
This document was modified in November 2000 to correct various errata. Changes were made to Sections 9.7, 14.4.7, and 17.4.1, and Notes 39 and 60.

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
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
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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
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Appendix 5 — Non-Ionizing Radiation (Other than Laser) and Fields Test Validation
Appendix 6 — Fire Protection: Flowchart for Selecting Materials of Construction

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.

2.4 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 standard to establish appropriate safety and health practices and determine the applicability of regulatory 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

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 Visual Hazard Alerts
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 — Electrical Test Methods 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

4.2 ANSI Standards
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

4.3 CEN/CENELEC Standards
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 IEC Standards
IEC 61010-1 — Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Equipment, Part 1: General Requirements

4.5 ISO Standards
ISO 10218 — Manipulating industrial robots--Safety

4.6 NFPA 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

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1 American National Standards Institute, 11 West 42nd Street, New York, New York 10036, USA, 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
5 National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, Massachusetts, 02269-9101, USA, www.nfpa.org
4.7 Other Standards and Documents


Burton, D.J., *Semiconductor Exhaust Ventilation Guidebook* 8

Uniform Building Code™ (UBC) 9

Uniform Fire Code™ 10

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

5 Terminology

5.1 Abbreviations and Acronyms

5.1.1 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.

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 ($K_e$ 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 2: 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 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.

5.2.16 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.

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

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

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

5.2.20 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.

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

5.2.22 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.

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

5.2.24 hazard — a condition that is a prerequisite to a mishap.

5.2.25 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.

5.2.26 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 3: The specified levels are based on normal conditions in a dry location.

5.2.27 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.

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

\[
Q = 4.043A\left(\frac{SP_b/d}{1+F_h}\right)^{0.5}
\]

where:

- \( Q \) = volumetric flow rate in \( m^3/sec \),
- \( A \) = cross sectional area of the duct in \( m^2 \),
- \( SP_b \) = hood static pressure in mm water gauge (w.g.), and
- \( d \) = density correction factor (unitless).

(US units: \( Q = 4005A\left(\frac{SP_b/d}{1+F_h}\right)^{0.5} \))

5.2.29 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.

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

5.2.31 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.

5.2.32 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.

5.2.33 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.

5.2.34 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.

5.2.35 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.

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

5.2.38 **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.

5.2.39 **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).

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

5.2.41 **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.

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


5.2.43 **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 5: 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.

5.2.44 **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.)

5.2.45 **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 $3 \times 10^4$ 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; subradio-frequencies; radiofrequency/microwave energy; and infrared, visible, and ultraviolet energies.

5.2.46 **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.

5.2.47 **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.)

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

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

5.2.50 **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).

5.2.51 **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.

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

5.2.53 **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.

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

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

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

5.2.57 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.

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

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

5.2.60 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.

5.2.61 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.

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

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

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

5.2.65 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.

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

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

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

5.2.69 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.)

5.2.70 testing — the term “testing” is used to describe measurements or observations used to validate and document conformance to designated criteria.

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

5.2.72 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.

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

5.2.74 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: 

\[ VP = \left(\frac{V}{4.043}\right)^2, \text{where } V = \text{air velocity in m/s, and } VP = \text{velocity pressure in mm water gauge (w.g.).} \]

[U.S. units: \( VP = \left(\frac{V}{4005}\right)^2, \text{where } V = \text{velocity in feet per second, and } VP = \text{velocity pressure in inches water gauge (w.g.)} \]

5.2.75 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: 

\[ Q = VA, \text{where } V = \text{air flow velocity, and } A = \text{the cross-sectional area of the duct or opening through which the air is flowing at standard conditions.} \]

5.2.76 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.

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 6: 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.

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 7: 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 8: 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 9: 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, 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 10: It is recommended that the user make a request for the supplier to 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 11: 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 12: 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 13: 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 14: 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 15: 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 16: 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., beryllium-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 17: 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 18: 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., beryllium-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 19: 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 20: 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 21: 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 22: 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 23: 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 24: This section does not address the defeatability of safety interlocks. See Section 11.7 for additional information.

11.6 Electromechanical devices and components are preferred, but solid-state devices and components may be used, provided that the safety interlock system, or relevant parts of the system, are evaluated for suitability for use. 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 25: 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 26: 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 27: Solid-state devices include operational amplifiers, transistors, and integrated circuits.

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 28: 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 29: 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 30: 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.

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

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

12.2.5 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 31: 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 32: 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 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.

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

NOTE 34: 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 35: 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 36: 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 37: 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) measured from any point on the surface of the equipment covers and associated controls to earth ground. (Refer to SEMI S9 or other appropriate standards for recognized test methods.)

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 between the main equipment grounding conductor terminal and any accessible metal surfaces that are: accessible to operator without the use of tools; and likely to become energized in a single-point failure condition. Refer to SEMI S9 or other appropriate standards for recognized test methods.

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 38: 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 39: 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 40: 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.

14.3 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 41: 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 42: Some jurisdictions require interlocking.

NOTE 43: 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 44: Controlling smoke may be sufficient when smoke is the only consequence (e.g., smoldering components that generate smoke).

NOTE 45: 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 46: The use of exhaust to remove smoke may be subject to regulations, such as building and fire codes.

NOTE 47: 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 48: 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.

NOTE 49: 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.

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”)).

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

NOTE 50: For the purposes of this section, “inoperable” includes the equipment state after an EMO is activated, and during maintenance of a duration less than the battery life expectancy of the fire detection system. Therefore, it is recommended that the detection system not require hazardous energies (e.g., line alternating current) to operate following an EMO activation.
14.4.4.8 A back-up power supply, capable of sustaining the detection system for 24 hours, should be provided.

NOTE 51: 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 52: 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 53: 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 54: 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.

NOTE 55: 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 potential damage to a cleanroom, and 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 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.

14.4.5.5 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.

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

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

NOTE 56: 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.

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

14.4.5.8 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.

14.4.5.9 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 57: 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 58: The permissibility of deactivation of suppression systems varies among jurisdictions.

14.4.5.10 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 59: The requirements for back-up power vary among jurisdictions.

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

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

NOTE 60: 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.

14.4.5.13 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.

14.4.5.14 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.

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

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

NOTE 61: 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.

14.4.5.17 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.

14.4.5.18 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.

14.4.5.19 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 62: 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 63: 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 64: 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 65: 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 66: Energy isolation devices for incompatible hazardous energy sources (e.g., electrical and water, incompatible gases) are recommended to be separated.

NOTE 67: 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 68: 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 69: 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 70: 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 71: 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 72: 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 73: 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.

19 Seismic Protection

NOTE 74: 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 75: 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 76: 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 77: 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 78: 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.

Table 1 Potentially Hazardous Surface Temperatures

<table>
<thead>
<tr>
<th>Accessible Parts</th>
<th>Maximum Surface Temperature, in °C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Metal</td>
</tr>
<tr>
<td>Handles, knobs, grips, etc., held or touched for short periods (5 seconds or less) in normal use.</td>
<td>60</td>
</tr>
<tr>
<td>Handles, knobs, grips, etc. held continuously in normal use.</td>
<td>51</td>
</tr>
<tr>
<td>External surfaces of equipment, or parts inside the equipment, that may be touched.</td>
<td>65</td>
</tr>
</tbody>
</table>
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 79: 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 80: 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 81: 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 82: 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 83: 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 84: 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 85: 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 86: It is recommended that environmental impacts be balanced against other factors, including safety and health, legal, and regulatory requirements.

NOTE 87: It is recommended that the manufacturer maintain awareness of relevant environmental regulations, either internally or through the user.

NOTE 88: 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 89: See Section 14 for fire suppression emission issues.

NOTE 90: 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 91: 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 CF₃, C₂F₆, NF₃, C₃F₈, and SF₆, 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 92: 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 93: 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 94: 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 95: 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 96: 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 97: 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 98: 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 be otherwise prevented or controlled (e.g., wet decks, spin coaters).

NOTE 99: 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).

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).
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 \( S_{Ph} \);
- 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 99: Sail switches (switches that are connected to a lever that relies upon air velocity to activate) are generally not recommended.

NOTE 100: It is recommended that the pressure or flow measuring point be located upstream of the first damper.

NOTE 101: 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 102: 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 103: It is recommended that exhaust optimization be achieved with total equipment static pressure requirements of \(-1\) to \(-38 \text{ mm} \) (\(-0.05\) to \(-1.5\)”) \( \text{H}_2\text{O} \) (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 104: 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 location(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 105: 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 106: 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 107: 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 108: 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 109: 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 110: 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 111: 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 112: It is recommended that equipment containing radioactive materials should demonstrate conformance to licensing with local regulatory agencies prior to shipment.

NOTE 113: 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 114: 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);

25.4.2 administrative controls (e.g., written warnings, standard operating procedures, labeling); and

25.4.3 personal protective equipment.

25.5 Equipment utilizing or producing potentially hazardous non-ionizing radiation should be labeled.

25.5.1 Hazard warning labels should be provided by the manufacturer when emission levels are measured that may impact cardiac pacemakers or magnetizable prostheses. These warning labels should be located where the emissions exceed the pacemaker limit. (See Appendix 5 for pacemaker labeling levels and references.)

25.6 The manufacturer should conduct an assessment to document conformance to the criteria specified in Sections 25.2.1 and 25.2.2. Engineering calculations may be used as part of this assessment. 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, source location(s), and discussion should be provided. See Appendix 5.

25.6.1 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 location(s), radiation levels, and recommended control measures.

25.6.2 Administrative control procedures recommended for operation, maintenance, or service activities should be documented in the operations and maintenance manuals.

26 Lasers

26.1 Equipment should be identified with a laser product classification based on the laser energy accessible during operation, per the applicable standard.

NOTE 115: A Class 1 label may be required in some jurisdictions, but is not currently required in the United States.

26.1.1 The laser energy (or power), wavelength, and temporal mode (continuous wave or pulsed) should be identified in the documentation provided to the user.

NOTE 116: The laser product classification for some equipment will be Class 1 or 2, even though an embedded laser is of a higher hazard classification.

26.1.1.1 If pulsed, the pulse repetition rate, pulse duration and description of the pulse waveform should be identified in the documentation provided to the user.

26.1.2 For Class 3b or 4 embedded laser systems, the above information and the physical location of the laser sources within the laser product should be
identified in the documentation provided to the user and in the maintenance manual.

26.1.2 Equipment should not exceed the laser product classification of Class 2; however, individual lasers may exceed this classification prior to integration into the final equipment assembly.

26.2 Equipment, including beam diagnostic or alignment tools, should be designed to prevent injury from all lasers during normal operation, and should minimize risk of injury during maintenance or service. Potential exposures should be controlled in the following order of preference:

26.2.1 Engineering controls (e.g., enclosures, shielding, filters, use of fiber optics to transmit energy, interlocks).

26.2.2 Temporary enclosures or control measures for maintenance, service, and non-routine tasks.

26.2.3 Administrative controls (e.g., written warnings, standard operating procedures, labeling).

26.2.4 Personal protective equipment.

NOTE 117: Temporary enclosures and personal protective equipment are considered to be administrative controls, because they require human action to implement.

NOTE 118: Certain classes of laser products are regulated around the world. Regulations and licensing requirements may cover activities such as importing, exporting, distributing, demonstrating, installing, servicing, and using these laser products.

26.3 The equipment supplier should provide the following in the operation and maintenance manuals:

- a description of laser-related hazards present during operation, maintenance, or service, and methods to minimize the hazard;
- justification for any procedures that require a laser controlled area and the dimensions of this hazard zone;
- administrative controls used in maintenance and service activities; and
- a description of necessary personal protective equipment.

26.4 The following detailed information should be available for the evaluator:

- justification for when engineering controls are not feasible to limit exposure during operation or maintenance tasks, and how administrative controls provide equivalent protection (see Section 26.2); and

- documentation showing compliance with an appropriate international laser product safety or industry standard, or the national standard for country of use.

27 Sound Pressure Level

27.1 Equipment should be designed to control exposures to sound pressure levels equal to or greater than 80 dBA continuous or intermittent sound pressure level, and 120 dB instantaneous (impulse) sound pressure level.

NOTE 119: It is recommended that efforts be made to decrease sound pressure levels as they approach 80 dBA (i.e., 77 to 80 dBA), due to the additive sound pressure level effects of multiple pieces of equipment in the same vicinity.

27.2 The order of preference for controlling exposures is as follows:

27.2.1 Engineering Controls (e.g., source sound pressure level reduction, absorption, enclosures, barriers, acoustic dampening) — At a minimum, the design of the engineering controls should consider the sound pressure levels and type, the frequency, and the appropriate control technologies.

27.2.2 Administrative Controls — Acceptable administrative controls should be limited to supplemental hazard warning labels and operating procedures.

NOTE 120: Noise labeling is typically implemented as signs located in the users facility.

27.3 Sound level surveys should be conducted by the manufacturer during equipment development for equipment that may emit hazardous sound pressure levels.

27.3.1 The survey should be conducted in accordance with a recognized standard. In addition, the following test criteria should be applied:

27.3.1.1 The equipment mode of operation during the sound pressure level tests should simulate as closely as possible the actual modes and operating positions that may be experienced by the equipment user.

27.3.1.2 Measurements should be taken in locations that best simulate actual positions of operators relative to the equipment. As a general guideline, the microphone should be traversed 1 meter from the equipment, 1.2 meters above the ground to simulate seated operators, 1.5 meters above the ground to simulate standing operators, and 3.5 meters (or as far as possible) away from the nearest walls or sound-reflecting objects. Measurements are taken 360 degrees around the equipment wherever possible.
Table 2  Sound Pressure Level Test Criteria

NOTE 121: Background level may be subtracted using an accepted method. If the sound pressure level difference is less than 3 dBA, the contribution of the source from the background cannot be adequately distinguished and the survey results would not be valid for values over 80 dBA.

<table>
<thead>
<tr>
<th>Difference between sound pressure level measured with noise source operating and background sound pressure level (dBA)</th>
<th>Correction to be subtracted from the sound pressure level measured with the noise source operating to obtain the sound pressure level due to noise source alone (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>2.5</td>
</tr>
<tr>
<td>5</td>
<td>1.7</td>
</tr>
<tr>
<td>6</td>
<td>1.3</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>0.8</td>
</tr>
<tr>
<td>9</td>
<td>0.6</td>
</tr>
<tr>
<td>10</td>
<td>0.4</td>
</tr>
</tbody>
</table>

27.3.2 If the measured sound pressure level is less than 70 dBA, the manufacturer should provide to the evaluator test data documenting sound pressure levels, survey equipment, equipment calibration, test conditions and results.

27.3.3 If the measured sound pressure level is greater than 70 dBA, the test data should include all of the information in Section 27.3.2, and should also include the expected duration of personnel exposure.

27.3.4 If measured sound pressure level is greater than 75 dBA, information should be provided in the equipment maintenance manual describing the sound pressure level(s) and location(s).

28 Related Documents

28.1 The following documents are sources of principles and practices of ventilation design.


ANSI/AIHA, Standard Z9.5-1992 Laboratory Ventilation


NFPA 45, Fire Protection for Laboratories Using Chemicals, National Fire Protection Association, 1 Batterymarch Park, Quincy, MA, USA

APPENDIX 1
ENCLOSURE OPENINGS

NOTE: The material in this appendix is an official part of SEMI S2 and was approved by full letter ballot procedures on December 15, 1999 by the North American Regional Standards Committee.

A1-1 This appendix provides guidance on sizes of openings in enclosures.

Table A1-1 Examples of Openings for Protection Against Access from Operators

<table>
<thead>
<tr>
<th>Distance Between Opening and Danger Point</th>
<th>Maximum Opening</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>inches</td>
</tr>
<tr>
<td>13–38</td>
<td>0.5–1.5</td>
</tr>
<tr>
<td>38–64</td>
<td>1.5–2.5</td>
</tr>
<tr>
<td>64–89</td>
<td>2.5–3.5</td>
</tr>
<tr>
<td>89–140</td>
<td>3.5–5.5</td>
</tr>
<tr>
<td>140–165</td>
<td>5.5–6.5</td>
</tr>
<tr>
<td>165–191</td>
<td>6.5–7.5</td>
</tr>
</tbody>
</table>

A1-1.1 Alternatively, an IEC accessibility probe, as specified in SEMI S9, may be used to determine suitability of mesh openings.

A1-2 Top Openings in Electrical Enclosures — The top openings in electrical enclosures should meet one of the following:

- not exceed 5 mm in any dimension, or
- not exceed 1 mm in width regardless of length, or
- be so constructed that direct, vertical entry of a falling object is prevented from reaching uninsulated live parts within the enclosure by means of trap or restriction (see Figure A1-1 below for examples of top cover designs that prevent such direct entry), or
- meet the intent through other equivalent means.

Figure A1-1

SLANTED OPENINGS

VERTICAL OPENINGS
APPENDIX 2
DESIGN PRINCIPLES AND TEST METHODS FOR EVALUATING EQUIPMENT EXHAUST VENTILATION — Design and Test Method Supplement Intended for Internal and Third Party Evaluation Use

NOTE: The material in this appendix is an official part of SEMI S2 and was approved by full letter ballot procedures on December 15, 1999 by the North American Regional Standards Committee.

A2-1 Introduction

A2-1.1 This appendix provides specific technical information relating to Section 22. In general, it provides guidelines for:

- ventilation design for semiconductor manufacturing equipment, and
- test validation criteria.

A2-1.2 This appendix is intended to be used as a starting point for reference during equipment design.

A2-1.3 This appendix is not intended to limit hazard or test evaluation methods or control strategies (e.g. design principles) employed by manufacturers or users. Many different methods may be employed if they provide a sufficient level of protection.

A2-1.4 This appendix is not intended to provide exhaustive methods for determining final ventilation specifications. Other methods may be used where they provide at least equivalent sensitivity and accuracy.

A2-1.5 The exhaust velocities, volume flow rates and pressures listed are derived from a mixture of successful empirical testing and regulatory requirements.

A2-1.6 Test validation criteria are generally referenced from the applicable internationally recognized standard. It is the user’s responsibility to ensure that the most current revision of the standard is used.

Table A2-1 Ventilation

<table>
<thead>
<tr>
<th>Hood Type</th>
<th>Recommended Test Methods</th>
<th>Typical Design and Test Exhaust Parameters (See NOTE 1.)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet Station</td>
<td>Primary: vapor visualization, air sampling</td>
<td>0.28–0.50 m/s (55–100 fpm) capture velocity for non-heated</td>
<td>ACGIH Industrial Ventilation Manual SEMI F15</td>
</tr>
<tr>
<td></td>
<td>Supplemental: Capture velocity, slot velocity, tracer gas, air sampling</td>
<td>0.36–0.76 m/s (70–150 fpm) capture velocity for heated</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>110–125% of the laminar flow volume flow rate across the top of the deck</td>
<td></td>
</tr>
<tr>
<td>Gas Cylinder Cabinets</td>
<td>Primary: face velocity, tracer gas</td>
<td>1.0–1.3 m/s (200–250 fpm) face velocity</td>
<td>ACGIH Industrial Ventilation Manual SEMI F15</td>
</tr>
<tr>
<td></td>
<td>Supplemental: vapor visualization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment Gas Panel Enclosure</td>
<td>Primary: tracer gas, static pressure</td>
<td>4–5 air changes per minute</td>
<td>ACGIH Industrial Ventilation Manual SEMI F15</td>
</tr>
<tr>
<td></td>
<td>Supplemental: vapor visualization</td>
<td>−1.3 to −2.5 mm (−0.05 to −0.1 in.) H₂O static pressure</td>
<td></td>
</tr>
<tr>
<td>Diffusion Furnace Scavenger</td>
<td>Primary: face velocity, vapor visualization</td>
<td>0.50–0.76 m/s (100–150) fpm face velocity</td>
<td>ACGIH Industrial Ventilation Manual SEMI F15</td>
</tr>
<tr>
<td></td>
<td>Supplemental: tracer gas, air sampling</td>
<td>NOTE: Do not use hot wire anemometer.</td>
<td></td>
</tr>
<tr>
<td>Chemical Dispensing Cabinets</td>
<td>Primary: static pressure</td>
<td>−1.3 to −2.5 mm (−0.05 to −0.1 in.) H₂O static pressure</td>
<td>ACGIH Industrial Ventilation Manual SEMI F15</td>
</tr>
<tr>
<td></td>
<td>Supplemental: vapor visualization, air sampling where safe, tracer gas where emission rates can be accurately calculated</td>
<td>2–3 air changes per minute</td>
<td></td>
</tr>
</tbody>
</table>
### Recommended Test Methods

<table>
<thead>
<tr>
<th>Hood Type</th>
<th>Recommended Test Methods</th>
<th>Typical Design and Test Exhaust Parameters (See NOTE 1.)</th>
<th>References</th>
</tr>
</thead>
</table>
| Parts-Cleaning Hoods       | Primary: face velocity, vapor visualization  
Supplemental: tracer gas, air sampling                                                   | 0.40–0.64 m/s (80–125 fpm) face velocity                                                                                   | ASHRAE Standard 110  
SEMI F15  
ACGIH Industrial Ventilation Manual                                      |
| Pump and Equipment Exhaust Lines | Primary: static pressure  
Supplemental: tracer gas                                                                  | –6 to –25 mm (–0.25 to –1.0 in.)  
H₂O static pressure  
125% maximum volume flow rate from pump                                                                                     | ACGIH Industrial Ventilation Manual  
SEMI F15                                                             |
| Glove Boxes                | Primary: static pressure, tracer gas  
Supplemental: vapor visualization, air monitoring                                            | No consensus for a reference at the time of publication of this guideline.                                                  | ACGIH Industrial Ventilation Manual  
SEMI F15                                                             |
| Drying/ Bake/ Test Chamber Ovens | Primary: static pressure, tracer gas  
Supplemental: vapor visualization, air monitoring                                            | –1.3 to –2.5 mm (–0.05 to –0.1 in.)  
H₂O static pressure                                                                                                          | SEMI F15  
ACGIH Industrial Ventilation Manual                                    |
| Spin-Coater (cup only)     | Primary: vapor visualization, velometry  
Supplemental: air sampling                                                                  | (see SEMI S2 Sections 23.5.1–3)                                                                                            | ACGIH Industrial Ventilation Manual                                       |
| Supplemental Exhaust       | Primary: capture velocity, vapor visualization, air sampling                                 | 0.50–0.76 m/s (100–150 fpm) capture velocity                                                                                | ACGIH Industrial Ventilation Manual                                       |

NOTE 1: All measurements should be within ± 20% of average for face velocity, ± 10% of average along the length of each slot for slot velocity, and ± 10% of average between slots for slot velocity.

### A2-2 Exhaust Optimization

#### A2-2.1 Exhaust Optimization

Exhaust optimization is the use of good ventilation design to create efficient equipment exhaust. The design and measurement methods discussed below confirm that equipment exhaust is acting as the manufacturer intended. This information is not meant to prohibit alternate methods of achieving or verifying good ventilation design. References for ventilation design are included at the end of this Appendix.

#### A2-2.2 Design Recommendations

- **A2-2.2.1** Equipment exhaust design can attempt to reduce inefficient static pressure losses caused by: friction losses from materials; openings, and duct geometries (elbows, duct expansions or contractions); turbulent air flow; fans; internal fittings such as blast gates and dampers; directional changes in airflow.

- **A2-2.2.2** Other good design principles can include minimizing distance between the source and hood, and reducing enclosure volumes.

- **A2-2.2.3** For non-chemical issues such as heat from electrical equipment, heat recapture rather than exhaust may be appropriate.

- **A2-2.2.4** The possible impact of highly directional laminar airflow found in most fabs should be considered when designing equipment exhaust.

#### A2-2.3 Recommended Equipment Controls

The location of internal blast gates or dampers inside equipment, and their appropriate settings, should be clearly identified. The number of equipment dampers and blast gates should be minimized. Gates/dampers should be lockable or otherwise securable. Static pressure or flow sensors installed on equipment by the manufacturer should have sufficient sensitivity and accuracy to measure exhaust flowrate fluctuations that place the equipment out of prescribed ranges.

#### A2-2.4 Recommended Measurement/Validation Method

- **A2-2.4.1** Measurements should be done after equipment components are assembled.

- **A2-2.4.2** Computer modeling can be done to predict exhaust flow and hazardous material transport in equipment by solving fluid mechanics conservation of energy and mass equations. Modeling can be used in the equipment design stage or to improve existing equipment. Computer models should be verified experimentally, using one or more of the methods discussed below.

- **A2-2.4.3** Tracer gas testing provides a method to test the integrity of hoods by simulating gas emission and measuring the effectiveness of controls. Testing until
there is a failure, and then slightly increasing the flow rate until the test is successful, can be used to help minimize air flow specifications.

A2-2.4.4 Chemical air or wipe monitoring can be used to confirm that chemical transport is not occurring into unintended areas of the equipment.

A2-2.4.5 Velocity profiling will confirm expected airflows, the direction of flow, and the effect of distance.

A2-2.4.6 Vapor visualization will confirm expected airflows, the direction of flow, and the effect of distance. Vapor visualization is the observation of aerosols (e.g., aerosols generated by using water, liquid nitrogen, or dry ice) so that exhaust flow patterns can be observed. Smoke tubes or aerosols may also be used, however they can produce contamination.

**A2-3 Chemical Laboratory Fume Hoods, Parts Cleaning Hoods**

Lab fume hoods and part cleaning hoods are designed to control emission by enclosing a process on five sides and containing the emission within the hood.

**A2-3.1 Design Recommendations**

A2-3.1.1 Fully enclosed on five sides, open on one side for employee access and process/parts placement and removals.

A2-3.1.2 Front (employee access side) should be provided with sliding door and/or sash.

A2-3.1.3 Minimize size of the hood based on process size.

A2-3.1.4 Minimize front opening size based on size of process and employee access needs.

A2-3.1.5 Ensure hood construction materials are compatible with chemicals used.

A2-3.2 Control Specifications — Face velocity is the specification generally used with hoods open on only one side.

A2-3.2.1 Generally acceptable laboratory fume hood face velocities range from 0.40 to 0.60 m/s (80–120 fpm) with no single measurement ± 20 % of average. 0.64 to 0.76 m/s (125–150 fpm) is recommended for hoods in which carcinogens or reproductive toxicants may be used.

A2-3.2.2 Velocities as low as 0.30 to 0.40 m/s (60–80 fpm) can be effective but require no cross drafts or competing air movement in the work area.

A2-3.2.3 An average face velocity of 0.50 m/s (100 fpm) is generally found to be acceptable in most applications.

A2-3.2.4 Face velocities of 0.64 to 0.76 m/s (125 to 150 fpm) may be required when a lab hood is installed in an area with laminar air flow.

A2-3.2.5 Face velocity above 0.76 m/s (150 fpm) should be avoided to prevent eddying caused by a lower pressure area in front of an employee standing at the hood.

**A2-3.3 Recommended Measurement/Validation Method**

A2-3.3.1 The preferred method is measurement of average face velocity and hood static pressure. Measurements are taken with a velometer or anemometer. Multiple measurements are taken in a grid, at least 10 to 40 per square meter (1–4 per square foot) of open area, in the plane opening of the hood. This allows representative, evenly spaced measurements to be taken (see also open-surface tanks).

A2-3.3.2 Additional confirmation by visualization check of containment using smoke or vapor testing.

A2-3.3.3 ASHRAE Method 110, or equivalent (use appropriate sections), for tracer gas testing of lab hoods may be used as a supplemental verification provided that an accurate emission rate can be defined. (ASHRAE 110 lists 3 tests: “as manufactured,” “as used,” and “as installed.” The “as manufactured” test is the test that is used most frequently.)

**A2-4 Wet Stations**

Wet stations are slotted hoods designed to capture laminar air flow while also capturing wet process emissions from the work area. Wet stations can be open on the front, top and both sides (it is usually preferable to enclose as much as possible).

**A2-4.1 Design Recommendations**

A2-4.1.1 Slots should be provided uniformly along the length of the hood for even distribution of airflow.

A2-4.1.2 Additional lip exhaust slots should be provided around tanks or sinks to control emissions.

A2-4.1.3 The plenum behind the slots should be sized to ensure even distribution of static pressure. These slots should be designed to ensure adequate airflow is provided by the side slots, and to minimize turbulence that could reduce exhaust performance.

A2-4.1.4 Velocity along length of slot should not vary by more than 10% of the average slot velocity.

A2-4.1.5 Additional use of end or side panels/baffles can reduce negative impact of side drafts.
A2-4.1.6 Exhaust volume settings should consider laminar air flow volumes and be balanced to minimize turbulence and to ensure capture.

A2-4.1.7 The station design should consider airflow patterns in the operating zone to minimize turbulent horizontal airflow patterns into and across the work deck.

A2-4.1.8 Additional considerations to reduce exhaust demand include providing covered tanks, and recessing tanks below deck level.

A2-4.2 Control Specifications

A2-4.2.1 Wet station specifications are complicated by the fact that wet stations generally do not have an easily definable face velocity to measure. A number of methods have been used and are all acceptable if used consistently and provided documentation indicates chemical containment meets the 1% of the OEL at distances beyond the plane of penetration at the exterior of the wet station.

A2-4.2.2 Maintain an average capture velocity of 0.33 to 0.50 m/s (65–100 fpm) immediately above a bath.

A2-4.2.3 Calculate the total exhaust volume requirement by determining the total volumetric flow of laminar air hitting the deck and increasing this value by 20 to 25%.

A2-4.2.4 For some wet stations that are partially enclosed from the top, an artificial plane opening (“face”) can be defined where the downward laminar air flow penetrates the capture zone (at “face velocity”) of the wet station. Depending on the hood design and laminar air flow provided, average face velocities can range from 0.20 to 0.50 m/s (40 to 100 fpm). The measurement location can greatly influence the measured face velocity; therefore, this method should be supplemented with at least one of the preceding methods for greater accuracy and reproducibility at the user’s facility.

A2-4.3 Recommended Measurement/Validation Method

A2-4.3.1 Confirmation of capture using vapor visualization.

A2-4.3.2 Confirmation of laminar flow of make up air into the station using vapor visualization.

A2-4.3.3 Tracer gas testing may be used as supplemental verification, provided an emission rate can be accurately defined.

A2-5 Supplemental Exhaust

Supplemental exhaust, if not designed into the equipment, can be provided by a flexible duct with a tapered hood. This can be placed in the work area to remove potential contaminants before they enter the breathing zone. Supplemental exhaust is frequently used during maintenance or service.

A2-5.1 Design Recommendations

A2-5.1.1 Retractable or movable non-combustible flex ducting for easy reach and placement within 150 to 300 mm (6 to 12 inches) of potential emissions to be controlled.

A2-5.1.2 Manual damper at hood to allow for local control, i.e., shut off when not required.

A2-5.1.3 Tapered hood with a plane opening as a minimum. The additional use of flanges or canopies to enclose the process will result in improved efficiency.

A2-5.2 Control Specifications

NOTE A2-1: This is one equation that is most commonly used. Other equations may be appropriate; see also ACGIH Industrial Ventilation Manual, and Semiconductor Exhaust Ventilation Guidebook.

A2-5.2.1 A minimum capture velocity of 0.50 m/s (100 fpm) is required at the contaminant generation point for releases of vapor via evaporation or passive diffusion. Ventilation should not be relied upon to prevent exposures to hazardous substances with release velocities (e.g., pressurized gases). For a plane open ended duct without a flange, the air flow required at a given capture velocity can be calculated by:

\[ Q = V(10X^2 + A) \]

Where: 
- \( Q \) = required exhaust air flow in m³/s (cfm) 
- \( V \) = capture velocity in m/s (fpm) at distance X from hood 
- \( A \) = hood face area in square meters (square feet) 
- \( X \) = distance from hood face to farthest point of contaminant release in meters (feet). NOTE: This is only accurate when X is within 1.5 diameters of a round opening, or within 0.25 circumference of a square opening.

A2-5.3 Recommended Measurement/Validation Method

A2-5.3.1 Measurement of capture velocity at farthest point of contaminant release. Measurements taken with a velocimeter or anemometer.

A2-5.3.2 Confirmation by visualization check of capture using vapor capture testing.

A2-6 Equipment Gas Panel Enclosures

Equipment gas panel enclosures, also known as gas boxes, jungle enclosures, gas jungle enclosures, valve
manifold boxes, and secondary gas panel enclosures, are typically six-sided fully enclosed enclosures with access panels/doors on at least one side. These ventilated enclosures are designed to contain and remove hazardous gases from the work area in the event of a gas piping failure or leak. Gas panel enclosures are typically of two types, those requiring no access while gas systems are charged, and those that must be opened during processing while gas systems are charged. There is also a distinct difference in control specifications for those with pyrophorics or other flammables vs. other HPMs, specifically in the control of pocketing.

**A2-6.1 Design Recommendations**

A2-6.1.1 Compartmentalize potential leak points.

A2-6.1.2 Minimize the total size of the panel and its enclosure.

A2-6.1.3 Minimize size and number of openings.

A2-6.1.4 Minimize static pressure requirements of the enclosure; control has been shown to be achievable with –1.3 to –2.5 mm (–0.05 to –0.1 in.) w.g.

A2-6.1.5 Design for sweep. Minimize the number and size of openings. Seal unnecessary openings (e.g., seams, utility holes).

A2-6.1.6 Where routinely used access doors are required:

- Make the access door as small as practical.
- Place the openings to the enclosure in the access door to minimize air flow requirements.
- Provide baffles behind the door to direct leaks away from the door and openings.
- Compartmentalize the enclosure so that access to one area does not affect air flow control in other areas.

**A2-6.2 Control Specifications**

A2-6.2.1 Exhaust volumes as low as 4–5 air changes per minute or less can be specified and meet the S2 criteria in Section 23.5 if the design principles listed above are considered when designing equipment and enclosures.

A2-6.2.2 Where there is potential for chemical exposure during access which can be controlled by face velocity, the enclosure should also provide a minimum face velocity of 0.36 to 0.76 m/s (70 to 150 fpm) when open. Face velocity should not be relied upon to control emissions from a pressurized fitting.

A2-6.2.3 Enclosures for pyrophoric or flammable gases should be designed to ensure adequately uniform dilution (i.e., prevent “pocketing”) and to prevent accumulation of pyrophoric and flammable gases above their lower explosive limit. Uniform dilution can generally be verified through exhaust vapor visualization techniques. Ventilation flow rate should be adequate to maintain concentrations below 25% of the lower explosive limit for the gas with the lowest LEL that is used in the enclosure. This can generally be verified using engineering calculations to verify dilution, and vapor visualization to verify mixing.

**A2-6.3 Recommended Measurement/Validation Method**

A2-6.3.1 Preferred validation by tracer gas testing per SEMI F15.

A2-6.3.2 Additional confirmation by visualization check of air flow, mixing and sweep using smoke or vapor testing.

A2-6.3.3 Measurement of average face velocity at inlet(s), opening(s), or routinely used access doors. Measurements should be taken with a velometer or anemometer. For larger openings, multiple measurements are taken in a grid, at least 10 to 40 per square meter (1–4 per square foot) of open area. Useful equation: \( V = 4.043 \left( \frac{VP}{d} \right)^{0.5} \), where \( V \) = velocity in m/s, \( VP \) = velocity pressure in mm H2O, and \( d \) = density correction factor (unitless).

**A2-7 Equipment Exhaust Ventilation Specifications and Measurements**

A2-7.1 Specifications for equipment exhaust should be provided by the supplier and define:

A2-7.1.1 The control specification or standard for the hood or enclosure, i.e., face velocity or capture velocity if applicable.

A2-7.1.2 The airflow in the duct required to maintain the control volume or flow required. Measurements should be made using the ACGIH pitot traverse method described below.

A2-7.1.3 The location where the Pitot traverse measurement in the duct was made.

A2-7.1.4 Static pressure requirements.

A2-7.1.5 Coefficient of Entry (\( C_e \)) (see definitions and Section 22.3).

A2-7.1.6 Hood Loss Factor (\( K \) or \( F_h \)) (see definitions and Section 22.3).

**A2-8 Duct Traverse Method**

A2-8.1 Because the air flow in the cross-section of a duct is not uniform, it is necessary to obtain an average by measuring velocity pressure (VP) at points in a number of equal areas in the cross-section. The usual
method is to make two traverses across the diameter of the duct at right angles to each other. Reading are taken at the center of annular rings of equal area. Whenever possible, the traverse should be made 7.5 duct diameters downstream and 3 diameters upstream from obstructions or directional changes such as an elbow, hood, branch entry, etc. Where measurements are made closer to disturbances, the results should be considered subject to some doubt and checked against a second location. If agreement within 10% of the two traverses is obtained, reasonable accuracy can be assumed and the average of the two readings used. Where the variation exceeds 10%, a third location should be selected and the two air flows in the best agreement averaged and used. The use of a single centerline reading for obtaining average velocity is a very coarse approximation and is not recommended. If a traverse cannot be done, then the centerline duct velocity should be multiplied by 0.9 for a coarse estimate of actual average duct velocity. Center line duct velocity should not be used less than 5 duct diameters from an elbow, junction, hood opening, or other source of turbulence.

A2-8.2 For ducts 150 mm (6 in.) and smaller, at least 6 traverse points should be used. For round ducts larger than 150 mm (6 in.) diameter, at least 10 traverse points should be employed. For very large ducts with wide variation in velocity, 20 traverse points will increase the precision of the air flow measurement.

A2-8.3 For square or rectangular ducts, the procedure is to divide the cross-section into a number of equal rectangular areas and measure the velocity pressure at the center of each. The number of readings should not be less than 16. Enough readings should be made so the greatest distance between centers is less than 150 mm (6 in.).

A2-8.4 The following data are required:
A2-8.4.1 The area of the duct at the traverse location.
A2-8.4.2 Velocity pressure at each point in the traverse and/or average velocity and number of points measured.
A2-8.4.3 Temperature of the air stream at the time and location of the traverse.
A2-8.4.4 The velocity pressure readings obtained are converted to velocities, and the velocities (not the velocity pressures) are averaged. Useful equation: \( V = 4.043 \left( \frac{VP}{d} \right)^{0.5} \), where \( V \) = velocity in m/s, \( VP \) = velocity pressure in mm H\(_2\)O, and \( d \) = density correction factor (unitless). Some monitoring instruments conduct this averaging internal to the instrument.

A2-8.5 Flow measurement taken at other than standard air temperatures should be corrected to standard conditions (i.e., 21°C [70°F], 760 mm [29.92 in.] Hg).
APPENDIX 3
DESIGN GUIDELINES FOR EQUIPMENT USING LIQUID CHEMICALS — Design and Test Method Supplement Intended for Internal and Third Party Evaluation Use

NOTE: The material in this appendix is an official part of SEMI S2 and was approved by full letter ballot procedures on December 15, 1999 by the North American Regional Standards Committee.

A3-1 Introduction
A3-1.1 This appendix provides specific technical information relating to Section 23. In general, it provides information on potential hazards, recommended control methods, and design considerations.
A3-1.2 This appendix is not intended to limit hazard evaluation methods or control strategies (e.g., design principles) employed by manufacturers. Alternative methods are acceptable if they provide an equivalent level of hazard control.
A3-1.3 This appendix is intended to be used as a starting point for reference during equipment design. An example would be during a formal hazard analysis in a brainstorming session.

Table A3-1 Liquid Chemicals

<table>
<thead>
<tr>
<th>Potential Hazard</th>
<th>Recommended Control Method</th>
<th>Design Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure to operators</td>
<td>Containment, control, and alarm notification for spills, leaks or vapors.</td>
<td>Appropriately sized secondary containment (minimum 110% volume of entire contents)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Equipment exhaust</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leak sensors to initiate auto shutdown</td>
</tr>
<tr>
<td>Controlled access to chemical containment areas.</td>
<td></td>
<td>Door/access cover interlocks that automatically depressurize the area of the system being accessed.</td>
</tr>
<tr>
<td>Control of access to point-of-operation hazards.</td>
<td></td>
<td>Physical guarding/presence-sensing devices</td>
</tr>
<tr>
<td>Exposure to maintenance personnel</td>
<td>Control of chemical delivery pressure; control of residual chemicals.</td>
<td>Depressurization upon system failure, interlock activation, or normal shutdown</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transparent doors/covers allow visual inspection.</td>
</tr>
<tr>
<td>Serviceability</td>
<td>Built-in system purge and flush capabilities</td>
<td>System components accessible and easy to service.</td>
</tr>
<tr>
<td>General equipment and component failure</td>
<td>Chemical resistance/compatibility</td>
<td>Appropriate materials used for equipment construction and components.</td>
</tr>
<tr>
<td></td>
<td>Pressure rating</td>
<td>Pressurized systems designed to withstand 150% of maximum foreseeable pressure, or provide a suitable relief valve.</td>
</tr>
<tr>
<td>Chemical delivery system leak</td>
<td>Durable bulk chemical containers</td>
<td>Use of approved (e.g., DOT, UN Dangerous Goods) containers in bulk distribution systems.</td>
</tr>
<tr>
<td></td>
<td>Control of pressurized vessels and piping.</td>
<td>Provide visual pressure indicators with or without alarms. Pressurized vessels and piping are designed and built to recognized standards.</td>
</tr>
<tr>
<td></td>
<td>Spill control</td>
<td>Automatic system pressure check prior to allowing dispense. Use of normally closed valves on distribution lines.</td>
</tr>
<tr>
<td></td>
<td>Drum change-out controls</td>
<td>Over-fill sensors on chemical baths</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Monitoring for excess flow.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Keyed and color-coded quick-connects</td>
</tr>
<tr>
<td>Potential Hazard</td>
<td>Recommended Control Method</td>
<td>Design Considerations</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-----------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Fire</td>
<td>Control of ignition sources.</td>
<td>NFPA 70 (NEC) Class I, Div. 2 wiring methods, intrinsically safe components, or nitrogen-purged enclosures. Physical separation of ignition sources and/or potentially flammable atmospheres. Use of low voltage to reduce the risk for ignition.</td>
</tr>
<tr>
<td></td>
<td>Control of static electricity (i.e., one type of ignition source).</td>
<td>Maintain ground continuity</td>
</tr>
<tr>
<td></td>
<td>Heat/fire/chemical detection</td>
<td>(No consensus for a specific recommendation at the time of publication of this guideline.)</td>
</tr>
<tr>
<td></td>
<td>Limiting concentrations of fuels and oxidizers.</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX 4
IONIZING RADIATION TEST VALIDATION — Design and Test Method Supplement Intended for Internal and Third Party Evaluation Use

NOTE: The material in this appendix is an official part of SEMI S2 and was approved by full letter ballot procedures on December 15, 1999 by the North American Regional Standards Committee.

A4-1 Introduction
A4-1.1 This appendix provides specific technical information relating to Section 24. In general, it provides information on hazard evaluation methods, examples of control strategies, and test validation criteria.

A4-1.2 This appendix is not intended to limit hazard evaluation methods or control strategies (e.g. design principles) employed by the manufacturers. Alternative methods are acceptable if they provide an equivalent level of hazard control.

A4-1.3 Test validation criteria are generally referenced from the applicable internationally recognized standard. It is the users responsibility to ensure that the most current revision of the standard (or its national equivalent) is used.

Table A4-1 Ionizing Radiation

<table>
<thead>
<tr>
<th>Ionizing Radiation Type</th>
<th>Emission Limit microsievert/hr (millirem/hr)</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>X or Gamma</td>
<td>Operator 2 μSv/hr (0.2 mrem/hr)</td>
<td>Direct doserate measurement with an Ion Chamber (or equivalent) calibrated to ± 10% of true doserate at the surface of the equipment (or at the closest approach) in all areas where the operator may have access with the ionizing radiation source active.</td>
</tr>
<tr>
<td></td>
<td>Maintenance and Service 10 μSv/hr (1 mrem/hr)</td>
<td>Direct doserate measurement with an Ion Chamber (or equivalent) calibrated to ± 10% of true doserate during simulated maintenance and service procedures. Measurements should be made at the surface emitting the ionizing radiation or the closest approach to the emitting surface with the ionizing radiation source active. NOTE: For these measurements, panels and/or shields should be removed only if removal is required for maintenance or service activities.</td>
</tr>
</tbody>
</table>

A4-2 Basic Radiation Control Methods

Time If the radiation field exists and it must be entered, then minimize the time spent in the field to minimize the exposure to the individual. This gives a linear dose reduction.

Distance If the radiation field is present, stay as far away from the source as possible to perform the required tasks. Dose is reduced by the square of the distance from the source.

Shielding If the radiation field is intense and the source is small, shielding the source is generally the most practical.

Quantity If there exists an opportunity to minimize the amount of radiation or radioactive material that is required for the task, then the exposure can be minimized also.
APPENDIX 5
NON-IONIZING RADIATION (OTHER THAN LASER) AND FIELDS TEST VALIDATION — Design and Test Method Supplement Intended for Internal and Third Party Evaluation Use, But Not for Field Survey of Installed Equipment

NOTE: The material in this appendix is an official part of SEMI S2 and was approved by full letter ballot procedures on December 15, 1999 by the North American Regional Standards Committee.

A5-1 Introduction
A5-1.1 This appendix provides specific technical information relating to Section 25. In general, it provides information on hazard evaluation methods and test validation criteria.

A5-1.2 This appendix is not intended to limit hazard evaluation methods or control strategies (e.g., design principles) employed by manufacturers. Alternative methods are acceptable if they provide an equivalent level of hazard control.

A5-1.3 Test validation criteria are generally referenced from the applicable internationally recognized standards. It is the user’s responsibility to ensure that the most current revision of the standard is used.

A5-2 Non-Ionizing Radiation Surveys should be conducted at the maximum operational power level and, when applicable, at the most limiting frequency.

A5-3 Measurements should be taken at the exterior surfaces of the equipment and at surfaces that maintenance and repair personnel could encounter, whenever practical (electric field measurements with paddle-shaped sensors may not be possible in some places due to the size and shape of the sensor).

Measurements for the purpose of evaluating emissions accessible to operators should be taken at the operators console and material loading station.

A5-4 Measurements to assess electromagnetic emissions from equipment for safety purposes should be taken in an area that is reasonably free of energy of the wavelengths/frequencies of interest, especially if the strength of the energy fluctuates in a manner that is unpredictable. Instruments used for safety-related measurements should be calibrated at a facility capable of calibrating such instruments using standards traceable to the National Institute of Standards and Technology in the USA or an equivalent standards service elsewhere, per the guidance of the instrument manufacturer. This should be determined by conducting surveys in the test area before the equipment is set up for the measurements. Measurements taken for safety purposes can also be combined with measurements taken to address electromagnetic interference concerns. The specific measurement locations may vary between electromagnetic interference and safety-related measurements.

NOTE A5-1: The values in the table below are shown as 20% of the limit stated in the applicable standard (referenced).

<table>
<thead>
<tr>
<th>Energy Category</th>
<th>Physical Quantity Measured (units)</th>
<th>Operator-Accessible Limit</th>
<th>Maintenance-and Service-Accessible Limit</th>
<th>Pacemaker Labeling Level</th>
<th>Testing Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static$^4$ 0 Hz. (e.g., static magnets in etch/implant equipment)</td>
<td>Magnetic Field Strength (A/m or Gauss) (See NOTES 1 and 2.)</td>
<td>8 mT (80 G)</td>
<td>40 mT (400 G)</td>
<td>0.5 mT (5 G)</td>
<td>Use a Hall effect probe at each location (use three axis probe or make three mutually orthogonal measurements at each location). Measure field at exterior surfaces of equipment (2 to 3 cm from the surface). Locate 5 gauss (G) line to post pacemaker warnings and 30 G to identify where flying tools, etc. and dislocations of magnetizable prostheses could become a hazard.</td>
</tr>
</tbody>
</table>

Table A5-1 Non-Ionizing Radiation
<table>
<thead>
<tr>
<th>Energy Category</th>
<th>Physical Quantity Measured (units)</th>
<th>Operator-Accessible Limit</th>
<th>Maintenance- and Service-Accessible Limit</th>
<th>Pacemaker Labeling Level</th>
<th>Testing Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub Radio-frequency¹</td>
<td>Electric Field Strength (V/m) (See NOTE 1.)</td>
<td>1–100 Hz 5 kV/m* 100 Hz to 3 kHz 500,000/f (Hz) in V/m</td>
<td>1–100 Hz 5 kV/m* 100 Hz to 3 kHz 500,000/f (Hz) in V/m</td>
<td>1 kV/m</td>
<td>Use a displacement sensor. Determine the maximum field strength and orientation at the surface of the equipment (2–3 cm). Remove field perturbations by using a long non-conductive handle extension or remote fiber optic readout. Locate 1 kV/m line to post pacemaker warnings.</td>
</tr>
<tr>
<td>Sub Radio-frequency¹</td>
<td>Magnetic Field Strength (A/m or G) (See NOTES 1 and 2.)</td>
<td>1–300 Hz 12/f (Hz) in mT 300 Hz to 3 kHz 0.04 mT (400 mG)*</td>
<td>1–300 Hz 12/f (Hz) in mT 300 Hz to 3 kHz 0.04 mT (400 mG)*</td>
<td>0.1 mT (1 G)</td>
<td>Use a loop sensor at each location (use three axis probe or make three mutually orthogonal measurements at each location). The sensor should be almost contacting the equipment surface (2 cm from surface). Identify 1 G line to post pacemaker warnings.</td>
</tr>
<tr>
<td>Power Frequency (50 or 60 Hz)¹,²</td>
<td>Electric Field Strength (V/m) (See NOTE 1.)</td>
<td>1 kV/m</td>
<td>2 kV/m</td>
<td>1 kV/m</td>
<td>See Sub radiofrequency Electric Field Testing Method, but probe is positioned as needed to determine distance to 1 kV/m.</td>
</tr>
<tr>
<td>Power Frequency (50 or 60 Hz)¹,²</td>
<td>Magnetic Field Strength (A/m or G) (See NOTES 1 and 2.)</td>
<td>0.02 mT (200 mG)</td>
<td>0.1 mT (1 G)</td>
<td>0.1 mT (1 G)</td>
<td>See Sub radiofrequency Magnetic Field Testing Method, but probe is positioned as needed to determine distance to 1 G pacemaker criterion.</td>
</tr>
<tr>
<td>Radiofrequency Field²</td>
<td>Induced current and contact current (mA)</td>
<td>Frequency-dependent: 180f (kHz) in mA through both feet 90f through each foot 90f for contact, where f is in MHz</td>
<td>Frequency-dependent: 400f (kHz) in mA through both feet, 200f through each foot 200f for contact, where f is in MHz</td>
<td>NA</td>
<td>Contact instrument vendor for suitable instrument based on frequency and emission characteristics. Measurement of induced and contact currents for freq. &lt; 100 MHz should be made when approaching 20% of the applicable electric field emission limit.</td>
</tr>
</tbody>
</table>

¹ See exception below for 50 and 60 Hz power frequencies.

² See exception below for 50 and 60 Hz power frequencies.
### Table A5-2 Optical Energy

<table>
<thead>
<tr>
<th>Physical Energy</th>
<th>Physical Quantity Measured (units)</th>
<th>Access Limit</th>
<th>Testing Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrared Energy</td>
<td>Irradiance W/m²</td>
<td>Wavelength dependent 20% of the applicable exposure limits. (See Reference 1.)</td>
<td>Thermocouple, thermopile, pyroelectric, photoelectric Direct measurements locating the maximum irradiance and orientation of the energy at the closest approach to the view port(s) or accessible leakage point(s).</td>
</tr>
<tr>
<td>700 nm to 1 mm (e.g., heating lamps)</td>
<td>Radiance W/m² - sr</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**NOTE 1:** It is assumed that electric and magnetic fields exist separately at frequencies below 300 MHz. It is assumed that electric and magnetic fields exist as a combined entity (electromagnetic radiation) at higher frequencies. Two evaluations are needed at frequencies <300 MHz and only one (usually made by measuring the electric field) at higher frequencies.

**NOTE 2:** 1 gauss (G) = 79.55 amperes per meter (A/m). 1 tesla (T) = 10,000 G, 1 millitesla (mT) = 10 G.
<table>
<thead>
<tr>
<th>Optical Energy</th>
<th>Physical Quantity Measured (units)</th>
<th>Access Limit</th>
<th>Testing Methods</th>
</tr>
</thead>
</table>
| Visible Light1 400 nm to 700 nm (e.g., heating lamps) | Irradiance µW/cm²  
(See NOTES 1, 2, and 3.)  
Radiance W/m² - sr | Wavelength dependent  
20% of the applicable exposure limits.  
(See Reference 1.) | Thermocouple, thermopile, pyroelectric, photoelectric  
Direct measurement locating the maximum irradiance and orientation of the light energy at the closest approach to view port(s) or accessible leakage point(s). |
| Ultraviolet Energy2 315 nm to 400 nm (e.g., plasma, stepper) | Irradiance mW/cm²  
(See NOTES 1 and 2.) | 0.2 mW/cm² | Photoelectric detectors with filters and or controlled phosphors  
Direct measurements locating the maximum irradiance and orientation of the energy at the closest approach to the view port(s) or accessible leakage point(s). |
| Ultraviolet Light2 180 nm to 315 nm (e.g., plasma, stepper) | Effective Irradiance µW/cm²  
(See NOTE 4.) | 0.02 µW/cm² | Photoelectric detectors with filters and/or controlled phosphors (See NOTE 5.)  
Direct measurements locating the maximum irradiance and orientation of the energy at the closest approach to the view port(s) or accessible leakage point(s). |

NOTE 1: “Irradiance” is essentially the same as “power density.”
NOTE 2: Lamp manufacturer data can sometimes be used to estimate and evaluate exposures using a spreadsheet.
NOTE 3: These guidelines cover visible, IR-A, and IR-B, and are frequency dependent. Separate evaluations may be needed for thermal or photochemical retinal hazards and infrared eye hazards.
NOTE 4: “Effective irradiance” is irradiance adjusted to account for the wavelength-dependent biological hazard. Permissible exposure time = 0.003 J/cm² divided by the effective irradiance.
NOTE 5: Instrumentation is commercially available that accounts for the wavelength dependence of the standard and gives results in effective irradiance.

A5-5 References
1. 1996 TLVs and BEIs Threshold Limit Values for Chemical Substances and Physical Agents Biological Exposure Indices, ACGIH, Cincinnati, OH
3. Guidelines on Limits of Exposure to Broad-Band Incoherent Optical Radiation (0.38 to 3 µM), Health Physics Vol. 73, No. 3 (September), pp.539-554, 1997
APPENDIX 6
FIRE PROTECTION: FLOWCHART FOR SELECTING MATERIALS OF CONSTRUCTION

NOTE: The material in this appendix is an official part of SEMI S2 and was approved by full letter ballot procedures on December 15, 1999 by the North American Regional Standards Committee.

Start

Can the system reasonably be constructed of non-combustible materials?

Yes

Construct from non-combustible materials

No

Can the system reasonably be constructed of materials which do not propagate flame?*

Yes

Construct of materials which do not propagate flame*

No

Assess the fire risks based on the materials of construction and process chemicals.

Design engineering controls to mitigate the fire risks based on materials of construction and process chemicals. This may include fire detection and suppression systems.

Yes

Is there a significant fire risk, based on process chemicals?

No

Does a qualified party (see Section 14.2.1) accept the risk assessment and engineering controls?

Yes

End

* beyond the ignition zone with or without the continued application of the ignition source
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 guideline 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 mentioned herein. This guideline is 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

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

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RELATED INFORMATION 1
EQUIPMENT/PRODUCT SAFETY PROGRAM

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

R1-1 Preface

R1-1.1 Compliance with design-based safety standards does not necessarily ensure adequate safety in complex or state-of-the-art systems. It is often necessary to perform hazard analyses to identify hazards that are specific to the system, and develop hazard control measures that adequately control the associated risk beyond those that are covered in existing design-based standards. This document provides guidelines for developing a deliberate, planned equipment/product safety (EPS) program integrating the compliance assessment activities with hazard analyses and other activities needed to provide a safe system throughout the life of equipment or products.

R1-1.2 An effective EPS program reduces the cost, schedule slips, and liability associated with the late identification and correction of hazards. To be most effective, an EPS program should be begun by the manufacturer early during the design phase. Starting early allows safety to be designed into the system and its subsystems, equipment, facilities, processes, procedures, and their interfaces and operations. These guidelines are designed to assist the manufacturer in planning and implementation of an effective EPS program.

R1-1.3 The lowest costs for implementing safety can be achieved when hazards are identified and resolved before hardware is built and firmware or software is coded. This guide is intended to provide the basis for a methodology for implementing a safety program for early and continued hazard identification and the elimination or reduction of associated risks.

R1-1.4 EPS program success depends directly upon management emphasis and support applied during the system design and development process and throughout the life cycle of the product. This emphasis should include the following management controls:

R1-1.4.1 Agreement from management that the EPS program will be maintained and supported throughout the product or facility life cycle;

R1-1.4.2 Clear and early statements of agreement with EPS objectives and requirements;

R1-1.4.3 Understanding of, and participation in, the risk acceptance process; and

R1-1.4.4 Continuing consideration of risk reduction during the management review process.

R1-2 Purpose

R1-2.1 This guide describes an approach for developing and implementing an EPS program of sufficient comprehensiveness to identify the hazards of a product and to develop design and administrative controls to prevent incidents. The EPS program addresses hazards from many sources to include system design, hazardous materials, advancing technologies, and new techniques. The goal is to eliminate hazards or reduce the associated risk to an acceptable level.

R1-3 Scope

R1-3.1 This guide applies to every activity of the product life cycle (e.g., research, technology development, design, test and evaluation, production, construction, checkout/calibration, operation, maintenance and support, modification and disposal).

R1-4 General Guidelines

R1-4.1 EPS Program — The supplier should establish and maintain an EPS program to support efficient and effective achievement of overall EPS objectives. Depending upon the needs of the company, the EPS Program may be a company wide program covering all projects, separate programs for each project, or some combination of the two.

R1-4.1.1 Management System — The supplier should establish an EPS management system to implement provisions of this guide commensurate with the needs of the program. The program manager should be responsible for the establishment, control, incorporation, direction and implementation of the EPS program policies and should assure that risk is identified and eliminated or controlled. The supplier should establish internal reporting systems and procedures for investigation and disposition of product related incidents and safety incidents, including potentially hazardous conditions not yet involved in an incident.

R1-4.2 EPS Design Guidelines

R1-4.2.1 EPS design requirements should be specified after review of pertinent standards, specifications, regulations, design handbooks, safety design checklists, and other sources of design guidance for applicability to the design of the system. The supplier should establish EPS design criteria derived from applicable data including the preliminary hazard analyses. These criteria should be the basis for developing system specification EPS requirements. The supplier should
continue to expand the criteria and requirements for inclusion in development specification during the subsequent program phases.

**R1-5 Detailed Guidelines**

R1-5.1 The purpose of the EPS program is to ensure that the equipment or product is designed and documented in a manner that reduces the safety risk associated with that equipment or product to a level that is acceptable to the customer. This consideration applies to all life cycle phases of the equipment or product. The following sections include detailed elements of a formal EPS program. Management should select or tailor the elements appropriate to their needs.

R1-5.2 EPS Program Plan (EPSPP) — The purpose of a EPS Program Plan (EPSPP) is to describe the tasks and activities of EPS management and engineering required to identify, evaluate, and eliminate/control hazards, or reduce the associated risk to an acceptable level throughout the system life cycle. The plan provides a basis of understanding of how to organize and execute an effective EPS program.

R1-5.2.1 EPS Program Scope and Objectives — Each EPSPP should describe, as a minimum, the following four elements of an effective EPS program:

- a planned approach for task accomplishment,
- qualified people to accomplish tasks,
- authority to implement tasks through all levels of management, and
- appropriate commitment of resources (both staffing and funding) to assure tasks are completed.

The scope and objectives should:

- Describe the scope of the overall program and the related EPS program.
- Identify the tasks and activities of EPS management and engineering functions. Describe the interrelationships between EPS and other functional elements of the program. Identify the other program requirements and tasks applicable to EPS.
- Account for major required EPS tasks and responsibilities.

R1-5.2.2 EPS Function — The EPSPP should describe:

R1-5.2.2.1 The EPS function within the organization of the total program, including organizational and functional relationships, and lines of communication. Other functional elements that are responsible for tasks that impact the EPS program should be included. This description should include the integration/management of associate suppliers, subcontractors and engineering firms. Review and approval authority of applicable tasks by EPS should be described.

R1-5.2.2.2 The responsibility and authority of EPS personnel, other supplier organizational elements involved in the EPS effort, subcontractors, and EPS groups. Identify the organizational unit responsible for executing each task and the authority in regard to resolution of identified hazards.

R1-5.2.2.2.1 One highly effective organizational approach to hazard resolution authority is through the use of a EPS Working Group (EPSWG). The activities of the EPSWG could include:

- Identifying safety deficiencies of the program and providing recommendations for corrective actions or prevention of reoccurrence.
- Reviewing and evaluating the hazard analyses to develop agreement that the hazards have been properly identified and controlled.
- Provide recommendations to the proper level of management concerning the need for additional hazard controls and the acceptability of residual risks.
- The staffing of the EPS function.
- The procedures by which the supplier will integrate and coordinate the EPS efforts.
- The process through which supplier management decisions will be made.
- Details of how resolution and action relative to EPS will be effected at the program management level possessing resolution and acceptance authority.

R1-5.2.3 EPS Program Milestones — The EPSPP should include:

- Identification of the major EPS program milestones. These should be related to major program milestones, program element responsibility, and required inputs and outputs.
- A program schedule of EPS tasks, including start and completion dates, reports, and reviews.
- Identification of subsystem, component, software safety activities as well as integrated system level activities (i.e., design analyses, tests, and demonstrations) applicable to the EPS program but specified in other engineering studies and development efforts to preclude duplication.

R1-5.2.4 General EPS Guidelines and Criteria — The EPSPP should:
• Describe general engineering requirements and design criteria for safety.
• Describe the risk assessment procedures (see SEMI S10). The hazard severity categories, hazard likelihood categories, and the EPS precedence that should be followed to satisfy the safety requirements of the program.
• Describe closed-loop procedures for taking action to resolve identified unacceptable risks including those involving non-developmental items.

R1-5.2.5 Hazard Analysis — The EPSPP should describe:

• The analysis techniques and formats to be used to identify hazards, their causes and effects, hazard elimination, or risk reduction requirements and how those requirements are met.
• Recommended techniques for identification of hazards and hazard scenarios include Preliminary Hazard Lists, Preliminary Hazard Analysis, HAZOPs, FMEA, FTA, “what if?” and process control analyses. Other types of hazard analysis techniques are discussed in a variety of sources, such as EN 1050, Annex B. No single method is the best for all types of systems, subsystems, subsystem interaction or facilities. A combination of techniques may be most appropriate.
• The integration of subcontractor or supplier hazard analyses and safety data with overall system hazard analyses.
• Efforts to identify and control hazards associated with materials used during the system’s life cycle.

R1-5.2.6 System Safety Data — The EPSPP should describe the approach for collecting and processing pertinent historical hazard, incident, and safety lessons learned, data.

R1-5.2.7 Safety Verification — The EPSPP should describe:

• The verification (test, analysis, inspection, etc.) methods to be used for making sure that safety is adequately demonstrated. Identify any requirements for safety certification, safety devices or other special safety verification or documentation requirements.
• Procedures for transmitting safety-related verification information to the customer or others for review and analysis.

R1-5.2.8 Audit Program — The EPSPP should describe the techniques and procedures to be employed to make sure the objectives and requirements of the EPS program are being accomplished.

R1-5.2.9 Incident Reporting — The supplier should describe in the EPSPP the incident alerting/notification, investigation and reporting process including notification of the customer.

R1-5.2.10 EPS Interfaces — The EPSPP should identify:

• The interface between EPS and all other applicable safety disciplines.
• The interface between EPS, systems engineering, and all other support disciplines such as: maintainability, quality control, reliability, software development, human factors engineering, and others as appropriate.
• The interface between EPS and product design, integration and test disciplines.

R1-5.3 Hazard Analysis Documentation

The hazard analysis process is used to identify hazards and their controls. This information should be documented in a closed loop tracking system to track the implementation of the controls and may also be required for presentation to management, the customer and others. The safety documentation could include a system description, the identification of hazards and their residual risks, as well as special procedures and precautions necessary for safety.

The documentation should include the following:

R1-5.3.1 System Description — This should consist of summary descriptions of the physical and functional characteristics of the system and its components. Reference to more detailed system and component descriptions, including specifications and detailed review documentation should be supplied when such documentation is available. The capabilities, limitations and interdependence of these components should be expressed in terms relevant to safety. The system and components should be addressed in relation to its function and its operational environment. System block diagrams or functional flow diagrams may be used to clarify system descriptions. Software and its role(s) should be included in this description.

R1-5.3.2 Data — This should consist of summaries of data used to determine the safety aspects of design features.

R1-5.3.3 Hazard Analysis Results — This should consist of a summary or a total listing of the results of the hazard analysis. Contents and formats may vary according to the individual requirements of the
program. The following data elements may be used for documenting the results of hazard analyses:

R1-5.3.3.1 System/Subsystem/Unit — The particular part of the system that is the concern in this part of the analysis. This is generally a description of the location of the component being considered.

R1-5.3.3.2 Component/Phase — The particular phase/component with which the analysis is concerned. This could be a system, subsystem, component, software, operating/maintenance procedure or environmental condition.

R1-5.3.3.3 Hazard Scenario Description — A description of the potential/actual hazards inherent in the item being analyzed, or resulting from normal actions or equipment failure, or handling of hazardous materials.

R1-5.3.3.4 Effect of Hazard — The detrimental effects that could be inflicted on the subsystem, system, other equipment, facilities or personnel, resulting from this hazard. Possible upstream and downstream effects can also be described.

R1-5.3.3.5 Recommended Action(s) — The recommended action(s) that are necessary and sufficient to eliminate or control the hazard. Sufficient technical detail is required in order to permit the design engineers and the customer to adequately develop and assess design criteria resulting from the analysis. Include alternative designs and life cycle cost impact where appropriate.

R1-5.3.3.6 Risk Assessment — A risk assessment for each hazard (classification of severity and likelihood). This may include an assessment of the risk prior to taking any action(s) to eliminate or control the hazard and a separate assessment of the risk following implementation of the Recommended Action(s). (See SEMI S10.)

R1-5.3.3.7 Remarks — Any information relating to the hazard not covered in other blocks; for example, applicable documents, previous failure data on similar systems, or administrative directions.

R1-5.3.3.8 Status — The status of actions to implement the recommended control, or other, hazard controls. The status should include not only an indication of “open” or “closed,” but also reference to the drawing(s), specification(s), procedure(s), etc., that support closure of the particular hazard. The person(s) or organization(s) responsible for implementation of the control should also be recorded.
## RELATED INFORMATION 2
### ADDITIONAL STANDARDS THAT MAY BE HELPFUL

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

### Table R2-1

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<td>IEC 60417</td>
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<td>IEC 60990</td>
<td>Methods of measurement of touch current and protective conductor current</td>
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<tr>
<td>IEC 61310-1</td>
<td>Safety of Machinery - Indication, Marking and Actuation - Part 1: Requirements for Visual, Auditory and Tactile Signals</td>
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<td>ISO 3461-1</td>
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<td>ISO 7000</td>
<td>Graphical Symbols for Use on Equipment - Index and Synopsis</td>
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<td>Labeling and Marking</td>
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<td>Tests for Flammability of Plastic Materials for Parts in Devices &amp; Appliances</td>
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<td>Electrical and Electronic Test, Measuring and Process Control Equipment</td>
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<td>NEMA 250</td>
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<td>NEMA ICS 1.1</td>
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<td>OSHA 29 CFR 1910.147</td>
<td>The control of hazardous energy (lockout/tagout)</td>
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### 1997 Uniform Building Code, Section 1632

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<td>UL471</td>
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<td>Industrial Control Equipment for use in Hazardous Locations</td>
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<tr>
<td>UL1450</td>
<td>Motor-Operated Air Compressors, Vacuum Pumps and Painting Equipment</td>
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<tr>
<td>UL1740</td>
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<tr>
<td>UL1995</td>
<td>Heating and Cooling Equipment</td>
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<tr>
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<td>Process Control Equipment</td>
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### Canadian Standards

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### European Standards

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RELATED INFORMATION 3
HAZARD LABELS

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

R3-1  INTRODUCTION: The system shown below is a single label design that combines requirements from ANSI Z535, used in the USA, and ISO 3864 and IEC 1310-1, used elsewhere in the world. The suitability of this design for any specific jurisdiction must be determined by the equipment manufacturer.

![Diagram of a combination ANSI/IEC hazard label format](image)

Figure R3-1
Example of a Combination ANSI/IEC Hazard Label Format

<table>
<thead>
<tr>
<th>†SIGNAL WORD (san serif font)</th>
<th>‡SAFETY ALERT SYMBOL</th>
</tr>
</thead>
</table>
| **DANGER - White Lettering / Red Background**  
(Safety Red: per ANSI Z535.4 - 15 parts Warm Red, 1 part Rubine Red, 1/4 part Black) | White Triangle / Red Exclamation Point |
| **WARNING - Black Lettering / Orange Background**  
(Safety Orange: per ANSI Z535.4 - 13 parts Yellow, 3 parts Warm Red, 1/4 part Black) | Black Triangle / Orange Exclamation Point |
| **CAUTION - Black Lettering / Yellow Background**  
(Safety Yellow: per ANSI Z535.4 - Pantone 108C) | Black Triangle / Yellow Exclamation Point |

NOTE 1: Message Panel Letter height (min. 0.10 inch or 2.54 mm high) for FAVORABLE reading conditions may, in some instances be reduced further for application to small products or products having limited surface area on which to apply the message. However, it should not be less than 0.05 in. (1.27 mm) for lower case letter height.

NOTE 2: Upon request from end-user(s), translation(s) to other languages may also be deemed appropriate.
Figure R3-2
Suggested IEC/ISO Symbols for Various Hazards
**RELATED INFORMATION 4**
**EMO REACH CONSIDERATIONS**

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

R4-1 INTRODUCTION: Although SEMI S8 limits EMO button heights to 164 cm, it does not explicitly address the situation where a person must reach over, say, a work surface to reach the EMO button. The calculations shown below show one method of addressing this situation. *Other issues, besides those shown below, must also be taken into account when locating EMO buttons; see SEMI S2 and SEMI S8.*

The maximum height allowed for an EMO is determined by the following equation: (design for 5% female)

\[
\text{Max height} = \text{Shoulder Height} + B
\]

Max height should never exceed:
- 164 cm for standing station
- 100 cm for sitting station

Where:
- \(A\) = Length of horizontal barrier to EMO
- \(B\) = Distance above shoulder
- \(C\) = Upper limb length for 5% female (always 51.5 cm)

And for 5% female:
- Standing shoulder height = 114.0 cm
- Sitting shoulder height = 46.5 cm

Ex. Standing:
\[
B^2 = C^2 - A^2
\]
If \(A = 30\) cm then
\[
B^2 = 51.5^2 - 30^2
\]
\(B = 41.8\) cm

The button could be located at a maximum of:
\(114 + 41.8 = 155.8\) cm from the floor

RELATED INFORMATION 5
SEISMIC PROTECTION

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

R5-1 Seismic Protection Checklist

Supporting Review Criteria for Seismic Protection of Related Components

If the answer to Questions A.1 or A.2 is “No,” or the answer to any other of these questions in the checklist is “Yes,” then a detailed analysis may need to be performed by a structural or mechanical engineer.

A. Equipment Anchorage

1. Have lateral force and overturning calculations been performed (see example)?
   - Yes
   - No
   Comments:

2. Are all modules fastened at a minimum of four points and can the fasteners support the forces identified in question 1 above?
   - Yes
   - No
   Comments:

3. Is it possible that there could be excessive seismic anchor movements that could result in relative displacements between points of support or attachment of the components (e.g., between vessels, pipe supports, main headers, etc.)?
   - Yes
   - No
   Comments:

4. Is there inadequate horizontal support?
   - Yes
   - No
   Comments:

5. Is there inadequate vertical supports and/or insufficient lateral restraints?
   - Yes
   - No
   Comments:

6. Are support fasteners inappropriately secured?
   - Yes
   - No
   Comments:

7. Is there inadequate anchorage of attached equipment?
   - Yes
   - No
   Comments:

NOTE R5-1: One way of judging whether supports, fasteners, or anchorages are “inadequate” or inappropriately secured is to determine whether their stress levels under seismic loading stay below the allowable stress levels set by building code. Such allowable stress levels are typically a fraction < 1 of the yield strength.
B. Equipment Assembly, Installation and Operation

1. Are the materials of construction of the components susceptible to seismic damage?
   - Yes
   - No
   Comments:

2. Are there significant cyclic operational loading conditions that may substantially reduce system fatigue life?
   - Yes
   - No
   Comments:

3. Are there any threaded connections, flange joints, or special fittings?
   - Yes
   - No
   Comments:

4. If answer to Question 4 is “Yes,” are these connections, joints, or special fittings in high stress locations?
   - Yes
   - No
   Comments:

5. Are there short or rigid spans that cannot accommodate the relative displacement of the supports (e.g., piping spanning between two structural systems)? Is hazardous gas piping provided with a “pigtailing” (i.e., spiral) or bent 3 times (z, y, and z direction) to absorb 3-dimensional displacements?
   - Yes
   - No
   Comments:

6. Are there large, unsupported masses (e.g., valves) attached to components?
   - Yes
   - No
   Comments:

7. Are there any welded attachments to thin wall components?
   - Yes
   - No
   Comments:

8. Could any sensitive equipment (e.g., control valves) be affected?
   - Yes
   - No
   Comments:

C. Seismic Interactions

1. Are there any points where seismically induced interaction with other elements, structures, systems, or components could damage the components (e.g., impact, falling objects, etc.)?
   - Yes
   - No
   Comments:

2. Could there be displacements from inertial effects?
   - Yes
   - No
   Comments:
R5-2 Derivation of Section 19, Seismic Load Guidelines

R5-2.1 The horizontal loadings of 94% and 63%, found in Sections 19.2.1 and 19.2.2, were based on following assumptions for factors in formula 32-2 in Section 1632.2 of the 1997 Uniform Building Code (UBC):

- \( a_p = 1.0 \) (i.e., treat the equipment as a rigid structure)
- \( C_a = 0.44(1.2) \) (i.e., seismic zone 4, soil profile type \( S_D \), and site 5 km from a seismic source type A)
- \( I_p = 1.0 \) and 1.5 for non-HPM and HPM equipment, respectively
- \( h_x/h_r = 0.5 \) (i.e., equipment attached at point halfway between grade elevation and roof elevation)
- \( R_p = 1.5 \) (i.e., shallow anchor bolts).

Starting with equation 32-2, letting \( I_p = 1.5 \), and substituting the above values:

\[
F_p \text{ (ultimate)} = \left[ \frac{1.0 \times 0.44(1.2) \times 1.5}{1.5} \right] \left[ 1 + 3(0.5) \right] W_p
\]

\[
= \left[ 0.44(1.2) \right] \left[ 1 + 1.5 \right] W_p
\]

\[
= \left[ 0.528 \right] \left[ 2.5 \right] W_p
\]

\[
= \left[ 1.32 \right] W_p
\]

NOTE R5-2: This number is now adjusted from ultimate strength loading to yield strength loading by dividing by 1.4:

\[
F_p \text{ (yield)} = \frac{F_p \text{ (ultimate)}}{1.4}
\]

\[
= \left[ 1.32 \right] / 1.4 \ W_p
\]

\[
= \left[ 0.94 \right] W_p
\]

And for \( I_p = 1.0 \),

\[
F_p \text{ (yield)} = \left[ .94 \right] \left[ 1.0/1.5 \right] W_p
\]

\[
= \left[ .63 \right] W_p
\]

Notes re selection of \( a_p \) value of 1.0:

- Table 16-O of 1997 UBC, line 3.C., was interpreted to read: “Any flexible equipment...”
- In structural terms, the structure of typical semiconductor equipment is considered “rigid.”

R5-2.2 Assumptions Used for Above Derivation

R5-2.2.1 Because typical semiconductor equipment is considered rigid, a frequency response analysis was not considered to be necessary.

R5-2.2.2 Seismic waves typically have vertical as well as horizontal components associated with them; however, these components typically arrive out of phase (i.e., they do not reach maximum values simultaneously). The vertical component serves to, in effect, reduce the amount of equipment mass that is available to resist overturning or toppling. The task force chose to take this into account by limiting the calculated weight available to resist overturning to 85% of the weight of the equipment. An alternate method, not chosen by the task force, could have been to simultaneously apply a vertical (Z) force.

R5-3 Source for Examples of Seismic Anchorage Details

R5-3.1 Detailed illustrations of examples of seismic anchorage details were developed by Working Group #9 of the Japan 300 mm (“J300”) effort, and were printed in their Report No. 9 in the 2nd Lecture, ICs Factory Design for 300 mm Wafer Line Standardizing Study, December, 1996.
Figure R5-1
Design Example
DESIGN EXAMPLE (continued; refer to Figure R5-1 for illustration of example)

Disclaimer: the calculations below are not a complete seismic analysis. A complete analysis might also include such things as: stress distribution through a multiple-fastener connection; prying action; bearing stress; simultaneous combined stresses on the fasteners; and a review of weld geometry. A complete seismic analysis should be done by a qualified engineer.

R5-4 Calculation of Lateral Force
R5-4.1 Lateral force on each leg is equal to \( F_p / \# \) of legs = \( F_p / 4 \)

R5-4.2 The lateral force acts as shear on the floor anchor fasteners and shear or tensile loading on the equipment anchor fasteners depending upon orientation. The actual reactions of the fasteners should be calculated by a qualified engineer.

R5-5 Calculation of Overturning Force
R5-5.1 Sum the moments of the reactions on the system about line through the legs A and B:

\[
(CW = +) \quad M_{AB} = 0 = F_p (h) - 0.85 W_p (L_2) - 2R(L_1) = 0
\]

\[
R = \frac{F_p (h) - 0.85 W_p (L_2)}{2L_1}
\]

\[
F_p = 0.94 W_p
\]

\[
R = \frac{W_p (0.94h - 0.85L_2)}{2L_1}
\]

If \( 0.94h \geq 0.85L_2 \), then there is a tension reaction, \( R \), at the two anchors, to resist overturning of system.

Example:
\( L_1 = 50 \text{ inch} \)
\( L_2 = 20 \text{ inch} \)
\( h = 36 \)
\( W = 5000 \text{ lbs} \)

Lateral force = \( F_p / 4 = 0.94(5000)/4 = 1175 \)

Overturning force = \( R = \frac{W_p (0.94h - 0.85L_2)}{2L_1} \)

\[= \frac{5000 (0.94(36) - 0.85(20))}{2(50)}\]

\( R = 842 \text{ lbs} \)
RELATED INFORMATION 6
CONTINUOUS HAZARDOUS GAS DETECTION

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

R6-1 Scope — This related information provides a list of gases for which continuous monitoring is recommended, and another list of gases for which continuous monitoring may be recommended depending on variables listed below. The list is not intended to be exhaustive (gases that do not appear on the list may need to be continuously monitored).

R6-2 Intent — The purpose of this Related Information is to provide equipment manufacturers with an indication as to what gases are currently continuously monitored by device manufacturers, as guidance for when it may be appropriate to provide an interface (see also Section 23).

R6-3 The following variables should be taken into consideration when determining the necessity for continuous monitoring:

- Chemical toxicity,
- Warning property/OEL ratio,
- Delivery pressure,
- LEL,
- Flow rate of potential leak,
- Engineering controls in place, and
- Concentration.

<table>
<thead>
<tr>
<th>Monitoring Recommended</th>
<th>Monitoring May Be Recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>ammonia</td>
<td></td>
</tr>
<tr>
<td>arsine</td>
<td>bromine</td>
</tr>
<tr>
<td>boron trifluoride</td>
<td>carbon dioxide</td>
</tr>
<tr>
<td>carbon monoxide</td>
<td>carbon tetrabromide</td>
</tr>
<tr>
<td>chlorine</td>
<td></td>
</tr>
<tr>
<td>diborane</td>
<td></td>
</tr>
<tr>
<td>dichlorosilane</td>
<td></td>
</tr>
<tr>
<td>disilane</td>
<td></td>
</tr>
<tr>
<td>fluorine</td>
<td></td>
</tr>
<tr>
<td>germane</td>
<td></td>
</tr>
<tr>
<td>germanium tetrafluoride</td>
<td></td>
</tr>
<tr>
<td>flammable mixtures</td>
<td>hydrogen bromide</td>
</tr>
<tr>
<td>containing hydrogen</td>
<td></td>
</tr>
<tr>
<td>hydrogen chloride</td>
<td></td>
</tr>
<tr>
<td>hydrogen fluoride</td>
<td></td>
</tr>
<tr>
<td>hydrogen selenide</td>
<td></td>
</tr>
<tr>
<td>hydrogen sulfide</td>
<td>Methane</td>
</tr>
<tr>
<td>methyl chloride</td>
<td>methyl fluoride</td>
</tr>
<tr>
<td>nitric oxide</td>
<td>nitrogen dioxide</td>
</tr>
<tr>
<td>nitrous oxide</td>
<td></td>
</tr>
<tr>
<td>nitrogen trifluoride</td>
<td></td>
</tr>
<tr>
<td>ozone</td>
<td></td>
</tr>
<tr>
<td>phosphine</td>
<td></td>
</tr>
<tr>
<td>silane</td>
<td></td>
</tr>
<tr>
<td>silicon tetrachloride</td>
<td></td>
</tr>
<tr>
<td>silicon tetrafluoride</td>
<td></td>
</tr>
<tr>
<td>sulfur dioxide</td>
<td></td>
</tr>
<tr>
<td>trichlorosilane</td>
<td></td>
</tr>
<tr>
<td>tungsten hexafluoride</td>
<td></td>
</tr>
</tbody>
</table>
RELATED INFORMATION 7
DOCUMENTATION OF IONIZING RADIATION (SECTION 24 AND
APPENDIX 4) INCLUDING RATIONALE FOR CHANGES

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

R7-1  International Background Information

R7-1.1  The International Atomic Energy Agency (IAEA)

Mailing address:

P.O. Box 100
Wagramerstrasse 5
A-1400, Vienna, Austria

Telephone: (+43-1) 2060-0; Facsimile: (+43-1) 20607;
E-mail: Official.Mail@iaea.org

R7-1.2  Basic approaches to radiation protection are consistent all over the world. The International Commission on Radiation Protection (ICRP) recommends that any exposure above the natural background radiation should be kept as low as reasonably achievable, but below the individual dose limits. The total individual dose limit for radiation workers over 5 years is 100 mSv, and for members of the general public, is 1 mSv per year. These dose limits have been established based on a prudent approach by assuming that there is no threshold dose below which there would be no effect. This hypothesis proposes that any additional dose will cause a proportional increase in the chance of a health effect. This relationship has not yet been established in the low dose range where the dose limits have been set.

R7-1.3  The ICRP and the IAEA recommend the individual dose must be kept as low as reasonably achievable and consideration must be given to the presence of other sources that may cause simultaneous radiation exposure to the same group of the public. Also, allowance for future sources or practices must be kept in mind so that the total dose received by an individual member of the public does not exceed the dose limit.

R7-2  How Does This Apply to the Semiconductor Industry?

R7-2.1  A person who can potentially be exposed to ionizing radiation during the normal course of business in excess of the annual limit for the general public should be considered a radiation worker. A radiation worker is trained to recognize and protect him or herself from the hazards of ionizing radiation. They may require exposure monitoring to determine compliance with local radiation regulations. Radiation workers are covered by a radiation safety program. A radiation safety program is an administrative control. Engineering controls minimize the need for spending resources in a large scale radiation program.

R7-2.2  The exposure limit for the radiation worker is 20 millisievert (2000 millirem) per year. Based on a 40 hour/week, 50 week/working year basis, the allowable ionizing radiation emissions are 10 microsieverts/hr (1.0 millirem/hr). This exposure rate should be evaluated as an emission rate from any accessible surface of the equipment (the closest approach to the surface that the radiation is penetrating).

R7-2.3  Maintenance technicians for radiation machines should be participants in the radiation safety program as radiation workers. The equipment should be designed to allow maintenance technicians access to areas that do not exceed 10 microsieverts/hr.

R7-2.4  Service technicians for radiation machines should be participants in their employer’s radiation safety program as radiation workers. The equipment should be designed to allow service technicians access to areas that exceed the 10 microsievert per hour level when operating, but not while the radiation is present.

R7-2.5  The person operating radiation producing equipment (Operator) should not be considered a radiation worker. The emission limit for the operator accessible areas is recommended to be 20% of the occupational limit. The maximum allowable ionizing radiation emissions for operator accessible areas is recommended to be 2 microsieverts/hr (0.2 millirem/hr). This exposure rate should be evaluated as an emission rate from any surface foreseeably accessible by an operator of the equipment, and should be measured as an instantaneous rate.

R7-3  Definitions

R7-3.1  accessible — a significant part of the whole body, head, or eyes.

R7-3.2  bremsstrahlung — is radiation produced by slowing of charged particles. The term means “braking radiation.”

NOTE R7-1: During design of shielding, the properties of the radiation should be considered as well as the properties of the shielding materials. Bremsstrahlung production should be minimized. Some shielding materials are considered
hazardous materials. These hazardous properties should be considered and identified.

R7-3.3 radiation machine — means any device capable of producing ionizing radiation except those devices with radioactive material as the only source of radiation.

R7-3.4 radiation producing machine — is a radiation machine that produces ionizing radiation as a by-product of the process it uses, e.g., ion implanter or scanning electron microscope.

R7-3.5 radiation worker — “worker” means an individual engaged in radiation related work under a license or certificate of registration issued by the Agency and controlled by a licensee or registrant, but does not include the licensee or registrant.

R7-3.6 radioactive material – means any material (solid, liquid, or gas) that emits ionizing radiation spontaneously.

R7-3.7 X-ray machine — is a radiation machine that generates X-rays as a primary function of the equipment. This category of radiation machine has a specific limit due to the existence of performance standards against which the equipment is evaluated. The equipment must be below this limit to be sold in some parts of the world.

R7-3.8 X-rays — are produced with electricity and therefore can be turned off. X-rays seem to be the most prevalent radiation type in semiconductor manufacturing equipment. They are produced when charged particles are slowed or stopped. This slowing results in “bremsstrahlung.” The majority of the equipment does not intentionally produce X-rays. This energy is a by-product of the process.

R7-4 Radioactive Materials
R7-4.1 Gamma radiation is a by-product of atomic transformations (decay) and is a release of energy from the nucleus. This radiation energy must be shielded since there is no off switch.

R7-4.2 Radioactive Materials are controlled by licensing. There are quantities of certain radioactive materials that are exempt from regulation. These sources should be identified.

R7-4.3 External radiation hazards from radioactive materials include gamma rays. These are controlled and evaluated much like the X-rays.

R7-4.4 Internal radiation hazards from radioactive materials include Alpha and Beta particles. Radioactive materials ingested or inhaled can be metabolized or damage surrounding tissue. Allowable levels of airborne radioactivity and radionuclide intakes are specified in regulations. The objective is still to maintain all exposure to ionizing radiation (internal and external) as low as reasonably achievable, but always less than the allowable regulatory limits.
RELATED INFORMATION 8
DOCUMENTATION OF NON-IONIZING RADIATION (SECTION 25 AND APPENDIX 5) INCLUDING RATIONALE FOR CHANGES

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

R8-1 The user of this table is responsible for obtaining the current revision of the standards cited for Occupational Exposure Limits (OEL).

R8-2 The emission values in Appendix 5 that are not to be exceeded were chosen based on a review of all known international standards as well as a consideration for best available control technology (i.e., lowest values currently achievable for each radiation type). Where a general public limit existed, 20% of this value was selected. Where there was no public limit, the value selected is generally 20% of the OEL value (instantaneous field strength measurement peak). The latter case would have the occupational and general public limits the same. Where there was an occupational exposure limit specified in a standard, the maintenance emission limit was set at 20% of this level.

R8-3 Most health standards differentiate between “occupational” and “general public” exposure criteria. IEEE C95.1 differentiates between “controlled access” and “uncontrolled access” exposures. According to C95.1 “controlled access” environments are those where “locations where there is exposure that may be incurred by persons who are aware of the potential for exposure as a concomitant of employment, by other cognizant persons, or as the incidental result of transient passage through areas where analysis shows the exposure levels may be above those shown in Table 2 but do not exceed those of Table 1, and where the induced currents may exceed the values in Table 2, Part B, but do not exceed the values of Table 1, Part B.” According to C95.1, “uncontrolled access” environments are “locations where there is the exposure of individuals who have no knowledge or control of their exposure. The exposure may occur in living quarters or workplaces where there are no expectations that the exposure levels may exceed those shown in Table 2 and where induced currents do not exceed those in Table 2, Part B.” Task force members advise that C95.1 “controlled access” and other “occupational exposure” standards should be applied to personnel performing maintenance and service of equipment and that “uncontrolled access” or other “general public” standards should be applied to equipment operators during routine work and to other locations. These IEEE definitions are particularly relevant to broadcast facilities as well as normal industrial environments such as fabs. Task force members recommend that uncontrolled access limits be applied to fetal exposure.

R8-4 As with the rationale in the Ionizing section, the operator is considered a member of the general public or to be in an uncontrolled area. Maintenance or service technicians should be trained to know how to control the hazardous energy and protect themselves from the hazard and its adverse effects.

R8-5 References

1. 1996 TLVs and BEIs Threshold Limit Values for Chemical Substances and Physical Agents Biological Exposure Indices, ACGIH, Cincinnati, OH
2. Guidelines on Limits of Exposure to Broad-Band Incoherent Optical Radiation (0.38 to 3 µM), Health Physics Vol. 73, No. 3 (September), pp.539-554, 1997
RELATED INFORMATION 9
LASER CHECKLIST

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

Laser Manufacturer: __________________________________
Model #: __________________________________________
Serial #: __________________________________________
Laser Hazard Classification: (During Operation)
1. Classification Number (e.g. 1, 2, 3a, 3b, 4): ________
2. Classification Standard(s) (e.g. FDA/CDRH, IEC, JIS, etc.): ________
   NOTE R9-1: If any laser contained in the equipment is Class 2, 3a, 3b or 4 laser system or product, the vendor should make available upon request a hazard evaluation to include the following information for each laser in the equipment (where applicable):

Laser Parameters
1. Laser medium type (HeNe, Nd:YAG, CO₂, Argon, Excimer, GaAs, etc.): __________
   Note: For Excimer lasers, specify gases: _______________
2. Wavelength(s) in nanometers (nm): _______________
3. Continuous Wave
   A. Peak Power in Watts (W): ________
   B. Available Power in Watts (W): ________
   C. Irradiance in Watts/square centimeter (W/cm²): ________
4. Pulse Characteristics
   A. Duration of Pulse in Seconds (s): ________
   B. Energy per Pulse in Joules (J): ________
   C. Frequency of Pulses (Pulse Repetition Frequency) in Hertz (Hz): ________
   D. Average Power in Watts (W): ________
   E. Radiant Exposure in Joules/square centimeter (J/cm²): ________
   F. Q-Switch controlled pulses ( ) Yes ( ) No
5. Beam Parameters
   A. Emerging beam diameter in millimeters (mm): ________
   B. Expanded beam diameter in millimeters (mm): ________
   C. Beam divergence in milliradians (mr): ________
   D. Collecting optics type: ________
   E. Focal length in millimeters (mm): ________
Laser Control Measures

1. Identify protective measures required during maintenance. __________________

2. Laser Controlled Area required for Maintenance procedures? ( ) Yes ( ) No

3. Laser Controlled Area required for Service procedures. ( ) Yes ( ) No

4. If a Nominal Ocular Hazard Distance (NOHD) is used as a control measure, then provide the NOHD calculations. See IEC 60825-1 for NOHD calculations.

NOTE R9-2: Attach a diagram of the laser beam path and the irradiance/radiant exposure at each significant point.

Personnel Protective Equipment (PPE) (for laser radiation hazards in excess of the MPE)

1. Optical Density (OD) of PPE required during maintenance activities: ___________

2. OD of PPE required during service activities: ___________

3. Recommended PPE manufacturer and model #: ______________________________

Table R9-1 Equipment Safety Features

<table>
<thead>
<tr>
<th>Equipment Safety Features (not an inclusive list)</th>
<th>USA</th>
<th>Europe</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>21 CFR 1040.10</td>
<td>EN 60825-1</td>
<td>JIS 6802</td>
</tr>
<tr>
<td>Paragraph</td>
<td>Paragraph</td>
<td>Paragraph</td>
<td>Examples</td>
</tr>
<tr>
<td>----------</td>
<td>------------</td>
<td>------------</td>
<td>----------</td>
</tr>
<tr>
<td>1. Protective Housing</td>
<td>( ) Yes ( ) No</td>
<td>(f)(1) 4.2</td>
<td>4.2.1 Aluminum or steel enclosures, windows that provide adequate attenuation, optical fibers or beam tubes.</td>
</tr>
<tr>
<td>2. Safety Interlocks</td>
<td>( ) Yes ( ) No</td>
<td>(f)(2) 4.3</td>
<td>4.2.2 See Section 11 of SEMI S2.</td>
</tr>
<tr>
<td>3. Remote Interlock Connector</td>
<td>( ) Yes ( ) No</td>
<td>(f)(3) 4.4</td>
<td>4.2.3 Usually a 12 to 24 volt set of contacts available to the user to integrate additional room control measures.</td>
</tr>
<tr>
<td>4. Key Control</td>
<td>( ) Yes ( ) No</td>
<td>(f)(4) 4.5</td>
<td>4.2.4 A key that is not removable in the operations mode.</td>
</tr>
<tr>
<td>5. Laser Radiation Emission Warning</td>
<td>( ) Yes ( ) No</td>
<td>(f)(5) 4.6</td>
<td>4.2.5 A light or indicator that warns the user of the emission through the aperture.</td>
</tr>
<tr>
<td>6. Beam Attenuator</td>
<td>( ) Yes ( ) No</td>
<td>(f)(6) 4.7</td>
<td>4.2.6 Shutters, beam blocks or water-cooled beam dumps</td>
</tr>
<tr>
<td>7. Location of Controls</td>
<td>( ) Yes ( ) No</td>
<td>(f)(7) 4.8</td>
<td>4.2.7</td>
</tr>
<tr>
<td>8. Viewing Optics</td>
<td>( ) Yes ( ) No</td>
<td>(f)(8) 4.9</td>
<td>4.2.8 Must block all hazardous wavelengths to acceptable levels.</td>
</tr>
<tr>
<td>9. Scanning Safeguard</td>
<td>( ) Yes ( ) No</td>
<td>(f)(9) 4.10</td>
<td>4.2.9 Shuts down if the scanning mechanism (such as a rotating mirror or galvanometer) fails.</td>
</tr>
<tr>
<td></td>
<td>Manual Reset Mechanism</td>
<td></td>
<td>(f)(10)</td>
</tr>
<tr>
<td>---</td>
<td>------------------------</td>
<td>---</td>
<td>---------</td>
</tr>
<tr>
<td>10.</td>
<td>( ) Yes</td>
<td>( ) No</td>
<td>A button or circuit that must be energized before the equipment resumes its functions.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Class Designation &amp; Warning Labels</th>
<th></th>
<th>(g)</th>
<th>5</th>
<th>4.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.</td>
<td>( ) Yes</td>
<td>( ) No</td>
<td>Identify which standard was used for each hazard classification.</td>
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</tr>
</tbody>
</table>

<table>
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<tbody>
<tr>
<td>12.</td>
<td>( ) Yes</td>
<td>( ) No</td>
<td>Identify the aperture.</td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Positioning of Labels</th>
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<th>4.3.1</th>
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<tbody>
<tr>
<td>13.</td>
<td>( ) Yes</td>
<td>( ) No</td>
<td>Conspicuous, but size is not specified.</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>User Information</th>
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<th>6.1</th>
<th>4.4.1</th>
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<tbody>
<tr>
<td>14.</td>
<td>( ) Yes</td>
<td>( ) No</td>
<td>SOPs, instruction manuals</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>Service Information</th>
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<th>4.4.2</th>
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<tr>
<td>15.</td>
<td>( ) Yes</td>
<td>( ) No</td>
<td>Accessible laser radiation levels during Service</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Measurements</th>
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<th>3.4</th>
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<td>( ) Yes</td>
<td>( ) No</td>
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<td>( ) Yes</td>
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<table>
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<tr>
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<tbody>
<tr>
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<td>( ) Yes</td>
<td>( ) No</td>
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<td>19.</td>
<td>( ) Yes</td>
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<tr>
<td>20.</td>
<td>( ) Yes</td>
<td>( ) No</td>
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RELATED INFORMATION 10
LASER CERTIFICATION REQUIREMENTS BY REGION OF USE

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

Table R10-1 Regional Laser Standards

<table>
<thead>
<tr>
<th></th>
<th>USA</th>
<th>Europe</th>
<th>Japan</th>
<th>Pacific Rim</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classification Standards</td>
<td>21 CFR 1040.10</td>
<td>EN 60825-1</td>
<td>JIS C 6802</td>
<td>IEC 60825-1</td>
</tr>
<tr>
<td>Certification Standards</td>
<td>21 CFR 1000-1010</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

R10-1 USA
Food and Drug Administration (FDA)
Center for Devices and Radiological Health (CDRH)

R10-1.1 Laser products must comply with the performance requirements of Title 21 of the Code of Federal Regulations Part 1040.10 (21 CFR 1040.10). Manufacturers (including modifiers) of laser products must certify to the FDA/CDRH in writing that the product complies with the requirements of 21 CFR SubChapter J.

R10-1.2 The reporting requirements are detailed in 21 CFR 1000–1010. Product report forms and the guidance document are available from the CDRH. These documents should soon be available from the CDRH Web server at:

http://www.fda.gov/cdrh

R10-1.3 The CDRH Office of Compliance can be reached by telephone at (301) 594-4654

R10-1.4 The CFR references may be obtained by searching the website at:


but these documents do not include figures or tables.

R10-1.5 When a laser product is imported, the importing company is considered the laser manufacturer and must certify the laser product.

R10-2 Europe
International Electrotechnical Commission (IEC)

R10-2.1 European governments have adopted IEC 60825-1 as the laser product safety standard. Manufacturers of laser products should comply with Section 2 of the IEC 60825-1 document. An IEC committee is currently working on a checklist for laser product manufacturers to follow to assess compliance with the IEC document. Other IEC 60825 series documents may apply to the product either now or in the future.

R10-2.2 EN 60825-1 is the normative standard, which has been adopted by the European Union and EFTA countries.

R10-2.2.1 The EN 60825-1 should be available through the various European government agencies or government printing offices.

R10-2.3 The laser product manufacturer should review ISO 11553 for requirements that apply to laser equipment that processes materials.

R10-2.4 The IEC document can be obtained from:

International Electrotechnical Commission
3, rue de Varembé • PO Box 131
1211 Geneva 20 • Switzerland
Tel: +41 22 919 02 11 • Fax: +41 22 919 03 00

or other participating national standards association (available on websites).

R10-2.5 The ISO document can be obtained from:

International Standards Organization (ISO)
1, rue de Varembé
Case postale 56
CH-1211 Genève 20
Switzerland
Telephone: + 41 22 749 01 11
Telefax: + 41 22 733 34 30

or other participating national standards association (available on websites).

R10-2.6 The IEC Website is located at:

http://www.iec.ch

R10-2.7 The ISO Website is located at:

http://www.iso.ch/
R10-3 Japan

R10-3.1. The Japanese Safety Association published an English version of the Japanese laser safety standard based on the IEC 60825 series document. This standard is Japanese Industrial Standard (JIS) C 6802. The Japanese version is still the official standard, but the English version has the warning hazards described with the Japanese symbols in the images.

R10-3.2. As in the IEC document the manufacturing requirements are specified in Section 2. There is a companion document JIS C 6801 that provides the Glossary of terms and their translations into English.

R10-3.3. The JIS documents can be obtained through the Japanese Safety Association.

R10-3.4. Japanese Standards Association
1-24 Akasaka 4
Minato-Ku
JP-107 TOKYO
TP: +81 3 3583 80 03
TF: +81 3 3586 20 29
http://www.jsa.or.jp/eng/catalog/frame.html is searchable

R10-3.5. Websites:
(In English) http://www.hike.te.chiba-u.ac.jp/ikeda/JIS/index.html
(In Japanese) http://www.jsa.or.jp

R10-4 Other (e.g., Pacific Rim)

R10-4.1 The manufacturer is responsible to determine the appropriate standard to use in other countries.

R10-4.2 In the absence of any specific standard for a country, the IEC 60825-1 document should be used as the guide for compliance.

R10-4.3 In many countries, prefectures, states, or provinces, local laser safety regulations exist. Much of this regulation is aimed at the user, but may include product performance requirements. The manufacturer has the responsibility to identify these requirements.

R10-4.4 Addresses of many national standards organizations are found at:
http://www.iec.ch/cs1sot-e.htm
RELATED INFORMATION 11
OTHER REQUIREMENTS BY REGION OF USE

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

R11-1 Japan — Earth Leakage Breaker/Ground Fault Circuit Interrupter/Ground Fault Equipment Protection Circuit Interrupter/Residual Current Devices

R11-1.1 Japanese regulations may require the use of Ground Fault Circuit Interrupter (GFCI), Ground Fault Equipment Protection Circuit Interrupter (GFEPIC), Residual Current Devices (RCD), or Earth Leakage Breaker (ELB) with the equipment.

EXCEPTION 1: The rating of the equipment is less than 20 amperes and less than 150 volts rms.

EXCEPTION 2: The equipment is supplied from the ungrounded secondary of an AC mains isolation transformer.

R11-1.2 The GFCI, GFEPIC, RCD or ELB, when required to satisfy Japanese requirements, should have trip ratings of not greater than 30 mA and 0.1 second.

EXCEPTION 1: If there is no accessible live circuit during maintenance tasks, trip ratings of up to 300 mA are acceptable.

EXCEPTION 2: If the equipment satisfies Exception 1 and the earth impedance is less than 50 ohms, a GFCI, GFEPIC, RCD or ELB of 500 mA maximum is acceptable.

EXCEPTION 3: If the equipment is connected to a source of supply that is provided with a GFCI, GFEPIC, RCD or ELB, an additional GFCI, GFEPIC, RCD or ELB is not required for the equipment.

R11-2 USA

R11-2.1 Nameplates — In addition to the nameplate requirement noted in the Electrical section of S2, equipment evaluated as “Industrial Machinery” per NFPA 79 and intended for use in the United States may be required to display additional nameplate information, such as ampere rating of the largest motor or load, short circuit interrupting capacity of the machine overcurrent protective device where furnished as part of the equipment, and the electrical diagram number(s) or the number of the index to the electrical diagrams. Furthermore, where overcurrent protection is provided, the equipment must be marked “overcurrent protection provided at machine supply terminals.”


R11-3 Europe

R11-3.1 Nameplates — In addition to the nameplate requirement noted in the Electrical section of S2, equipment evaluated as “Industrial Machinery” per IEC 60204-1 (EN 60204-1) and intended for use in Europe may be required to display additional nameplate information, such as: certification mark, where required; current rating of the largest motor or load; short-circuit interrupting capacity of the machine overcurrent protective device, where furnished as part of the equipment; and the electrical diagram number(s) or the number of the index to the electrical drawings.

R11-3.1.1 Where only a single motor controller is used, this information may instead be provided on the machine nameplate where it is plainly visible.

R11-3.1.2 The full-load current shown on the nameplate shall be not less than the combined full-load currents for all motors and other equipment that can be in operation at the same time under normal conditions of use. Where unusual loads or duty cycles require oversized conductors, the required capacity shall be included in the full-load current specified on the nameplate.

R11-3.2 European Union requires compliance to CE marking.

R11-4 Worldwide — Hazard Alert Labels

R11-4.1 USA — Labels intended for use in the USA should conform to ANSI Z535.4.

R11-4.2 Other Countries — Labels intended for use in countries other than the USA should conform to ISO 3864.
RELATED INFORMATION 12
LIGHT TOWER COLOR AND AUDIBLE ALERT CODES

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

R12-1 Colors for Light Towers
R12-1.1 Where used for safety, a light tower should have the following characteristics:

Table R12-1 Light Tower Color Code

<table>
<thead>
<tr>
<th>Color</th>
<th>Explanation</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>Hazardous, dangerous or abnormal condition requiring immediate attention</td>
<td>Pressure/temperature out of safe limits; Voltage drop; Breakdown Overtravel of a stop position Indication that a protective device has stopped the machine, e.g., overload</td>
</tr>
<tr>
<td>Yellow</td>
<td>Abnormal, caution/marginal condition; Change or impending change of critical condition requiring monitoring and/or intervention (e.g., by re-establishing the intended function)</td>
<td>Pressure/temperature exceeding normal limits Tripping of protective device Automatic cycle or motors running; some value (pressure, temperature) is approaching its permissible limit. Ground fault indication. Overload that is permitted for a limited time.</td>
</tr>
<tr>
<td>Green</td>
<td>Normal condition; machine ready</td>
<td>Pressure/temperature within normal limits Indication of safe condition or authorization to proceed. Machine ready for operation with all conditions normal or cycle complete and machine ready to be restarted.</td>
</tr>
</tbody>
</table>

R12-2 Audible Alert (Buzzer) Code
R12-2.1 Where used for safety, audible alert (buzzer) for the light tower should have the following characteristics:

Table R12-2 Light Tower Buzzer Code

<table>
<thead>
<tr>
<th>Color</th>
<th>Audible Alert (Buzzer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>Continuous</td>
</tr>
<tr>
<td>Yellow</td>
<td>Intermittent</td>
</tr>
<tr>
<td>Green</td>
<td>Intermittent/no sound (selectable)</td>
</tr>
</tbody>
</table>
RELATED INFORMATION 13
SURFACE TEMPERATURE DOCUMENTATION

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

The following is some of the research leading to the values in Table 1 in Section 18 of this guideline.

R13-1 The proposed Hazardous Temperature Limits were derived from UL195011 and IEC95012 by adding ambient temperature (25°C) to the maximum temperature rise allowed for external parts of information technology equipment. Because several SEMI members have questioned whether these limits might subject operators and maintenance personnel to contact with potentially hazardous temperatures, a review has been done of several other sources of suggested temperature limits.

R13-2 The proposed hazardous surface temperatures for handling and touching of metal handles, knobs, etc., for brief periods in normal use is 60°C. Assuming a brief handling time to be 5 seconds or less, this limit is supported in MIL-STD-147213, MIL-HDBK-759A14 and EN56315 (which are the same or more conservative by 2°C), and is equal to the pain and tissue damage threshold listed in the Human Factors Design Handbook16. Thus, this temperature limit seems appropriate for momentary (five seconds or less) contact with uncoated metal handles, knobs, etc., and other material with high thermal conductivity.

R13-3 The proposed hazardous surface temperatures for handling and touching of glass/porcelain handles, knobs, etc., for brief periods in normal use is 70°C. This temperature limit is supported by MIL-STD-1472 and EN563. MIL-HDBK-759 is not applicable because it must be assumed that it applies only to material with high thermal conductivity.

R13-4 The proposed hazardous surface temperatures for handling and touching of plastic/rubber handles, knobs, etc., for brief periods in normal use is 85°C. This temperature limit is similarly supported by MIL-STD-1472 and EN563. MIL-HDBK-759 is not applicable.

R13-5 The proposed hazardous surface temperatures for continuous handling and touching of metal handles, knobs, etc., during normal usage is 55°C. It is suggested, based on observations of semiconductor equipment in use, that a continuous handling time of one minute be used. With this duration, the limit of the MIL-STD and the MIL-HDBK ranges from 49 to 52°C. The EN563 burn threshold limit for contact with metal for one minute is 51°C. The burning heat pain level listed in the Human Factors Design Handbook is 49°C (no time frame given; assume high thermal conductivity material). Thus, the proposed temperature limit appears to be somewhat high for reasonably foreseeable extended handling contact with uncoated metal handles, knobs, etc., and other material with high thermal conductivity. The Section 18 Table 1 limit is 51°C, which might be somewhat painful to more sensitive personnel, but should not result in tissue damage.

R13-6 The proposed hazardous surface temperatures for extended handling and touching of glass/porcelain handles, knobs, etc., during normal usage (again assuming 1 minute) is 65°C. The limit of MIL-STD-1472D is 59°C for “prolonged contact” with glass. The EN563 burn threshold limit at 1 minute is 56°C. Thus, the proposed temperature limit appears to be slightly high for reasonably foreseeable extended handling contact with glass/porcelain surfaces of moderate thermal conductivity. The Section 18 Table 1 limit is 56°C, which is the more conservative of the recommendations. This limit could be raised based upon the results of the risk assessment for actual and foreseeable normal usage.

R13-7 Similarly, the proposed hazardous surface temperatures for extended handling and touching of plastic/rubber handles, knobs, etc., during normal usage (again assuming 1 minute) is 75°C. The limit of MIL-STD-1472D is 69°C for “prolonged contact” with plastic. The EN563 burn threshold limit at 1 minute is 60°C. Thus, the proposed temperature limit again appears to be slightly high for reasonably foreseeable extended handling contact with plastic/rubber surfaces of low thermal conductivity. The Section 18 Table 1 limit is 60°C, which is the more conservative of the recommendations. This limit could be raised based upon the results of the risk assessment for actual and foreseeable normal usage.

R13-8 The proposed hazardous surface temperatures for external surfaces and internal parts which may be
touched are 70°C for metal, 80°C for glass/porcelain, and 95°C for plastic/rubber. It is assumed that this limit applies to inadvertent touching by the operator/maintenance person, resulting in the person instantly breaking contact with the hot surface. There are no analogs in either the MIL-STD or the MIL-HDBK for these temperature limits. The EN563 burn threshold range for one-second contact with uncoated metal is 65 to 70°C, while the range for one-second contact with glass is 80 to 86°C. The proposed temperature limit appears to be slightly high for reasonably foreseeable inadvertent contact with external metal surfaces. The Section 18 Table 1 limit for contact with external metal surfaces is 65°C, which is the conservative end of the EN563 range.

R13-9 No information was available to support or refute the temperature limits for contact with external plastic/rubber surfaces. With regard to internal parts, the proposed temperature limits may be adequate given the foreseeable cooling which would likely occur prior to handling of internal parts. The actual thermal lag of components likely to be handled could be verified by thermocouple readings on specific equipment during a risk assessment.

Table R13-1 Allowable Surface Temperatures (°C) for Handles, Knobs, Grips, etc., Held for Short Periods Only (5 seconds or less)

<table>
<thead>
<tr>
<th></th>
<th>Metal</th>
<th>Glass, Porcelain, Vitreous Material</th>
<th>Plastic, Rubber</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN563</td>
<td>58</td>
<td>70</td>
<td>n/a</td>
</tr>
<tr>
<td>MIL-STD-1472</td>
<td>60</td>
<td>68</td>
<td>85</td>
</tr>
<tr>
<td>MIL-HDBK-759</td>
<td>60</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Section 18 Table 1 Value</td>
<td>60</td>
<td>70</td>
<td>85</td>
</tr>
</tbody>
</table>

Table R13-2 Allowable Surface Temperatures (°C) for Handles, Knobs, Grips, etc., Held in Normal Use

<table>
<thead>
<tr>
<th></th>
<th>Metal</th>
<th>Glass, Porcelain, Vitreous Material</th>
<th>Plastic, Rubber</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN563</td>
<td>51</td>
<td>56</td>
<td>60</td>
</tr>
<tr>
<td>MIL-STD-1472</td>
<td>49</td>
<td>59</td>
<td>69</td>
</tr>
<tr>
<td>MIL-HDBK-759</td>
<td>52</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Section 18 Table 1 Value</td>
<td>51</td>
<td>56</td>
<td>60</td>
</tr>
</tbody>
</table>

Table R13-3 Allowable Surface Temperatures (°C) for External Surface of Equipment Which May Be Momentarily Touched

<table>
<thead>
<tr>
<th></th>
<th>Metal</th>
<th>Glass, Porcelain, Vitreous Material</th>
<th>Plastic, Rubber</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN563</td>
<td>65-70</td>
<td>80-86</td>
<td>n/a</td>
</tr>
<tr>
<td>MIL-STD-1472</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>MIL-HDBK-759</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Section 18 Table 1 Value</td>
<td>65</td>
<td>80</td>
<td>95</td>
</tr>
</tbody>
</table>

Table R13-4 Allowable Surface Temperatures (°C) for Parts, Inside the Equipment, Which May Be Momentarily Touched

<table>
<thead>
<tr>
<th></th>
<th>Metal</th>
<th>Glass, Porcelain, Vitreous Material</th>
<th>Plastic, Rubber</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN563</td>
<td>n/a</td>
<td>68</td>
<td>85</td>
</tr>
<tr>
<td>MIL-STD-1472</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>MIL-HDBK-759</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Section 18 Table 1 Value</td>
<td>65</td>
<td>80</td>
<td>95</td>
</tr>
</tbody>
</table>

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.

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