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

NOTICE: Section 26 below will be withdrawn upon July 1, 2006 publication and replaced by the new Section 26 including: figures and tables as shown in Delayed Revisions Section 1. The EH&S Committee has voted that implementation of the information is OPTIONAL before the effective date.

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

NOTE 122: 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 123: 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.

26.1.1.2 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 124: Temporary enclosures and personal protective equipment are considered to be administrative controls, because they require human action to implement.

NOTE 125: 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 126: 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 127: 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 128: 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.

Difference between sound pressure level measured with noise source operating and background sound pressure level (dBA)	*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)*
3	3
4	2.5
5	1.7
6	1.3
7	1
8	0.8
9	0.6
10	0.4

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.

ACGIH, Hazard Assessment and Control Technology in Semiconductor Manufacturing, 1989, distributed by Lewis Publishers, Chelsea, Michigan.

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

Burgess, Ellenbecker, Treitman, Ventilation for Control of the Work Environment, John Wiley, NY, 1989

Burton, D.J., IVE, Inc., Industrial Ventilation Workbook, 3rd Edition, 1995, Lab Ventilation Workbook, 1994; 2974 South Oakwood, Bountiful, Utah 84010

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

Williams, M. and D.G. Baldwin, Semiconductor Industrial Hygiene Handbook, Noyes Publications, Park Ridge, NJ, 1995, ISBN 0-8155-1369-0

APPENDIX 1
ENCLOSURE OPENINGS

NOTICE: 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

Distance Between Opening and Danger Point		*Maximum Opening*	
mm	*inches*	*mm*	*inches*
13–38	0.5–1.5	6	0.250
38–64	1.5–2.5	10	0.375
64–89	2.5–3.5	11.9	0.470
89–140	3.5–5.5	16	0.625
140–165	5.5–6.5	19	0.750
165–191	6.5–7.5	22	0.875

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

NOTICE: 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

Hood Type	*Recommended Test Methods*	*Typical Design and Test Exhaust Parameters (See NOTE 1.)*	*References*
Wet Station	Primary: vapor visualization, air sampling Supplemental: Capture velocity, slot velocity, tracer gas, air sampling	0.28–0.50 m/s (55–100 fpm) capture velocity for non-heated 0.36–0.76 m/s (70–150 fpm) capture velocity for heated 110–125% of the laminar flow volume flow rate across the top of the deck	ACGIH Industrial Ventilation Manual SEMI F15
Gas Cylinder Cabinets	Primary: face velocity, tracer gas Supplemental: vapor visualization	1.0–1.3 m/s (200–250 fpm) face velocity	ACGIH Industrial Ventilation Manual SEMI F15
Equipment Gas Panel Enclosure	Primary: tracer gas, static pressure Supplemental: vapor visualization	4–5 air changes per minute –1.3 to –2.5 mm (–0.05 to –0.1 in.) H_2O static pressure	ACGIH Industrial Ventilation Manual SEMI F15
Diffusion Furnace Scavenger	Primary: face velocity, vapor visualization Supplemental: tracer gas, air sampling	0.50–0.76 m/s (100–150) fpm face velocity NOTE: Do not use hot wire anemometer.	ACGIH Industrial Ventilation Manual SEMI F15
Chemical Dispensing Cabinets	Primary: static pressure Supplemental: vapor visualization, air sampling where safe, tracer gas where emission rates can be accurately calculated	–1.3 to –2.5 mm (–0.05 to –0.1 in.) H_2O static pressure 2–3 air changes per minute	ACGIH Industrial Ventilation Manual SEMI F15

Hood Type	*Recommended Test Methods*	*Typical Design and Test Exhaust Parameters (See NOTE 1.)*	*References*
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.) H_2O 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.) H_2O 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 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* — Measurements should be made to identify optimal exhaust levels and confirm that safety and process requirements are being addressed. The manufacturer should be able to identify any critical equipment locations for chemical capture, and quantify appropriate exhaust values. Multiple validation/ measurement methods may be needed.

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 m^3/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 velometer 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: $V = 4.043\ (VP/d)^{0.5}$, where V = velocity in m/s, VP = velocity pressure in mm H_2O, 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: $V = 4.043\ (VP/d)^{0.5}$, where V = velocity in m/s, VP = velocity pressure in mm H_2O, 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

NOTICE: 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

Potential Hazard	*Recommended Control Method*	*Design Considerations*
Exposure to operators	Containment, control, and alarm notification for spills, leaks or vapors.	Appropriately sized secondary containment (minimum 110% volume of entire contents) Equipment exhaust Leak sensors to initiate auto shutdown.
	Controlled access to chemical containment areas.	Door/access cover interlocks that automatically depressurize the area of the system being accessed.
	Control of access to point-of-operation hazards.	Physical guarding/presence-sensing devices
Exposure to maintenance personnel	Control of chemical delivery pressure; control of residual chemicals.	Depressurization upon system failure, interlock activation, or normal shutdown Transparent doors/covers allow visual inspection.
	Serviceability	Built-in system purge and flush capabilities System components accessible and easy to service.
General equipment and component failure	Chemical resistance/compatibility	Appropriate materials used for equipment construction and components.
	Pressure rating	Pressurized systems designed to withstand 150% of maximum foreseeable pressure, or provide a suitable relief valve.
Chemical delivery system leak	Durable bulk chemical containers	Use of approved (e.g., DOT, UN Dangerous Goods) containers in bulk distribution systems.
	Control of pressurized vessels and piping.	Provide visual pressure indicators with or without alarms. Pressurized vessels and piping are designed and built to recognized standards.
	Spill control	Automatic system pressure check prior to allowing dispense. Use of normally closed valves on distribution lines.
	Drum change-out controls	Over-fill sensors on chemical baths Monitoring for excess flow. Keyed and color-coded quick-connects

Potential Hazard	*Recommended Control Method*	*Design Considerations*
Fire	Control of ignition sources.	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.
	Control of static electricity (i.e., one type of ignition source).	Maintain ground continuity
	Heat/fire/chemical detection Limiting concentrations of fuels and oxidizers.	(No consensus for a specific recommendation at the time of publication of this guideline.)

APPENDIX 4
IONIZING RADIATION TEST VALIDATION — Design and Test Method Supplement Intended for Internal and Third Party Evaluation Use

NOTICE: 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

Ionizing Radiation Type	*Emission Limit microsievert/hr (millirem/hr)*	*Test Method*
X or Gamma	Operator 2 μSv/hr (0.2 mrem/hr)	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.
X or Gamma	Maintenance and Service 10 μSv/hr (1 mrem/hr)	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.

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 form 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

NOTICE: 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 A5-1 Non-Ionizing Radiation

Energy Category	*Physical Quantity Measured (units)*	*Operator-Accessible Limit*	*Maintenance- and Service-Accessible Limit*	*Pacemaker Labeling Level*	*Testing Methods*
Static[4] 0 Hz. (e.g., static magnets in etch/implant equipment)	Magnetic Field Strength (A/m or Gauss) (See NOTES 1 and 2.)	8 mT (80 G)	40 mT (400 G)	0.5 mT (5 G)	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.

Energy Category	*Physical Quantity Measured (units)*	*Operator-Accessible Limit*	*Maintenance- and Service-Accessible Limit*	*Pacemaker Labeling Level*	*Testing Methods*
Sub Radio-frequency[1] 1 Hz to 3 kHz (e.g., electromagnets in etch equipment) *See exception below for 50 and 60 Hz power frequencies.	Electric Field Strength (V/m) (See NOTE 1.)	1–100 Hz 5 kV/m* 100 Hz to 3 kHz 500,000/f (Hz) in V/m	1–100 Hz 5 kV/m* 100 Hz to 3 kHz 500,000/f (Hz) in V/m	1 kV/m	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.
Sub Radio-frequency[1] 1 Hz to 3 kHz (e.g., electromagnets in etch equipment) *See exception below for 50 and 60 Hz power frequencies.	Magnetic Field Strength (A/m or G) (See NOTES 1 and 2.)	1–300 Hz 12/f (Hz) in mT 300 Hz to 3 kHz 0.04 mT (400 mG)*	1–300 Hz 12/f (Hz) in mT 300 Hz to 3 kHz 0.04 mT (400 mG)*	0.1 mT (1 G)	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.
Power Frequency (50 or 60 Hz) [1,5] (e.g., electromagnets in etch equipment)	Electric Field Strength (V/m) (See NOTE 1.)	1 kV/m	2 kV/m	1 kV/m	See Sub radiofrequency Electric Field Testing Method, but probe is positioned as needed to determine distance to 1 kV/m.
Power Frequency (50 or 60 Hz) [1,5] (e.g., electromagnets in etch equipment)	Magnetic Field Strength (A/m or G) (See NOTES 1 and 2.)	0.02 mT (200 mG)	0.1 mT (1 G)	0.1 mT (1 G)	See Sub radiofrequency Magnetic Field Testing Method, but probe is positioned as needed to determine distance to 1 G pacemaker criterion.
Radio-frequency Field [2] 3 kHz to 100 kHz (e.g., RF used to generate plasma)	Induced current and contact current (mA)	Frequency-dependent: 180f (kHz) in mA through both feet 90f through each foot 90f for contact. where f is in MHz	Frequency-dependent: 400f (kHz) in mA through both feet, 200f through each foot 200f for contact. where f is in MHz	NA	Contact instrument vendor for suitable instrument based on frequency and emission characteristics. Measurement of induced and contact currents for freq. < 100 MHz should be made when approaching 20% of the applicable electric field emission limit.

Energy Category	*Physical Quantity Measured (units)*	*Operator-Accessible Limit*	*Maintenance- and Service-Accessible Limit*	*Pacemaker Labeling Level*	*Testing Methods*
Radio-frequency Field [2] 100 kHz to 100 MHz (e.g., RF used to generate plasma)	Induced current and contact current (mA)	18 mA through both feet 9 mA through each foot 9 mA contact	40 mA through both feet 20 mA through each foot 20 mA contact	NA	Contact instrument vendor for suitable instrument based on frequency and emission characteristics. Measurement of induced and contact currents for freq. < 100 MHz should be made when approaching 20% of the applicable electric field emission limit.
Radio-frequency Field [2] 3 kHz to 300 MHz (e.g., RF used to generate plasma)	Electric Field Strength (V/m) (See NOTE 1.)	Frequency dependent (see ANSI/IEEE C95.1). 20% of Uncontrolled limit in Table 2 of C95.1	Frequency dependent (see ANSI/IEEE C95.1). 20% of Controlled limit in Table 1 of C95.1	NA	Use a diode rectifier or displacement sensor at each location (use three axis probe or make three mutually orthogonal measurements at each location). Measurements should be made at 20 cm from the surface.
Radio-frequency Field [2] 3 kHz to 300 MHz (e.g., RF used to generate plasma)	Magnetic Field Strength (A/m) (See NOTES 1 and 2.)	Frequency dependent (see ANSI/IEEE C95.1). 20% of Uncontrolled limit in Table 2 of C95.1	Frequency dependent (see ANSI/IEEE C95.1). 20% of Controlled limit in Table 1 of C95.1	NA	Use a coil sensor at each location (use three axis probe or make three mutually orthogonal measurements at each location) Measurements should be made at 20 cm of the surface.
Radio-frequency Fields [2] 300 MHz to 300 GHz (e.g., RF used to generate plasma)	Power Density (mW/cm^2) (See NOTE 1.)	Frequency dependent (see ANSI/IEEE C95.1). 20% of Uncontrolled limit in Table 2 of C95.1	Frequency dependent (see ANSI/IEEE C95.1). 20% of Controlled limit in Table 1 of C95.1	NA	Use a diode rectifier or thermocouple at each location (use three axis probe or make three mutually orthogonal measurements at each location). Measurements should be made at 20 cm of the surface.

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 A5-2 Optical Energy

Optical Energy	*Physical Quantity Measured (units)*	*Access Limit*	*Testing Methods*
Infrared Energy[1] 700 nm to 1 mm (e.g., heating lamps)	Irradiance W/m^2 (See NOTES 1, 2, and 3.) Radiance W/m^2 - sr	Wavelength dependent 20% of the applicable exposure limits. (See Reference 1.)	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).

Optical Energy	*Physical Quantity Measured (units)*	*Access Limit*	*Testing Methods*
Visible Light[1] 400 nm to 700 nm (e.g., heating lamps)	Irradiance μW/cm^2 (See NOTES 1, 2, and 3.) Radiance W/m^2 - 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 Energy[1] 315 nm to 400 nm (e.g., plasma, stepper)	Irradiance mW/cm^2 (See NOTES 1 and 2.)	0.2 mW/cm^2	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 Light[1] 180 nm to 315 nm (e.g., plasma, stepper)	Effective Irradiance μW/cm^2 (See NOTE 4.)	0.02 μW/ cm^2	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

2. ANSI/IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, C95.1-1991, Piscataway, New Jersey

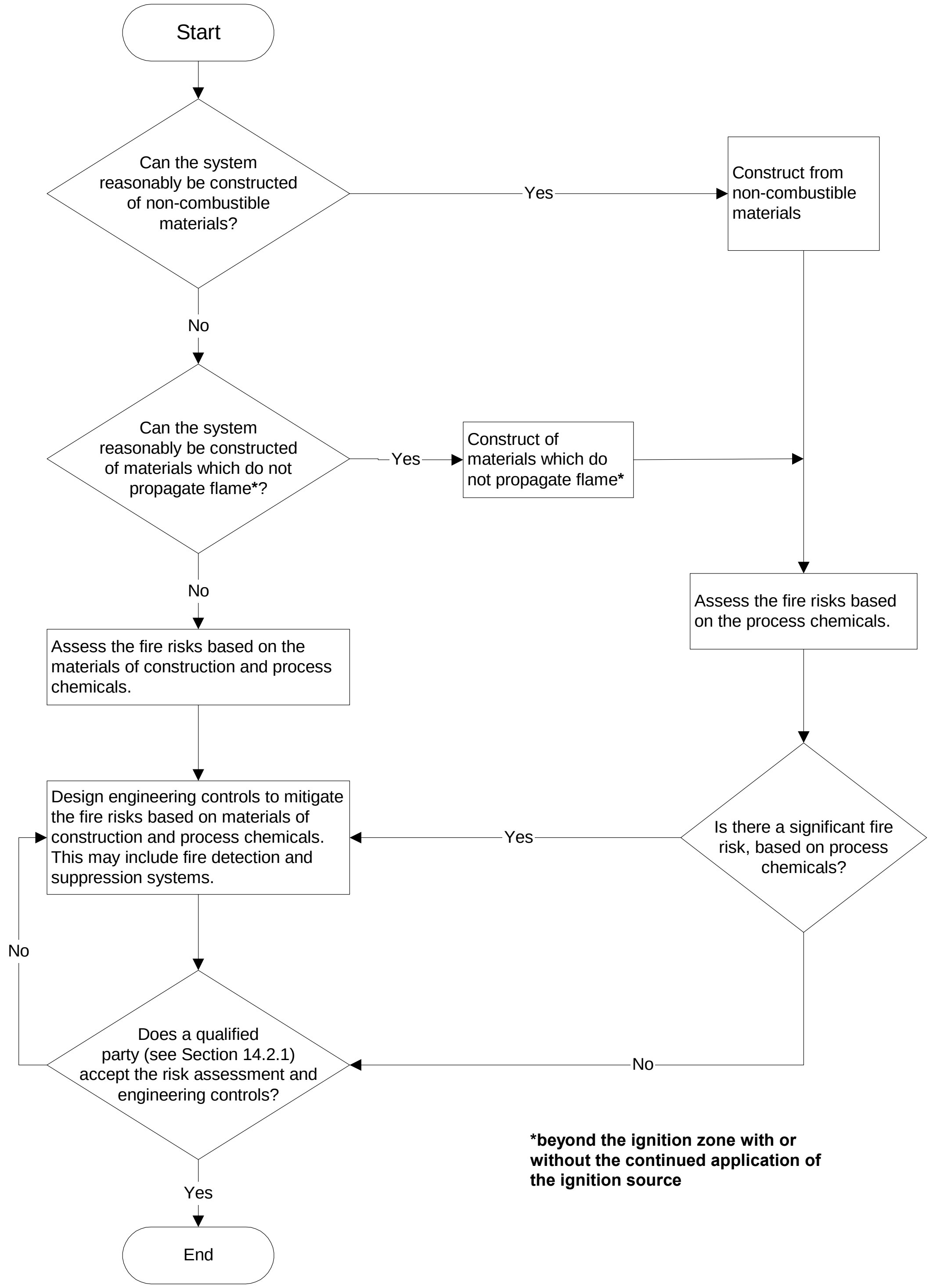
3. Guidelines on Limits of Exposure to Broad-Band Incoherent Optical Radiation (0.38 to 3 μM), Health Physics Vol. 73, No. 3 (September), pp.539-554, 1997

4. ICNIRP 1994 "Guidelines on Limits of Exposure to Static Magnetic Fields," Health Physics Vol 66 (1) (January), pp. 100-106, 1994

5. Interim Guidelines on the Limits of Exposure to 50/60 Hz Electric and Magnetic Fields, IRPA/ICNIRP Guidelines, Health Physics Vol. 58, No. 1 (January), pp. 113-122, 1990

APPENDIX 6
FIRE PROTECTION: FLOWCHART FOR SELECTING MATERIALS OF CONSTRUCTION

NOTICE: 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.



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

RELATED INFORMATION INDEX

NOTICE: The RI index below will be withdrawn upon July 1, 2006 publication and replaced by a new RI Index that captures the appropriate Related Information as approved by the EH&S Committee ballot. The EH&S Committee has voted that implementation of the information is OPTIONAL before the effective date.

CONTENTS

RELATED INFORMATION 1
EQUIPMENT/PRODUCT SAFETY PROGRAM

NOTICE: 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

NOTICE: 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

International Standards	*Title*
IEC 60204-1	Safety of Machinery - Electrical Equipment of Machines, Part 1
IEC 60417	Graphical Symbols for Use on Equipment
IEC 60664	Insulation Coordination for Equipment within Low-voltage Systems
IEC 60825-1	Safety of Laser Products, Part 1: Equipment Classification, Requirements and User's Guide
IEC 60950	Safety of Information Technology Equipment, including Electrical Business Equipment
IEC 60990	Methods of measurement of touch current and protective conductor current
IEC 61310-1	Safety of Machinery - Indication, Marking and Actuation - Part 1: Requirements for Visual, Auditory and Tactile Signals
ISO 3461-1	General Principles for the Creation of Graphical Symbols - Part 1: Graphical Symbols for Use on Equipment
ISO 3864	Safety Colours and Safety Signs
ISO 7000	Graphical Symbols for Use on Equipment - Index and Synopsis
USA Standards	*Title*
ANSI Z535.1 to ANSI Z535.5	Labeling and Marking
ANSI/UL 94	Tests for Flammability of Plastic Materials for Parts in Devices & Appliances
ANSI/UL 499	Electric Heating Appliance
ANSI/UL 508	Industrial Control Equipment
ANSI/UL 991	Tests for Safety-Related Controls Employing Solid-State
UL 1012	Power Units Other than Class 2
ANSI/UL 1778	UPS Equipment
ANSI/UL 1950	Information Technology Equipment
ANSI/UL 1998	Safety-Related Software
ANSI/UL 3101-1	Electrical Equipment for Laboratory Use; Part 1: General Requirements
ANSI Z136.1	American National Standard for Safe Use of Lasers
ASTM Volume 10.03	Electrical Protective Equipment
ISA S82.02	Electrical and Electronic Test and Measuring Equipment
ISA S82.03	Electrical and Electronic Process Measuring and Control
Factory Mutual Data Sheet 7-7	Semiconductor Fabrication Facilities
FMRC 3810	Electrical and Electronic Test, Measuring and Process Control Equipment
NFPA 70	National Electrical Code
NFPA 70E	Electrical Safety Requirements for Employee Workplaces
NFPA 79	Electrical Standard for Industrial Machinery
NFPA 318	Standard for the Protection of Cleanrooms
NEMA 250	Enclosures for Electrical Equipment (1000 Volts Maximum)
NEMA ICS 1.1	Safety Guidelines for the Application, Installation, and Maintenance of Solid-State Control
OSHA 29 CFR 1910.132-138	Personal Protective Equipment
OSHA 29 CFR 1910.147	The control of hazardous energy (lockout/tagout)

OSHA 29 CFR 1910.332-335	Safety Related Work Practices [electrical]
1997 Uniform Building Code, Section 1632	Structural Design Requirements -- Earthquake Design -- Lateral Force on Elements of Structures, Nonstructural Components and Equipment Supported by Structures
UL73	Motor Operated Appliances
UL471	Commercial Refrigerators and Freezers
UL698	Industrial Control Equipment for use in Hazardous Locations
UL1450	Motor-Operated Air Compressors, Vacuum Pumps and Painting Equipment
UL1740	Robots and Robotic Equipment
UL1995	Heating and Cooling Equipment
UL2011	Factory Automation Equipment
UL3111-1	Electrical Measuring and Test Equipment
UL3121-1	Process Control Equipment
Canadian Standards	*Title*
CAN/CSA C22.1	Canadian Electrical Code, Part I
CAN/CSA C22.2 No. 0	General Requirements - Canadian Electrical Code, Part II
CAN/CSA C22.2 No. 107.1	Commercial and Industrial Power Supplies
CAN/CSA C22.2 No. 234	Safety of Component Power Supplies
CAN/CSA C22.2 No. 950	Safety of Information Technology Equipment, including Electrical Business Equipment
CAN/CSA C22.2 No. 1010	Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use
European Standards	*Title*
EN 292-1	Safety of Machinery - Basic terminology and Technical principles
EN 292-2	Safety of Machinery - Technical Principles and Specifications
EN 294	Safety of Machinery - Safety distance to prevent danger zones being reached by upper limbs
EN 418	Functional Aspects of Machinery Emergency Stop Equipment
EN 626-2	Elimination or reduction of risk to health from hazardous substances emitted by machinery - Part 2: Methodology leading to verification procedures
EN 811	Safety of Machinery - Safety distance to prevent zones being reached by lower limbs
EN 953	Safety of machinery - guards - general requirements for the design and construction of fixed and moving guards
EN 954-1	Safety of machinery - safety-related parts of control systems, Part 1: General principle for design.
EN 1037	Safety of machinery - Prevention of unexpected start-up
EN 1088	Safety of Machinery - Interlocking devices with and without guard locking
EN 1093-1	Evaluation of the emission of airborne hazardous substances - Part 1: Selection of test methods
EN 1093-9	Evaluation of the emission of airborne hazardous substances - Part 9: Pollutant concentration parameter - Room Method
EN 50178	Electronic equipment for use in power installations
EN 60204-1	Safety of Machinery - Electrical equipment of machines, Part 1
EN 60529	Degree of Protection Provided by Enclosure (IP Codes)
EN 60825-1	Safety of Laser Products, Part 1: Equipment Classification, Requirements and User’s Guide
EN 60950	Specifications for Safety of Information Technology Equipment, including Electrical Business Equipment
EN 61010-1	Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory

Japanese Standards	*Title*
JIS C 0602	General Rules of Color Identification for Protective Conductor and Neutral Conductor
JIS C 4610	Circuit breakers for equipment
JIS B 6015	Electrical Equipment of Machine Tools
JIS C 8371	Residual current operated circuit breakers

RELATED INFORMATION 3
HAZARD LABELS

NOTICE: 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.*

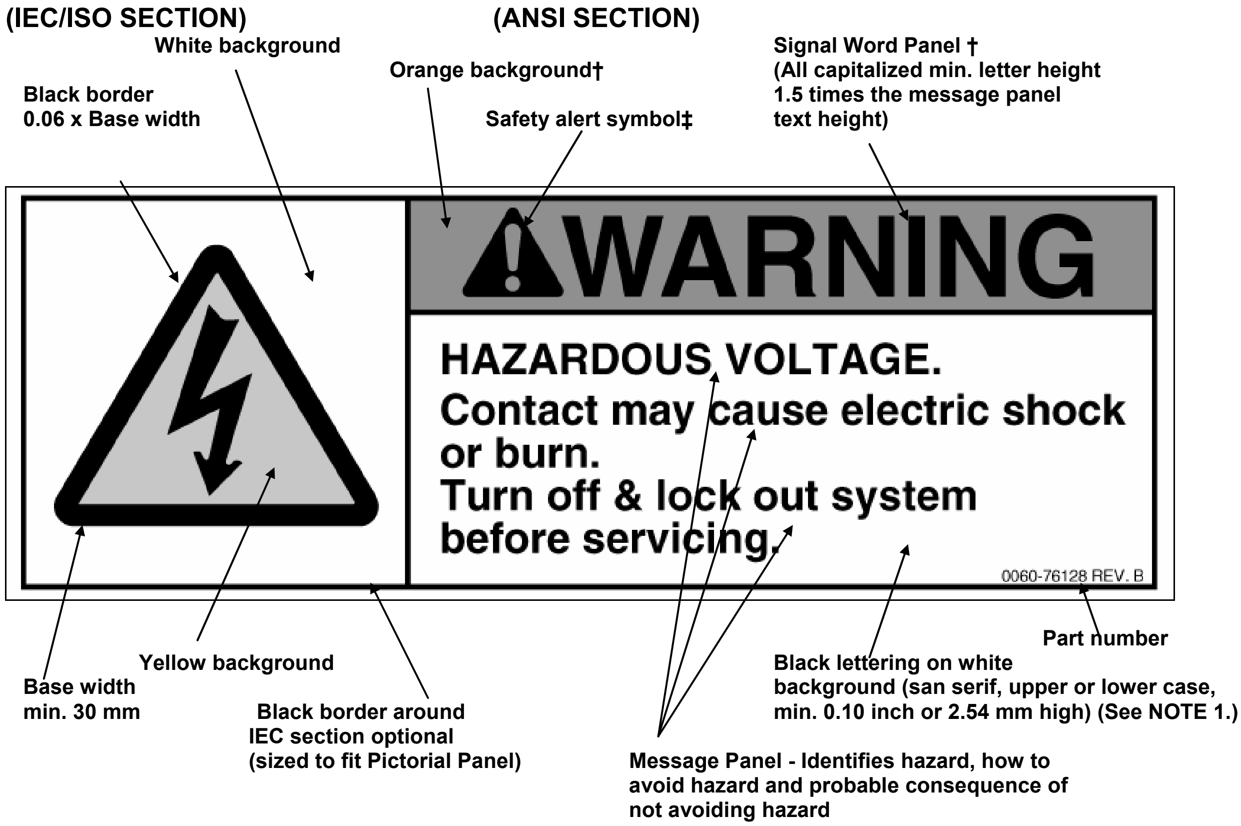


Figure R3-1
Example of a Combination ANSI/IEC Hazard Label Format

†SIGNAL WORD (san serif font)	‡SAFETY ALERT SYMBOL
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.

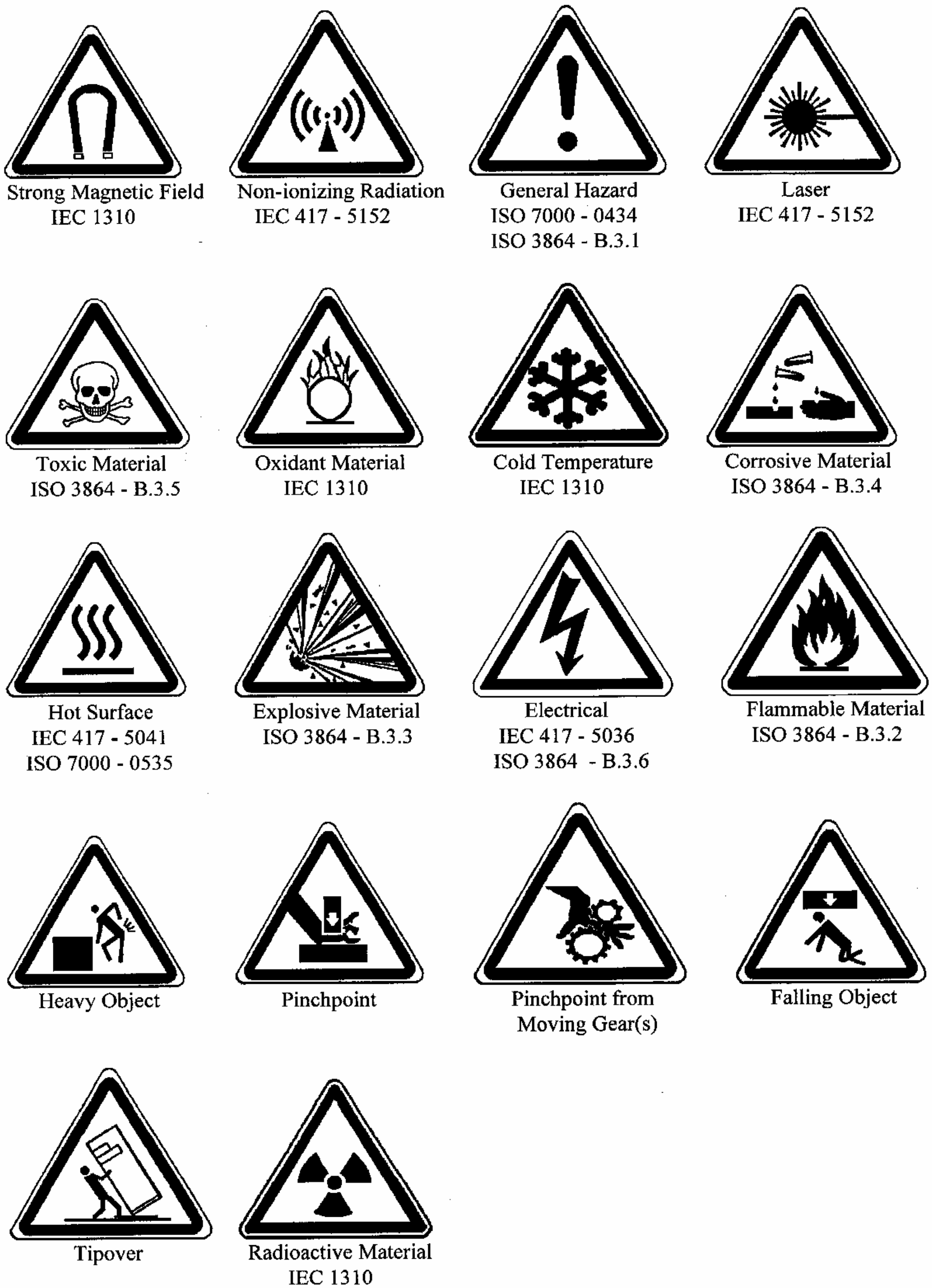


Figure R3-2
Suggested IEC/ISO Symbols for Various Hazards

RELATED INFORMATION 4
EMO REACH CONSIDERATIONS

NOTICE: 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)

Max height = 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:

$B^2 = C^2 - A^2$

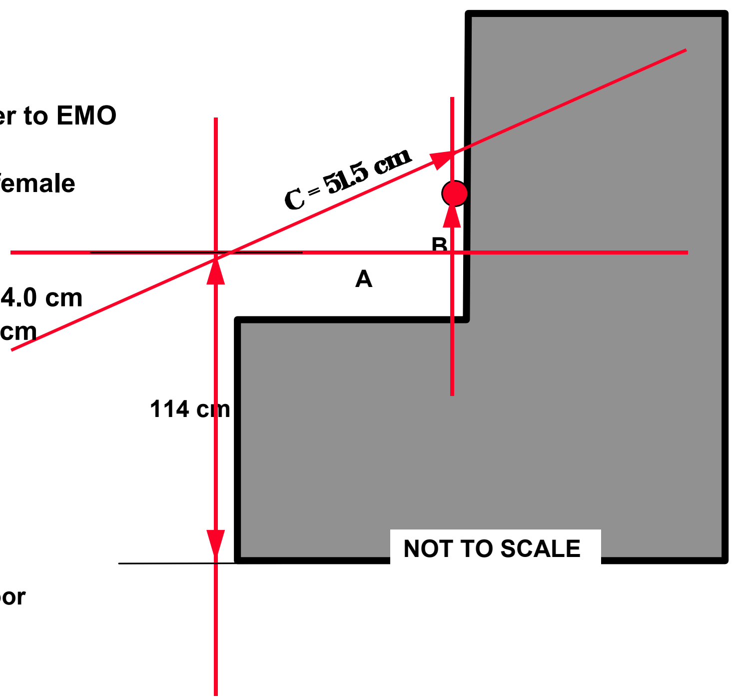
If A = 30 cm then

$B^2 = 51.5^2 - 30^2$

B = 41.8 cm

The button could be located at a maximum of:

114 + 41.8 = <u>155.8 cm</u> from the floor



RELATED INFORMATION 5
SEISMIC PROTECTION

NOTICE: 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 "pigtail" (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:

- $F_{p\,(ultimate)} = [(1.0 * 0.44(1.2) * 1.5)/ 1.5]\ [1 + 3(0.5)]\ W_p$

$= [0.44(1.2)]\ [1 + 1.5]\ W_p$
$= [0.528]\ [2.5]\ W_p$
$= [1.32]\ W_p$

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

- $F_{p\,(yield)} = F_{p\,(ultimate)} / 1.4$

$= [1.32] / 1.4\ W_p$
$= [0.94]\ W_p$

And for $I_p = 1.0$,

- $F_{p\,(yield)} = [.94]\ [1.0/1.5]\ W_p$

$= [.63]\ W_p$

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*.

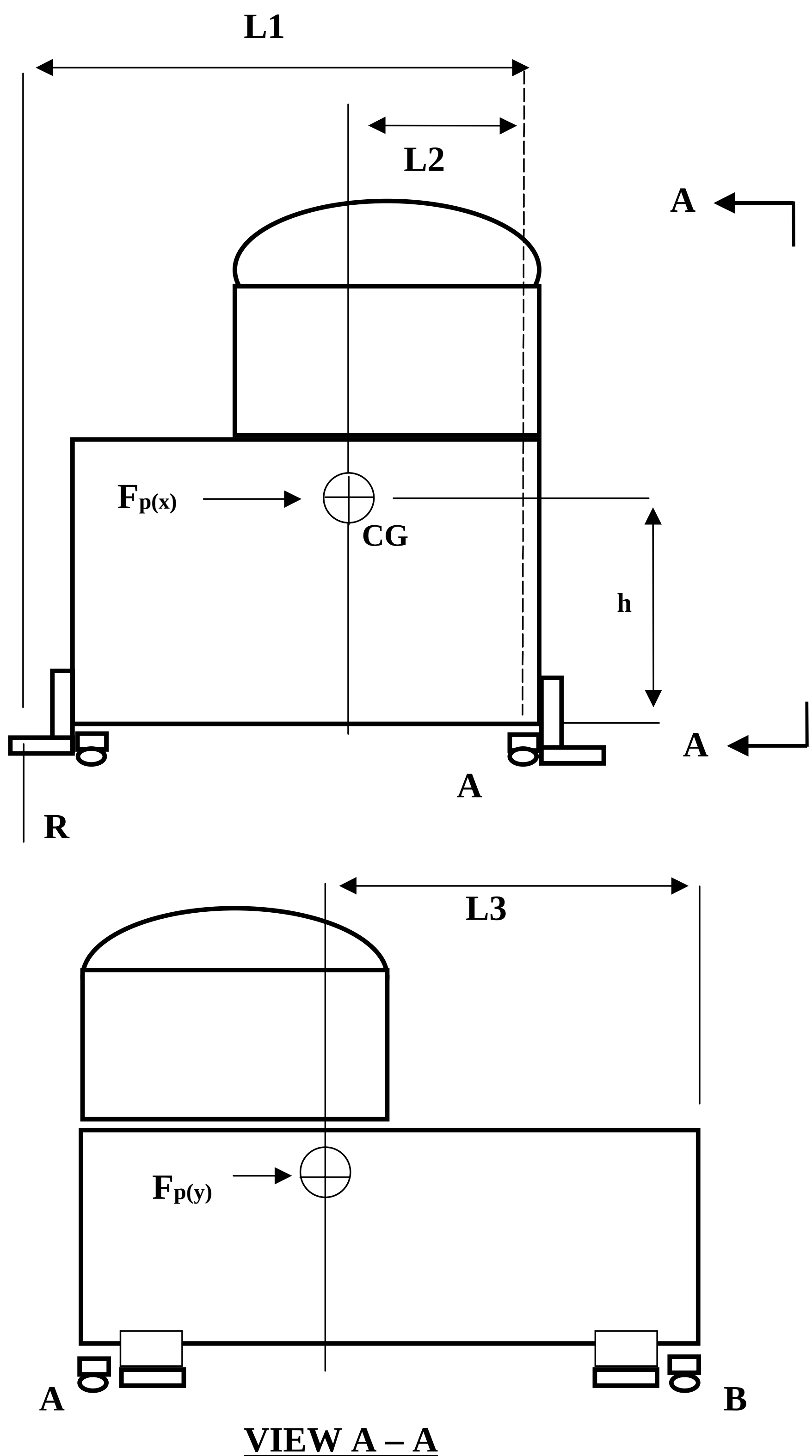


Figure R5-1
Design Example

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:

$$(CW =+)\ \sum M_{AB} = 0 = F_P(h) - 0.85W_P(L_2) - 2R(L_1) = 0$$

$$R = \frac{F_P(h) - 0.85W_P(L_2)}{2L_1}$$

$$F_P = 0.94W_P$$

$$R = \frac{W_P(0.94h - 0.85L_2)}{2L_1}$$

If 0.94h ≥ $0.85L_2$, then there is a tension reaction, R, at the two anchors, to resist overturning of system.

Example:
L1 = 50 inch
L2 = 20 inch
h= 36
W = 5000 lbs

Lateral force = Fp/4 = 0.94(5000)/4 = 1175

Overturning force = $R = \dfrac{W_P(0.94h - 0.85L_2)}{2L_1}$

$$= \frac{5000\,(0.94(36) - 0.85(20))}{2(50)}$$

R = 842 lbs

RELATED INFORMATION 6
CONTINUOUS HAZARDOUS GAS DETECTION

NOTICE: 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.

Monitoring Recommended	*Monitoring May Be Recommended*
	ammonia
arsine	
boron trifluoride	
	bromine
	carbon dioxide
carbon monoxide	
	carbon tetrabromide
chlorine	
diborane	
dichlorosilane	
disilane	
fluorine	
germane	
germanium tetrafluoride	
flammable mixtures containing hydrogen	
	hydrogen bromide
hydrogen chloride	
hydrogen fluoride	
hydrogen selenide	
hydrogen sulfide	
	Methane
methyl chloride	
	methyl fluoride
nitric oxide	
	nitrogen dioxide
	nitrous oxide
nitrogen trifluoride	
ozone	
phosphine	
silane	
silicon tetrachloride	
silicon tetrafluoride	
sulfur dioxide	
trichlorosilane	
tungsten hexafluoride	

RELATED INFORMATION 7
DOCUMENTATION OF IONIZING RADIATION (SECTION 24 AND APPENDIX 4) INCLUDING RATIONALE FOR CHANGES

NOTICE: 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 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

NOTICE: 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 levels 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

3. ICNIRP 1994 “Guidelines on Limits of Exposure to Static Magnetic Fields”, Health Physics Vol 66 (1) (January), pp. 100-106, 1994

4. IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, C95.1-1991, Piscataway, New Jersey

5. Interim Guidelines on the Limits of Exposure to 50/60 Hz Electric and Magnetic Fields, IRPA/ICNIRP Guidelines, Health Physics Vol. 58, No. 1(January), pp. 113-122, 1990

RELATED INFORMATION 9
LASER CHECKLIST

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

NOTICE: 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, CO_2, 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/cm^2): _ ________

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/cm^2): ________

   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

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

Equipment Safety Features (not an inclusive list)			*USA*	*Europe*	*Japan*	
			21 CFR 1040.10	*EN 60825-1*	*JIS 6802*	
			Paragrap h	*Paragrap h*	*Paragrap h*	*Examples*
10.	Manual Reset Mechanism	( ) Yes ( ) No	(f)(10)	4.3.1	4.2.2(c)	A button or circuit that must be energized before the equipment resumes its functions.
11.	Class Designation & Warning Labels	( ) Yes ( ) No	(g)	5	4.3	Identify which standard was used for each hazard classification.
12.	Aperture Label	( ) Yes ( ) No	(g)(5)	5.7	4.3.7	Identify the aperture.
13.	Positioning of Labels	( ) Yes ( ) No	(g)(9)	5.1	4.3.1	Conspicuous, but size is not specified.
14.	User Information	( ) Yes ( ) No	(h)(1)	6.1	4.4.1	SOPs, instruction manuals
15.	Service Information	( ) Yes ( ) No	(h)(2)	6.2	4.4.2	Accessible laser radiation levels during Service
16.	Measurements	( ) Yes ( ) No	(e)	8	3.4	
17.	Classification	( ) Yes ( ) No	(c)	9	3.3.3	
18.	Certification Information		21 CFR	TBD by Europe	TBD by Japan	
19.	Certification Label	( ) Yes ( ) No	1010.2			
20.	Identification Label	( ) Yes ( ) No	1010.3			

RELATED INFORMATION 10
LASER CERTIFICATION REQUIREMENTS BY REGION OF USE

NOTICE: 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

	USA	*Europe*	*Japan*	*Pacific Rim*
Classification Standards	21 CFR 1040.10	EN 60825-1	JIS C 6802	IEC 60825-1
Certification Standards	21 CFR 1000-1010	TBD	TBD	TBD

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:

http://www.access.gpo.gov/nara/cfr/cfr-table-search.html

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

NOTICE: 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 (GFEPCI), 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, GFEPCI, 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, GFEPCI, 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, GFEPCI, RCD or ELB, an additional GFCI, GFEPCI, 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.”

R11-2.1 *Hazard Communication* — Federal government OSHA regulations, found in 29 CFR 1910.1200, establish various requirements for labeling of containers of hazardous chemicals and providing Material Safety Data Sheets.

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

NOTICE: 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

Color	*Explanation*	*Examples*
Red	Hazardous, dangerous or abnormal condition requiring immediate attention	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
Yellow	Abnormal, caution/marginal condition; Change or impending change of critical condition requiring monitoring and/or intervention (e.g., by re-establishing the intended function)	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.
Green	Normal condition; machine ready	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.

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

Color	*Audible Alert (Buzzer)*
Red	Continuous
Yellow	Intermittent
Green	Intermittent/no sound (selectable)

RELATED INFORMATION 13
SURFACE TEMPERATURE DOCUMENTATION

NOTICE: 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 UL1950[12] and IEC950[13] 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-1472[14], MIL-HDBK-759A[15] and EN563[16] (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 Handbook[17]. 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

12 UL 1950, Safety of Information Technology Equipment, 1989 (Underwriters Laboratory Standard).

13 IEC 950, Safety of Information Technology Equipment, 1986 (International Electrotechnical Commission Standard).

14 MIL-STD-1472D, Human Engineering Design Criteria for Military Systems, Equipment & Facilities (Military Standard).

15 MIL-HDBK-759A, Handbook for Human Engineering Design Guidelines, 1981 (Military Handbook).

16 EN 563, Safety of Machinery – Temperatures of Touchable Surfaces, 1994 (European Normative Standard).

17 Human Factors Design Handbook, Second Edition, Woodson, Tillman & Tillman, 1992 (Reference).

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)

	Metal	*Glass, Porcelain, Vitreous Material*	*Plastic, Rubber*
EN563	58	70	n/a
MIL-STD-1472	60	68	85
MIL-HDBK-759	60	n/a	n/a
Section 18 Table 1 Value	60	70	85

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

	Metal	*Glass, Porcelain, Vitreous Material*	*Plastic, Rubber*
EN563	51	56	60
MIL-STD-1472	49	59	69
MIL-HDBK-759	52	n/a	n/a
Section 18 Table 1 Value	51	56	60

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

	Metal	*Glass, Porcelain, Vitreous Material*	*Plastic, Rubber*
EN563	65-70	80-86	n/a
MIL-STD-1472	n/a	n/a	n/a
MIL-HDBK-759	n/a	n/a	n/a
Section 18 Table 1 Value	65	80	95

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

	Metal	*Glass, Porcelain, Vitreous Material*	*Plastic, Rubber*
EN563	n/a	68	85
MIL-STD-1472	n/a	n/a	n/a
MIL-HDBK-759	n/a	n/a	n/a
Section 18 Table 1 Value	65	80	95

RELATED INFORMATION 14
RECOMMENDATIONS FOR DESIGNING AND SELECTING FAIL-TO-SAFE EQUIPMENT CONTROL SYSTEMS (FECS) WITH SOLID STATE INTERLOCKS AND EMO

NOTICE: This related information is not an official part of SEMI S2. It was derived from original Task Force activity. This related information was approved for publication by line item ballot vote on July 2003.

NOTE 1: Determination of the suitability of this material is solely the responsibility of the user.

R14-1 Safety Philosophy

R14-1.1 The following documents should control applicability of criteria in order of precedence as shown:

1. regulatory codes and standards
2. applicable sections of SEMI S2
3. SEMI Safety Guidelines
4. this Related Information
5. other appropriate standards for functional safety

R14-2 Purpose

R14-2.1 This Related Information describes approaches to using alternative technology and technical concepts to achieve functional safety in semiconductor manufacturing equipment.

R14-2.2 *Who can make use of this Related Information* — Recommendations for Designing and Selecting Fail-to Safe Control Systems (FECS) with Solid State Interlocks and EMO may be used by semiconductor equipment manufacturers, system integrators, end users and suppliers of automation systems as well as independent third parties.

R14-3 Scope

R14-3.1 *Applicability* — This Related Information applies to facilities, equipment and machinery used to manufacture, measure, assemble and test semiconductor products and therefore need a high level of safety to protect people, machines, the environment and the industrial processes.

R14-3.2 This Related Information is intended for use by semiconductor equipment manufacturers, system integrators, end users and suppliers of automation systems as well as independent third parties as an orientation to design and architecture of automation systems based on safety-related components. The safety-related automation system executes safety functions to bring the equipment into a safe condition or to maintain it in a safe condition when a hazardous event occurs.

R14-3.3 This Related Information specifies a technical concept for equipment control systems, which does not require the exclusive use of hardwired electromechanical safety components.

R14-3.4 *Contents* — This Related Information contains the following sections:

1. Purpose
2. Scope
3. Limitations
4. Referenced Standards
5. Terminology and Definitions
6. State-of-the-Art Safety Control System — Comprised of Solid State Electronics
7. Philosophy and General Concepts
8. Guide to Assessment and Test Methods
9. Safety Performance
10. Application Examples
11. Related Documents

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

R14-4 Limitations

R14-4.1 This Related Information does not contain the technical detail necessary to design equipment control systems.

R14-4.2 This Related Information is not intended to be used to verify compliance to local regulatory requirements.

R14-4.3 It is not the philosophy of this Related Information to give advice on what must be done to achieve a certain safety performance for equipment control systems, but it gives advice on how to achieve a specified level of safety functionality using industrial controllers (e.g. programmable logic controllers), distributed input/output (I/O) functions and network communications.

R14-4.4 Where references to standards have been incorporated into this Related Information. These references do not imply applicability of the entire standards, but only of the sections referenced.

R14-4.5 Because of the variety of uses for FECS described in this Related Information, those responsible for the application and use of FECS must satisfy themselves that all necessary steps have been taken to assure that each application and use meets all performance and safety requirements, including any applicable laws, regulations, codes and standards. The illustrations, charts and layout examples shown in this Related Information are solely for purposes of example.

R14-5 Referenced Standards

R14-5.1 *SEMI Standards*

SEMI E54 — Sensor/Actuator Network Standard

SEMI E81 — Provisional Specification for CIM Framework Domain Architecture

SEMI E98 — Provisional Standard for the Object-Based Equipment Model (OBEM)

SEMI S10 — Safety Guideline For Risk Assessment

R14-5.2 *IEC Standards*[18]

NOTE 2: International standards bodies are indicated, with the equivalent national standards shown in parenthesis.

IEC 60204-1 (EN 60204-1) — Safety of Machinery – Electrical Equipment of Machines - Part 1: General Requirements

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

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

NOTE 3: IEC 61508 consists of 7 parts, IEC 61508-1 through IEC 61508-7

R14-5.3 *ISO Standards*[19]

NOTE 4: International standards bodies are indicated, with the equivalent national standards shown in parenthesis.

ISO 10218 (EN 775) — Manipulating Industrial Robots-Safety

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

ISO 13849-2 (EN 954-2) — Safety of Machinery-Safety-Related Parts of Control Systems – Part 2 Validation

ISO/IEC 13850 (EN 418) — Safety of Machinery – Emergency Stop – Principles of Design

ISO 14118 (EN 1037) — Safety of Machinery – Prevention of Unexpected Start-Up

ISO 14119 (EN 1088) — Safety of Machinery-Interlocking Devices Associated with Guards – Principles for Design & Selection

ISO 14121 (EN 1050) — Safety of Machinery-Principles of Risk

NOTE 5: National and local Codes and Standards must be applied as required by the installation location. Examples of some that might apply are included below.

R14-5.4 *ANSI Standards*[20]

ANSI/IEEE C95.1 (United States) — Standards for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields

ANSI/ISA-S84.01-1996 — Application of Safety Instrumented Systems for the Process Industry

ANSI/RIA R15.06 (United States) — Industrial Robots and Robot System – Safety Requirements

R14-5.5 *National Fire Protection Association*[21]

NFPA 79 (United States) — Electrical Standard for Industrial Machinery

R14-5.6 *VDI Standards*[22]

VDI/VDE 2180 Bl.2 (Germany) — Safety of Process Control Technology

R14-5.7 *DIN V VDE Standards*[23]

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

R14-6 Terminology

R14-6.1 *Abbreviations and Acronyms*

R14-6.1.1 *ATL* — Approved Testing Laboratory

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

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

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

21 National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101, USA, www.nfpa.org

22 VDE-Verlag GmbH, Bismarkstrasse 33, 10625 Berlin, Germany, www.vde.de

23 VDE-Verlag GmbH, Bismarkstrasse 33, 10625 Berlin, Germany, www.vde.de