than or equal to each bin from Table R1-1. “Worse than” means the magnitude is lower and the duration is longer. The row and column headings show only single values instead of ranges. For example, there are 15 sags in the 50% magnitude, 0.4s entry of Table R1-2. The bold number 15 in Table R1-2 is the sum of all 15 individual bold entries in Table R1-1. This means 15 sags will have magnitude less than or equal to 50% and duration longer than 0.4s.

3 Reprinted with the permission of The Institute of Electrical and Electronic Engineers, Inc. (IEEE), 445 Hoes Lane, P.O. Box 1331 Piscataway, NJ 08855-1331, USA

4 IEEE 1346 — Recommended Practice for Evaluating Electrical Power and System Compatibility with Electronic Process Equipment.

Table R2-1 Count of Events in Each Bin

	Time Bin in Seconds				
Magnitude Bin	*0.0s < 0.2s*	*0.2s < 0.4s*	*0.4s < 0.6s*	*0.6s < 0.8s*	*>/= 0.8s*
> 80–90%	1	1	1	1	1
> 70–80%	1	1	1	1	1
> 60–70%	1	1	1	1	1
> 50–60%	1	1	1	1	1
> 40–50%	1	1	**1**	**1**	**1**
> 30–40%	1	1	**1**	**1**	**1**
> 20–30%	1	1	**1**	**1**	**1**
> 10–20%	1	1	**1**	**1**	**1**
0–10%	1	1	**1**	**1**	**1**

Table R2-2 Sum of Events Worse Than or Equal to Each Magnitude and Duration

Magnitude			*Time in Seconds*		
% of Nominal Voltage	*0.0s*	*0.2s*	*0.4s*	*0.6s*	*0.8s*
90%	45	36	27	18	9
80%	40	32	24	16	8
70%	35	28	21	14	7
60%	30	24	18	12	6
50%	25	20	**15**	10	5
40%	20	16	12	8	4
30%	15	12	9	6	3
20%	10	8	6	4	2
10%	5	4	3	2	1

SEMI F51-0200
GUIDE FOR ELASTOMETRIC SEALING TECHNOLOGY

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 December 15, 1999. Initially available on www.semi.org February 2000; to be published February 2000.

1 Purpose

1.1 The purpose of this document is to introduce a basic guide for the use of seals in semiconductor fabrication equipment. Also, to introduce the diverse chemical and physical requirements for the many process applications, and to reduce cost of ownership and improve up-time through the use of appropriate sealing materials. It is important that equipment users, suppliers, OEMs, and seal manufacturers use the same terminology and that communication can take place at the same level so that actual performance of the equipment can be discussed.

2 Scope

2.1 This guide is applicable to the use of seals in specific operating environments used in the fabrication of semiconductor devices. The guide will aid in defining the seal parameters for the various process environments. It includes those elastomeric seals that come in contact with process liquids and or gases.

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

3 Limitations

3.1 The application of this guide is limited to elastomeric sealing technology performance as used in semiconductor manufacturing and related process equipment.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI C3 — Specifications for Gases

SEMI D9 — Definitions for Flat Panel Display Substrates

SEMI E45 — Test Method for the Determination of Inorganic Contamination from Minienvironments

SEMI F21 — Classification of Airborne Molecular Contaminant Levels in Clean Environments

SEMI P5 — Specification for Pellicles

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

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *ATM* — Atmospheric

5.1.2 *BCD* — Bulk Chemical Dispensing System

5.1.3 *CVD* — Chemical Vapor Deposition

5.1.4 *DI* — De-ionized

5.1.5 *HDP* — High Density Plasma

5.1.6 *HF* — Hydrofluoric Acid

5.1.7 *LPCVD* — Low Pressure Chemical Vapor Deposition

5.1.8 *MOCVD* — Metal Organic Chemical Vapor Deposition

5.1.9 *OEM* — Original Equipment Manufacturer

5.1.10 *PPB* — Parts per Billion

5.1.11 *PVD* — Physical Vapor Deposition

5.1.12 *RF* — Radio Frequency

5.1.13 *RTP* — Rapid Thermal Process

5.1.14 *T.O.C. (total organic carbons*) — hydrocarbons which can appear in a process from a variety of sources including breakdown of O-ring materials.

5.1.15 *UPDI* — Ultra Pure De-ionized

5.1.16 *UV* — Ultraviolet

5.2 *Definitions*

5.2.1 *acid* — a corrosive material whose chemical reaction characteristic is that of an electron acceptor (SEMI F21, SEMI S4).

5.2.2 *anion* — a negatively charged ion that is attracted to an anode in electrolysis.

5.2.3 *cation* — a positively charged ion; an ion that is attracted to the cathode in electrolysis. These are typically ions of metallic elements.

5.2.4 *chemical/mechanical wear* — injury to the surface of an object or partial obliteration of or altering caused by rubbing, stress or chemical/mechanical use.

5.2.5 *chemical breakdown* — the degradation of a seal as the result of a chemical reaction.

5.2.6 *chemical property* — chemical durability is a measure of corrosion or attack of a glass surface when subjected to a specific reagent, such as acid, base, or water at a specific concentration for a specific time and temperature (SEMI D9).

5.2.7 *chemical reaction* — a process that involves change in the structure of ions or molecules.

5.2.8 *compatibility* — the ability of the molecules of a seal to coexist with process chemistries without the degradation of either.

5.2.9 *corrosives* — a chemical that causes visible destruction of, or irreversible alterations in, living tissue by chemical action at the site of contact. A chemical is considered to be corrosive if, when tested on the intact skin of albino rabbits by the method described in the U.S. Department of Transportation in Appendix A to 49 CFR 173, it destroys or changes irreversibly the structure of the tissue at the site of contact following an exposure period of four hours. This term shall not refer to action on inanimate surfaces (SEMI S4).

5.2.10 *de-ionized water* — (specified with specific resistivity ≥ 18 MΩcm, cations: Na, Fe, Ca ≤ 0.2 µg/l) (SEMI E45).

5.2.11 *degradation* — a chemical reaction leading to the reduction to a simpler molecular structure. See also chemical breakdown.

5.2.12 *ion* — an atom or group of atoms that has lost or gained one or more electrons.

5.2.13 *leachables* — atoms or molecules which escape from the body of a material under vacuum, heat or chemical attack.

5.2.14 *leak rate* — rate at which an environment loses a vacuum (Millitorr litres/second).

5.2.15 *outgassing* — process whereby molecules of air or other gases adhere to the surface of the vacuum vessel or component therein and become liberated under vacuum conditions. Sometimes known as degassing.

5.2.16 *oxidizer gas* — a gas which will support combustion or increase the burning rate of a combustible material with which it may come in contact (SEMI S4).

5.2.17 *particle* — materials which can be distinguished from the film whether on the film surface or embedded in the film (SEMI P5).

5.2.18 *particle generation* — molecules of material generated due to degradation of a material.

5.2.19 *permeation* — the tendency for a gas or liquid to pass through a seal structure by osmosis or diffusion.

5.2.20 *silica* — silicon dioxide, occurring as quartz, etc.

5.2.21 *swell resistance* — the ability of a material to resist increasing its volume when it has been immersed in a liquid or exposed to vapor.

5.2.22 *temperature* — a measure of heat usually expressed in degrees Celsius or Fahrenheit. Temperature values shall be expressed in degrees Celsius (SEMI C3).

5.2.23 *weight loss* — reduction in mass of a sealing compound through the result of a chemical or physical reaction.

5.2.24 *vacuum integrity* — a subjective measure of the efficiency of a vacuum vessel.

6 Related Documents

6.1 *SEMI Standard*

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

SEMI F40 — Practice for Preparing Liquid Chemical Distribution Components for Chemical Testing

6.2 *Other Documents*

Millipore 9th Annual Microelectronics Technical Symposium, May 20, 1991, "Contamination Derived from O-Rings", Robert Matthews[1]

RTP'97 5th International Conference on Advanced Thermal Processing of Semiconductors, "Sealing Technology for the Semiconductor Industry", Dalia Vernikovsky[2]

1 Millipore Corporation, 80 Ashby Road, Bedford, MA, USA, 01730-2271

2 Greene, Tweed & Co., 2157D O'Toole Avenue, San Jose, CA, USA, 95131

7 Considerations for Use in Ultra Pure De-ionized Water (UPDI)

NOTE 2: See Figure 1.

7.1 De-ionized water is used in many wafer processing steps and shall not contribute any contaminants to the processes. The most common sealing requirements in DI water systems are filters, valves, flow and pressure regulators, and fittings.

7.2 Contaminants in DI water fall primarily into three categories. They are ion contamination, T.O.C.'s and bacterial growth. Contaminant levels are usually measured in parts per billion (PPB).

7.3 Ion contamination problems are caused by anionic and cationic elements in DI water such as fluorides, chlorides, sulfates, etc. These can be leached from seals as well as the DI plumbing.

7.4 Cations (mostly metallic ions) are leached from seals as well as the plumbing that delivers the DI water. In order to kill bacteria which have a propensity to grow in DI water, the water is either heated (80°C+), ozonated, or bombarded with UV light, or possibly a combination of these three elements. This poses unique problems for seals used in the DI system and can cause the following problems: Contamination of the DI water caused by T.O.C.'s being leached from the seals and plumbing.

7.5 Seal breakdown caused by ozone attack, or seal deterioration due to UV exposure. T.O.C.'s are of great concern since they can adhere to wafers and result in degraded oxide quality and hazy films. Ozone and UV deterioration of the seals usually leads to particulate contamination. These can be as small as single atoms or molecules to gross particle size contamination.

7.6 Considerations:

- What method of sterilization (i.e., chemical, thermal or radiation)?
- Concerns for cations, anions, or T.O.C.'s?
- Seal life expectation?

8 Considerations for Use in Corrosives (Acids, Bases), Oxidizers, and Solvents

NOTE 3: See Figure 2.

8.1 Inorganic wet chemicals at high concentration levels and in some cases at elevated temperatures are readily used in front-end semiconductor processing in the fabrication of semiconductor devices. Most common sealing requirements are in acid recirculation and chemical distribution systems (mostly BCD's). Component systems include pumps, filters, megasonic seals, gaskets for pipeline interfaces and valves.

8.2 Of primary concern when specifying a specific seal for an application are issues relating to resistance to chemical reaction. Design considerations should include resistance to chemical breakdown, static vs. dynamic environments, pressure, temperature, leachables, particle generation.

8.3 Chemical and Thermal Degradation involves the incompatibility of the seals to the process chemistries. An example is Hydroflouric Acid (HF) dissolves silicone elastomers. The same is true of temperature degradation (i.e., Piranha or Phosphoric Acids) where the process temperature causes thermally and chemically induced effects on the seal. That also contributes to the mechanical failure of the seal.

8.4 Leaching is most commonly associated with metal filler systems of the seal, which usually introduce metallic ions. This is a continuous occurrence as long as the seal is in the system.

8.4.1 *Particles* — Particles can be the result of mechanical damage of the seal or as a result of leaching or chemical degradation or foreign material present on the seal surface. Particles can end up on the wafer and cause defects.

8.4.2 *Summary* — All cases of the above contamination can create electrical shorts, voids, and unwanted doping.

8.4.3 *Solvents* — Incompatibility of elastomers or seals with solvent chemistries may cause contamination.

8.4.3.1 For example, there are degrees of incompatibility:

8.4.3.1.1 If the seal is dissolved by the solvent, then a catastrophic failure occurs where the solvent leaks out of the liquid process loop. This is associated with mis-processed wafers.

8.4.3.1.2 Another type of solvent seal interaction is the swelling of the elastomer or the leaching of small amounts of elastomer. Excessive swelling of the elastomer can result in premature seal failures and a higher cost of ownership caused by increased frequency of seal change outs.

9 Considerations for Use In Thermal Processes

NOTE 4: See Figure 3.

9.1 Diffusion processes are used primarily for growth of oxide layers and to anneal crystal damage caused by implant. Diffusion furnaces are usually batch process equipment where the process atmosphere is constrained within quartz tubes. The seals of these tubes are exposed to temperatures of 250–300°C. This requires

that the seals not only be capable of withstanding these high temperatures but also that they not out-gas or permeate adversely affecting the purity of the process. Also of concern is the possible particle generation caused by the seals as they expand and contract due to temperature cycling (see Section 8.4.1).

9.1.1 Factors include:

- Temperature capability of material and process temperature.
- Static or dynamic state of seal.
- Proper sizing and fit of seal to gland.

10 Considerations for Use in Plasma Systems (Etch, CVD, and PVD)

NOTE 5: See Figure 4.

10.1 Considerations for sealing components for use in plasma applications shall include proximity to plasma, plasma reactor temperature, chemical composition of plasma, plasma energy, and chemical leaching by the plasma.

10.2 Contamination from the inherent seal components and particle generation is directly related to other considerations mentioned above.

10.2.1 Factors include:

- Seal composition and resistance to chemical attack.
- Proximity to source and intensity of RF.
- Temperature capability of material and process temperature.
- Static or dynamic state of seal.
- Proper sizing and fit of seal to gland.

Categories for Consideration

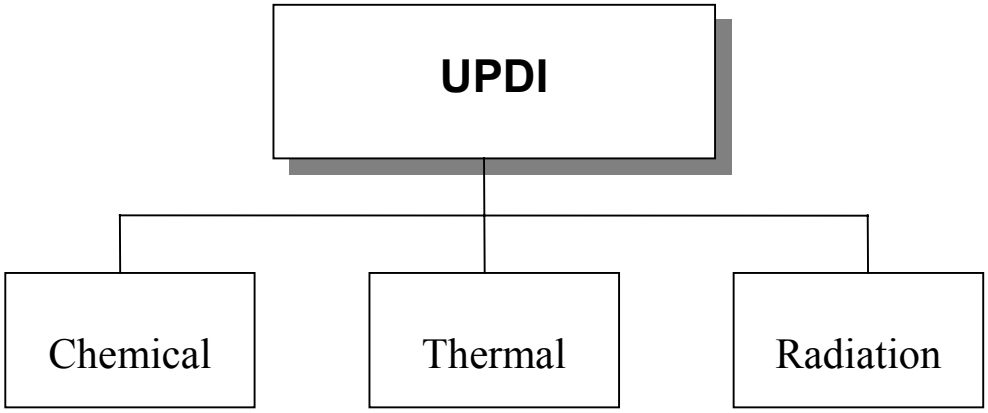

Figure 1
UPDI Chart

Categories for Consideration

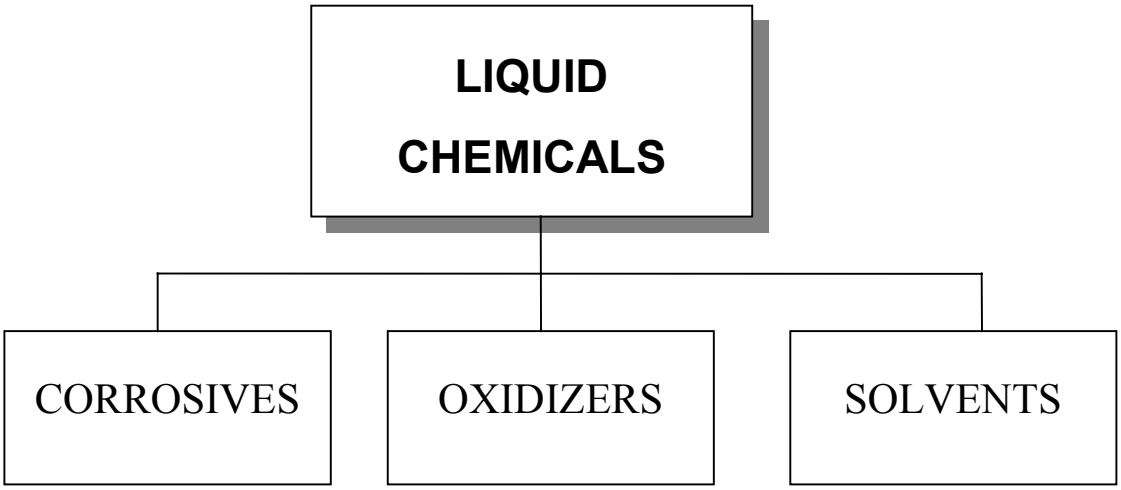

Figure 2
Liquid Chemical Chart

Categories for Consideration

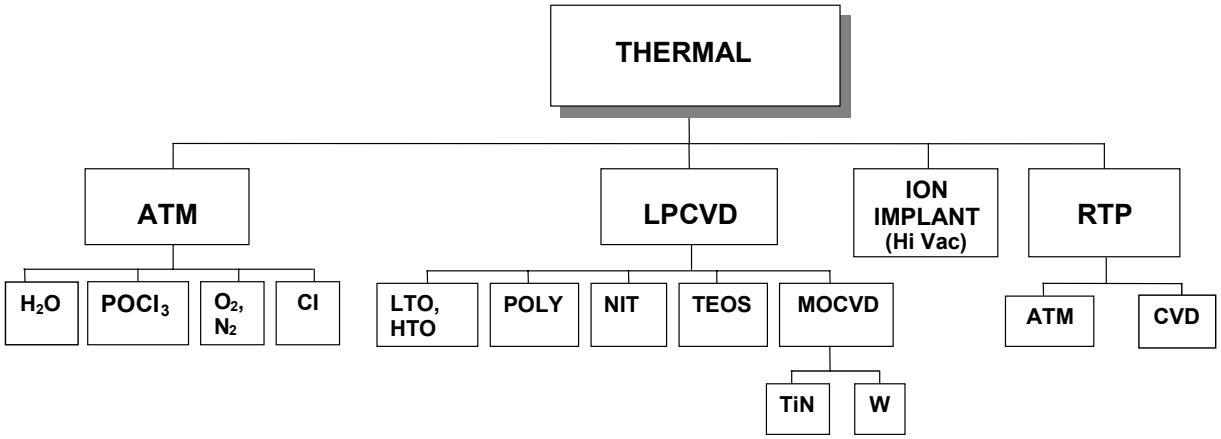

Figure 3
Thermal Chart

Categories for Consideration

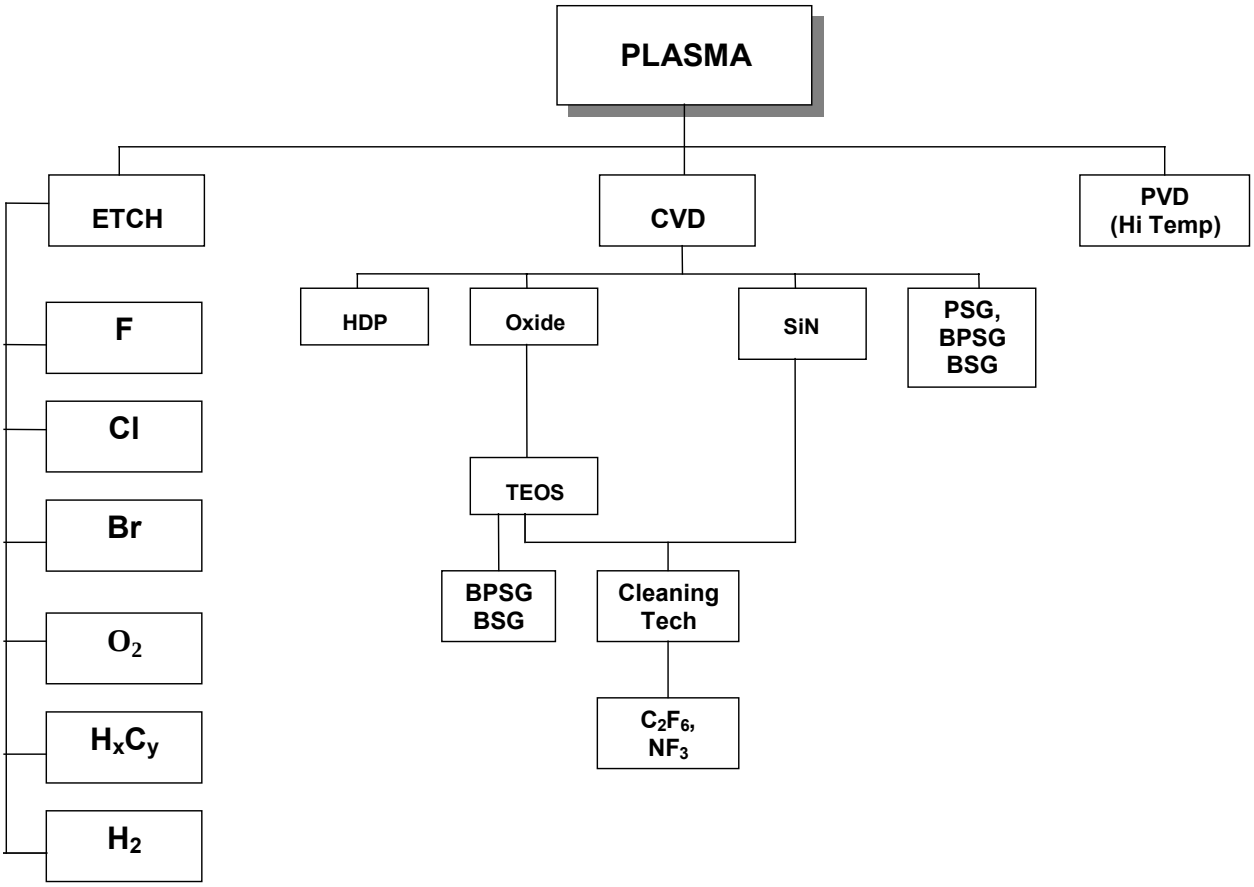

Figure 4
Plasma Chart

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SEMI F52-1101
DIMENSIONAL SPECIFICATION FOR METRIC PFA TUBES FOR LIQUID CHEMICAL DISTRIBUTION IN SEMICONDUCTOR AND FLAT PANEL DISPLAY MANUFACTURING

This specification was technically approved by the Global Liquid Chemical Distribution Systems Committee and is the direct responsibility of the Japanese Liquid Chemical Distribution Systems Committee. Current edition approved by the Japanese Regional Standards Committee on June 19, 2001. Initially available on www.semi.org August 2001; to be published November 2001. Originally published June 2000.

1 Purpose

1.1 This document defines sizes and their measurement methods of metric PFA tubes for liquid chemical distribution in semiconductor and flat panel display manufacturing equipment and facilities.

2 Scope

2.1 This document applies to metric tubes made from PFA.

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

3 Referenced Standards

3.1 *ISO Standards* [1]

ISO 4397 — Fluid Power System and Components – Connectors and Associated Components – Outside Diameters of Tubes and Inside Diameters of Hoses

3.2 *JASO Standards* [2]

JASO F 409-91 — Fittings for Polyamide (Nylon) Tube

JASO M 317-73 — Nylon Tube for Automobile Air Brake Piping

3.3 *JIS Standards* [3]

JIS B 7502 — External Micrometer

JIS B 8381 — Fittings for Flexible Tube Used at Atmospheric Pressure

JIS K 6890 — Tube Made from Tetra-fluoroethylene Resin

3.4 *SAE Standards* [4]

SAE J 844 — Nonmetallic Air Brake System Tubing

SAE J 1394 — Metric Nonmetallic Air Brake System Tubing

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Terminology

4.1 *Abbreviations and Acronyms*

4.1.1 *ID* — Inside Diameter

4.1.2 *ISO* — International Organization for Standardization

4.1.3 *JASO* — Japan Automobile Standard

4.1.4 *JIS* — Japanese Industrial Standard

4.1.5 *OD* — Outside Diameter

4.1.6 *PFA* — Tetrafluoroethylene Perfluoroalkylvinylether Copolymer

4.1.7 *SAE* — Society of Automotive Engineers

4.2 *Definitions*

4.2.1 *dial thickness gauge* — an instrument used to measure wall thickness with a dial meter.

4.2.2 *liquid chemical* — acid, alkali, organic solvent, and pure water used for wet stations; resists and developers used for track system; and other chemicals used for process or maintenance (such as slurry of chemical-mechanical polishing) of equipment or facilities.

4.2.3 *outside diameter tolerance* — allowable deviation of the outside diameter of PFA tube from the specified dimension.

4.2.4 *projector* — an instrument used to measure shape and dimension of an object by optically projecting it at a given magnification. Also referred to as a measuring projector or profile projector.

1 International Organization for Standardization, 1, rue de Varembe, Case postale 56 CH-1211 Geneve.

2 Japanese Automobile Standards Organization / Society of Automotive Engineers of Japan, Goban-cho Center Bldg., 10-2 Goban-cho, Chiyoda-ku, Tokyo 102-0076.

3 Japan Standards Association, 4-1-24 Akasaka, Minato-ku, Tokyo 107-8440.

4 Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

4.2.5 *wall thickness* — thickness of the wall of the PFA tube.

4.2.6 *wall thickness deviation* — deviation of wall thickness.

4.2.7 *wall thickness tolerance* — allowable deviation of actual measurement of wall thickness from its specification.

5 Nominal Size and Dimensional Specification

5.1 A nominal tube size is indicated by "outside diameters/inside diameter". This document provides specifications for eight nominal tube sizes as shown in Table 1.

5.2 The indication of the nominal size for metric PFA tubes is preferably printed on each package for shipping.

Table 1 Tube Size (mm)

OD/ID	25/22	19/16	12/10	10/8	8/6	6/4	4/3	3/2
OD Tolerance	± 0.2	± 0.15	± 0.15	± 0.12	± 0.12	± 0.1	± 0.1	± 0.1
Wall Thickness	1.5	1.5	1.0	1.0	1.0	1.0	0.5	0.5
Wall Thickness Tolerance	± 0.15	± 0.15	± 0.1	± 0.1	± 0.1	± 0.1	± 0.05	± 0.05
Wall Thickness Deviation	0.15	0.15	0.1	0.1	0.1	0.1	0.05	0.05

NOTE 1: The specified sizes should be measured at 23 ± 3°C. The specimen should be kept in the environment for more than 1 hour prior to the measurement.
NOTE 2: Refer to JASO F 409-91 and JASO M 317-73 for outside and inside diameter of 10/8, 8/6 and 6/4 tubes.
NOTE 3: Refer to JIS B 8183 for outside and inside diameter of 8/6 and 6/4 tubes.
NOTE 4: Refer to JIS B 6890 for outside and inside diameter of 12/10, 10/8, 8/6, 6/4, 4/3 and 3/2 tubes.
NOTE 5: Refer to SAE J 844 for outside diameter of 19/16 tube.
NOTE 6: Refer to SAE J 1394 for outside and inside diameter of 8/6 and 6/4 tubes.
NOTE 7: Refer to ISO 4397 for outside diameter of 25/22, 12/10, 10/8, 8/6 and 4/3 tubes.

6 Measurement Procedures

6.1 *Outside Diameter* — Measure the diameters at both ends of tube with a dial thickness gauge at 4 points in 45 degree intervals (see Figure 1). It is calculated with the following formula:

*Outside Diameter = 1/2 * (maximum reading + minimum reading)*

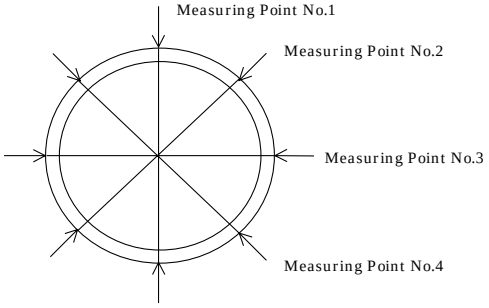

Figure 1
Outside Diameter Measurement

6.2 *Wall Thickness* — Measure the wall thickness at both ends of tube with a dial thickness gauge at 8 points in 45 degree intervals (see Figure 2). If it is not practical to use a dial thickness gauge, prepare a 1 mm long test piece and measure it with a projector. It is calculated with the following formula:

*Wall Thickness = 1/2 * (maximum reading + minimum reading)*

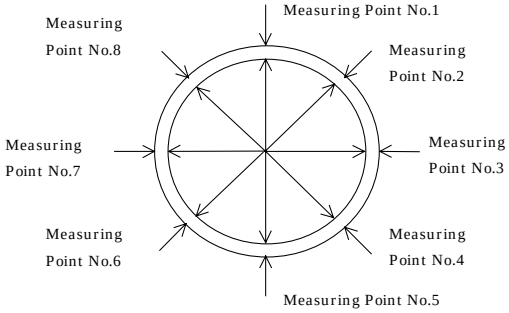

Figure 2
Wall Thickness Measurement

6.3 *Wall Thickness Deviation* — Use maximum and minimum readings of Section 6.2 and calculate the deviation with the following formula:

Wall Thickness Deviation = maximum reading – minimum reading

6.4 Other specifications including surface roughness, deviation from circular form, and physical property values may be determined upon agreement between the supplier and user.

6.5 Refer to JIS B 7502, External Micrometer for a dial thickness gauge.

7 Related Documents

7.1 *SEMI Standards*

SEMI F7 — Test Method to Determine the Tensile Strength of Tube Fitting Connections Made of Fluorocarbon Materials

SEMI F8 — Test Method for Evaluating the Sealing Capabilities of Tube Fitting Connections Made of Fluorocarbon Materials, When Subjected to Tensile Forces

SEMI F9 — Test Method to Determine the Leakage Characteristics of Tube Fitting Connections Made of Fluorocarbon Materials, When Subjected to a Side Load Condition

SEMI F10 — Test Method to Determine the Internal Pressure Required to Produce a Failure of a Tube Fitting Connection Made of Fluorocarbon Materials

SEMI F11 — Test Method to Obtain an Indication of the Thermal Characteristics of Tube Fitting Connections Made of Fluorocarbon Materials

SEMI F12 — Test Method to Determine the Sealing Capabilities of Fittings, Made of Fluorocarbon Materials, after Being Subjected to a Heat Cycle

SEMI F53-0600
TEST METHOD FOR EVALUATING THE ELECTROMAGNETIC SUSCEPTIBILITY OF THERMAL MASS FLOW CONTROLLERS

This test method 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 March 2, 2000. Initially available on www.semi.org April 2000; to be published June 2000.

1 Purpose

1.1 The purpose of this document is to define a structured method for testing and evaluating the electromagnetic susceptibility of thermal mass flow controllers.

2 Scope

2.1 This document contains the requirements and test method that can be used to evaluate whether a thermal mass flow controller will maintain its functional characteristics when subjected to EMI levels typical of the industry. The test method covers both the radiated susceptibility (RS) and conducted susceptibility (CS) of the controller when exposed to EMI. The electromagnetic susceptibility requirements are extracted from MIL-STD-461C and SAMA PMC-33.1, and the test method is a composite of the RS03, CS01, CS02, and CS06 test methods defined in MIL-STD 462.

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

3 Limitations

3.1 This test method is not designed for AC-powered MFCs. The test method addresses electromagnetic susceptibility of MFCs through DC power leads and control signals.

4 Referenced Standards

4.1 *Military Standards* [1]

MIL-STD-461C — Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference

MIL-STD-462 — Measurement of Electromagnetic Interference Characteristics

MIL-STD-463A — Electromagnetic Interference and Electromagnetic Compatibility Technology Definitions and Systems of Units

4.2 *Scientific Apparatus Makers Associations* [2]

SAMA PMC — 33.1 Electromagnetic Susceptibility of Process Control Instrumentation, Scientific Apparatus Makers Associations

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *CS* — conducted susceptibility

5.1.2 *dB* — decibels

5.1.3 *DC* — direct current

5.1.4 *EMC* — electromagnetic compatibility

5.1.5 *EMI* — electromagnetic interference

5.1.6 *GHz* — gigahertz

5.1.7 *kHz* — kilohertz

5.1.8 *MFC* — mass flow controller

5.1.9 *MHz* — megahertz

5.1.10 *MIL-STD* — Military Standard

5.1.11 *psia* — pounds per square inch absolute

5.1.12 *psig* — pounds per square inch gauge

5.1.13 *RF* — radio frequency

5.1.14 *RG-58* — a specification for a particular type of coaxial cable

5.1.15 *rms* — root mean square

5.1.16 *RS* — radiated susceptibility

5.1.17 *T* — teslas

1 Available from Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, PA 19120

2 Portions of this method are excerpted from SAMA Standard PMC 31.1-1980 with permission of the publisher, Process Measurements & Control Section, SAMA, 1101 16th St., N. W. Washington, DC 20036

5.1.18 *V* — volt

5.1.19 *V/m* — volts/meter

5.2 *Definitions*

5.2.1 *conducted susceptibility* — equipment vulnerability to conducted emissions.

5.2.2 *electromagnetic* — all energy of electrical or magnetic nature; i.e., electric current flow or magnetic field.

5.2.3 *electromagnetic compatibility* — the capability of electronic equipment or systems to be operated in the intended operational electromagnetic environment at designed levels of efficiency.

5.2.4 *electromagnetic interference* — impairment of a wanted electromagnetic signal by an electromagnetic disturbance.

5.2.5 *ground* — a conducting connection, whether intentional or accidental, by which an electric circuit or piece of equipment is connected to the earth, or to some conducting body of relatively large extent.

5.2.6 *limit* — the level of susceptibility that a stated standard allows.

5.2.7 *noise (electrical)* — unwanted electrical signals that produce undesirable effects in the circuits of control systems in which they occur.

5.2.8 *radiated susceptibility* — equipment vulnerable to radiated emissions.

5.2.9 *stable* — the state a signal level obtains when its magnitude varies by less than or equal to ± 2.0% of full scale over a one minute period.

6 Summary of Method

6.1 This test method describes the test equipment and procedures for determining if the thermal mass flow controller is susceptible to both radiated and conducted interference. Initially, the controller is exposed to radiated electric fields over a frequency range from 14 kHz to 1 GHz at field strength levels less than 10 volts/meter (V/m). Furthermore, the controller's power leads will be tested for susceptibility to voltage transients with 10 µs rise times. See flow chart of the test method, Figure 1.

7 Interferences

7.1 MFCs are located in areas where electromagnetic (EM) fields are present. If an MFC is susceptible to the fields, then the delivered flow by the MFC could be adversely effected. The magnitude of the EM field's effect on the MFC performance shall be quantified by this test method.

8 Apparatus

8.1 Radiated Electric Field Susceptibility (RS-03)

8.2 Signal Generator, 14 kHz to 1 GHz

8.3 Audio Power Amplifier, 14 kHz to 1 MHz

8.4 RF Power Amplifier #1, 1 MHz to 400 MHz

8.5 RF Power Amplifier #2, 500 MHz to 1 GHz

8.6 Field Strength Meter

8.7 Oscilloscope

8.8 Parallel Element Antenna, 14 kHz to 20 MHz

8.9 Biconical Antenna, 30 MHz to 200 MHz

8.10 Conical Log Spiral Antenna, 300 MHz to one GHz

8.11 Tripod

8.12 Coaxial Cable, 50-ft, RG-58, with BNC male plugs at each end.

8.13 X10 Attenuator Scope Probe

8.14 Assorted Coax Cables for Interconnects

8.15 *Flow Standard* — Installed downstream and in series with the flow through the MFC. The flow standard shall be capable of measuring flow to within ± 0.3% of full scale.

8.16 *Flow Output Monitor* — Connected to the MFC output and signal common/ground points. The monitor/recorder shall be capable of measuring over a range of 0–10 VDC to within ± 5 mV.

8.17 Transient Susceptibility of Power and Control Leads (CS-06) (Conducted Susceptibility)

8.18 Spike Generator, with series and parallel outputs

8.19 Oscilloscope, dual channel

8.20 X10 Attenuator Probe

8.21 X100 Scope Attenuator Probe, two each

8.22 Test Leads, 12-in long with banana plugs at each end, four each

9 Reagents and Materials

9.1 *Test Gas* — Nitrogen with a dew point of less than or equal to -40°C and at a source delivery pressure of 35 psig.

10 Safety Precautions

10.1 *Safety Precautions* — This test method may involve hazardous materials, operations, and equipment.

10.2 The user must have a working knowledge of the respective instrumentation, must practice proper handling of test components, and must understand good laboratory practices. The user should not operate the components in such a manner as to exceed the ratings (i.e., pressure, temperature, flow, and voltage).

10.3 *Technical Precautions* — These tests are to be performed in a shielded or screened room to prevent possible problems with nearby instrumentation or electrical systems caused by the EM fields. At a minimum, the instrumentation associated with this test series (see Figure 2) must be shielded from the EM fields to ensure their proper operation.

11 Preparation of Apparatus

11.1 The test gas source and delivery system must be capable of satisfying the test volume flow rate at a constant pressure, ± 0.1 psia.

11.2 The test gas source and delivery system must be capable of delivering a gas at ambient temperature ± 1°C for the duration of each analysis. The ambient temperature shall be held to 22°C ± 1°C.

12 Calibration and Standardization

12.1 For each test, verify that calibration of test equipment is up-to-date.

13 Procedure

13.1 Install the MFC into the test setup per manufacturer's recommendations.

13.2 Apply power to all devices shown in Figure 3 per manufacturer's specifications. Allow the devices to warm up for the duration specified by the equipment manufacturer.

13.3 Purge the system with nitrogen for a length of time equal to ten times the amount of time it takes to replace the system volume once, when the test MFC is at its full-scale rated flow rate.

13.4 Close inlet shut-off valve. Then close the outlet shut-off valve located adjacent to the MFC (see Figure 2). Adjust the MFC setpoint to zero flow. Wait for the signals to become stable. Record the following on the data sheet:

- MFC indicated flow,
- Flow standard flow,
- Ambient temperature,
- Gas temperature, and
- Gas pressure.

13.5 Ensure that the inlet and outlet shut-off valves adjacent to the MFC (see Figure 2) are open. Adjust the MFC setpoint to 50%. Ensure that all manufacturer's recommended conditions are met for the MFC. Once the output signals become stable, record the MFC output signal, the flow standard output signal, the ambient and gas temperature, and the gas pressure on the data sheet in Table 1.

13.6 Ensure that the MFC power leads and control signal cables are shielded in the area that will be irradiated by the EM fields. The cable shielding shall be intact up to the connector. The type of shielding and connector shall be recorded on the data sheet in Table 1.

13.7 *Radiated Electric Field Susceptibility (RS-03)*

13.7.1 Testing from 14 kHz to 20 MHz:

13.7.1.1 Mount the parallel element antenna on a tripod at a distance of one meter from the controller and connect the antenna to the audio power amplifier using the 50-ft length of RG-58 coaxial cable (see Figure 3). Set the switch to low frequency range.

13.7.1.2 Connect the amplifier input to the signal generator output.

13.7.1.3 Turn on amplifier and signal generator.

13.7.1.4 Using the X10 probe, connect the scope across the antenna terminals.

NOTE 2: It is important to use the X10 probe rather than a coax that terminates in 50 ohms. The audio amplifier will not drive the required voltage into 50 ohms.

13.7.1.5 Set frequency output of the signal generator to 14 kHz.

13.7.1.6 Turn off signal generator modulation and set voltage across the antenna input connector at 35-V rms.

NOTE 3: With this voltage applied to the antenna at frequencies below one MHz, the required field strength of 10 V/m at a distance of one meter from the antenna should be established.

13.7.1.7 If, at any frequency, the required voltage cannot be developed across the antenna terminals, set to the maximum possible without exceeding equipment ratings.

13.7.1.8 When voltage is set, turn on modulation and adjust for 50% amplitude modulation with the internal one kHz source.

13.7.1.9 Check operation of the controller in the presence of this radiated field. Record the MFC indicated flow, flow standard output, and the frequency on the data sheet in Table 1.

13.7.1.10 Before changing frequency as described in Sections 13.7.1.10–13.7.1.15, reduce the voltage amplitude to zero.

13.7.1.11 Set frequency to 20 kHz and repeat Sections 13.7.1.6–13.7.1.9.

13.7.1.12 Set frequency to 50 kHz and repeat Sections 13.7.1.6–13.7.1.9.

13.7.1.13 Set frequency to 100 kHz and repeat Sections 13.7.1.6–13.7.1.9.

13.7.1.14 Set frequency to 200 kHz and repeat Sections 13.7.1.6–13.7.1.9.

13.7.1.15 Set frequency to 500 kHz and repeat Sections 13.7.1.6–13.7.1.9.

13.7.1.16 Set frequency to one MHz and repeat Sections 13.7.1.6–13.7.1.9.

13.7.1.17 Shut down the test equipment. Then remove the audio amplifier and install RF power amplifier #1 in its place.

13.7.1.18 Having exceeded one MHz, turn antenna switch to the high frequency range.

13.7.1.19 Turn on test equipment and resume testing.

13.7.1.20 Set output of the signal generator to two MHz and set field strength to 10 V/m, using field strength meter at the controller location.

NOTE 4: If, at any frequency, the required field cannot be developed, set to the maximum possible without exceeding equipment ratings.

13.7.1.21 When voltage is set, turn on modulation and adjust for 50% amplitude modulation with the internal one kHz source.

13.7.1.22 Check operation of the controller in the presence of this radiated field. Record the MFC indicated flow, the flow standard output, and the frequency on the data sheet.

13.7.1.23 Before changing frequency as described in Sections 13.7.1.23–13.7.1.25 reduce the field amplitude to zero.

13.7.1.24 Set frequency to 5 MHz and repeat Sections 13.7.1.19–13.7.1.22.

13.7.1.25 Set frequency to 10 MHz and repeat Sections 13.7.1.19–13.7.1.22.

13.7.1.26 Set frequency to 20 MHz and repeat Sections 13.7.1.19–13.7.1.22.

13.7.1.27 After testing at fixed frequencies, sweep the signal source from 50 kHz to 20 MHz at an amplitude of about 35 V rms or 10 V/m. If a malfunction occurs during the sweep, stop and go back to that frequency range and try to find the malfunction by testing at single frequencies. Record the MFC indicated flow, the flow standard outputs, and the frequency. If the malfunction cannot be found by testing at single frequencies and only shows up when sweeping, the problem is probably that the signal source has to switch ranges at certain frequencies and during the switching can create strong transient noise. Only the results at single frequencies can be trusted; the sweep is only to locate the problems, not to completely define them.

13.7.1.28 Reduce signal source output to zero and de-energize test equipment.

13.7.1.29 Disconnect and remove parallel element antenna.

13.7.1.30 Testing from 30 MHz to 200 MHz:

13.7.1.31 Mount biconical antenna on the tripod. Test in a sequence similar to that in Sections 13.7.1.1–13.7.1.9.

13.7.1.32 Verify that RF power amplifier #1 is still in place.

13.7.1.33 At a minimum, test at the following frequencies: 30 MHz, 40 MHz, 50 MHz, 60 MHz, 70 MHz, 80 MHz, 90 MHz, 100 MHz, 120 MHz, 140 MHz, 160 MHz, 180 MHz, and 200 MHz.

13.7.1.34 At each frequency, set the field strength to 10 V/m using the field strength meter at the controller location with the antenna in both the vertical and the horizontal positions.

13.7.1.35 Check operation of the controller in the presence of the radiated fields generated. Record the MFC indicated flow, the flow standard outputs, and the frequency on the data sheet.

13.7.1.36 After testing at fixed frequencies, sweep the signal source from 30 MHz to 200 MHz. If a malfunction occurs during the sweep, stop and go back to the faulty frequency range and try to find the malfunction by testing at single frequencies. Record the MFC indicated flow, the flow standard outputs, and the frequency on the data sheet. If the malfunction cannot be found by testing at single frequencies and only shows up when sweeping, the problem is probably that the signal source has to switch ranges at certain frequencies and can create strong transient noise during the switching. Only the results at single frequencies can be trusted; the sweep is only to locate problems, not to completely define them.

13.7.1.37 Reduce signal source output to zero and de-energize test equipment.

13.7.2 Testing from 300 MHz to one GHz:

13.7.2.1 Mount the conical log spiral antenna on the tripod. Test in a sequence similar to that in Sections 13.7.1.1–13.7.1.9.

13.7.2.2 Verify that RF power amplifier #1 is still in place.

13.7.2.3 Test at the following frequencies, using RF power amplifier #1: 300 MHz and 400 MHz. Record the MFC indicated flow, flow standard outputs, and the frequency for each test point on the data sheet.

13.7.2.4 After completion of the test at 400 MHz, reduce amplitude of signal source to zero and shut down test equipment.

13.7.2.5 Disconnect RF power amplifier #1, install RF power amplifier #2, turn on equipment, and resume testing.

13.7.2.6 Test at the following frequencies using RF power amplifier #2: 500 MHz, 600 MHz, 700 MHz, 800 MHz, 900 MHz, and 990 MHz.

13.7.2.7 Check operation of the controller in the presence of the fields generated. Record the MFC indicated flow, the flow standard outputs, and the frequency for each test point on the data sheet.

13.7.2.8 After testing at fixed frequencies, sweep the signal source from 300 MHz to 990 MHz. If a malfunction occurs during the sweep, stop and go back to that frequency range and try to find the malfunction by testing at single frequencies. Record the MFC indicated flow, the flow standard outputs, and the frequency on the data sheet. If the malfunction cannot be found by testing at single frequencies and only shows up when sweeping, the problem is probably that the signal source has to switch ranges at certain frequencies and during the switching can create strong transient noise. Only the results at single frequencies can be trusted; the sweep is only to locate problems, not to completely define them.

13.7.2.9 Reduce signal source output to zero, de-energize test equipment, and disassemble test setup.

13.8 *Transient Susceptibility of Power and Control Leads (CS-06) (Conducted Susceptibility)*

NOTE 5: If any calibration is required during the performance of this procedure, such calibration shall be done in accordance with manufacturers' specifications.

13.8.1 *Spikes on DC Power Lines*

13.8.1.1 Verify that the test equipment and DC power are off before making connections for performing tests on DC-powered equipment.

13.8.1.2 Connect the parallel output of the spike generator between the binding posts as shown in Figure 4.

NOTE 6: The output from the spike generator must be from the *parallel output*. Otherwise, the DC power supply would be shorted by a low DC resistance.

13.8.1.3 The spike is injected across the DC power line to ground, not in series.

13.8.2 Spike on positive DC Lead:

13.8.2.1 Connect spike generator output between positive DC lead and ground and adjust spike generator output control for minimum amplitude.

13.8.2.2 Using the X100 probe, connect one channel on the scope to monitor the amplitude of the spike applied on the positive lead. Put the scope probe ground clip on the green wire safety ground, not on any of the spike generator output terminals.

13.8.2.3 Energize test equipment and observe polarity of low amplitude spikes to determine the polarity of the transient. Connection to the generator output should be such that positive spikes are applied on the positive lead. If the pulses are negative, reverse leads at the generator output.

13.8.2.4 Apply DC power.

13.8.2.5 With the scope synchronized to line voltage and the spike repetition rate set so that the spike will move slowly across the screen, increase spike amplitude to 100% of the voltage rating of the input power or MFC malfunction. Record the MFC indicated flow, the flow standard outputs, and the spike amplitude on the data sheet.

13.8.2.6 If the controller is not initially susceptible below the voltage rating and if the equipment is digital, hold the upper limit condition for five minutes. This condition need only be held momentarily if the controller is analog. Record the MFC indicated flow and flow standard outputs on the data sheet.

13.8.2.7 Reduce spike amplitude control, de-energize test equipment, and turn off DC power before switching spike polarity.

13.8.2.8 Reverse leads at the spike generator output to apply negative spikes to the controller.

13.8.2.9 Energize test equipment.

13.8.2.10 Repeat Sections 13.8.2.4 through 13.8.2.6 with the negative voltage spikes applied to the positive lead. Then go on to Section 13.8.2.11.

13.8.2.11 Reduce spike amplitude to zero, de-energize test equipment, and turn off DC power.

13.8.3 Spike on negative DC Lead:

13.8.3.1 Connect spike generator output between negative DC lead and ground and adjust spike generator output control for minimum amplitude.

13.8.3.2 Using the X100 probe, connect one channel of the scope to the negative lead in order to monitor the amplitude of the spike applied on the negative lead. Put the scope probe ground clip on the green wire safety ground, not on any of the spike generator output terminals.

13.8.3.3 Energize test equipment and observe polarity of low amplitude spikes to determine the polarity of the transient. Connection to the generator output should be such that positive spikes are applied on the negative lead. If pulses are negative, reverse leads at generator output.

13.8.3.4 Repeat Sections 13.8.2.4 through 13.8.2.6 with the positive voltage spikes applied to the negative lead. Then go on to Section 13.8.3.5.

13.8.3.5 Reduce spike amplitude control, de-energize test equipment, and turn off DC power before switching spike polarity.

13.8.3.6 Reverse leads at the spike generator output to apply negative spikes to the controller.

13.8.3.7 Energize test equipment.

13.8.3.8 Repeat Sections 13.8.2.4 through 13.8.2.6 with the negative voltage spikes applied to the negative lead. Then go on to Section 13.8.3.9.

13.8.3.9 Reduce spike amplitude to zero, de-energize test equipment, turn off the DC power, and disconnect equipment from test setup patch panel.

13.8.4 Spike on control (setpoint) signal lead:

13.8.4.1 Connect spike generator output between control signal lead and ground and adjust spike generator output control for minimum amplitude.

13.8.4.2 Using the X100 probe, connect one channel on the scope to monitor the amplitude of the spike applied on the setpoint lead. Put the scope probe ground clip on the green wire safety ground, not on any of the spike generator output terminals.

13.8.4.3 Energize test equipment and observe polarity of low amplitude spikes to determine the polarity of the transient. Connection to the generator output should be such that positive spikes are applied on the setpoint lead. If pulses are negative, reverse leads at generator output.

13.8.4.4 Apply the maximum DC control signal level.

13.8.4.5 Repeat Sections 13.8.2.5 and 13.8.2.6 with the positive voltage spikes applied to the setpoint lead. Then go on to Section 13.8.4.6.

13.8.4.6 Reduce spike amplitude control, de-energize test equipment, and turn off DC power before switching spike polarity.

13.8.4.7 Reverse leads at the spike generator output to apply negative spikes to the controller.

13.8.4.8 Energize test equipment.

13.8.4.9 Apply the maximum DC control signal level.

13.8.4.10 Repeat Sections 13.8.2.5 and 13.8.2.6 with negative voltage spike applied to the setpoint lead.

13.8.4.11 Reduce spike amplitude to zero, de-energize test equipment, turn off the DC power, and disconnect equipment from test setup patch panel.

14 Calculations or Interpretation of Results

14.1 *Calculations*

NOTE 7: Use the data sheet (see Table 1) to record the test data. Then record the calculated values at each data point in Table 2.

14.1.1 Convert MFC indicated flow output data (v) and the flow standard output data to percent of full-scale flow as follows:

MFC Indicated Flow:

Percent of Full-Scale Flow =

$$\frac{\text{Output Data (v)} \times 100}{\text{Full Scale output (v)}}$$

14.1.2 Record on data sheet for each measurement point.

14.1.3 Flow Standard (actual flow)

14.1.3.1 Follow the manufacturer's recommendations for the flow standard output conversion to percent of full scale.

14.1.4 Record on data sheet for each measurement point.

14.1.5 Calculate the zero-corrected percent of full-scale values for both the MFC indicated flow and the flow standard output as follows:

MFC Indicated Flow or Standard Flow = MFC or Flow Standard Value (%FS) at a Data Point – MFC or Flow Standard Value (%FS) at the Zero Flow

14.1.6 Record these values at each data point in Table 2.

14.1.7 Calculate the change in flow for the MFC and flow standard as follows:

Change in Flow (%FS) = MFC Standard Value (%FS) Corrected for Zero – MFC or Flow Standard Value (%FS) Corrected for Zero at Reference Conditions

14.1.7.1 Where reference conditions are defined by 50% FS flow with the EMI source at zero field strength.

14.1.8 Record these values in Table 2.

14.2 *Interpretation of Results*

14.2.1 The changes in flow columns in Table 2 give an indication of the effect of EM susceptibility, both radiated and conducted. If the effect is larger than can be tolerated for the process in the fab, two steps may be necessary. EM field strength and frequency measurements should be made at the fab under normal operating conditions. If EM measurements in the fab match areas that cause unacceptable effects on the MFC, shielding may be necessary to reduce the effect. Shielding design is beyond the scope of this test method.

15 Illustrations

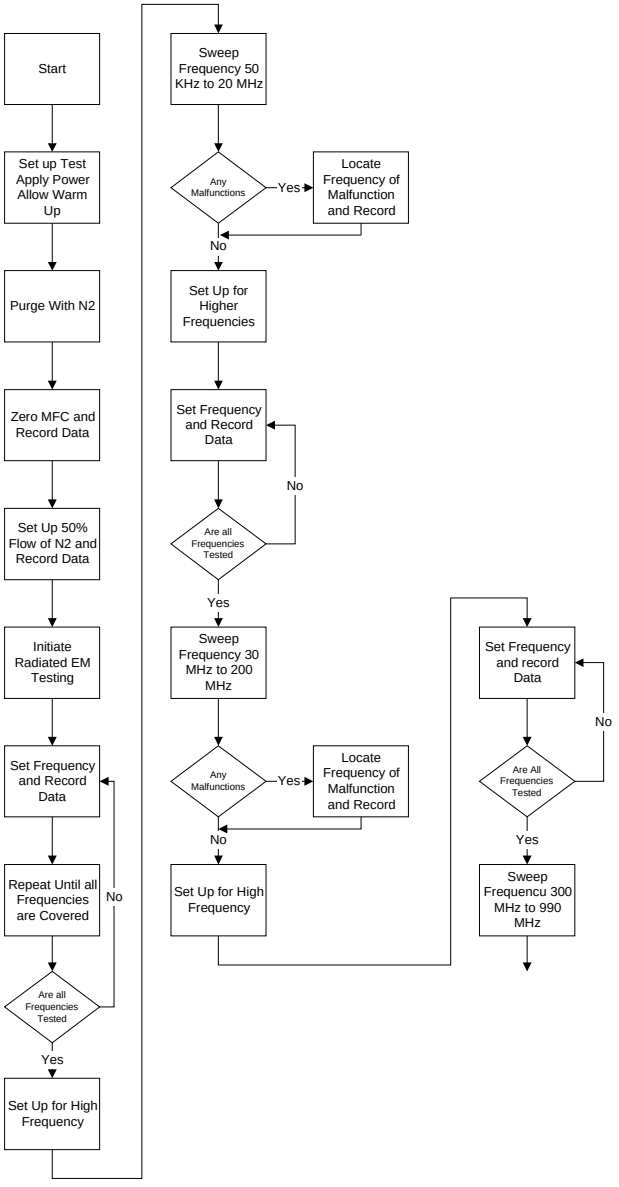

Figure 1
Flow Chart of Test Method