SEMI C53-0704
SPECIFICATIONS FOR DIMETHYL SULFOXIDE (DMSO) [GRADES 1 AND 2]

These specifications were technically approved by the Global Liquid Chemicals Committee and are the direct responsibility of the European Liquid Chemicals Committee. Current edition approved by the European Regional Standards Committee on April 30, 2004. Initially available at www.semi.org June 2004; to be published July 2004. Originally published November 2001; previously published November 2002.

1 Purpose

1.1 The purpose of this document is to standardize requirements for dimethyl sulfoxide used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results.

2 Scope

2.1 The scope of this document is all grades of DMSO used in the semiconductor industry.

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

3 Limitations

3.1 None.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI C1 — Guide for the Analysis of Liquid Chemicals

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

5 Terminology

5.1 None.

6 Physical Property (for information only)

Density (d 20/4)	1.10 g/mL

7 Requirements

7.1 The requirements for dimethyl sulfoxide for grades 1 and 2 are listed in Table 1.

8 Grade 1 and Grade 2 Procedures

8.1 *Assay* — Analyze the sample by gas chromatography (see SEMI C1, Guidelines for Assay by Wide Bore Column Gas Chromatography). The parameters cited have given satisfactory results.

8.1.1 *Column* — 50 meter × 320 micron I.D. fused silica capillary, coated with 5 micron film of OV-1 or equivalent (100% methyl silicone which has been surface bonded and cross linked).

Column Temperature:	135°C isothermal
Injector Temperature:	240°C
Detector Temperature:	280°C
Sample Size:	1 µl
Carrier Gas:	Helium at 1.2 mL/min.
Detector:	Flame ionization
Approximate Retention Times (min):	
Dimethylsulfide	3.8
Dimethylsulfoxide	10.9
Dimethylsulfone	14.1

8.2 *Color* — Using a colorimeter, compare sample in a specific glass tube with flat bottom, graduated at 113 and 250 mm, with a standardized color reference disk CAA (Scale 2.5 to 30 APHA units).

8.3 *Water* — Use a Karl Fischer (KF) coulometer, consisting of a titration beaker, an electrode generator and an electrode indicator with double platinum wire; having as reagents Hydranal Coulomat A solution at the anode and Hydranal Coulomat C solution at the cathode. Add 500 µl of sample, taking care to protect the sample from moisture. Read directly the water content of sample in µg of water.

8.4 *Acidity* — Use a potentiograph with a compound glass electrode and a titration vat with nitrogen inlet. To 100 mL of sample add 5 mL of water, 5 mL of methanol and 2 drops of titan yellow under nitrogen-stream. The titration is performed with N/100 tetrabutylammonium hydroxide (TBAH) in isopropanol. The equivalence point is at about −400 mV. The density (see SEMI C1) of the Dimethyl sulfoxide sample to be titrated must be determined to express the result in (meq/g).

8.5 *Residue after Evaporation* — The residue after evaporation is defined as the relative amount of residue remaining after evaporation of a sample of DMSO followed by heating of the residue: Heat a clean 200 mL beaker at 105°C in an oven for 30 min., cool for 30 min. in a dessicator charged with calcium chloride and weigh. Place 100 g of DMSO into the 200 mL tared beaker. Evaporate the liquid gently, so that boiling does not occur, in a hood protected from any possibility of contamination. When all the sample has evaporated, dry the residue in an oven at 105°C for 30 minutes and cool the beaker for 30 min in a dessicator charged with calcium chloride and reweigh.

8.5.1 Calculate the residue as parts per million (ppm).

8.6 *Trace Metal Determination* — The following method has given satisfactory results in determining trace metal impurities at the value specified for each of the following trace metals: aluminum (Al), antimony (Sb), arsenic (As), barium (Ba), boron (B), cadmium (Cd), calcium (Ca), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), lithium (Li), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), tin (Sn), titanium (Ti), vanadium (V) and zinc (Zn). Alternate methods may be used as long as the method has been validated according to SEMI C1.

8.7 *Special Reagents*

8.7.1 *Water* — The water used for all the dilution, calibration, and standards should meet suggested guidelines for pure water for semiconductor processing.

8.7.2 *Sample Preparation* — In a clean environment, dilute 25 mL of sample by adding 25 mL of water. Prepare reagent blanks.

8.7.3 *Analysis* — Using the prepared sample and reagent blanks, analyze the elements by inductively coupled plasma (ICP). The density (see SEMI C1) of the DMSO sample must be determined to express the result in ppb.

8.7.4 *Notes*

NOTE 1: Each laboratory is responsible for verifying the validity of the method within its own operation.

Table 1 Impurity Limit and Other Requirements for Dimethyl Sulfoxide

	Grade 1	Grade 2
	(specification)	(specification)
Assay (CH_3SOCH_3)	99.8% min.	99.8% min.
$DMSO_2$ ($CH_3SO_2CH_3$)	0.05% max.	0.05% max.
DMS (CH_3SCH_3)	0.05% max.	0.05% max.
Color (APHA)	10 max.	10 max.
Water (H_2O)	0.05% max.	0.05% max.
Acidity	0.0007 meq/g max.	0.0007 meq/g max.
Residue after evaporation (ppm)	50	50
Aluminum (Al)	50 ppb max.	10 ppb max.
Antimony (Sb)	50 ppb max.	10 ppb max.
Arsenic (As)	50 ppb max.	10 ppb max.
Barium (Ba)	50 ppb max.	10 ppb max.
Boron (B)	50 ppb max.	10 ppb max.
Cadmium (Cd)	50 ppb max.	10 ppb max.
Calcium (Ca)	50 ppb max.	10 ppb max.
Chromium (Cr)	50 ppb max.	10 ppb max.
Copper (Cu)	50 ppb max.	10 ppb max.
Iron (Fe)	50 ppb max.	10 ppb max.
Lead (Pb)	50 ppb max.	10 ppb max.
Lithium (Li)	50 ppb max.	10 ppb max.
Magnesium (Mg)	50 ppb max.	10 ppb max.
Manganese (Mn)	50 ppb max.	10 ppb max.
Nickel (Ni)	50 ppb max.	10 ppb max.
Potassium (K)	50 ppb max.	10 ppb max.
Sodium (Na)	50 ppb max.	10 ppb max.
Tin (Sn)	50 ppb max.	10 ppb max.
Titanium (Ti)	50 ppb max.	10 ppb max.
Vanadium (V)	50 ppb max.	10 ppb max.
Zinc (Zn)	50 ppb max.	10 ppb max.

SEMI INTERNATIONAL STANDARDS

SAFETY GUIDELINES

Semiconductor Equipment and Materials International

SEMI S1-0701[E]
SAFETY GUIDELINE FOR EQUIPMENT SAFETY LABELS

This safety guideline was technically approved by the Global Environmental Health and Safety Committee and is the direct responsibility of the North American Environmental Health and Safety Committee. Current edition approved by the North American Regional Standards Committee on April 30, 2001. Initially available at www.semi.org May 2001; to be published July 2001. Originally published in 1986; previously published in 1990.

This document replaces S1-90 in its entirety.

[E] This standard was editorially modified in January 2005 to correct a spelling error. Changes were made to Appendix 2.

1 Purpose

1.1 This guideline provides guidance for the content and format of equipment safety labels and gives examples of symbols to use.

1.2 This guideline is intended for use by equipment manufacturers to create safety labels that alert persons to hazards associated with the equipment.

1.3 This guideline is intended to provide a unified international semiconductor-industry-specific safety labeling format.

2 Scope

2.1 This guideline is intended to assist in developing safety labels for manufacturing equipment used in the semiconductor industry.

NOTE 1: This guideline may also be used for the design of safety signs for the facilities where semiconductor manufacturing equipment is installed.

NOTE 2: The guidance provided in this document may also be adapted to help communicate safety information in installation instructions, operation and maintenance manuals, and other similar written communication relating to a product.

NOTE 3: This guideline may also be adapted for the design of computerized user interfaces on equipment.

NOTE 4: In order to present a more consistent user interface, it is recommended that the use of the words DANGER, WARNING, and CAUTION, in such interfaces be limited to the meanings and uses given for them in this guideline.

2.2 This document contains the following sections:

1. Purpose
2. Scope
3. Limitations
4. Referenced Standards
5. Terminology
6. General Provisions
7. Formats
8. Signal Words
9. Symbols
10. Word Messages
11. Lettering
12. Colors
13. Placement

14. Translation

15. Related Documents

Appendix 1 — Safety Symbols

Appendix 2 — Translations of Signal Words

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

3 Limitations

3.1 Various components or assemblies used in semiconductor manufacturing equipment may carry safety labels that are designed and affixed in accordance with other international standards. It is not the intent of this guideline to replace or supersede such labeling requirements.

3.2 Some safety label formats and content are dictated by other applicable standards and guidelines or by law (e.g., laser labeling and chemical hazard communication labeling in certain countries of use). It is not the intent of this guideline to replace or supersede such labeling requirements.

3.3 New safety labels and safety labels that are significantly redesigned should conform to the latest version of SEMI S1. This guideline is not intended to be applied retroactively.

4 Referenced Standards

NOTE 5: Unless otherwise indicated, all documents cited shall be the latest published versions.

4.1 *SEMI Standards*

SEMI S10 — Safety Guideline for Risk Assessment

4.2 *ANSI Standards*[1]

ANSI Z535.1 — Safety Color Code

ANSI Z535.3 — Criteria for Safety Symbols

ANSI Z535.4 — Product Safety Signs and Labels

4.3 *ISO Standards*[2]

ISO 3864 — Safety Colours and Safety Signs

4.4 *IEC Standards*[3]

IEC 61310-1 — Safety of Machinery - Indication, Marking and Actuation - Part 1: Requirements for Visual, Auditory and Tactile Signals

5 Terminology

5.1 *hazard* — a condition that is a prerequisite to a mishap.

5.2 *mishap* — an unplanned event or series of events that results in death, injury, occupational illness, damage to or loss of equipment or property, or environmental damage.

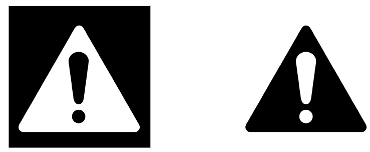
5.3 *panel* — area of a safety label having a distinctive background color which is different from other areas, or which is delineated by a line, border, or margin. See Figures 3 and 4 for examples of panel placement.

5.4 *safety alert symbol* — a specific symbol (see Figure 1) that indicates a potential personal injury hazard.

1 American National Standards Institute, 11 West 42nd Street, New York, New York 10036, USA, http://www.ansi.org

2 International Organization for Standardization, C.P.56, CH-1211 Geneva 20, Switzerland, http://www.iso.ch

3 International Electrotechnical Commission, 1 rue de Varembe, Geneva, Switzerland, http://www.iec.ch



(Left: For DANGER,   Right: For WARNING and CAUTION)

Figure 1
Safety Alert Symbols for Signal Word Panel Use

5.5 *safety label* — a sign, label, or decal that provides safety information.

5.6 *signal word* — the word that calls attention to the safety label and designates a degree or level of hazard seriousness.

5.7 *surround shape* — a geometric configuration that is placed around a symbol and which conveys additional safety information.

5.8 *symbol* — a graphical representation, either abstract or representational, of a hazard, a consequence of engaging a hazard, or a method to avoid a hazard, or some combination of these ideas.

NOTE 6: Some label design standards use the term “pictorial” in the same sense as this guideline uses the term “symbol.”

5.9 *target audience* — the audience to be advised of the hazard.

6 General Provisions

6.1 Safety labels should communicate information about specific hazards. Safety labels should be simple, direct, and understandable by the target audience.

6.2 *Content* — Safety labels should communicate:

6.2.1 the seriousness of the hazard (indicated by the signal word);

6.2.2 the nature of the hazard (e.g., type of hazard) or the probable consequence of engaging the hazard; and

6.2.3 how the hazard can be avoided.

6.3 See Figure 2 for examples of how this information can be communicated on a safety label.

Figure 2
Examples of How Product Safety Labels Communicate Content
(Note that the order and content of the word message is flexible).

6.4 *Identifier* — Safety labels should have a unique identifier (e.g., a part number) printed on the label, to facilitate ordering replacement labels from the equipment manufacturer.

NOTE 7: If a safety label becomes illegible, the user may want to replace it.

6.5 *Durability* — Safety labels should have a reasonable useful life. Determination of reasonable useful life should take into consideration the expected life of the product and the intended environment of use.

NOTE 8: Two factors that may be used for judging useful life are color stability and legibility when viewed at a safe viewing distance. Legibility is affected by letter height.

7 Formats

7.1 Safety labels should consist of at least three panels: signal word panel, word message panel, and symbol panel. Figure 3 provides examples of some possible horizontal and vertical formats incorporating these panels.

EXCEPTION 1: A symbol panel is not necessary for labels that indicate only potential property damage hazards.

EXCEPTION 2: When space limitations exist, such as under guards or on small parts, for safety labels whose target audience is maintenance or service personnel, symbol-only formats with surround shapes (i.e., no signal word, word message, or symbol panels; see Figures 7, 8, and 9) may be used. In this case, borders around the surround shapes should be used. Alternatively, for the same situations, a safety label may be used that has a signal word panel and a word message panel but does not have a symbol panel.

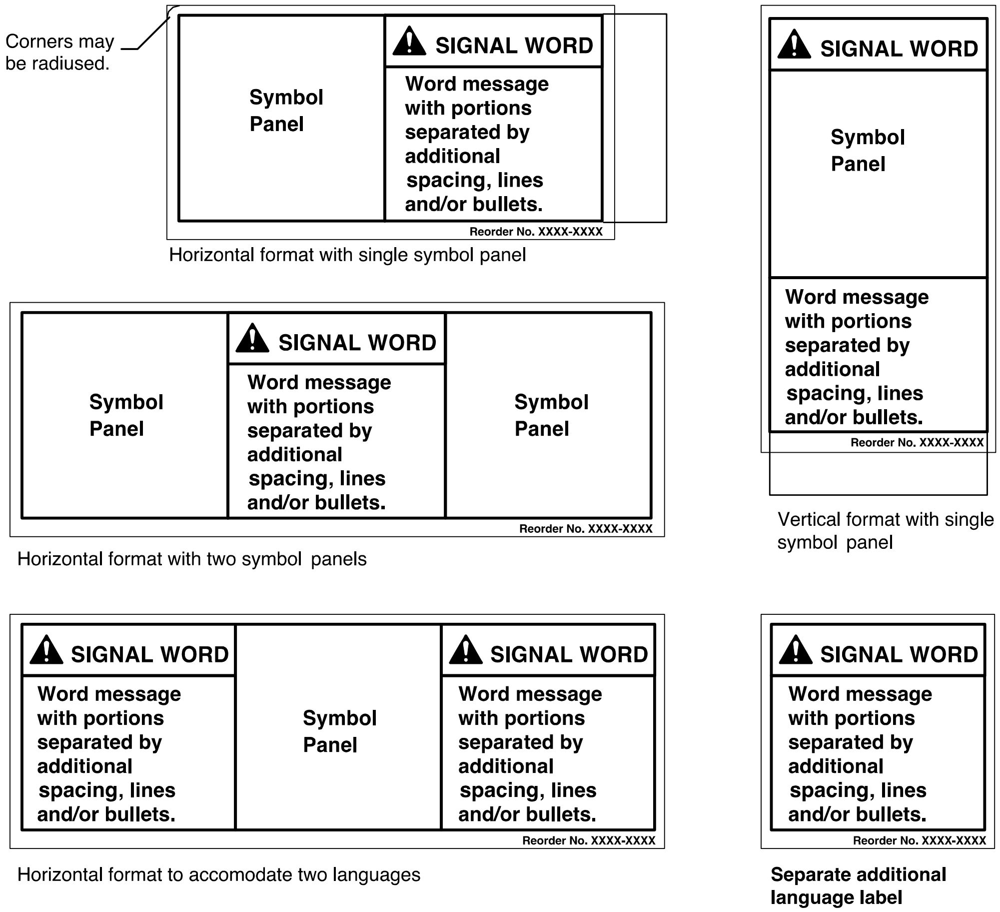


Figure 3
Examples of Format Options for Product Safety Labels

7.2 *Multiple Hazard Formats* — More than one hazard may be conveyed on a single safety label (see Figure 4 for examples).

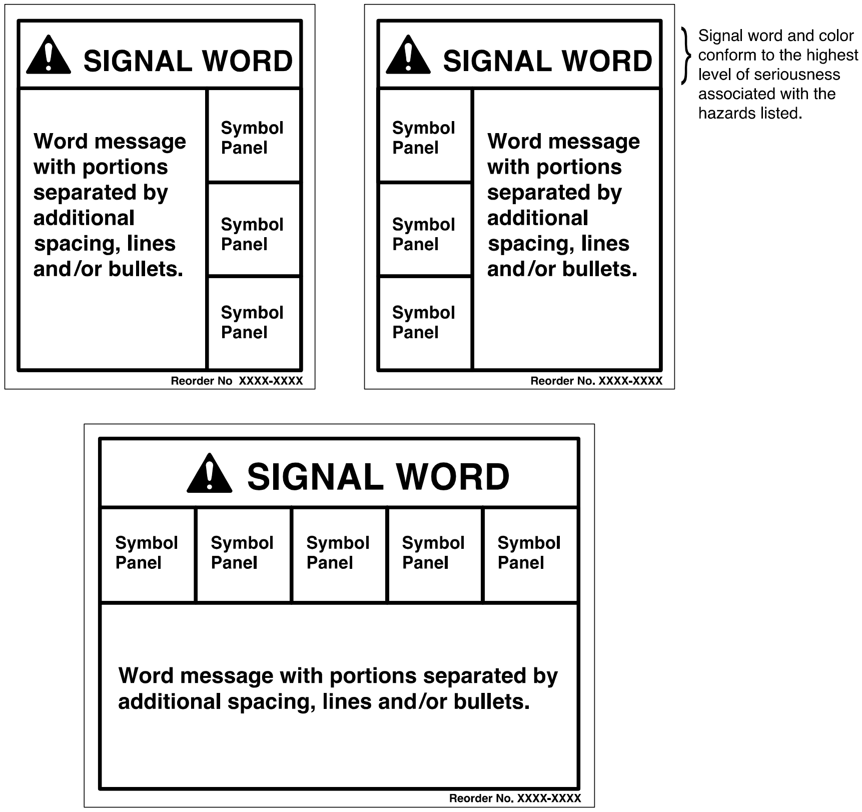


Figure 4
Examples of Multi-Hazard Safety Label Formats

8 Signal Words

8.1 The signal words for safety labels are DANGER, WARNING, and CAUTION.

8.1.1 DANGER is the signal word used to indicate an imminently hazardous situation that, if not avoided, will result in death or severe injury. This signal word is to be limited to the most extreme situations.

8.1.2 WARNING is the signal word used to indicate a potentially hazardous situation which, if not avoided, could result in death or severe injury.

8.1.3 CAUTION is the signal word used to indicate a potentially hazardous situation which, if not avoided, could result in moderate or minor injury. It may also be used to alert against unsafe practices.

NOTE 9: CAUTION without the safety alert symbol may be used as a signal word to indicate a potentially hazardous situation which, if not avoided, could result in property damage.

NOTE 10: SEMI S10 contains examples of ways to categorize severe, moderate, and minor injuries.

8.2 The signal word is placed in the signal word panel.

8.2.1 For DANGER, WARNING, and CAUTION signal words, the safety alert symbol (see Figure 1) is located immediately to the left of and on the same level as the signal word (see Figure 5).

Figure 5
Signal Word Panels

8.2.2 The safety alert symbol should not be used to alert persons to property-damage-only hazards.

8.2.3 When multiple hazard situations are addressed on one safety label, and the hazards are classified at different levels of seriousness, the signal word corresponding to the greatest hazard level should be used.

9 Symbols

9.1 Symbols are graphic representations chosen to convey specific safety messages.

9.2 The symbol panel should contain the safety label's symbol(s).

9.2.1 More than one symbol panel may be used on a safety label.

NOTE 11: See also Section 7.2.

9.2.2 More than one symbol may be used in each symbol panel.

9.3 Symbols may be used to clarify or supplement a portion of a safety label's word message.

NOTE 12: In some cases, symbols may replace the word message. See the exception to Section 10.2.

9.4 A symbol should represent the nature of the hazard, or the potential consequence of engaging the hazard, or actions to be taken to avoid the hazard.

9.5 Symbols should be compatible with the safety label's word message.

NOTE 13: It is preferable to use the symbols shown in Appendix 1.

NOTE 14: For additional information on symbol design, see Annex A of ANSI Z535.3.

9.6 Symbols should be shown in their appropriate surround shape as defined in Section 9.10.

9.7 When an effective symbol does not exist or cannot be created to illustrate the specific hazard or specific avoidance information, the ISO 3864 general warning symbol should be used with a text message that conveys specific information about the hazard (see Figure 6).

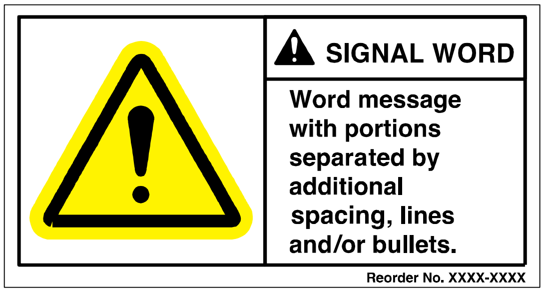


Figure 6
Safety Label with General Warning Symbol

9.8 *Location* — Symbols should be located on safety labels in the areas designated in the examples in Figures 2, 3, and 4, or located in a similar manner. If multiple symbols are used on a multi-hazard safety label, the symbols should appear in the same order as the safety information described in the word message.

EXCEPTION: Location of the safety alert symbol is governed by section 8.2.1.

9.9 *Safety Alert Symbol* — The safety alert symbol is composed of an equilateral triangle surrounding an exclamation mark.

NOTE 15: See Figures 1 and 5 and Section 12.3.4 for format and color information.

9.10 *Symbol Surround Shapes* — Safety symbols should be shown in their appropriate surround shapes (see Figures 7, 8, and 9).

NOTE 16: This is for purposes of international harmonization. The surround shapes have been taken from ISO 3864 and IEC 61310-1.

9.10.1 *Hazard Identification Surround Shape (see Figure 7)* — A symbol located inside a hazard identification surround shape should be used to indicate a personal injury hazard.

9.10.1.1 *Format and Color* — The background color should be yellow. The triangular band should be black. The symbol or pictorial representing the hazard should be black. The border should be yellow; the border is optional if the surrounding background is yellow or white. See Figure 7 for more information.

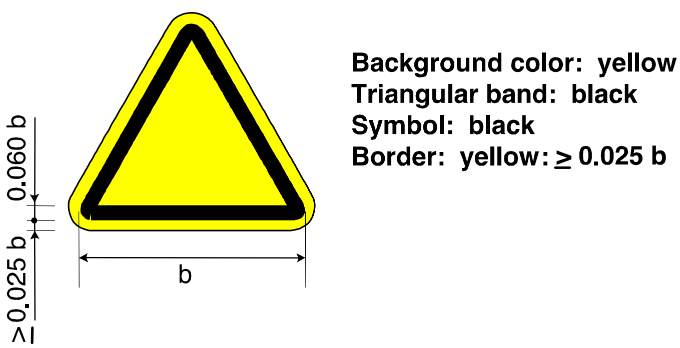


Figure 7
Hazard Identification Symbol Surround Shape

9.10.2 *Prohibition Surround Shape (see Figure 8)* — A symbol located inside a prohibition surround shape should be used to indicate that an action should not be taken or should be stopped.

9.10.2.1 *Format and Color* — The prohibition surround shape should be a circular band with a diagonal bar. The background color should be white. The circular band and diagonal bar should be red. The symbol representing the prohibited action should be black and is preferably shown behind the red slash. The border should be white; the border is optional if the surrounding background is white or yellow. See Figure 8 for more information.

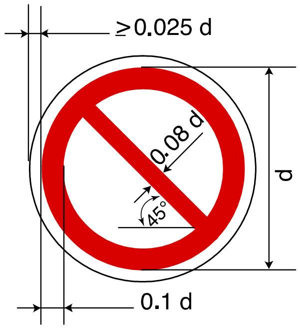


Figure 8
Prohibition Symbol Surround Shape

9.10.3 *Mandatory Action Surround Shape (see Figure 9)* — A symbol located inside a mandatory action surround shape should be used to indicate that an action should be taken to avoid a hazard.

9.10.3.1 *Format and Color* — The background color should be blue. The symbol representing the mandatory action should be white. The border should be white; the border is optional if the surrounding background is white. See Figure 9 for more information.

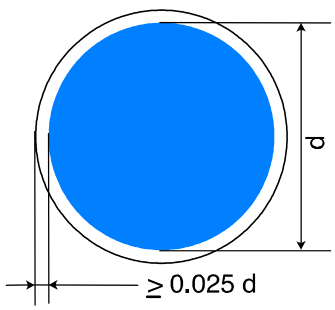


Figure 9
Mandatory Action Symbol Surround Shape

10 Word Message

10.1 The word message is placed in the word message panel.

10.2 The word message preferably contains a description of the hazard, the consequence of engaging the hazard, and how to avoid the hazard. The ordering of this content in the word message is flexible.

EXCEPTION: Parts or all of the word message may be omitted, depending on such factors as whether the message can be inferred from a symbol, other text messages, user training, or the context in which the safety label is used.

10.3 The word message on a safety label should be concise and readily understood.

10.4 Messages on the same safety label that warn of different hazards should be formatted, when feasible, to prevent them from visually blending together. Bullets, lines, and extra line spacing are examples of such formatting.

10.5 When detailed instructions, precautions, or consequences would require a lengthy message, the message may alternatively refer the reader to another source for additional safety information. Examples of such sources include safety instructions, operation and maintenance manuals, service manuals, operating procedures, and safety bulletins.

11 Lettering

11.1 Signal words should be in the lettering style shown in Appendix 2.

11.2 For languages using the "Roman" alphabet, such as the official languages used in the Americas and in much of the European Union, the lettering should be a combination of upper- and lowercase sans serif letters. Uppercase only lettering may be used for short messages or for emphasis of individual words.

NOTE 17: Preferred Roman sans serif lettering styles include those named Arial, Arial Bold, Folio Medium, Franklin Gothic, Helvetica, Helvetica Bold, and Univers.

11.3 Lettering should be of a size that enables a person with normal vision, including corrected vision, to read the safety label at a safe viewing distance from the hazard.

NOTE 18: Related Information 1 provides an example of a method of calculating minimum letter heights.

NOTE 19: The proportions and spacing of individual letters also affect readability.

12 Colors

12.1 *Color Specifications* — Colors should conform to those colors specified in ISO 3864.

NOTE 20: For purposes of reproduction, the closest PANTONE® color match for opaque safety colors is:

- Red – PANTONE 485
- Orange – PANTONE 152
- Yellow – PANTONE 109
- Blue – PANTONE 2945

(PANTONE® is a registered trademark of Pantone, Inc.).

NOTE 21: Perceived color will be different under colored light (e.g., "yellow room") conditions. The committee knows of no current technical solution.

12.2 *Symbol and Surround Shape Color Specifications* — See section 9.10 for symbol and surround shape color criteria.

12.3 *Signal Word Panel* — The three signal words should be colored as follows (see Figure 5):

12.3.1 The word DANGER should be in white letters on a red background.

12.3.2 The word WARNING should be in black letters on an orange background.

12.3.3 The word CAUTION should be in black letters on a yellow background.

12.3.4 *Safety Alert Symbol* — The solid triangle portion should be the same color as the signal word lettering, and the exclamation mark portion should be the same color as the signal word panel background.

12.4 *Optional Use of Red* — The color red may be used in a symbol to indicate heat or fire.

13 Placement

13.1 *Location of Safety Labels* — Safety labels should be permanently attached to the equipment and, when possible, located near the hazard.

13.2 *Safe Viewing Distance* — Safety labels should be placed to allow the viewer enough time to:

- be informed by the safety label; and
- have sufficient time to avoid the hazard or take appropriate evasive action to reduce the potential harm from the hazard.

13.3 *Placement* — Safety labels should be placed so that they are legible, non-distracting, and not hazardous in themselves.

13.4 *Inadvertent Removal, Visual Blockage* — Safety labels should not be located in areas where they may be removed by the motion of equipment or rendered ineffective by situational conditions.

13.4.1 Safety labels should not be blocked from view by moveable panels such as doors, windows, and racks where this would limit the effectiveness of the blocked label.

14 Translation

14.1 This guideline is not intended to suggest that safety labels be written in or translated into any particular language.

NOTE 22: National laws may require that safety label information be provided in one or more particular languages.

15 Related Documents

15.1 *ANSI Standards*[1]

ANSI C95.2 — Radio-Frequency Warning Symbol

ANSI N2.1 — Radiation Symbol

ANSI N12.1 — Fissile Material Symbol

ANSI Z136.1 — Safe Use of Lasers

ANSI Z535.2 — Environmental and Facility Safety Signs

ANSI Z535.5 — Accident Prevention Tags

15.2 *NEMA Standard*[4]

NEMA 77 — Standards for Warning Labels

15.3 *NFPA Standards*[5]

NFPA 70 — National Electrical Code

NFPA 178 — Standard Symbols for Fire Fighting Operations

15.4 *NIST Documents*[6]

NBSIR 80-2003 — Workplace Safety Symbols

NBSIR 80-2088 — The Assessment of Safety Symbol Understandability by Different Testing Methods

NBSIR 82-2485 — Symbols for Industrial Safety

15.5 *United States of America Government Document*[7]

21 CFR Part 1040 — Performance Standards for Light-Emitting Products

15.6 *IEC Standards*[8]

IEC 60825-1 — Safety of Laser Products - Part 1: Equipment Classification, Requirements and User's Guide

15.7 *ISO Standards*[9]

ISO 9186 — Comprehension Testing of Graphical Symbols

4 National Electrical Manufacturers Association, 2101 L Street, N.W., #300, Washington, D.C. 20037, USA, http://www.nema.org

5 National Fire Protection Association, Batterymarch Park, Quincy, MA 02269, USA, http://www.nfpa.org

6 U.S. Department of Commerce, National Institute of Standards and Technology, Center for Building Technology, Washington, D.C., USA, http://www.nist.gov/public_affairs/faqs/qpubs.htm

7 U.S. Government Printing Office, Washington, D.C., USA, http://bookstore.gpo.gov/prf/ordinfo.html

8 International Electrotechnical Commission, 1 rue de Varembe, Geneva, Switzerland, http://www.iec.ch

9 International Organization for Standardization, C.P.56, CH-1211 Geneva 20, Switzerland, http://www.iso.ch

APPENDIX 1
SAFETY SYMBOLS

NOTE: The material in this appendix is an official part of SEMI S1 and was approved by full letter ballot procedures on April 30, 2001 by the North American Regional Standards Committee.

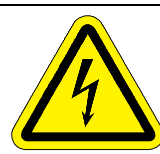
This appendix illustrates symbols used on safety labels for hazards commonly found in the semiconductor manufacturing industry. Additional symbols may need to be developed for other hazards (see *ANSI Z535.3-1998 Informative Annex A* for an example of symbol development guidelines).

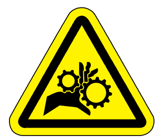
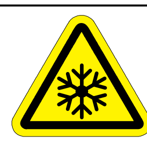
To determine what symbol should be used on a safety label, it is first necessary to determine what message is to be communicated. Symbols may enhance a safety label's meaning and may be useful to communicate across many languages.

When appropriate, the following symbols should be used.

NOTE A1-1: Some symbols (e.g., laser, biohazard, and radiation) are required by law or regulation in some jurisictions.

Table A1-1 Hazard Identification Symbols

#	*Referent*	*Source*	*Symbol*	*Description*
1	**Flammable Material**	**IEC 61310**		Flames
2	**Explosive Material, Explosion Hazard**	**IEC 61310**		Object exploding
3	**Danger: Electricity, Electrical Hazard**	**IEC 61310, ISO 3864**		Lightning bolt
4	**Corrosive Material, Corrosion**	**IEC 61310**		Test tube, hand, drops
5	**Toxic Material, Poison**	**IEC 61310**		Skull and crossbones
6	**Slip Hazard**	**ANSI Z535.3**		Person falling on surface
7	**Trip Hazard**	**ANSI Z535.3**		Person tripping over object

#	*Referent*	*Source*	*Symbol*	*Description*
8	**Drop,** **Fall Hazard**	**IEC 61310**		Person falling
9	**Lifting Hazard,** **Heavy Object**			Person bent over weight, strain flare above back
10	**Tipover**			Person with object tipping over and arrow
11	**Entanglement Hazard** **(hand in gears)**	**ANSI Z535.3**		Hand in gears Note: other body parts or orientations may be substituted as necessary
12	**Pinch point** **(hand in rollers)**	**ANSI Z535.4**		Hand in rollers Note: other body parts or orientations may be substituted as necessary
13	**Cut/Sever** **(hand and sharp object)**	**ANSI Z535.3**		Hand and sharp object Note: other body parts or orientations may be substituted as necessary
14	**Crush Hazard**			Hand between two surfaces, arrow Note: other body parts or orientations may be substituted as necessary
15	**Heat,** **Hot Surface**	**ISO 3864, ISO 7000**		Heat waves
16	**Cold**			Snow flake
17	**Strong Magnetic Field**			Horseshoe magnet

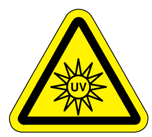
#	*Referent*	*Source*	*Symbol*	*Description*
18	**Radioactive Material, Radiation Hazard**	**IEC 61310**		Abstract three blades
19	**Laser Beam**	**IEC 60825-1**		Radiating sunburst, line
20	**Biological Risk, Biohazard**	**IEC 61310**		Abstraction
21	**Non-Ionizing Radiation, Radio Frequency**	**IEC 61310**		Abstract radiation transmitter
22	**UV Light Hazard**			The letters “UV” inside a sunburst
23	**Inhalation Hazard (e.g., toxic gas, asphyxiation hazard)**			Human figure breathing in particles
24	**General Warning (should be supplemented with words)**	**ISO 3864**		Exclamation point (See Figure 6 for an example of a safety label using the General Warning symbol)

Table A1-2 Mandatory Action Symbols

#	*Referent*	*Source*	*Symbol*	*Description*
1	**Wear Eye Protection**	**IEC 61310**		Head with eyeglasses
2	**Wear Ear Protection**	**IEC 61310**		Head with ear protection

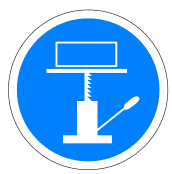
#	*Referent*	*Source*	*Symbol*	*Description*
3	**Wear Head Protection**	**IEC 61310**		Head with hard hat
4	**Wear Respiratory Protection**	**IEC 61310**		Head with respirator
5	**Wear Safety Boots**	**IEC 61310**		Shoes (one with metal plate shown)
6	**Wear Safety Gloves**	**IEC 61310**		Two gloves
7	**Lift with Mechanical Assistance**			Mechanical jack supporting object
8	**Lift with Two Persons**			Two persons grasping object
9	**Read Manual**			Person reading open book
10	**Lock Out in De-Energized State**			ON and OFF symbols next to locked clasp

Table A1-3 Prohibition Symbols

#	*Referent*	*Source*	*Symbol*	*Description*
1	**No Smoking**	**ANSI Z535.3**		Lighted cigarette
2	**No Open Flame**	**IEC 61310**		Lighted match
3	**No Access For Unauthorized Persons**	**IEC 61310**		Person shouting with outstretched hand
4	**No Portable Transmitters**			Wireless telephone
5	**No Pacemakers**			Ball and line attached to heart
6	**General Prohibited Action** **(should be supplemented with words)**	**ISO 3864**		Prohibition surround shape

APPENDIX 2
TRANSLATIONS OF SIGNAL WORDS

NOTE: The material in this appendix is an official part of SEMI S1 and was approved by full letter ballot procedures on April 30, 2001 by the North American Regional Standards Committee.

Translation of the signal words and word message are optional considerations. If the signal word of a safety label is to be translated, the following translations should be used.

Language	DANGER	WARNING	CAUTION
Chinese:	危険	警告	注意
Danish:	FARE	ADVARSEL	FORSIGTIG
Dutch:	GEVAAR	WAARSCHUWING	VOORZICHTIG
English:	DANGER	WARNING	CAUTION
Finnish	VAARA	VAROITUS	HUOMIO
French:	DANGER	AVERTISSEMENT	ATTENTION
German:	GEFAHR	WARNUNG	VORSICHT
Greek:	ΚΙΝΔΥΝΟΣ	ΠΡΟΕΙΔΟΠΟΙΗΑΣΗ	ΠΡΟΣΟΧΗ
Italian:	PERICOLO	AVVERTENZA	ATTENZIONE
Japanese:	危険	警告	注意
Korean:	위험	경고	주의
Norwegian:	FARE	ADVARSEL	FORSIKTIG
Portuguese:	PERIGRO	ATENÇÃO	CUIDADO
Russian:	ОПАСНО	ОСТОРОЖНО	ВНИМАНИЕ
Spanish:	PELIGRO	ADVERTENCIA	ATENCIÓN
Swedish:	FARA	VARNING	OBSERVERA
Turkish:	TEHLİKE	UYARI	DİKKAT

NOTICE:

Paragraphs entitled “NOTE” are not an official part of this safety guideline and are not intended to modify or supersede the official safety guideline. These have been supplied by the committee to enhance the usage of the safety guideline.

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

The user’s attention is called to the possibility that compliance with this guideline may require use of copyrighted material or of an invention covered by patent rights. By publication of this guideline, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this guideline. Users of this guideline 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
MINIMUM LETTER HEIGHT CALCULATIONS

NOTE: This related information is not an official part of SEMI S1 and is not intended to modify or supersede the official guideline. It has been derived from the informative Annex B of ANSI Z535.4-1998. Publication is authorized by vote of the responsible committee. Determination of the suitability of this material is solely the responsibility of the user.

R1-1 A common concern when designing safety labels is determining the minimum letter height of text. This Related Information describes one method that may be used to determine a minimum letter height.

Table R1-1 Examples of Word Message Uppercase Letter Heights at Various Viewing Distances

Viewing Distance	***Minimum** Letter Height for FAVORABLE Reading Conditions*	***Recommended** Letter Height for FAVORABLE Reading Conditions*	***Recommended** Letter Height for UNFAVORABLE Reading Conditions*
300 mm (12 in.) or less*	2 mm (0.08 in)	2 mm (0.08 in)	2 mm (0.08 in)
600 mm (24 in.)	2.5 mm (0.10 in)	4 mm (0.16 in)	4 mm (0.16 in)
900 mm (35 in.)	3 mm (0.12 in)	4.75 mm (0.19 in)	6 mm (0.24 in)
1.2 m (47 in.)	3.5 mm (0.14 in)	5.5 mm (0.22 in)	8 mm (0.31 in)
1.5 m (59 in.)	4 mm (0.16 in)	6.25 mm (0.25 in)	10 mm (0.39 in)
1.8 m (71 in.)	4.5 mm (0.18 in)	7 mm (0.28 in)	12 mm (0.47 in)
2.1 m (83 in.)	5 mm (0.20 in)	7.75 mm (0.31 in)	14 mm (0.55 in)
2.4 m (94 in.)	5.5 mm (0.22 in)	8.5 mm (0.33 in)	16 mm (0.63 in)

* 2 mm (0.079 in.) is the suggested minimum type size for use on safety labels.

Calculations for **Recommended** Letter Heights (in mm) for FAVORABLE Reading Conditions:

600 mm or less: (viewing distance in mm) / 150

>600 mm to 6 m: [(viewing distance in mm **-** 600) x .0025] + 4

Calculation for **Recommended** Letter Heights for UNFAVORABLE Reading Conditions (all distances):

(viewing distance) / 150

NOTICE:

Paragraphs entitled "NOTE" are not an official part of this safety guideline and are not intended to modify or supersede the official safety guideline. These have been supplied by the committee to enhance the usage of the safety guideline.

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

The user's attention is called to the possibility that compliance with this guideline may require use of copyrighted material or of an invention covered by patent rights. By publication of this guideline, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this guideline. Users of this guideline 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 S2-0703a[E]
ENVIRONMENTAL, HEALTH, AND SAFETY GUIDELINE FOR SEMICONDUCTOR MANUFACTURING EQUIPMENT

This safety guideline was technically approved by the Global Environmental, Health, and Safety Committee and is the direct responsibility of the North American Environmental, Health, and Safety Committee. Current edition approved by the North American Regional Standards Committee on April 11, 2003. Initially available on www.semi.org June 2003; to be published July 2003. Originally published in 1991; previously published in March 2003.

[E] This standard was modified in September 2004 to correct editorial errors. Changes were made to Notices preceding Sections 1 and 11.6.

NOTICE: This document contains material that has been balloted and approved by the SEMI Environmental Health and Safety Committee, but is not immediately effective. This material and the date on which it becomes effective are included in Delayed Revisions Sections 1 and 2. The provisions of this information are not an authoritative part of the document until their effective dates. The main body of SEMI S2-0703 remains the authoritative version. Some or all of the provisions of revisions not yet in effect may optionally be applied prior to the effective date, providing they do not conflict with portions of the authoritative version other than those that are to be revised or replaced as part of the deferred change, and are labeled accordingly. Material that is to be replaced by revisions that are not yet in effect is preceded by a NOTICE indicating its status.

1 Purpose

1.1 This safety guideline is intended as a set of performance-based environmental, health, and safety (EHS) considerations for semiconductor manufacturing equipment.

2 Scope

2.1 *Applicability* — This guideline applies to equipment used to manufacture, measure, assemble, and test semiconductor products.

2.2 *Contents* — This document contains the following sections:

1. Purpose
2. Scope
3. Limitations
4. Referenced Standards
5. Terminology
6. Safety Philosophy
7. General Provisions
8. Evaluation Process
9. Documents Provided to User
10. Hazard Warning Labels
11. Safety Interlock Systems
12. Emergency Shutdown
13. Electrical Design
14. Fire Protection
15. Heated Chemical Baths
16. Ergonomics and Human Factors
17. Hazardous Energy Isolation
18. Mechanical Design
19. Seismic Protection
20. Automated Material Handlers
21. Environmental Considerations
22. Exhaust Ventilation
23. Chemicals
24. Ionizing Radiation
25. Non-Ionizing Radiation and Fields
26. Lasers
27. Sound Pressure Level
28. Related Documents

Appendix 1 — Enclosure Openings

Appendix 2 — Design Principles and Test Methods for Evaluating Equipment Exhaust Ventilation

Appendix 3 — Design Guidelines for Equipment Using Liquid Chemicals

Appendix 4 — Ionizing Radiation Test Validation

Appendix 5 — Non-Ionizing Radiation (Other than Laser) and Fields Test Validation

Appendix 6 — Fire Protection: Flowchart for Selecting Materials of Construction

NOTICE: A new Appendix will be added (in numerical order) upon July 1, 2006 publication as shown in Delayed Revisions Section 1. The EH&S Committee has voted that addition of this Appendix section is OPTIONAL before the Effective Date.

2.3 *Precedence of Sectional Requirements* — In the case of conflict between provisions in different sections of this guideline, the section or subsection specifically addressing the technical issue takes precedence over the more general section or subsection.

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

3 Limitations

3.1 This guideline is intended for use by supplier and user as a reference for EHS considerations. It is not intended to be used to verify compliance with local regulatory requirements.

3.2 It is not the philosophy of this guideline to provide all of the detailed EHS design criteria that may be applied to semiconductor manufacturing equipment. This guideline provides industry-specific criteria, and refers to some of the many international codes, regulations, standards, and specifications that should be considered when designing semiconductor manufacturing equipment.

3.3 Existing models and subsystems should continue to meet the provisions of SEMI S2-93A. Models with redesigns that significantly affect the EHS aspects of the equipment should conform to the latest version of SEMI S2. This guideline is not intended to be applied retroactively.

3.4 In many cases, references to standards have been incorporated into this guideline. These references do not imply applicability of the entire standards, but only of the sections referenced.

4 Referenced Standards

NOTICE: New Referenced Standards will be added (in alphabetical or numerical order as appropriate) upon July 1, 2006 publication as shown in Delayed Revisions Section 1. The EH&S Committee has voted that implementation of the information is OPTIONAL before the effective date.

4.1 *SEMI Standards*

SEMI E6 — Facilities Interface Specifications Guideline and Format

SEMI F5 — Guide for Gaseous Effluent Handling

SEMI F14 — Guide for the Design of Gas Source Equipment Enclosures

SEMI F15 — Test Method for Enclosures Using Sulfur Hexafluoride Tracer Gas and Gas Chromatography

SEMI S1 — Safety Guideline for Equipment Safety Labels

SEMI S3 — Safety Guideline for Heated Chemical Baths

SEMI S6 — Safety Guideline for Ventilation

SEMI S7 — Safety Guidelines for Environmental, Safety, and Health (ESH) Evaluation of Semiconductor Manufacturing Equipment

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

SEMI S9 — Safety Guideline for Electrical Design Verification Tests for Semiconductor Manufacturing Equipment

SEMI S10 — Safety Guideline for Risk Assessment

SEMI S12 — Guidelines for Equipment Decontamination

SEMI S13 — Safety Guidelines for Operation and Maintenance Manuals Used with Semiconductor Manufacturing Equipment

SEMI S14 — Safety Guidelines for Fire Risk Assessment and Mitigation for Semiconductor Manufacturing Equipment

4.2 *ANSI Standards*[1]

ANSI/IEEE C95.1 — Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz

ANSI/RIA R15.06 — Industrial Robots and Robot Systems -- Safety Requirements

ANSI/ISA S84.01 — Application of Safety Instrumented Systems for the Process Industry

4.3 *CEN/CENELEC Standards*[2]

1 American National Standards Institute, New York Office: 11 West 42nd Street, New York, NY 10036, USA. Telephone: 212.642.4900; Fax: 212.398.0023 Website: www.ansi.org

2 European Committee for Standardization (CEN)/European Committee for Electrotechnical Standardization (CENELEC), Central Secretariat: rue de Stassart 35, B-1050 Brussels, Belgium

EN 775 — Manipulating industrial robots--Safety

EN 1050 — Safety of Machinery--Risk Assessment

EN 1127-1 — Explosive atmospheres -- Explosion prevention and protection -- Part 1: Basic concepts and methodology

4.4 *DIN Standards*[3]

DIN V VDE 0801 — Principle for Computers in Safety-Related Systems

4.5 *IEC Standards*[4]

IEC 61010-1 — Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Equipment, Part 1: General Requirements

IEC 61508 — Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems

4.6 *ISO Standards*[5]

ISO 10218 — Manipulating industrial robots—Safety

ISO 13849-1 (EN 954-10) — Safety of Machinery - Safety-Related Parts of Control Systems

4.7 *NFPA*[6] *Standards*

NFPA 12 — Standard on Carbon Dioxide Extinguishing Systems

NFPA 13 — Standard for Installation of Sprinkler Systems

NFPA 72 — National Fire Alarm Code

NFPA 497 — Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas

NFPA 704 — Identification of the Fire Hazards of Materials

NFPA 2001 — Standard on Clean Agent Fire Extinguishing Systems

4.8 *Other Standards and Documents*

ACGIH, *Industrial Ventilation Manual*[7]

ASHRAE Standard 110 — Method of Testing Performance of Laboratory Fume Hoods[8]

Burton, D.J., *Semiconductor Exhaust Ventilation Guidebook*[9]

Uniform Building Code™ (UBC) [10]

Uniform Fire Code™[11]

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

5 Terminology

NOTICE: New Acronyms and Definitions will be added in alphabetical order to the Terminology Section upon July 1, 2006 publication as shown in Delayed Revisions Sections 1 and 2. The EH&S Committee has voted that implementation of the information is OPTIONAL before the effective date.

5.1 *Abbreviations and Acronyms*

5.1.1 *ACGIH*® — American Conference of Governmental Industrial Hygienists (ACGIH is a registered trademark of the American Conference of Governmental Industrial Hygienists.)

5.1.2 *ASHRAE* — American Society of Heating, Refrigeration, and Air Conditioning Engineers

5.2 *Definitions*

5.2.1 *abort switch* — a switch that, when activated, interrupts the activation sequence of a fire detection or fire suppression system.

5.2.2 *accredited testing laboratory* — an independent organization dedicated to the testing of components, devices, or systems; competent to perform evaluations based on established safety standards; and recognized by a governmental or regulatory body.

5.2.3 *baseline* — for the purposes of this document, "baseline" refers to operating conditions, including process chemistry, for which the equipment was designed and manufactured.

5.2.4 *breathing zone* — imaginary globe, of 600 mm (two foot) radius, surrounding the head.

3 Available from Deutches Institut für Normung e.V., Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-10787 Berlin, Germany, website: www.din.de

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

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

6 National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269, Website: www.nfpa.org

7 ACGIH, 1330 Kemper Meadow Road, Cincinnati, Ohio 45240, USA, www.acgih.org

8 ASHRAE, 1791 Tullie Circle, NE, Atlanta, Georgia 30329, USA, www.ashrae.org

9 IVE, Inc., 2974 South Oakwood, Bountiful, Utah 84010, USA, www.eburton.com

10 International Conference of Building Officials, 5360 Workman Mill Road, Whittier, California 90601-2298, USA, www.icbo.org

11 International Fire Code Institute, 5360 Workman Mill Road, Whittier, California 90601-2298, USA, www.ifci.org

5.2.5 *capture velocity* — the air velocity that at any point in front of the exhausted hood or at the exhausted hood opening is necessary to overcome opposing air currents and to capture the contaminated air at that point by causing it to flow into the exhausted hood.

5.2.6 *carcinogen* — confirmed or suspected human cancer-causing agent as defined by the International Agency for Research on Cancer (IARC) or other recognized entities.

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

5.2.8 *cleanroom* — a room in which the concentration of airborne particles is controlled to specific limits.

5.2.9 *coefficient of entry (C_e)* — the ratio of actual airflow into the exhausted hood to the theoretical airflow if all hood static pressure could be converted into velocity, as would be the case if the hood entry loss factor (K or F_h) were zero. $C_e = (VP/|SP_h|)^{0.5}$ where VP = duct velocity pressure and SP_h = hood static pressure (see also Appendix 2).

5.2.10 *combustible material* — for the purpose of this guideline, a combustible material is any material that does propagate flame (beyond the ignition zone with or without the continued application of the ignition source) and does not meet the definition in this section for noncombustible material. (See also the definition for *noncombustible material*.)

5.2.11 *equipment* — a specific piece of machinery, apparatus, process module, or device used to execute an operation. The term “equipment” does not apply to any product (e.g., substrates, semiconductors) that may be damaged as a result of equipment failure.

5.2.12 *face velocity* — velocity at the cross-sectional entrance to the exhausted hood.

5.2.13 *facilitization* — the provision of facilities or services.

5.2.14 *fail-safe* — designed so that a failure does not result in an increased risk.

NOTE 1: For example, a fail-safe temperature limiting device would indicate an out-of-control temperature if it were to fail. This might interrupt a process, but would be preferable to the device indicating that the temperature is within the control limits, regardless of the actual temperature, in case of a failure.

5.2.15 *Fail-to-safe equipment control system (FECS)* — A safety-related programmable system of control circuits designed and implemented for safety functions in accordance with recognized standards such as ISO 13849-1 (EN 954-1) or IEC 61508, ANSI SP 84. These systems [e.g. safety Programmable Logic Controller (PLC), safety-related Input and Output (I/O) modules] diagnose internal and external faults and react upon detected faults in a controlled manner in order to bring the equipment to a safe state.

NOTE 2: A FECS is a subsystem to a (PES) Programmable Electronic System as defined in IEC61508 -4 Definitions

NOTE 3: Related Information 14 provides additional information on applications of FECS design.

5.2.16 *failure* — the termination of the ability of an item to perform a required function. Failure is an event, as distinguished from “fault,” which is a state.

5.2.17 *fault* — the state of an item characterized by inability to perform a required function, excluding the inability during preventive maintenance or other planned actions, or due to lack of external resources.

5.2.18 *fault-tolerant* — designed so that a reasonably foreseeable single point failure does not result in an unsafe condition.

5.2.19 *flammable gas* — any gas that forms an ignitable mixture in air at 20 °C (68 °F) and 101.3 kPa (14.7 psia).

5.2.20 *flammable liquid* — a liquid having a flash point below 37.8 °C (100 °F).

5.2.21 *flash point* — the minimum temperature at which a liquid gives off sufficient vapor to form an ignitable mixture with air near the surface of the liquid, or within the test vessel used.

5.2.22 *gas cylinder cabinet* — cabinet used for housing gas cylinders, and connected to gas distribution piping or to equipment using the gas. Synonym: gas cabinet.

5.2.23 *gas panel* — an arrangement of fluid handling components (e.g., valves, filters, mass flow controllers) that regulates the flow of fluids into the process. Synonyms: gas jungle, jungle, gas control valves, valve manifold.

5.2.24 *gas panel enclosure* — an enclosure designed to contain leaks from gas panel(s) within itself. Synonyms: jungle enclosure, gas box, valve manifold box.

5.2.25 *hazard* — a condition that is a prerequisite to a mishap.

5.2.26 *hazardous production material (HPM)* — a solid, liquid, or gas that has a degree-of-hazard rating in health, flammability, or reactivity of class 3 or 4 as ranked by NFPA 704 and which is used directly in research, laboratory, or production processes that have as their end product materials that are not hazardous.

5.2.27 *hazardous voltage* — unless otherwise defined by an appropriate international standard applicable to the equipment, voltages greater than 30 volts rms, 42.4 volts peak, 60 volts dc are defined in this document as hazardous voltage.

NOTE 4: The specified levels are based on normal conditions in a dry location.

5.2.28 *hood* — in the context of Section 22 and Appendix 2 of this guideline, "hood" means a shaped inlet designed to capture contaminated air and conduct it into an exhaust duct system.

5.2.29 *hood entry loss factor (K or F_h)* — a unitless factor that quantifies hood efficiency. If the hood is 100% efficient, then K or F_h = 0. Related equations:

$Q = 4.043A[(SP_h/d)/(1+F_h)]^{0.5}$

where:

Q = volumetric flow rate in m^3/sec,

A = cross sectional area of the duct in m^2,

SP_h = hood static pressure in mm water gauge (w.g.),

and d = density correction factor (unitless).

(US units: $Q = 4005A[(SP_h/d)/(1+F_h)]^{0.5}$

where:

Q = volumetric flow rate in cfm.

A = cross sectional area of the duct in ft^2,

SP_h = hood static pressure in inches water gauge (w.g.),

and d = density correction factor (unitless).)

5.2.30 *incompatible* — as applied to chemicals: in the context of Section 23 of this guideline, describes chemicals that, when combined unintentionally, may react violently or in an uncontrolled manner, releasing energy that may create a hazardous condition.

5.2.31 *intended reaction product* — chemicals that are produced intentionally as a functional part of the semiconductor manufacturing process.

5.2.32 *interlock* — a mechanical, electrical or other type of device or system, the purpose of which is to prevent or interrupt the operation of specified machine elements under specified conditions.

5.2.33 *ionizing radiation* — alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions in human tissue.

5.2.34 *laser* — any device that can be made to produce or amplify electromagnetic radiation in the wavelength range from 180 nm to 1 mm primarily by the process of controlled stimulated emission.

5.2.35 *laser product* — any product or assembly of components that constitutes, incorporates, or is intended to incorporate a laser or laser system (including laser diode), and that is not sold to another manufacturer for use as a component (or replacement for such component) of an electronic product.

5.2.36 *laser source* — any device intended for use in conjunction with a laser to supply energy for the excitation of electrons, ions, or molecules. General energy sources, such as electrical supply mains, should not be considered to be laser energy sources.

5.2.37 *laser system* — a laser in combination with an appropriate laser energy source, with or without additional incorporated components.

5.2.38 *likelihood* — the expected frequency with which a mishap will occur. Usually expressed as a rate (e.g., events per year, per product, or per substrate processed).

5.2.39 *local exhaust ventilation* — local exhaust ventilation systems operate on the principle of capturing a contaminant at or near its source and moving the contaminant to the external environment, usually through an air cleaning or a destructive device. It is not to be confused with laminar flow ventilation. Synonyms: LEV, local exhaust, main exhaust, extraction system, module exhaust, individual exhaust.

5.2.40 *lower explosive limit* — the minimum concentration of vapor in air at which propagation of flame will occur in the presence of an ignition source. Synonyms: LEL, lower flammability limit (LFL).

5.2.41 *maintenance* — planned or unplanned activities intended to keep equipment in good working order. (See also the definition for *service.*)

5.2.42 *mass balance* — a qualitative, and where possible, quantitative, specification of mass flow of input and output streams (including chemicals, gases, water, deionized water, compressed air, nitrogen, and by-products), in sufficient detail to determine the effluent characteristics and potential treatment options.

5.2.43 *material safety data sheet (MSDS)* — written or printed material concerning chemical elements and compounds, including hazardous materials, prepared in accordance with applicable standards.

NOTE 5: Examples of such standards are USA government regulation 29 CFR 1910.1200, and Canadian WHMIS (Workplace Hazardous Material Information System).

5.2.44 *mishap* — an unplanned event or series of events that results in death, injury, occupational illness, damage to or loss of equipment or property, or environmental damage.

NOTE 6: For the purpose of this guideline, a “series of events” is limited to those events resulting from a single point failure. See also Section 6.5.

5.2.45 *noncombustible material* — a material that, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat. Typical noncombustible materials are metals, ceramics, and silica materials (e.g., glass and quartz). (See also the definition for *combustible material*.)

5.2.46 *non-ionizing radiation* — forms of electromagnetic energy that do not possess sufficient energy to ionize human tissue by means of the interaction of a single photon of any given frequency with human tissue. Non-ionizing radiation is customarily identified by frequencies from zero hertz to 3×10^{15} hertz (wavelengths ranging from infinite to 100 nm). This includes: static fields (frequencies of 0 hertz and infinite wavelengths); extremely low frequency fields (ELF), which includes power frequencies; subradiofrequencies; radiofrequency/microwave energy; and infrared, visible, and ultraviolet energies.

5.2.47 *non-recycling, deadman-type abort switch* — a type of abort switch that must be constantly held closed for the abort of the fire detection or suppression system. In addition, it does not restart or interrupt any time delay sequence for the detection or suppression system when it is activated.

5.2.48 *occupational exposure limits (OELs)* — for the purpose of this document, OELs are generally established on the basis of an eight hour workday. Various terms are used to refer to OELs, such as permissible exposure levels, Threshold Limit Values®, maximum acceptable concentrations, maximum exposure limits, and occupational exposure standards. However, the criteria used in determining OELs can differ among the various countries that have established values. Refer to the national bodies responsible for the establishment of OELs. (Threshold Limit Value is a registered trademark of the American Conference of Governmental Industrial Hygienists.)

5.2.49 *operator* — a person who interacts with the equipment only to the degree necessary for the equipment to perform its intended function.

5.2.50 *parts-cleaning hood* — exhausted hood used for the purpose of cleaning parts or equipment. Synonym: equipment cleaning hood.

5.2.51 *positive-opening* — as applied to electromechanical control devices. The achievement of contact separation as a direct result of a specified movement of the switch actuator through non-resilient members (i.e., contact separation is not dependent upon springs).

5.2.52 *potentially hazardous non-ionizing radiation emissions* — for the purposes of this guideline, non-ionizing radiation emissions outside the limits shown in Appendix 5 are considered potentially hazardous.

5.2.53 *pyrophoric material* — a chemical that will spontaneously ignite in air at or below a temperature of 54.4°C (130°F).

5.2.54 *radio frequency (rf)* — electromagnetic energy with frequencies ranging from 3 kHz to 300 GHz. Microwaves are a portion of rf extending from 300 MHz to 300 GHz.

5.2.55 *readily accessible* — capable of being reached quickly for operation or inspection, without requiring climbing over or removing obstacles, or using portable ladders, chairs, etc.

5.2.56 *recognized* — as applied to standards; agreed to, accepted, and practiced by a substantial international consensus.

5.2.57 *rem* — unit of dose equivalent. Most instruments used to measure ionizing radiation read in dose equivalent (rems or sieverts). 1 rem = 0.01 sievert.

5.2.58 *reproductive toxicants* — chemicals that are confirmed or suspected to cause statistically significant increased risk for teratogenicity, developmental effects, or adverse effects on embryo viability or on male or female reproductive function at doses that are not considered otherwise maternally or paternally toxic.

5.2.59 *residual* — as applied to risks or hazards: that which remains after engineering, administrative, and work practice controls have been implemented.

5.2.60 *risk* — the expected losses from a mishap, expressed in terms of severity and likelihood.

5.2.61 *safe shutdown condition* — a condition in which all hazardous energy sources are removed or suitably contained and hazardous production materials are removed or contained, unless this results in additional hazardous conditions.

5.2.62 *safety critical part* — discrete device or component, such as used in a power or safety circuit, whose proper operation is necessary to the safe performance of the system or circuit.

5.2.63 *service* — unplanned activities intended to return equipment that has failed to good working order. (See also the definition for *maintenance.*)

5.2.64 *severity* — the extent of the worst credible loss from a mishap caused by a specific hazard.

5.2.65 *sievert (Sv)* — unit of dose equivalent. Most instruments used to measure ionizing radiation read in dose equivalent (rems or sieverts). 1 Sv = 100 rems.

5.2.66 *standard temperature and pressure* — for ventilation measurements, either dry air at 21°C (70°F) and 760 mm (29.92 inches) Hg, or air at 50% relative humidity, 20°C (68°F), and 760 mm (29.92 inches) Hg.

5.2.67 *supervisory alarm* — as applied to fire detection or suppression systems; an alarm indicating a supervisory condition.

5.2.68 *supervisory condition* — as applied to fire detection or suppression systems; condition in which action or maintenance is needed to restore or continue proper function.

5.2.69 *supplemental exhaust* — local exhaust ventilation that is used intermittently for a specific task of finite duration.

5.2.70 *supplier* — party that provides equipment to, and directly communicates with, the user. A supplier may be a manufacturer, an equipment distributor, or an equipment representative. (See also the definition for *user*.)

5.2.71 *testing* — the term "testing" is used to describe measurements or observations used to validate and document conformance to designated criteria.

5.2.72 *trouble alarm* — as applied to fire detection or suppression systems; an alarm indicating a trouble condition.

5.2.73 *trouble condition* — as applied to fire detection or suppression systems; a condition in which there is a fault in a system, subsystem, or component that may interfere with proper function.

5.2.74 *user* — party that acquires equipment for the purpose of using it to manufacture semiconductors. (See also the definition for *supplier*.)

5.2.75 *velocity pressure (VP)* — the pressure required to accelerate air from zero velocity to some velocity V. Velocity pressure is proportional to the kinetic energy of the air stream. Associated equation:

$VP = (V/4.043)^2$, where V = air velocity in m/s, and VP = velocity pressure in mm water gauge (w.g.).

[U.S. units: $VP = (V/4005)^2$, where

V = velocity in feet per second, and

VP = velocity pressure in inches water gauge (w.g.)]

5.2.76 *volumetric flow rate (Q)* — in the context of Section 22 and Appendix 2 of this guideline, Q = the volume of air exhausted per unit time. Associated equation: Q = VA, where V = air flow velocity, and A = the cross-sectional area of the duct or opening through which the air is flowing at standard conditions.

5.2.77 *wet station* — open surface tanks, enclosed in a housing, containing chemical materials used in the manufacturing of semiconductor materials. Synonyms: wet sink, wet bench, wet deck.

6 Safety Philosophy

6.1 A primary objective of the industry is to eliminate or control hazards during the equipment's life cycle (i.e., the installation, operation, maintenance, service, and disposal of equipment).

6.2 The assumption is made that operators, maintenance personnel, and service personnel are trained in the tasks that they are intended to perform.

6.3 The following should be considered in the design and construction of equipment:

- regulatory requirements;
- industry standards;
- this guideline; and
- good engineering and manufacturing practices.

6.4 This guideline should be applied during the design, construction, and evaluation of semiconductor equipment, in order to reduce the expense and disruptive effects of redesign and retrofit.

NOTICE: Section 6.5 below will be withdrawn upon July 1, 2006 publication and replaced by the new Section 6.5 including: figures and tables as shown in Delayed Revisions Section 2. The EH&S Committee has voted that implementation of the information is OPTIONAL before the effective date.

6.5 No reasonably foreseeable single-point failure condition or operational error should allow exposure of personnel, facilities, or the community to hazards that could result in death, significant injury, or significant equipment damage.

NOTE 7: The intent is to control single fault conditions that result in significant risks (i.e., Critical, High, or Medium risks based on the example risk assessment matrix in SEMI S10).

6.6 Equipment safety features should be fail-safe or of a fault-tolerant design and construction.

6.7 Components and assemblies should be used in accordance with their manufacturers' ratings and specifications, where using them outside the ratings would create a safety hazard.

6.8 A hazard analysis should be performed to identify and evaluate hazards. The hazard analysis should be initiated early in the design phase, and updated as the design matures.

NOTICE: Section 6.8.1 below will be withdrawn upon July 1, 2006 publication and replaced by the new Section 6.8.1 including: figures and tables as shown in Delayed Revisions Section 2. The EH&S Committee has voted that implementation of the information is OPTIONAL before the effective date.

6.8.1 The hazard analysis should include consideration of:

- the application or process;
- the hazards associated with each task;
- anticipated failure modes;
- the probability of occurrence and severity of a mishap;
- the level of expertise of exposed personnel and the frequency of exposure;
- the frequency and complexity of operating, servicing and maintenance tasks; and
- safety critical parts.

NOTE 8: EN 1050 contains examples of hazard analysis methods.

6.8.2 The risks associated with hazards should be characterized using SEMI S10.

6.9 The order of precedence for resolving identified hazards should be as follows:

6.9.1 *Design to Eliminate Hazards* — From the initial concept phase, the supplier should design to eliminate hazards.

NOTE 9: It is recommended that the supplier continue to work to eliminate identified hazards.

6.9.2 *Incorporate Safety Devices* — If identified hazards cannot be eliminated or their associated risk adequately controlled through design selection, then the risk should be reduced through fixed, automatic, or other protective safety design features or devices.

NOTE 10: It is recommended that provisions be made for periodic functional checks of safety devices, when applicable.

6.9.3 *Provide Warning Devices* — If design or safety devices cannot effectively eliminate identified hazards or adequately reduce associated risk, a means should be used to detect the hazardous condition and to produce a warning signal to alert personnel of the hazard.

6.9.4 *Provide Hazard Warning Labels* — Where it is impractical to eliminate hazards through design selection or adequately reduce the associated risk with safety or warning devices, hazard warning labels should be provided. See Section 10 for label information.

6.9.5 *Develop Administrative Procedures and Training* — Where hazards are not eliminated through design selection or adequately controlled with safety or warning devices or warning labels, procedures and training should be used. Procedures may include the use of personal protective equipment.

6.9.6 A combination of these approaches may be needed.

7 General Provisions

7.1 This guideline should be incorporated by reference in equipment purchase specifications. The user and supplier should agree on deviations from this guideline. The intent is for the user to purchase equipment conforming with SEMI S2, not to design the equipment.

7.2 The equipment must comply with laws and regulations that are in effect at the location of use. All equipment requiring certification or approval by government agencies must have this certification or approval as required by regulations.

NOTE 11: It is recommended that the supplier request from the user information regarding local laws and regulations.

7.3 The manufacturer should maintain an equipment/product safety program to identify and eliminate hazards or control risks in accordance with the order of precedence (see Section 6.9).

7.3.1 The supplier should provide the user's designated representative with bulletins that describe safety related upgrades or newly identified significant hazards associated with the equipment. This should be done on an ongoing basis as needed.

7.4 Model-specific tools and accessories necessary to operate, maintain, and service equipment safely should be provided with the equipment or specified by the supplier.

NOTE 12: The official values in this guideline are expressed in The International System of Units (SI). Values that:

- are expressed in Inch-Pound (also known as "US Customary" or "English") units,
- are enclosed in parentheses, and
- directly follow values expressed in SI units
- are not official, are provided for reference only, and might not be exact conversions of the SI values.

8 Evaluation Process

8.1 This section describes the evaluation of equipment to this guideline, the contents of the evaluation report, and supporting information needed to perform the evaluation.

8.2 *General* — The evaluating party (see Section 8.4) should evaluate the equipment according to this guideline and create a written evaluation report.

NOTE 13: The intent is that the "should" provisions of this guideline be used as the basis for evaluating conformance. The intent is also that the "may," "suggested," "preferred," "recommended," and "NOTE" provisions of this guideline not be used for evaluating conformance.

8.2.1 Conformance to specific sections of SEMI S2 may be achieved by instructions included in the supplier's equipment installation instructions (reference SEMI E6) or other documentation.

8.3 *Evaluation Report Contents: General* — The evaluation report should include only the manuals (Section 9.6) and the design-specific sections (Sections 10 through 27). The Appendices should be used in the evaluation, and referenced in the report, only as they pertain to the specific application.

8.3.1 For each numbered section, the evaluation report should state one of the following, and provide supporting rationale:

- "Conforms" — equipment conforms to the section or to the intent of the section.
- "Does not Conform" — equipment conforms to neither the section nor to the intent of the section.
- "N/A" — section is not applicable to equipment.

8.3.1.1 The results of a risk assessment indicating no significant risk may be used in determining that the equipment conforms to the intent of a section.

8.3.1.2 The evaluation report should include a determination per SEMI S10 of the level of risk associated with nonconformance findings.

8.3.1.3 Supporting rationale may include test data or documented engineering rationale.

8.4 *Evaluation Report Contents: Other Information* — The evaluation report should also include:

- manufacturer's model number;
- serial number of unit(s) evaluated;
- the date(s) that the equipment was evaluated;
- a system/equipment description including configuration, options, and essential diagrams; and
- a statement of the qualifications of the evaluating party. An in-house body, independent laboratory, or product safety consulting firm ("third party") meeting the provisions of SEMI S7 may be used to supply testing or evaluation of conformance to this document.

8.5 *Supporting Information Provided to Evaluator* — The following documentation should be provided to, or developed by, the evaluator, as necessary to demonstrate conformance to the provisions of this guideline.

NOTE 14: It is recommended that the manufacturer's typical configuration and process be used for evaluation purposes. Alternatively, a process agreed upon between the user and the supplier may be used.

NOTE 15: Special options or configurations that may pose additional hazards and are not included in the initial evaluation may need a separate review. It is recommended that upgrades, retrofits, and other changes that affect the safety design of the equipment be evaluated for conformance.

8.5.1 *General Information*

- Written system description, including hardware configuration and function(s), power requirements, power output, and other information necessary to understand the design and operation of the equipment.
- Engineering data used to provide the rationale that the equipment and subassembly seismic anchorages are designed to satisfy the applicable design loads (see Section 19, Seismic Protection).
- Descriptions of the purpose and function of safety devices, such as: emergency off devices (EMOs), interlocks, pressure relief devices, and limit controls.
- A hazard analysis (see Section 6.8).
- Ergonomics evaluation (see Section 16).
- A list of safety critical parts and, for each one, evidence of certification, or documentation showing that the component is suitable for its application.
- A residual fire risk assessment as described in Section 14.2.
- Tests results, certifications, and design specifications that are necessary to evaluate the equipment with respect to fire safety. Descriptions of the fire detection and suppression equipment and controls should also be provided.

8.5.2 *Industrial Hygiene Information*

8.5.2.1 An industrial hygiene report, which should include, as applicable:

- ventilation assessment (see Section 22);

- chemical inventory and hazard analysis (see Section 23);
- ionizing radiation assessment (see Section 24);
- non-ionizing radiation assessment (see Section 25);
- laser assessment (see Section 26); and
- audio sound pressure level assessment (see Section 27).

8.5.3 *Environmental Information* (see Section 21) — Documentation substantiating the following:

- consideration or inclusion of features that conserve resources (e.g., energy, water, deionized water, compressed gases, chemicals, and packaging);
- consideration of features that would promote equipment and component reuse or refurbishing, or material recycling upon decommissioning;
- consideration or inclusion of features for resource recycling or reuse;
- chemical selection methods and criteria (see Section 21.2.3);
- consideration of integrating effluent and emission controls into the equipment; and
- efforts to reduce wastes, effluents, emissions, and by-products.

NOTE 16: For purposes of Section 8.5.3, documentation may include design notes, metrics (whether normalized or not), meeting minutes, pareto evaluations, or other analyses.

9 Documents Provided to User

9.1 This section describes the documents that the supplier provides to the user.

9.2 *Evaluation Report* — Upon request by the user, the supplier should provide the user with a summary of the SEMI S2 evaluation report (see Section 8) or the full report.

9.2.1 Nonconformances noted in the report should be addressed by the supplier, by providing either an action plan or a justification for acceptance. The justification should include countermeasures in place and a risk characterization per SEMI S10.

9.3 *Seismic Information* — Refer to Section 19 of this document.

9.4 *Environmental Documentation* — The manufacturer should provide the user with the following environmental documentation as applicable:

9.4.1 Energy consumption information, including idle, average, and peak operating conditions, for the manufacturer's most representative ("baseline") process.

9.4.2 Mass balance, including idle, average, and peak operating conditions, for the manufacturer's most representative ("baseline") process.

NOTE 17: The mass balance may include resource consumption rates, chemical process efficiencies, wastewater effluent and air emission characterization, solid and hazardous waste generation (quantity and quality), and by-products.

9.4.3 Information regarding routes of unintended release (of effluents, wastes, emissions, and by-products) and methods and devices to monitor and control such releases. This should include information on features to monitor, prevent, and control unintended releases (see Section 21.2.4).

9.4.4 Information regarding routes of intended release (of effluents, wastes, and emissions) and features to monitor and control such releases (see Section 21.2.5).

9.4.5 A list of items that become solid waste as a result of the operation, maintenance, and servicing of the equipment, and that are constructed of or contain substances whose disposal might be regulated (e.g., berylium-containing parts, vapor lamps, mercury switches, batteries, contaminated parts, maintenance wastes).

9.5 *Industrial Hygiene Information* — Refer to Sections 22–27 of this document.

9.6 *Manuals*

9.6.1 The supplier should provide the user with manuals based on the originally intended use of the equipment. The manuals should describe the scope and normal use of the equipment, and provide information to enable safe facilitization, operation, maintenance, and service of the equipment.

9.6.2 The manuals should conform to SEMI S13.

NOTE 18: Fire suppression agents, and chemicals used to test fire detection or suppression systems, fall under the MSDS provisions of SEMI S13 when they are provided with the equipment.

NOTE 19: Hazardous energies within fire detection or suppression systems fall under the hazardous energy control provisions of SEMI S13 when fire detection or suppression systems are provided with the equipment.

9.6.3 In addition to the provisions of SEMI S13, the manuals should include:

- specific written instructions on routine Type 4 tasks, excluding troubleshooting (refer to Section 13.3);
- instructions for energy isolation ("lockout/tagout") (refer to Section 17.2);

- descriptions of the emergency off (EMO) and interlock functions;
- a list of hazardous materials (e.g., lubricants, cleaners, coolants) required for maintenance, ancillary equipment or peripheral operations, including anticipated change-out frequency, quantity, and potential for contamination from the process;
- a list of items that become solid waste as a result of the operation, maintenance, and servicing of the equipment, and that are constructed of or contain substances whose disposal might be regulated (e.g., berylium-containing parts, vapor lamps, mercury switches, batteries, contaminated parts, maintenance wastes); and
- maintenance and troubleshooting procedures needed to maintain the effectiveness of safety design features or devices (i.e., engineering controls).

9.6.4 Information should be provided regarding potential routes of unintended releases (see Section 21.2.4).

9.6.5 Recommended decontamination and decommissioning procedures should be provided in accordance with SEMI S12, and should include the following information:

- identity of components and materials of construction, in sufficient detail to support recycling, refurbishment, and reuse decisions (see Section 8.5.3); and
- residual hazardous materials, or parts likely to become contaminated with hazardous materials, that may be in the equipment prior to decommissioning.

NOTE 20: It is recommended that the manual state that changes to the typical process chemistry or to the equipment could alter the anticipated environmental impact.

9.6.6 *Maintenance Procedures with Potential Environmental Impacts* — The supplier's recommended maintenance procedures should:

- identify procedural steps during which releases might occur, and the nature of the releases; and
- identify waste characteristics and methods to minimize the volume of effluents, wastes, or emissions generated during maintenance procedures.

9.7 *Fire Protection Documentation* — The equipment supplier should provide:

- a summary fire protection report as described in Section 14.3;
- descriptions of optional fire risk mitigation features (see Section 14.3.2);

NOTE 21: It is recommended that this be provided prior to purchase.

- fire detection system operations, maintenance, and test manuals;
- fire suppression system operations, maintenance, and test manuals;
- acceptance documents provided by licensed designers and installers (see Sections 14.4.4.12 and 14.4.5.16); and
- a list of any special apparatus needed to test the fire detection or suppression features of the equipment. The list should note whether the apparatus is included with the equipment, or is sold separately.

10 Hazard Warning Labels

10.1 Where it is impractical to eliminate hazards through design selection or to adequately reduce the associated risk with safety or warning devices, hazard warning labels should be provided to identify and warn against hazards.

10.2 Labels should be durable and suitable for the environment of the intended use.

10.3 Labels should conform to SEMI S1.

EXCEPTION: Some hazard label formats and content are dictated by law (e.g., laser labeling and chemical hazard communication labeling in certain countries of use) and may not conform to SEMI S1.

11 Safety Interlock Systems

11.1 This section covers safety interlocks and safety interlock systems.

NOTE 22: If a fire detection or suppression system is provided with the equipment, see Section 14 for additional information.

11.2 Where appropriate, equipment should use safety interlock systems that protect personnel, facilities, and the community from hazards inherent in the operation of the equipment.

NOTE 23: Safety critical parts whose primary function is to protect the equipment (e.g., circuit breakers, fuses) are typically not considered to be safety interlocks.

11.3 Safety interlock systems should be designed such that, upon activation of the interlock, the equipment, or relevant parts of the equipment, is automatically brought to a safe condition.

11.4 Upon activation, the safety interlock should alert the operator immediately.

EXCEPTION: Alerting the operator is not expected if a safety interlock triggers the EMO circuit (see Section 12) or otherwise removes power to the user interface.

NOTE 24: An explanation of the cause is preferred upon activation of a safety interlock.

11.5 Safety interlock systems should be fault-tolerant and designed so that the functions or set points of the system components cannot be altered without disassembling, physically modifying, or damaging the device or component.

EXCEPTION: When safety interlock systems having adjustable set points or trip functions are used, access should be limited to maintenance or service personnel by requiring a deliberate action, such as using a tool or special keypad sequences, to access the adjustable devices or to adjust the devices.

NOTE 25: This section does not address the defeatability of safety interlocks. See Section 11.7 for additional information.

NOTICE: Section 11.6 below will be withdrawn upon July 1, 2006 publication and replaced by the new Section 11.6 including: figures and tables as shown in Delayed Revisions Section 2. The EH&S Committee has voted that implementation of the information is OPTIONAL before the effective date.

11.6 Electromechanical devices and components are preferred. Solid-state devices and solid state components may be used, provided that the safety interlock system, or relevant parts of the system, are evaluated for suitability for use in accordance with appropriate standard(s). The evaluation for suitability should take into consideration abnormal conditions such as overvoltage, undervoltage, power supply interruption, transient overvoltage, ramp voltage, electromagnetic susceptibility, electrostatic discharge, thermal cycling, humidity, dust, vibration, and jarring.

EXCEPTION: Where the severity of a reasonably foreseeable mishap is deemed to be Minor per SEMI S10, a software-based interlock may be considered suitable.

NOTE 26: Where a safety interlock is provided to safeguard personnel from a Severe or Catastrophic mishap as categorized by SEMI S10, consideration of positive-opening type switches is recommended.

NOTE 27: Evaluation for suitability for use may also include reliability, self-monitoring, and redundancy as addressed under standards such as NEMA ICS 1.1 and UL 991.

NOTE 28: Solid-state devices include operational amplifiers, transistors, and integrated circuits.

11.6.1 FECS may be used in conjunction with electromechanical or solid state devices and components provided the programmable safety control system conforms to an appropriate standard for electronic safety systems. Components of the FECS should be tested and certified according to the requirements of the standard used. Examples of recognized electronic safety systems standards include IEC 61508 ISO 13849-1 (EN 954-1), ANSI/ISA SP84.01 DIN/V/VDE-0801.

NOTE 29: Paragraph 13.4.3 states additional assessment criteria for safety-related components and assemblies.

NOTE 30: A FECS is a subsystem of a (PES) Programmable Electronic System. IEC 61508 is the preferred standard for complex PES.

NOTE 31: Related Information 14 provides additional information on applications of FECS design.

11.7 The safety interlock system should be designed to minimize the need to override safety interlocks during maintenance activities.

11.7.1 Safety interlocks that safeguard personnel during operator tasks should not be defeatable without the use of a tool.

11.7.2 When maintenance access is necessary to areas protected by interlocks, defeatable safety interlocks may be used, provided that they require an intentional operation to bypass.

11.7.2.1 Upon exiting or completing the maintenance mode, all safety interlocks should be automatically restored.

11.7.2.2 If a safety interlock is defeated, the maintenance manual should identify administrative controls to safeguard personnel or to minimize the hazard.

11.8 The restoration of a safety interlock should not initiate equipment operation or parts movement where this can give rise to a hazardous condition.

11.9 Switches and other control device contacts should be connected to the ungrounded side of the circuit so that a short circuit to ground does not result in the interlocks being satisfied.

11.10 Where a hazard to personnel is controlled through the use of an enclosure, the enclosure should either: require a tool to gain access and be labeled regarding the hazard against which it protects personnel; or be interlocked. In addition to enclosures, physical barriers at the point of hazard should be included where inadvertent contact is likely.

NOTE 32: Where the removal of a cover exposes a hazard, consider additional labels. See Section 10 for guidance.

12 Emergency Shutdown

12.1 The equipment should have an "emergency off" (EMO) circuit. The EMO actuator (e.g., button), when activated, should place the equipment into a safe shutdown condition, without generating any additional hazard to personnel or the facility.

EXCEPTION 1: An EMO circuit is not needed for equipment rated 2.4 kVA or less, where the hazards are only electrical in nature, provided that the main disconnect meets the accessibility provisions of Section 12.5.2 and that the effect of disconnecting the main power supply is equivalent to activating an EMO circuit.

EXCEPTION 2: Assemblies that are not intended to be used as stand-alone equipment, but rather within an overall integrated system, and that receive their power from the user's system, are not required to have an emergency off circuit. The assembly's installation manual should provide clear instructions to the equipment installer to connect the assembly to the integrated system's emergency off circuit.

NOTE 33: It is recommended that the emergency off function not reduce the effectiveness of safety devices or of devices with safety-related functions (e.g., magnetic chucks or braking devices) necessary to bring the equipment to a safe shutdown condition effectively.

NOTE 34: If a fire detection or suppression system is provided with the equipment, see Section 14 for additional information.

12.1.1 If the supplier provides an external EMO interface on the equipment, the supplier should include instructions for connecting to the interface.

12.2 Activation of the emergency off circuit should deenergize all hazardous voltage and all power greater than 240 volt-amps in the equipment beyond the main power enclosure.

EXCEPTION 1: A non-hazardous voltage EMO circuit (typically 24 volts) and its supply may remain energized.

EXCEPTION 2: Safety related devices (e.g., smoke detectors, gas/water leak detectors, pressure measurement devices, etc.) may remain energized from a non-hazardous power source.

EXCEPTION 3: A computer system performing data/alarm logging and error recovery functions may remain energized, provided that the energized breaker(s), receptacle(s), and each energized conductor termination are clearly labeled as remaining energized after EMO activation. Hazardous energized parts that remain energized after EMO activation should be insulated or guarded to prevent inadvertent contact by maintenance personnel.

EXCEPTION 4: Multiple units mounted separately with no shared hazards and without interconnecting circuits with hazardous voltages, energy levels or other potentially hazardous conditions may have:

- separate sources of power and separate supply circuit disconnect means if clearly identified, or
- separate EMO circuits, if they are clearly identified.

12.2.1 The EMO circuit should not include features that are intended to allow it to be defeated or bypassed.

12.2.2 The EMO circuit should consist of electromechanical components.

EXCEPTION 1: Solid-state devices and components may be used, provided the system or relevant parts of the system are evaluated and found suitable for use. The components should be evaluated and found suitable considering abnormal conditions such as over voltage, under voltage, power supply interruption, transient over voltage, ramp voltage, electromagnetic susceptibility, electrostatic discharge, thermal cycling, humidity, dust, vibration and jarring. The final removal of power should be accomplished by means of electromechanical components.

EXCEPTION 2: FECS may be used provided the FECS conforms to an appropriate standard for electronic safety systems. Components of the FECS should be tested and certified according to the requirements of the standard used. IEC 61508 and ISO 13849-1 (EN 954-1) are examples of internationally recognized electronic safety systems standards. The final removal of power should be accomplished by means of electromechanical components.

NOTE 35: Paragraph 13.4.3 states additional assessment criteria for safety-related components and assemblies.

NOTE 36: A FECS is a subsystem of a (PES) Programmable Electronic System. IEC 61508 is the preferred standard for complex PES.

12.2.3 All EMO circuits should be fault-tolerant.

12.2.4 Resetting the EMO switch should not re-energize circuits, equipment, or subassemblies.

12.2.5 The EMO circuit should shut down the equipment by deenergizing rather than energizing control components.

12.2.6 The EMO circuit should require manual resetting so that power cannot be restored automatically.

12.3 The emergency off button should be red and mushroom shaped. A yellow background for the EMO should be provided.

NOTE 37: Non-lockable self-latching (i.e., twist- or pull-to-release) EMO buttons may be required by regulations.

12.4 All emergency off buttons should be clearly labeled as “EMO,” “Emergency Off,” or the equivalent and should be clearly legible from the viewing location. The label may appear on the button or on the yellow background.

12.5 Emergency off buttons should be readily accessible from operating and regularly scheduled maintenance locations and appropriately sized to enable activation by the heel of the palm.

12.5.1 Emergency off buttons should be located or guarded to minimize accidental activation.

12.5.2 No operation or regularly scheduled maintenance location should require more than 3 m (10 feet) travel to an EMO button.

12.5.3 The person actuating or inspecting the EMO button should not be exposed to serious risks of tripping or falling or of coming in contact with energized electrical parts, moving machinery, surfaces or objects operating at high temperatures, or other hazardous equipment.

12.6 See Section 13.5 for additional EMO guidelines when EMOs are used with UPSs.

13 Electrical Design

13.1 This section covers electrical and electronic equipment that use hazardous voltages.

13.2 *Types of Electrical Work* — The following are the four types of electrical work defined by this guideline:

Type 1 — Equipment is fully deenergized.

Type 2 — Equipment is energized. Energized circuits are covered or insulated.

NOTE 38: Type 2 work includes tasks where the energized circuits are or can be measured by placing probes through suitable openings in the covers or insulators.

Type 3 — Equipment is energized. Energized circuits are exposed and inadvertent contact with uninsulated energized parts is possible. Potential exposures are no greater than 30 volts rms, 42.4 volts peak, 60 volts dc or 240 volt-amps in dry locations.

Type 4 — Equipment is energized. Energized circuits are exposed and inadvertent contact with uninsulated energized parts is possible. Potential exposures are greater than 30 volts rms, 42.4 volts peak, 60 volts dc, or 240 volt-amps in dry locations. Potential exposures to radio-frequency currents, whether induced or via contact, exceed the limits in Table A5-1 of Appendix 5.

13.3 *Energized Electrical Work* — The supplier should design the equipment to minimize the need to calibrate, modify, repair, test, adjust, or maintain equipment while it is energized, and to minimize work that must be performed on components near exposed energized circuits. The supplier should move as many tasks as practical from category Type 4 to Types 1, 2, or 3. Routine Type 4 tasks, excluding troubleshooting, should have specific written instructions in the maintenance manuals. General safety procedures (e.g., wearing appropriate Personal Protective Equipment and establishing barriers) for troubleshooting, including Type 4 work, should be provided.

13.4 *Electrical Design* — Equipment should conform to the appropriate international, regional, national or industry product safety requirements.

13.4.1 Nonconductive or grounded conductive physical barriers should be provided:

- Where it is necessary to reach over, under, or around, or in close proximity to hazards.
- Where dropped objects could cause shorts or arcing.
- Where failure of liquid fittings from any part of the equipment would result in the introduction of liquid into electrical parts.
- Over the line side of the main disconnect.
- Where maintenance or service tasks on equipment in dry locations are likely to allow inadvertent contact with uninsulated energized parts containing either: potentials greater than 30 volts rms, 42.4 volts peak, or 60 volts dc; or power greater than 240 volt-amps.

NOTE 39: A dry location can be considered to be one that is not normally subject to dampness or wetness.

NOTE 40: Removable nonconductive and noncombustible covers are preferred.

13.4.2 Where test probe openings are provided in barriers, the barriers should be located, and the probe openings should be sized, to prevent inadvertent contact with adjacent energized parts, including the energized parts of the test probes.

13.4.3 Where failure of components and assemblies could result in a risk of electric shock, fire, or personal injury, those components and assemblies should be certified by an accredited testing laboratory and used in accordance with the manufacturer’s specifications, or otherwise evaluated to the applicable standard(s).

NOTE 41: With the exception of implementation of ground fault protection, shunt trip units that require power to trip (actuate) are not recommended to be used in a safety control circuit, because they are not fail-safe.

13.4.4 Electrical wiring for power circuits, control circuits, grounding (earthing) and grounded (neutral) conductors should be color coded according to appropriate standard(s) per Section 13.4, or labeled for easy identification at both ends of the wire. Where color is used for identification, it is acceptable to wrap conductor ends with appropriate colored tape or sleeving; the tape or sleeving should be reliably secured to the conductor.

EXCEPTION 1: Internal wiring on individual components, e.g., motors, transformers, meters, solenoid valves, power supplies.

EXCEPTION 2: Flexible cords.

EXCEPTION 3: Nonhazardous voltage multi-conductor cables (e.g., ribbon cables).

EXCEPTION 4: When proper color is not available for conductors designed for special application (e.g., high-temperature conductors used for furnaces and ovens).

13.4.5 Grounding (earthing) conductors and connectors should be sized to be compatible in current rating with their associated ungrounded conductors according to appropriate standard(s) per Section 13.4.

13.4.6 Electrical enclosures should be suitable for the environment in which they are intended to be used.

13.4.7 Enclosure openings should safeguard against personnel access to uninsulated energized parts. (Refer to Appendix 1 for examples of openings for protection against access from operators.)

13.4.8 Top covers of electrical enclosures should be designed and constructed to prevent objects from falling into the enclosures. (Refer to Appendix 1 for examples of acceptable top enclosure openings.)

13.4.9 The current interrupting capacity (also known as amperes interrupting capacity, or AIC) of the equipment main disconnect should be identified in the facility installation and maintenance manuals.

13.4.10 The equipment should be provided with main overcurrent protection devices and main disconnect devices rated for at least 10,000 rms symmetrical amperes interrupting capacity (AIC).

NOTE 42: Some facilities may require higher AIC ratings due to electrical distribution system design.

EXCEPTION: Cord- and plug-connected single phase equipment, rated no greater than 240 volts line-to-line/150 volts line-to-ground and no greater than 2.4 kVA, may have overcurrent protection devices with interrupting capacity of at least 5,000 rms symmetrical amperes interrupting capacity (AIC).

13.4.11 Equipment should be designed to receive incoming electrical power from the facility to a single feed location that terminates at the main disconnect specified in Section 13.4.9. This disconnect, when opened, should remove all incoming electrical power in the equipment from the load side of the disconnect. The disconnect should also have the energy isolation ("lockout") capabilities specified in Section 17.

EXCEPTION 1: Equipment with more than one feed should be provided with provisions for energy isolation (lockout) for each feed and be marked with the following text or the equivalent at each disconnect: "WARNING: Risk of Electric Shock or Burn. Disconnect all [number of feed locations] sources of supply prior to servicing." It is preferred that all of the disconnects for the equipment be grouped in one location.

EXCEPTION 2: Multiple units mounted separately with no shared hazards and without interconnecting circuits with hazardous voltages, energy levels or other potentially hazardous conditions may have:

- separate sources of power and separate supply circuit disconnect means, if they are clearly identified; or
- separate EMO circuits, if they are clearly identified.

13.4.12 A permanent nameplate listing the manufacturer's name, machine serial number, supply voltage, phase, frequency and full-load current should be attached to the equipment where plainly visible after installation. Where more than one incoming supply circuit is to be provided, the nameplate should state the above information for each circuit.

NOTE 43: Additional nameplate information may be required depending on the location of use.

13.5 *Uninterruptable Power Supplies (UPSs)* — This section applies to UPSs with outputs greater than: 30 volts rms, 42.4 volts peak; 60 volts dc; or 240 volt-amps.

13.5.1 Whenever a UPS is provided with the equipment, its location and wiring should be clearly described within the installation and maintenance manual.

13.5.2 Power from the UPS should be interrupted when any of the following events occur:

- the emergency off actuator (button) is pushed; or
- the main equipment disconnect is opened; or

- the main circuit breaker is opened.

EXCEPTION: Upon EMO activation, the UPS may supply power to the EMO circuit, safety related devices, and data/alarm logging computer systems as described in the exception clauses of Section 12.2.

13.5.3 The UPS may be physically located within the footprint of the equipment provided that the UPS is within its own enclosure and is clearly identified.

13.5.4 The UPS should be certified by an accredited testing laboratory and be suitable for its intended environment (e.g., damp location, exposure to corrosives).

13.5.5 The UPS wiring should be identified as “UPS Supply Output” or equivalent at each termination point where the UPS wiring can be disconnected.

13.6 *Electrical Safety Tests*

13.6.1 Equipment connected to the facility branch circuit with a cord and plug should not exhibit surface leakage current greater than 3.5 milliampere (mA) as determined by testing completed in accordance with “Leakage Current Test for Plug-and-Cord Equipment” in SEMI S9.

EXCEPTION: Equipment with leakage current exceeding 3.5 mA is acceptable if documentation is provided to substantiate that the equipment is fully compliant with an applicable product safety standard that explicitly permits a higher leakage current.

13.6.2 Equipment grounding circuits should have a measured resistance of one-tenth (0.1) ohm or less as determined by testing in accordance with SEMI S9.

13.7 Equipment in which flammable liquids or gases are used should be assessed to determine if additional precautions (e.g., purging) in the electrical design are necessary.

NOTE 44: NFPA 497 and EN 1127-1 provide methods for making this assessment.

14 Fire Protection

14.1 *Overview* — This section applies to fire hazards that are internal to the equipment.

14.1.1 This section provides minimum safety considerations for fire protection designs and controls on the equipment.

14.1.2 This section also provides minimum considerations for fire detection and suppression systems when provided with the equipment.

NOTE 45: Detailed guidance on fire risk assessment and mitigation for semiconductor manufacturing equipment is provided in SEMI S14.

14.2 *Risk Assessment*

14.2.1 A documented risk assessment should be performed or accepted by a party qualified to determine and evaluate fire hazards and the potential need for controls. The risk assessment should consider normal operations and reasonably foreseeable single-point failures within the equipment. It should not consider exposure to fire or external ignition sources not within the specified use environment.

NOTE 46: This risk assessment can be combined with the overall hazard analysis performed for this guideline, provided the risk assessor has the required professional expertise to perform risk assessments for fire hazards. SEMI S7 describes qualifications for such an assessor.

14.2.2 If an accurate risk assessment depends on the user’s adherence to specified procedures or conditions of use, the supplier should describe such procedures or conditions and state their importance.

14.2.3 SEMI S14 should be used to assess and report risks to property and the environment.

14.3 *Reporting*

14.3.1 A summary report should be provided to the user. The summary should include the following characterizations, per SEMI S10, for each residual fire hazard identified:

- the assigned Severity;
- the assigned Likelihood; and
- the resulting Risk Category.

14.3.2 Optional fire risk reduction features should be described in the pre-purchase information provided to the user.

14.3.3 The scope and effectiveness of the means of fire risk reduction should also be identified and reported, including the expected risk reduction (as described in Section 14.3.1).

14.3.4 If, due to fire hazards within the equipment, thermal or non-thermal (e.g., smoke) damage is possible outside of the equipment, then this possibility should be reported to the user. This report should include a qualitative description of the foreseen scenario.

14.4 *Fire Risk Reduction*

14.4.1 *Materials of Construction* — Equipment should be constructed of noncombustible materials wherever reasonable. If process chemicals do not permit the use of noncombustible construction, then the equipment should be constructed of materials, suitable for the uses and compatible with the process chemicals used, that contribute least to the fire risk.

NOTE 47: Some regional codes (e.g., Uniform Fire Code) may require construction with noncombustible materials.

14.4.1.1 The flowchart in Appendix 6 may be used for the selection of materials of construction for equipment.

14.4.1.2 Any portion of equipment that falls within the scope of SEMI F14 (Guide for the Design of Gas Source Equipment Enclosures) should be designed in accordance with that guide.

14.4.2 *Elimination of Process Chemical Hazards* — The option of substituting non-flammable process chemicals for flammable process chemicals should be considered.

14.4.3 *Engineering Controls*

14.4.3.1 Fire risks resulting from process chemicals may be reduced using engineering controls (e.g., preventing improper chemical mixing, preventing temperatures from reaching the flash point).

14.4.3.2 Fire risks resulting from materials of construction may be reduced using engineering controls (e.g., non-combustible barriers that separate combustible materials of construction from ignition sources, installing a fire suppression system that extinguishes ignited materials).

14.4.3.3 Equipment power and chemical sources that present unacceptable fire risks should be interlocked with the fire detection and suppression systems to prevent start-up of the equipment or delivery of chemicals when the fire detection or suppression is inactive.

NOTE 48: Some jurisdictions require interlocking.

NOTE 49: Refer to Section 6.5 for criteria for acceptability.

14.4.3.4 Shutdown or failure of a fire detection or suppression system need not interrupt the processing of product within the equipment by immediately shutting down the equipment, but should prevent additional processing until the fire detection or suppression is restored. Software or hardware may be used for this function.

14.4.3.5 Controlling smoke by exhausting it (using the supplier-specified equipment exhaust) from the cleanroom may be used to reduce fire risks from the generation of products of combustion. When used, this reduction method should be combined with detection or suppression when flames can be propagated.

NOTE 50: Controlling smoke may be sufficient when smoke is the only consequence (e.g., smoldering components that generate smoke).

NOTE 51: For controlling smoke to be effective, the smoke must be removed not only from the equipment, but also from the cleanroom. This is typically accomplished by using ducted exhaust.

NOTE 52: The use of exhaust to remove smoke may be subject to regulations, such as building and fire codes.

NOTE 53: The use of exhaust to remove smoke may create hazards within the exhaust system. Therefore, a description of the expected discharge (i.e., anticipated air flow rate, temperature, and rate of smoke generation) into the exhaust system may be important information for installation of equipment.

14.4.4 *Fire Detection* — The following criteria apply to any fire detection system determined to be appropriate for fire protection by the fire risk assessment:

NOTE 54: Heat detectors, smoke sensing devices, and other devices used solely for monitoring equipment status may not need to meet these requirements. Some local jurisdictions, however, may require that all smoke detectors be connected to building systems and be compliant with all applicable fire alarm codes.

14.4.4.1 The fire detection system, which includes detectors, alarms and their associated controls, should be certified by an accredited testing laboratory and suitable for the application and for the environment in which it is to be used.

NOTE 55: Such certifications typically require that the components of fire detection systems are readily identifiable and distinguishable from other components in the equipment.

14.4.4.2 The fire detection, alarm and control system should be installed in accordance with the requirements of the certification in Section 14.4.4.1, and in accordance with requirements of the appropriate international or national codes or standards (e.g., NFPA 72).

14.4.4.3 The fire detection system should be capable of interfacing with the facility's alarm system. It may be preferable for the equipment supplier to specify the location and performance of detectors, but not provide them, so that the user may better integrate the detection in the equipment with that in the facility. This alternative should be negotiated explicitly with the user.

14.4.4.4 The fire detection system should activate alarms audibly and visually at the equipment.

14.4.4.5 Manual activation capability for the fire detection system should be considered, for the purpose of providing notification to a constantly attended location.

14.4.4.6 Activation of trouble or supervisory conditions should result in all of the following:

- notification of the operator;

- allowing the completion of processing of substrates in the equipment;
- prevention of processing of additional substrates until the trouble or supervisory condition is cleared; and
- providing, through an external interface, a signal to the facility monitoring system or a constantly attended location.

NOTE 56: Some local jurisdictions require that such alarms signal the building/facility fire alarm systems.

14.4.4.7 The fire detection system should be capable of operating at all times, including when the equipment is inoperable (e.g., equipment controller problems) or in maintenance modes (e.g., some or all of the equipment's hazardous energies are isolated ("locked out"). For the purpose of this section, "inoperable" includes the equipment states after an EMO is activated and after the equipment has had its hazardous energies isolated (i.e., has been "locked out"). Therefore, the detection system should not require hazardous voltages (e.g., line alternating current) to operate anything other than the equipment within the detection system's control enclosure. Sensors and other devices outside the detection system's control enclosure should not require hazardous voltage.

EXCEPTION: Operability is not required during maintenance of the fire detection system.

14.4.4.7.1 Power at a hazardous voltage may be supplied to the detection system controller enclosure after the equipment EMO is activated or after the equipment has had its hazardous energies isolated only if the wiring providing the hazardous voltage is separated from other wiring and is suitably labeled.

14.4.4.7.2 If the hazardous voltage supply to the detection system controller is not disconnected by the energy isolation method that removes the other hazardous voltages from the equipment, there must also be separate hazardous energy isolation capability for the hazardous voltage supplies to the detection system controller enclosure.

14.4.4.8 A battery or other regulatory agency acceptable emergency power alternative, capable of sustaining the detection system for 24 hours, should be provided.

NOTE 57: Back-up power must be provided in accordance with local regulations. The requirements for back-up power vary among jurisdictions.

14.4.4.9 The fire detection system should remain active following EMO activation.

14.4.4.10 There may be cases where the internal power supply for a detection system cannot supply power for the full length of extended maintenance procedures (i.e., procedures longer than the expected duration of the back-up power supply). In such cases, the supplier should provide written procedures for either removing the fire hazard or safely supplying power to the fire detection system.

14.4.4.11 Activation of the fire detection system should shut down the equipment within the shortest time period that allows for safe equipment shutdown. This includes shutdown of any fire-related hazard source that could create additional fire risks for the affected module or component.

NOTE 58: See Sections 14.4.3.3 and 14.4.3.4 for related provisions.

EXCEPTION 1: A non-recycling, deadman abort switch is acceptable on detection systems that are used for equipment shutdown, but not on those used for activation of a suppression system.

EXCEPTION 2: Activation of the fire detection system should not remove power from fire and safety systems.

14.4.4.12 The equipment design and configuration should not prevent licensed parties from certifying the design and installation of fire detection systems.

NOTE 59: This is not meant to suggest installation by licensed parties; however, some jurisdictions require fire detection and suppression system installers to be licensed as specified by the jurisdiction.

14.4.5 *Fire Suppression* — The following criteria apply to any fire suppression system determined to be appropriate by the fire risk assessment.

NOTE 60: As a fire detection system is generally required to provide the initiating sequence for the suppression system, it is the intention of this guideline that this be the same fire detection system described in Section 14.4.4.

14.4.5.1 The fire suppression system, which includes nozzles, actuators, and their associated controls, should be certified by an accredited testing laboratory and suitable for the application and for the environment in which it to be used.

NOTE 61: Such certifications typically require that the components of fire suppression systems are readily identifiable and distinguishable from other components in the equipment. This includes adequate labeling of piping.

14.4.5.2 The fire suppression agent should be accepted for the application by an accredited testing laboratory. The suppression agent selection process should include an evaluation of the amount and storage location of the suppression agent and of potential damage to a cleanroom and the environment. The least damaging effective agent should be selected. If more than one agent is effective, the options should be specified to the user so that the user may specify which agent should be provided with the equipment. The supplier should also specify if the user may provide the agent.

14.4.5.3 The fire suppression agent and delivery system should be designed and installed in accordance with the appropriate international or national standard (e.g., NFPA 12, NFPA 13, NFPA 2001). It may be preferable for the equipment supplier to specify the location and performance of suppression system components, but not provide them, so that the user may better integrate the suppression in the equipment with that in the facility. This alternative should be negotiated explicitly with the user.

14.4.5.4 The assessment of the equipment to SEMI S2 should include the risks associated with the suppression systems.

NOTE 62: This includes risks (e.g., chemical exposure, noise, and asphyxiation) introduced by the incorporation of the suppression system.

14.4.5.5 Activation of the fire suppression system should alarm audibly and visually at the equipment. This may be done by the same system that initiates activation.

14.4.5.6 If the discharge is likely to present a risk to personnel, the alarm should provide adequate time to allow personnel to avoid the hazard of the agent discharge.

14.4.5.6.1 If there is a confined space in the equipment, the asphyxiation hazard posed by the suppression system should be assessed.

14.4.5.7 The fire suppression system should be capable of operating at all times, including when equipment is inoperable and during equipment maintenance.

NOTE 63: For the purpose of this section, "inoperable" includes the equipment state after the EMO is activated.

EXCEPTION: Most suppression systems contain sources of hazardous energy. These sources should be capable of being isolated (i.e., "locked out") to protect personnel.

14.4.5.8 The fire suppression system should remain active following EMO activation.

14.4.5.9 There may be cases where the internal power supply for a suppression system cannot supply power for the full length of extended maintenance procedures (i.e., procedures longer than the expected duration of the back-up power supply). In such cases, the supplier should provide written procedures for either removing the fire hazard or safely supplying power to the fire suppression system.

14.4.5.10 Allowances can be made to provide for the deactivation of an automatic discharge of the suppression system when in the maintenance mode. Such deactivation switches should be supervised (i.e., if the suppression system is deactivated, there should be an indication to the user and the resumption of production in the equipment should be prevented.)

NOTE 64: Hazardous energies associated with the fire suppression system may be isolated (i.e., "locked out") using an energy isolation procedure (see Section 17) during equipment maintenance.

NOTE 65: The permissibility of deactivation of suppression systems varies among jurisdictions.

14.4.5.11 A back-up power supply, capable of sustaining the suppression system for 24 hours, should be included where the suppression system requires independent power from the detection system used to activate the suppression.

NOTE 66: The requirements for back-up power vary among jurisdictions.

14.4.5.12 The fire suppression system should be capable of interfacing with the facility's alarm system. This may be done via the fire detection system.

14.4.5.13 Activation of the fire suppression system should shut down the equipment within the shortest time period that allows for safe equipment shutdown.

NOTE 67: See Sections 14.4.3.3 and 14.4.3.4 for related provisions.

EXCEPTION: Activation of the fire suppression system should not remove power from fire and safety systems.

14.4.5.14 The fire suppression system should be capable of manual activation, which should shut down the equipment and activate an alarm signal locally and at a constantly attended location.

14.4.5.15 The fire suppression system should be tested on a representative sample of the equipment. The test procedure should include a suppression agent discharge test, unless precluded for health or environmental reasons. This test may be performed at the equipment supplier's or other similar facility, but should be performed under conditions that adequately duplicate any factors (e.g., equipment exhaust) that may reduce the effectiveness of the suppression. This representative sample need not be fully operational, but should duplicate those factors (e.g., exhaust, air flow) that could negatively affect the performance of the system.

14.4.5.16 Procedures for controlling access to the suppression agent source (e.g., protecting agent cylinders from disconnection by unauthorized personnel) should be provided.

14.4.5.17 The equipment design and configuration should not prevent licensed parties from certifying the design and installation of fire suppression systems.

NOTE 68: This is not meant to suggest installation by licensed parties; however, some jurisdictions require fire detection and suppression system installers to be licensed as specified by the jurisdiction.

14.4.5.18 *Installation of Piping for Fire Suppression Agent* — The fire suppression piping system should be:

- made from corrosion-resistant components,
- designed to minimize water accumulation around components and control other conditions that promote corrosion, and
- designed so mechanical inspections are easily performed.

14.4.5.19 Piping should be designed, installed, and tested to ensure that it is capable of containing the high pressures generated by the discharge of the suppression agent.

14.4.5.20 The supplier should provide information necessary for proper field installation of piping.

14.5 *Warnings and Safe Work Practices* — Warnings and safe work practices related to fire detection and suppression features of the equipment (e.g., restrictions on using open flames within range of active fire detection systems, hazardous stored energy in pressurized suppression systems) should be part of the documentation provided by the supplier.

14.6 *Maintenance and Testing of Fire Detection and Suppression Systems* — The equipment supplier should provide detailed maintenance and testing procedures for the fire systems provided with each piece of equipment. These procedures should include testing frequency, as well as details of special equipment required for testing.

14.6.1 Chemical generating test apparatus (e.g., canned smoke) should be avoided for cleanroom applications.

NOTE 69: Information about UV/IR generating sources used for testing fire detection systems may require consideration of Section 25 (Non-Ionizing Radiation).

14.6.2 The maintenance testing procedure should include testing of the facility interface and verifying that all the equipment fire detection and suppression systems are functional.

14.6.3 The detection and suppression systems should be designed so that preventative maintenance of components does not degrade their performance (e.g., by resulting in displacement or destruction of sensors).

14.6.4 Supplier should document the sound pressure level generated during suppression agent discharge, if the test is performed.

14.6.5 Materials or procedures used for testing and maintenance of the fire detection and suppression system should not degrade the equipment's ability to perform its intended function.

14.6.6 Suppliers should describe hazardous energies present in fire detection and suppression systems, and provide instructions for their proper isolation (see Section 17.2).

14.7 *Environmental* — Suppliers should provide guidance to users regarding the impact on emissions of any fire suppression agents used in the equipment.

15 Heated Chemical Baths

15.1 Refer to SEMI S3 for the minimum safety design considerations for heated chemical baths. Each heated chemical bath should have the following:

- grounded or GFCI-protected heater;
- power interrupt;
- manual reset;
- automatic temperature controller;
- liquid level sensor;
- fail-safe over-temperature protection;
- proper construction materials;
- exhaust failure interlock; and
- overcurrent protection.

NOTE 70: See Section 14 for fire protection risk assessment considerations for baths using combustible or flammable chemicals.

16 Ergonomics and Human Factors

16.1 *General* — Ergonomics and human factors design principles should be incorporated into the development of equipment to identify and eliminate or mitigate ergonomics- and human factors-related hazards.

16.2 *Provisions for Conformance* — Equipment should be assessed to the guidelines set forth in SEMI S8. The Supplier Ergonomic Success Criteria (SESC; see SEMI S8), or the equivalent, should be used to document the assessment.

17 Hazardous Energy Isolation

17.1 *General*

17.1.1 Lockable energy isolation capabilities should be provided for tasks that may result in contact with hazardous energy sources.

17.1.2 Where service tasks may be safely performed on subassemblies, energy isolation devices (e.g., circuit breakers, disconnect switches, manual valves) may be provided for the subassemblies for use as an alternative to shutting down the entire equipment system. The isolation devices should isolate all hazardous energy to the subassemblies and be capable of being locked in the position in which the hazardous energy is isolated.

17.1.3 The person actuating or inspecting an energy isolating device should not be exposed to serious risks of tripping or falling or of coming in contact with energized electrical parts, moving machinery, surfaces or objects operating at high temperatures, or other hazardous equipment.

NOTE 71: Hazardous energies include electrical, stored electrical (e.g., capacitors, batteries), chemical, thermal/cryogenic, stored pressure (e.g., pressurized containers), suspended weight, stored mechanical (e.g., springs), generated pressure (e.g., hydraulics and pneumatics), and other sources that may lead to the risk of injury.

NOTE 72: In order to minimize down-time and provide ease of use, it is preferred to have energy isolation devices located in the areas where maintenance or service is performed.

NOTE 73: Energy isolation devices for incompatible hazardous energy sources (e.g., electrical and water, incompatible gases) are recommended to be separated.

NOTE 74: Isolation of hazardous energy may include: deenergizing of hazardous voltage; stopping flow of hazardous production material (HPM); containing HPM reservoirs; depressurizing or containing HPM and pneumatic lines; deenergizing or totally containing hazardous radiation; discharging of residual energy in capacitors; stopping of hazardous moving parts; and shutting off hazardous temperature sources.

NOTE 75: Energy isolation devices with integral locking capabilities are preferred, but may not be feasible or commercially available, in which case detachable lockout adapters may be used.

NOTE 76: See Section 14 for information on fire protection hazardous energies.

17.2 *Installation and Maintenance Manuals*

17.2.1 Installation and maintenance manuals should identify the types of hazardous energies within the equipment.

17.2.2 Installation and maintenance manuals should provide specific instructions for the equipment on how to:

- shut down the equipment in an orderly manner;
- locate and operate all the equipment's energy isolating devices;
- affix energy isolating ("lockout/tagout") devices;
- relieve any stored energies;
- verify that the equipment has actually been isolated and deenergized; and
- properly release the equipment from its isolated state.

17.2.3 Where the manufacturer provides written maintenance procedures for tasks within subassemblies, and intends that these tasks be performed without controlling hazardous energies at the entire equipment level, the installation and maintenance manuals should provide appropriate energy isolation procedures at the subassembly level.

17.3 *Electrical Energy Isolation*

17.3.1 The main energy isolation capabilities (equipment supply disconnect) should be in a location that is readily accessible and should be lockable only in the deenergized position.

NOTE 77: For equipment with multiple incoming supply sources, it is recommended that all of the energy isolation devices be located in one area.

17.4 *Non-Electrical Energy Isolation*

17.4.1 The equipment should include provisions and procedures so that hazardous energy sources, such as pressurized systems and stored energy, can be isolated or reduced to a zero energy state prior to maintenance or service work.

17.4.2 The hazardous energy isolation devices should be in a location that is readily accessible.

17.4.3 The hazardous energy isolation devices should be capable of being locked in the position in which the hazardous energy is isolated.

18 Mechanical Design

18.1 This section covers hazards due to the mechanical aspects of the equipment.

NOTE 78: This is similar to the essential requirements of European Union directives. The supplier has the option of demonstrating compliance by choosing standards that are appropriate to the machine and application.

NOTE 79: Pressurized vessels must meet applicable codes and regulations.

18.2 *Machine Stability* — Equipment, components, and fittings should be designed and constructed so that they are stable under reasonably foreseeable shipping, installation, and operating conditions. The need for special handling devices and anchors should be indicated in the instructions. Unanchored equipment in its installed condition should not overbalance when tilted in any direction to an angle of 10 degrees from its normal position.

NOTE 80: See IEC 61010-1 for an example of stability tests.

18.3 *Break-up During Operation* — The various parts of the equipment and its linkages should be able to withstand the stresses to which they are subjected when used as designed. Precautions should be taken to control risks from falling or flying objects.

18.3.1 The potential effects of fatigue, aging, corrosion, and abrasion for the intended operating environment should be considered as part of the mechanical hazards risk assessment.

18.3.2 Where a risk of rupture or disintegration remains despite the measures taken (e.g., a substrate chuck that loses its vacuum), the moving parts should be mounted and positioned in such a way that, in case of rupture, their fragments will be contained.

18.3.3 Both rigid and flexible pipes carrying liquids or gases should be able to withstand the foreseen internal and external stresses and should be firmly attached or protected against external stresses and strains. Based on the application, an appropriate factor of safety should be included.

18.4 *Moving Parts* — The moving parts of equipment should be designed, built, and positioned to avoid hazards. Where hazards persist, equipment should be fitted with guards or protective devices that reduce the likelihood of contact that could lead to injury.

18.4.1 Where the machine is designed to perform operations under different conditions of use (e.g., different speeds or energy supplies), it should be designed and constructed in such a way that selection and adjustment of these conditions can be performed safely.

18.4.2 *Selection of Protection Against Hazards Related to Moving Parts* — Guards or protective devices used to protect against hazards related to moving parts should be selected on the basis of a risk assessment that includes the:

- hazards that are being guarded against;
- probability of occurrence and severity of injury of each hazard scenario; and
- frequency of removal of guards.

18.4.3 Guards and protection devices. Guards should:

- reduce the risk that personnel will contact the mechanical hazard to an acceptable level; and
- not give rise to additional risk.

18.5 *Lifting Operations* — Equipment presenting hazards due to lifting operations (e.g., falling loads, collisions, tipping) should be designed and constructed to reduce the risk to an acceptable level.

18.6 *Extreme Temperatures* — Surfaces that are accessible to personnel, and that are at high (per temperature limits in Table 1) or very cold temperatures (below -10°C [14°F]), should be fitted with guards or designed out.

18.6.1 Where it is not feasible to protect or design out the exposures to extreme temperature, temperatures exceeding the limits are permitted, provided that either of the following conditions is met:

- unintentional contact with such a surface is unlikely; or
- the part has a warning indicating that the surface is at a hazardous temperature.

Table 1 Potentially Hazardous Surface Temperatures

Accessible Parts	*Maximum Surface Temperature, in °C*		
	Metal	*Glass, Porcelain, Vitreous Material*	*Plastic, Rubber*
Handles, knobs, grips, etc., held or touched for short periods (5 seconds or less) in normal use.	60	70	85
Handles, knobs, grips, etc. held continuously in normal use.	51	56	60
External surfaces of equipment, or parts inside the equipment, that may be touched.	65	80	95

19 Seismic Protection

NOTE 81: Users have facilities located in areas that are susceptible to seismic activity. The end user may require more stringent design criteria because of increased site vulnerability (e.g., local soil conditions and building design may produce significantly higher accelerations) and local regulatory requirements. Certified drawings and calculations may be required in some jurisdictions.

19.1 *General* — The equipment should be designed to control the risk of injury to personnel, adverse environmental impact, equipment and facility damage due to movement, overturning, or leakage of chemicals (including liquid splashing), during a seismic event. The design should also control equipment damage due to failure of fragile parts (e.g., quartzware, ceramics) during a seismic event.

NOTE 82: These criteria are intended to accomplish two things:

(1) allow equipment suppliers to correctly design the internal frame and components to withstand seismic forces; and

(2) allow equipment designers to provide end-users with the information needed to appropriately secure the equipment within their facility.

19.1.1 Because preventing all damage to equipment may be impractical, the design should control the failure of parts that may result in increased hazard (e.g., hazardous materials release, fire, projectile).

NOTE 83: It is recommended that the hazard analysis described in Section 6.8 be used to evaluate both the risk of part failure and the effectiveness of control measures.

19.1.1.1 These parts should be accessible for evaluation of damage.

NOTE 84: SEMI S8 contains guidelines for maintainability and serviceability; these may be used to determine accessibility.

19.2 *Design Loads* — The equipment, subassemblies, and all devices used for anchoring the equipment should be designed as follows:

19.2.1 For equipment containing hazardous production materials (HPMs), the equipment should be designed to withstand a horizontal loading of 94% of the weight of the equipment, acting at the equipment's center of mass.

19.2.2 For equipment not containing hazardous production materials (HPMs), the equipment should be designed to withstand a horizontal loading of 63% of the weight of the equipment, acting at the equipment's center of mass.

NOTE 85: Subassemblies may include transformers, vessels, power supplies, vacuum pumps, monitors, fire suppression components, or other items of substantial mass that are attached to the equipment.

19.2.3 Horizontal loads should be calculated independently on each of the X and Y axes, or on the axis that produces the largest loads on the anchorage points.

19.2.4 When calculating for overturning, a maximum value of 85% of the weight of the equipment should be used to resist the overturning moment.

NOTE 86: Because equipment may be placed into service anywhere in the world, it is recommended that the seismic protection design of the equipment be based upon requirements that allow the equipment, as designed, to be installed in most sites worldwide. The above loads are based on 1997 Uniform Building Code (UBC) requirements for rigid equipment in Seismic Zone 4, and are assumed to satisfy most design situations worldwide.

NOTE 87: If the equipment or internal component is flexible as defined by the UBC, is located above the midheight of the building, or is within 5 km of a major active fault, the horizontal design loadings in Sections 19.2.1 and 19.2.2 may not be conservative. Likewise, there are several conditions for which the horizontal design loadings are overly conservative (e.g., rigid equipment with rigid internal components located at grade, or sites with favorable soils conditions). For these conditions, designing based on the more detailed approach in the UBC may result in a more economical design. It is recommended that the user engage a professional mechanical, civil, or structural engineer to make these determinations.

19.3 The supplier should provide the following data and procedures to the user. This information should be included in the installation instructions as part of the documentation covered in Section 9.

- A drawing of the equipment, its support equipment, its connections (e.g., ventilation, water, vacuum, gases) and the anchorage locations identified in Section 19.4.
- The type of feet used and their location on a base frame plan drawing.
- The weight distribution on each foot.
- Physical dimensions, including width, length, and height of each structurally independent module.
- Weight and location of the center of mass for each structurally independent module.
- Acceptable locations on the equipment frame for anchorage.

NOTE 88: A "structurally independent module" reacts to seismic loads by transferring substantially all of the loads to its own anchorages, as opposed to transferring the loads to adjacent modules.

19.4 The locations of the tie-ins, attachments, or seismic anchorage points should be clearly identified.

NOTE 89: It is not the intent of SEMI S2 that the supplier provide the seismic attachment point hardware. Such hardware may be provided as agreed upon between supplier and user.

NOTE 90: It is the responsibility of the user to verify that the vibration isolation, leveling, seismic reinforcing, and load distribution is adequate.

20 Automated Material Handlers

20.1 This section covers automated material handlers, which include:

- substrate handlers;
- industrial robots and industrial robot systems; and
- unmanned transport vehicles (UTVs).

NOTE 91: Substrate handlers typically handle a single substrate at a time, and are distinguished from industrial robots by their small load capacity.

20.2 *General* — The means of incorporating personnel safeguarding into automated material handlers should be based on a hazard analysis. The hazard analysis should include consideration of the size, capacity, speed, and spatial operating range of the handler.

20.2.1 *Subsystem Stops* — If a separate stop button is used for the automated material handler, it should be differentiated from the EMO button.

20.3 *Substrate Handlers* — See Section 20.2, *General*.

20.4 *Industrial Robots and Industrial Robot Systems* — Industrial robots and industrial robot systems should meet the requirements of appropriate national or international standards, e.g., ANSI/RIA R15.06, ISO 10218, EN 775. If there are deviations from these standards because of semiconductor applications of the robot, these deviations may be found acceptable based on risk assessments.

20.5 *UTVs*

NOTE 92: There are two basic types of UTVs: (1) the floor-traveling (including both rail-guided and rail-independent) UTV, that automatically travels on the floor to a specified destination where it is unloaded or loaded; and (2) the space-traveling UTV, which automatically travels without resting on the floor (e.g., in the space below the ceiling) to a specified destination where it is loaded or unloaded. UTVs do not include rail-guided mechanisms that are attached to equipment (such as in wet benches).

20.5.1 *Collision Avoidance* — UTVs generally travel in wide areas and are used in a system rather than stand alone operation. UTVs should be equipped with a non-contact approach sensing device so that they do not inadvertently contact people or other objects.

20.5.2 *UTVs: Loading and Unloading Equipment*

20.5.2.1 UTVs should be interlocked with equipment such as semiconductor process equipment, automated load ports, stockers, ground-based conveyors, and automated warehouses as needed to ensure that the load remains secure and that the UTV and transfer components are not in conflict with one another.

20.5.2.2 If loading results in an unsafe condition, the equipment should detect and indicate the condition, and movement of all loading equipment should stop immediately. The system should not reset or restart automatically.

21 Environmental Considerations

21.1 This section covers environmental impacts throughout the life of the equipment.

NOTE 93: It is recommended that environmental impacts be balanced against other factors, including safety and health, legal, and regulatory requirements.

NOTE 94: It is recommended that the manufacturer maintain awareness of relevant environmental regulations, either internally or through the user.

NOTE 95: The user is responsible for providing the manufacturer with information regarding any environmental restrictions that are specific to a given site and that may impact equipment design (e.g., cumulative emissions limits, permit requirements, site-specific programs).

NOTE 96: See Section 14 for fire suppression emission issues.

NOTE 97: References to “process” in this section are meant to refer to the baseline process.

21.2 *Design*

21.2.1 The following design guidelines apply to all phases of equipment life, from concept to decommissioning and disposal.

NOTE 98: The documentation described in Sections 8.5.3 and 9.4 provide information that can be used for evaluating conformance to this section.

21.2.2 *Resource Conservation*

21.2.2.1 The manufacturer should consider resource conservation (i.e., reduction, reuse, recycling) during equipment design, for example:

- water reuse or water recycling within the equipment;
- reduced chemical consumption, energy use, and water use (e.g., reducing resource use when no process is occurring);

- reduced use of resources during maintenance procedures (e.g., parts cleaning procedures could include minimum rinse rates and rinse times);
- recycling or reusing chemicals in the equipment, rather than consuming only new materials;
- reducing volume of packaging, increasing recycled content of packaging, and/or designing reusable packaging.

21.2.3 *Chemical Selection*

21.2.3.1 Chemical selection for process, maintenance, and utility uses (e.g., gases, etchants, strippers, cleaners, lubricants, and coolants) should take into account effectiveness, environmental impacts, volume, toxicity, by-products, decommissioning, disposal, and recyclability; use of the least hazardous chemical is preferred. To the extent practicable, the utilities, maintenance, and process should be designed so that the equipment operates without the use of:

- ozone depleting substances (ODSs) as identified by the Montreal Protocol, such as chlorofluorocarbons (CFCs), methylchloroform, hydrochlorofluorocarbons (HCFCs), and carbon tetrachloride, or
- perfluorocompounds (PFCs), including CF_4, C_2F_6, NF_3, C_3F_8, and SF_6, and CHF_3 due to their global warming potential.

21.2.4 *Prevention and Control of Unintended Releases*

21.2.4.1 Equipment design, including feed, storage, and waste collection systems, should prevent potential unintended releases. At a minimum:

21.2.4.2 Secondary containment for liquids should be capable of holding at least 110% (see first row of Table A3-1 of Appendix 3) of the volume of the single largest container, or the largest expected volume for any single point failure.

NOTE 99: In some circumstances secondary containment may be specified by the equipment supplier, but provided by the user.

21.2.4.3 Chemical storage containers and secondary containment should be designed for accessibility and easy removal of collected material.

21.2.4.4 Secondary containment should have alarms and gas detection or liquid sensing, as appropriate, or have recommended sensing points identified in the equipment installation instructions.

21.2.4.5 Equipment design should allow personnel to determine all in-equipment container levels conveniently without having to open the containers, where ignorance of the level could result in an inadvertent release.

21.2.4.6 Overfill level detectors and alarms should be provided for in-equipment containers.

21.2.4.7 Secondary containment and other control systems should be designed to ensure that chemicals cannot be combined, where the combination could result in an inadvertent release.

21.2.4.8 Equipment components should be compatible with chemicals used in the manufacturing process. Chemical systems should be designed for the specified operating conditions, and have sufficient mechanical strength and corrosion resistance for the intended use.

21.2.4.9 Equipment should be able to accept a signal from a monitoring device and stop the supply of chemical, at the first non-manual valve within the affected system.

21.2.4.10 Chemical distribution systems should be capable of automatic shutoff and remote shutdown.

21.2.5 *Effluents, Wastes, and Emissions*

NOTE 100: It is recommended that the manufacturer document its efforts to minimize the equipment's generation of hazardous wastes, solid wastes, wastewater, and air emissions.

NOTE 101: It is recommended that SEMI F5 be used for guidance in gaseous effluent handling.

21.2.5.1 Equipment design that allows connection to a central waste collection system is preferred, except where collection at the equipment may facilitate recycling or reuse opportunities or otherwise reduce environmental impacts.

NOTE 102: It is recommended that individual drains and exhausts be kept separate (e.g., separate outlets for acid drain, solvent drain, deionized (DI) water drain; acid exhaust, solvent exhaust).

21.2.5.1.1 Point-of-use collection containers should be designed for accessibility as well as the possible reuse and recycling of the collected materials.

21.2.5.2 Equipment should use partitions, double-contained lines, or other similar design features to prevent the mixing of incompatible waste streams.

21.2.5.3 The manufacturer should evaluate the feasibility of including integrated controls for effluent and emission treatment.

21.2.5.4 Dilution in excess of process or safety requirements should not be used to reduce contaminant discharge concentrations.

21.2.5.5 Segregation of effluents, wastes, and emissions should be provided in the following cases:

- where chemically incompatible;

- where segregation facilitates recycling or reuse; or
- where separate abatement or treatment methods are required.

NOTE 103: It is recommended that the equipment design documentation show evidence of consideration of by-products generated during equipment operation, clean-up, maintenance, and repair. By-products can include deposits in drains or ducts, and replaceable parts (e.g., batteries, vapor lamps, contaminated parts).

21.2.6 *Decommissioning and Disposal*

21.2.6.1 Equipment design should address (see Section 8.5.3 for documentation provisions) construction material and component reuse, refurbishment, and recycling.

21.2.6.2 The equipment should be designed to facilitate equipment decontamination and disposal, e.g., by use of removable liners or replaceable modules. This includes minimizing the number of parts that become contaminated with hazardous materials.

NOTE 104: It is recommended that SEMI S12 "Guidelines for Equipment Decontamination" be used for guidance during equipment decontamination.

22 Exhaust Ventilation

22.1 Equipment exhaust ventilation should be designed to prevent potentially hazardous chemical exposures to employees as follows:

22.1.1 As primary control when normal operations present potentially hazardous chemical exposures to employees by diffusive emissions that cannot be otherwise prevented or controlled (e.g., wet decks, spin coaters).

NOTE 105: In the context of this section, "primary control" means that it is the control of first choice (e.g., rather than personal protective equipment).

22.1.2 As supplemental control when intermittent activities (e.g., chamber cleaning, implant source housing cleaning) present potentially hazardous chemical exposures to employees which cannot reasonably be controlled by other means. Supplemental exhaust hoods or enclosures may be integrated into the equipment design, or supplied completely by the equipment user.

22.1.2.1 When a procedure (e.g., cleaning) specified by the supplier requires exhaust ventilation, the supplier should include the minimum criteria for exhaust during the procedure.

22.1.3 As secondary control when a single-point failure presents the potential for employee exposures to hazardous materials, and this exposure cannot be controlled by other means (e.g., use of all welded fittings).

EXCEPTION: Secondary exhaust control enclosures for non-welded connections (e.g., valve manifold boxes that enclose piping jungles) are not included in this guideline for those hazardous gases that are transported below atmospheric pressure (e.g., via vacuum piping systems) if it can be demonstrated that equivalent leak protection is provided. Equivalent protection may include such things as equipping the vacuum delivery system with a fail-safe (e.g., to close) valve automatically activated by a loss of vacuum pressure. Loss of vacuum pressure should also activate a visual and audible alarm provided in visual or audible range of the operator.

22.2 Equipment exhaust ventilation should be designed and a ventilation assessment conducted (see Section 23.5, Appendix 2, and SEMI S6) to control, efficiently and safely, for potential worst-case, realistic employee exposures to chemicals during normal operation, maintenance, or failure of other equipment components (hardware or software). All design criteria and test protocols should be based on recognized methods. See also Section 23.3.

22.3 Documentation should be developed showing the equipment exhaust parameters and relevant test methods, and should include (see also Appendix 2):

- duct velocity (where needed to transport solid particles);
- volumetric flow rate Q;
- capture velocity (where airborne contaminants are generated outside an enclosure);
- face velocity (where applicable);
- hood entry loss factor F_h or K;
- coefficient of entry $C_{e.}$;
- hood static pressure SP_h;
- duct diameter at the point of connection to facilities; and
- location(s) on the duct or hood where all ventilation measurements were taken.

22.4 Exhaust flow interlocks should be provided by the manufacturer on all equipment that uses hazardous production materials (HPMs) where loss of exhaust may create a hazard. Flow (e.g., pitot probe) or static pressure (e.g., manometer) switches are the preferred sensing methods.

NOTE 106: Sail switches (switches that are connected to a lever that relies upon air velocity to activate) are generally not recommended.

NOTE 107: It is recommended that the pressure or flow measuring point be located upstream of the first damper.

NOTE 108: Section 11 contains provisions for safety interlocks.

22.4.1 When the exhaust falls below the prescribed set point, an alarm should be provided within audible or visible range of the operator, and the process equipment should be placed in a safe stand-by mode. A time delay and exhaust setpoint for the equipment to go into standby mode may be allowable, based on an appropriate risk assessment. The system should be capable of interfacing with the facility alarm system.

NOTE 109: It is recommended that non-HPM chemical process exhaust be equipped with audible and visible indicators only.

22.4.2 Exhaust flow interlocks and alarms should require manual resetting.

22.4.3 Exhaust flow interlocks should be fault-tolerant.

22.5 Equipment and equipment components should be designed using good ventilation principles and practices to ensure chemical capture and to optimize exhaust efficiency (see Appendix 2).

NOTE 110: It is recommended that exhaust optimization be achieved with total equipment static pressure requirements of –1 to –38 mm (–0.05 to –1.5") H_2O (see also Section A2-1 of Appendix 2, and Section 8.3.6.1 of SEMI S6-93).

23 Chemicals

23.1 The manufacturer should generate a chemical inventory identifying the chemicals anticipated to be used or generated in the equipment. At a minimum, this should include chemicals in the recipe used for equipment qualification or "baseline" recipe, as well as intended reaction products and anticipated by-products. Chemicals on this list that can be classified as hazardous production materials (HPMs), or odorous (odor threshold < 1 ppm) or irritant chemicals (according to their material safety data sheets), should also be identified.

23.2 A hazard analysis (see Section 6.8) should be used as an initial determination of chemical risk as well as to validate that the risk has been controlled to an appropriate level.

23.2.1 The hazard analysis, at a minimum, should address the following conditions:

- potential mixing of incompatible chemicals;
- potential chemical emissions during routine operation;
- potential chemical emissions during maintenance activities; and
- potential key failure points and trouble spots (e.g., fittings, pumps).

23.2.2 All routes of exposure (e.g., respiratory, dermal) should be considered in exposure assessment.

23.3 The order of preference for controls in reducing chemical-related risks is as follows:

23.3.1 substitution or elimination (see also Section 21.2.2);

23.3.2 engineering controls (e.g., enclosure, ventilation, interlocks);

23.3.3 administrative controls (e.g., written warnings, standard operating procedures);

23.3.4 personal protective equipment.

23.4 The design of engineering controls (e.g., enclosure, ventilation, interlocks) should include consideration of (see also Appendix 3):

- pressure requirements;
- materials incompatibility;
- equipment maintainability;
- chemical containment; and
- provisions for exhaust ventilation (see Section 22).

23.5 During equipment development, the supplier should conduct an assessment that documents conformance to the following airborne chemical control criteria (see also Appendix 2). All measurements should be taken using recognized methods with documented sensitivities and accuracy. A report documenting the survey methods, equipment operating parameters, instrumentation used, calibration data, results, and discussion should be available.

23.5.1 There should be no chemical emissions to the workplace environment during normal equipment operation. Conformance to this section can be shown by demonstrating ambient air concentrations to be less than 1% of the Occupational Exposure Limit (OEL) in the worst-case personnel breathing zone. Where a recognized method does not provide sufficient sensitivity to measure 1% OEL, then the lower detection limit of the method may be used to satisfy this criterion.

23.5.2 Chemical emissions during maintenance activities should be minimized. Conformance to this section can be shown by demonstrating ambient air concentrations to be less than 25% of the OEL, in the anticipated worst-case personnel breathing zone, during maintenance activities.

23.5.3 Chemical emissions during equipment failures should be minimized. Conformance to this section can be shown by demonstrating ambient air concentrations to be less than 25% of the OEL, in the anticipated worst-case personnel breathing zone, during a realistic worst-case system failure.

NOTE 111: The use of direct reading instrumentation under simulated operating, maintenance, or failure conditions is the preferred measurement method. Where used, it is recommended that the sample location(s) be representative of the worst-case, realistic exposure locations(s). It is recommended that the peak concentration be directly compared to the OEL to demonstrate conformance to Sections 23.5.1–23.5.3.

NOTE 112: It is recommended that integrated sampling methods be used when direct-reading instrumentation does not have adequate sensitivity, or when direct-reading technology is not available for the chemicals of interest. Where integrated sampling is used, it is recommended that the sample duration and locations(s) be representative of the worst-case, realistic, anticipated exposure time and locations. The resulting average concentration is directly compared to the OEL to demonstrate conformance to Sections 23.5.1–23.5.3.

NOTE 113: Tracer gas testing (see SEMI F15 for an acceptable method) may be used when direct-reading instrumentation does not have adequate sensitivity, or when direct-reading technology is not available for the chemicals of interest. Tracer gas testing should be used where testing conditions may be hazardous (e.g., system failure simulation with potential release of hazardous gas to atmosphere). It is recommended that tracer gas testing be used only when an accurate rate of chemical emission can be determined. Where used, it is recommended that the sample location(s) be representative of the worst-case, realistic exposure location(s).

23.5.4 Chemical emissions outside the enclosure during a realistic worst-case system failure should be less than the lower of the following two values: 25% of the lower explosive limit (LEL), or 25% of the OEL.

23.6 Equipment that uses hazardous gases may require continuous detection and, if so, should have sample points mounted in the equipment, or have recommended sampling points identified in the equipment installation instructions. Where the gas supply is part of or controlled by the equipment, the equipment should be able to accept a signal from an external monitoring device and shut down the supply of the gas.

23.7 Appropriate hazard warning labels should be placed at all chemical enclosure access openings.

24 Ionizing Radiation

24.1 This section covers equipment that produces ionizing radiation (e.g., X-rays, gamma rays) or uses radioactive sources.

24.2 Accessible emissions of ionizing radiation should be designed as low as reasonably achievable. This criteria can be met by demonstrating conformance to the provisions in Sections 24.2.1 and 24.2.2 and Appendix 4.

24.2.1 Accessible levels of ionizing radiation during normal operations should be less than 2 microsieverts (0.2 millirem) per hour above background. See also Table A4-1 of Appendix 4.

24.2.2 Accessible levels of ionizing radiation during maintenance and service procedures should be less than 10 microsieverts (1 millirem) per hour above background. See also Table A4-1 of Appendix 4.

24.2.3 Access to radioactive contamination or internal exposure (e.g., inhalation, ingestion) to radioactive materials should be minimized. The hazards and controls for the prevention of personnel contamination and internal exposures should be detailed in the operation and maintenance manuals.

NOTE 114: The use of radioactive material is strictly regulated around the world. Import, export, and transportation of radioactive materials is also highly regulated. Licenses may be required to possess, use, and distribute radioactive materials.

NOTE 115: Many regions require both user and import licenses, and the timely acquisition of these licenses depends on the information provided by the equipment supplier.

NOTE 116: Radiation producing machines are also regulated around the world. Regulations and licensing requirements may cover activities such as importing, exporting, installing, servicing and using radiation producing equipment.

24.2.4 The manufacturer should supply, in the user documentation, a contact phone number and address for the manufacturer's radiation safety support personnel.

24.3 Equipment should be designed to minimize access or exposure to ionizing radiation during normal operation, maintenance, and service. Potential exposures should be controlled in the following order of preference:

24.3.1 *Engineering Controls* — Engineering controls (e.g. shielding, interlocks) should be the primary mechanism to minimize emission of ionizing radiation or access to ionizing radiation.

24.3.1.1 Radiation shielding for the equipment facilities connections (e.g., gas and exhaust lines) should be designed such that removal and replacement of the shielding during installation is minimized.

24.3.2 Non-defeatable safety interlocks should be provided on barriers preventing maintenance access to radiation fields in excess of 10 microsieverts (μSv) or 1 millirem per hour.

24.3.3 *Administrative Controls* — When administrative controls (e.g., distance, time, standard operating procedures, labeling) are to be used, the equipment supplier should provide detailed documentation explaining the use of the administrative controls.

24.4 Equipment utilizing or producing ionizing radiation should be labeled appropriately.

NOTE 117: Label contents are typically controlled by regulation in the country in which the equipment is to be used.

24.5 The manufacturer should conduct an assessment to document conformance to the criteria specified in Sections 24.2.1 through 24.2.2 during normal equipment operation, maintenance, and service.

24.5.1 A radiation survey should be used to confirm design compliance and serve as a baseline survey (see also Table A4-1 of Appendix 4).

24.5.2 Measurements should be taken using recognized methods with documented sensitivities and accuracy. A report documenting the survey methods, equipment operating parameters, instrumentation used, calibration data, source locations, results, and discussion should be made available.

24.5.3 If supplemental administrative controls are recommended based on survey results or calculations, a discussion should be provided in the operations and maintenance manuals describing the source locations, radiation levels, and recommended control measures.

NOTE 118: Ionizing radiation sources must be registered or licensed according to the regulations of the country of destination. These radiation sources must conform to the regulations of central or local government agencies, whichever is stricter.

NOTE 119: It is recommended that equipment containing radioactive materials should demonstrate conformance to licensing with local regulatory agencies prior to shipment.

NOTE 120: Equipment that uses particle acceleration in its process has the potential for generating ionizing radiation as a result of nuclear interactions between the accelerated particles and various materials. These materials can include materials of construction of the equipment, accumulated residual process materials in the equipment, and the target materials.

25 Non-Ionizing Radiation and Fields

25.1 This section covers equipment that produces non-ionizing radiation, except laser sources, in the following categories:

- static electric and magnetic (0 Hz),
- sub-radio frequency electric and magnetic fields (< 3 kHz),
- radio frequency (3 kHz–300 GHz),
- infrared radiation (700 nm–1 mm),
- visible Light (400 nm–700 nm), and
- ultraviolet Light (180–400 nm).

25.2 Potentially hazardous non-ionizing radiation emissions that are accessible to any personnel should be limited to the lowest practical level. This criterion can be met by demonstrating conformance to the following provisions:

EXCEPTION: Emissions of non-ionizing radiation exceeding the cardiac pacemaker limits in Appendix 5 but less than the levels in Sections 25.2.1 and 25.2.2 should be identified with appropriate labeling. See also Section 25.5.1.

25.2.1 Accessible levels of non-ionizing radiation during normal operations are less than the Operator-Accessible Limit (see Appendix 5);

25.2.2 Accessible levels of non-ionizing radiation during maintenance and service procedures are less than the Maintenance- and Service-Accessible Limit (see Appendix 5).

25.3 Sources of potentially hazardous non-ionizing radiation should be identified in the operation and maintenance manuals, and appropriate parameters listed. Parameters include frequency, wavelength, power levels, continuous wave or pulsed (see also Appendix 5). If pulsed, parameters also include the pulse repetition rate, pulse duration, and description of the pulse waveform.

EXCEPTION: Visible sources which are intended to be viewed or which provide illumination (e.g., display panels, visible alarm indicators), and are not lasers, do not need to be identified.

NOTE 121: It is recommended that UV/IR generators that are part of fire protection test apparatus, and are provided with the equipment, be considered as possible sources of potentially hazardous non-ionizing radiation.

25.4 Equipment should be designed to minimize access or exposure to non-ionizing radiation during normal operation, maintenance, and service. Potential exposures should be controlled in the following order of preference:

25.4.1 engineering controls (e.g., enclosure, shielding, guarding, grounding, interlocks);