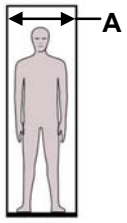
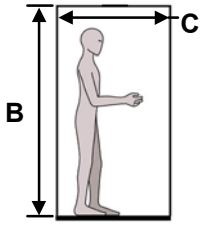
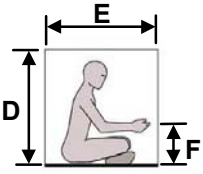
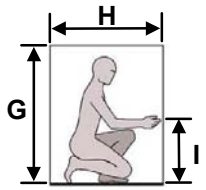
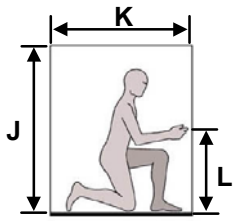
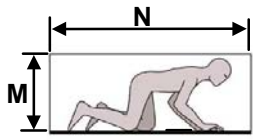
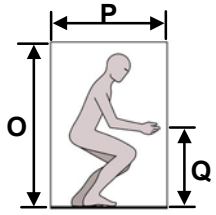
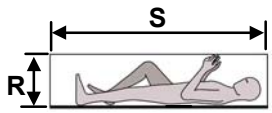
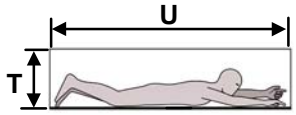
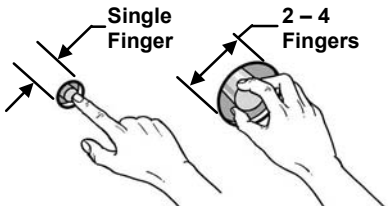
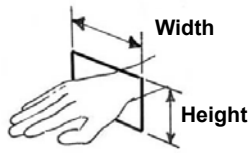
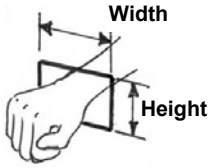
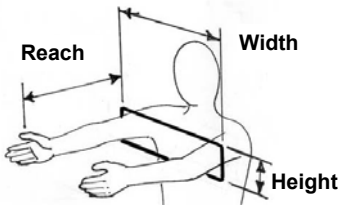
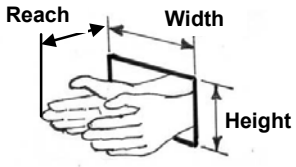
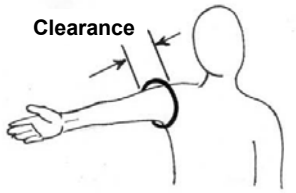
Section 7: Maintainability and Serviceability

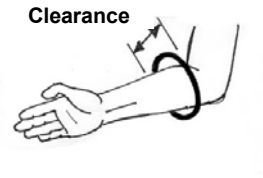
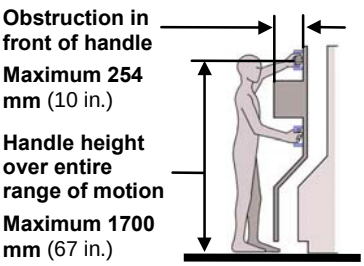
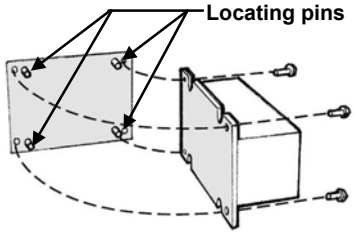
Section	*Indicator*	*Figure*
7.1	Minimum lighting level in routine maintenance areas is required where the operator has to read information, use a hand tool, or make a connection. This provision can be met by providing integral lighting or portable lighting which can be temporarily attached such that it does not have to be hand held. Acceptance criterion: minimum 300 lux (30 fc)	
7.2	Full Body Clearance NOTE A: Forward horizontal distances are measured away from the equipment or obstruction for body clearance in a given posture. NOTE B: Clearances should be provided based on the nature of the tasks performed in the designated area. NOTE C: When determining the appropriate working space required for a given task, first define the working height. Once this is known, determine the posture(s) associated with the working height and use Sections 7.2.1–7.2.9 to determine the minimum working area for that posture. NOTE D: Minimum working heights are used to determine postures for sustained activities (tasks which take longer than 5 minutes or have a total duration of greater than 1 hour per shift).	
7.2.1	Any posture: upper body clearance (shoulder width) A: Acceptance criterion: minimum 610 mm (24 in.)	
7.2.2	Standing B: Overhead clearance: minimum 1980 mm (78 in.) C: Forward horizontal clearance: minimum 690 mm (27 in.)	
7.2.3	Sitting-on-Floor D: Overhead clearance**:** minimum 1000 mm (39 in.) E: Forward horizontal clearance: minimum 690 mm (27 in.) F: Working height**:** minimum 280 mm (11 in.)	

Section	*Indicator*	*Figure*
7.2.4	Squatting G: Overhead clearance: minimum 1220 mm (48 in.) H: Forward horizontal clearance**:** minimum 790 mm (31 in.) I: Working height**:** minimum 460 mm (18.1 in.)	
7.2.5	Kneeling J. Overhead clearance (from floor): minimum 1450 mm (57 in.) K. Forward horizontal clearance: minimum 1220 mm (48 in.) L. Working height: minimum 640 mm (25.2 in.)	
7.2.6	Kneeling Crawl**:** M. Overhead clearance measured from floor: minimum 740 mm (29 in.) N. Forward horizontal clearance**:** minimum 1520 mm (60 in.)	
7.2.7	Stooping O. Overhead clearance**:** minimum 1450 mm (57 in.) P. Forward horizontal clearance**:** minimum 1020 mm (40 in.) Q. Working height**:** minimum 640 mm (25.2 in.)	
7.2.8	Supine lying on back R. Height (overhead)**:** minimum 430 mm (17 in.) S. Length (forward)**:** minimum 1980 mm (78 in.)	
7.2.9	Prone or crawl space T. Height (overhead): minimum 510 mm (20 in.) U. Length (forward): minimum 2440 mm (96 in.)	

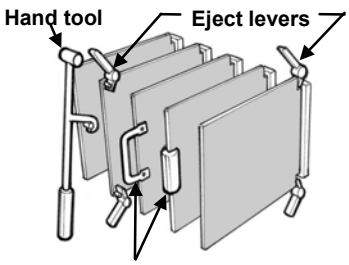
Section 7: Maintainability and Serviceability

Section	*Indicator*	*Figure*
7.3	Hand/arm clearance. (Note: where appropriate to do so, adjustments have been made for cleanroom gloves.) NOTE A: Access openings should have smooth edges. NOTE B: If hinged doors are used, they should not interfere with access.	
7.3.1	Clearance provided for finger access round (diameter) or square. One finger: minimum 32 mm (1.25 in.) 2, 3 or 4 finger twist of small knob: minimum object diameter + 58 mm (2.3 in.)	
7.3.2	Clearance provided for flat hand wrist access. Height, palm thickness: minimum 89 mm (3.5 in.) Width, palm width: minimum 114 mm (4.5 in.)	
7.3.3	Clearance provided for fist to wrist access. Height (fist thickness): minimum height 89 mm (3.5 in.) Width (fist width): minimum width 127 mm (5.0 in.)	
7.3.4	Clearance provided for two hands arm to shoulders access (does not ensure visual access) Reach maximum 610 mm (24.0 in.) Width: minimum 483 mm (19.0 in) Height: minimum 114 mm (4.5 in.)	
7.3.5	Clearance provided for two hands, hand to wrist access (does not ensure visual access) Reach: maximum 203 mm (8.0 in.) Width: minimum 191 mm (7.5 in) Height: minimum 114 mm (4.5 in.)	
7.3.6	Clearance provided for one arm to shoulder access (does not ensure visual access) Minimum clearance 132 mm (5.2 in.)	

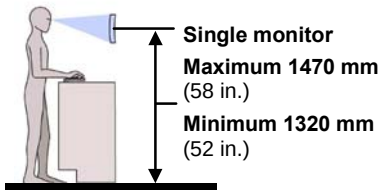
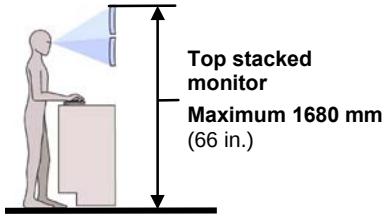
Section 7: Maintainability and Serviceability

Section	*Indicator*	*Figure*
7.3.7	Clearance provided for one arm to elbow access, diameter, or square area (does not ensure visual access). Minimum 119 mm (4.7 in.)	
7.4	Maintenance and Service Access	
7.4.1	Enclosures or covers must, unless fully removable, be self-supporting, in the open position, and not require manual support during maintenance. Exceptions may be allowed for self-closing doors for fire safety or compliance reasons. Acceptance criterion: supports present	
7.4.2	Access covers should be equipped with full-handed grasp areas or other means for opening them. Acceptance criterion: handles present, refer to Section 6 for design criteria	
7.4.3	Height of access cover handle over the entire range of motion required for operation or maintenance. There should be no greater than a 254 mm (10 in.) deep obstruction in front of the handle. Acceptance criterion: maximum 1700 mm (67 in.)	
7.5	Replaceable Components	
7.5.1	Serviceable components are replaceable as modular packages, and are configured for rapid removal and replacement. Acceptance criterion: serviceable components configured as described	
7.5.2	Serviceable components should not be stacked directly on one another (i.e., a lower layer should not support an upper layer). Acceptance criterion: serviceable components independently accessible	
7.5.3	Heavy components (objects which have a lifting index of 0.5 or greater, see SESC, Section 1.0) or bulky components (greater than 36 inches in length) requiring frequent removal/installation should include guide/locating aids to assist in positioning. Acceptance criterion: guide/locating pins present	 Example of locating pins
7.5.4	Cables, connectors, plugs, and receptacles should be labeled, keyed, color coded, or otherwise configured to make connection easier and prevent cross connection. This feature is assessed only if a SEMI S2 assessment is not being conducted. Acceptance criterion: identification present, keyed where needed	

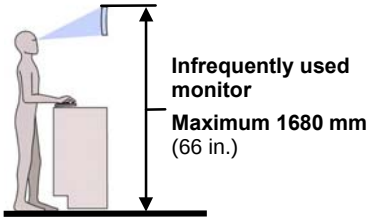
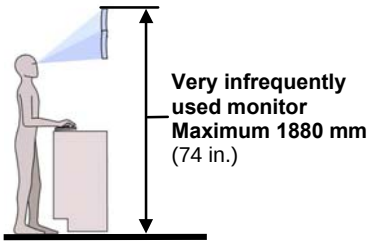
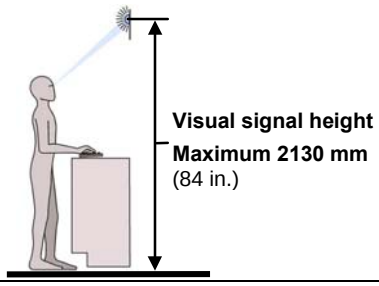
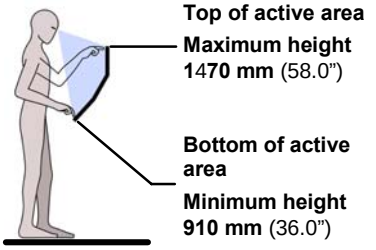
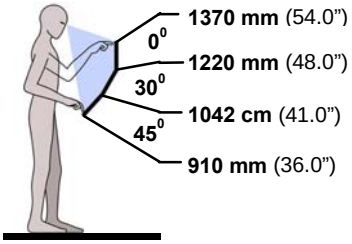
Section 7: Maintainability and Serviceability

Section	*Indicator*	*Figure*
7.5.5	Circuit boards mounted in a card cage configuration should have gripping or ejecting aids for mounting and removal. Acceptance criterion: finger access, gripping, or ejecting aids available	 **Circuit board removal device examples**

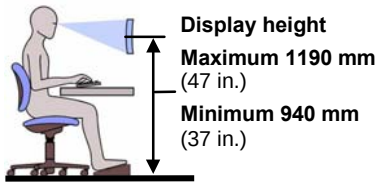
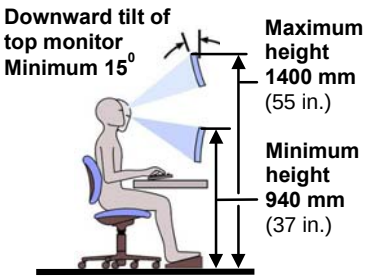
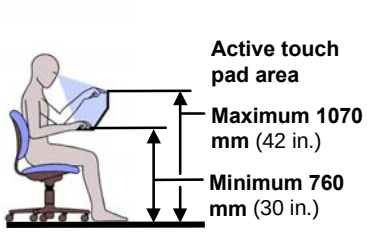
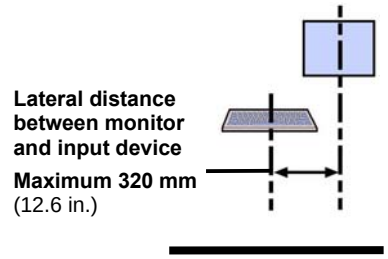
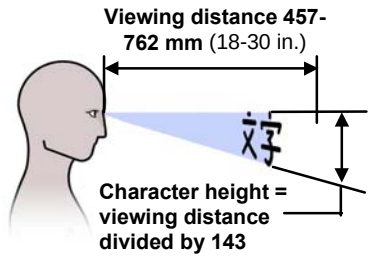
Section 8: Display Location

Section	*Indicator*	*Figure*
8.0	Display Location NOTE: Angle-adjustable displays allow the user optimize the viewing angle to control glare and maximize comfort.	
8.1	Location for operator primary interface, standing station. NOTE: A standing station is one where the operator can assume a standing posture or use a tall stool or chair which places the operator at approximately the same height as a standing posture.	
8.1.1	Height of video display terminal (single monitor). Does not include touchscreens, measured from floor to center of screen. Acceptance criteria: maximum 1470 mm (58 in.) minimum 1320 mm (52 in.) NOTE: The display user should be able to view a display while maintaining a near-neutral posture.	
8.1.2	Height of video display terminal (stacked monitors). Does not include touchscreens, measured from floor to top line of the top monitor. Acceptance criterion: maximum 1680 mm (66 in.) The primary monitor in a stacked configuration is the bottom monitor.	

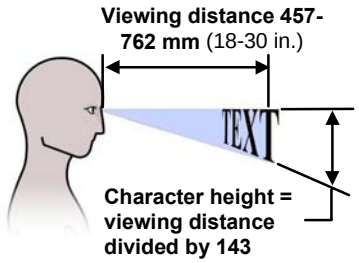
Section 8: Display Location

Section	*Indicator*	*Figure*
8.1.3	Height of infrequently used video display terminal (viewed briefly less often than once per hour) measured to top line of monitor. Acceptance criterion: maximum 1680 mm (66 in.)	
8.1.4	Height of very infrequently used video display terminal (viewed briefly less often than once per day) measured to top line of monitor. Acceptance criterion: maximum 1880 mm (74 in.)	
8.1.5	Height of infrequently viewed visual signal measured to the top of the signal. This guideline does not apply to light towers. Acceptance criterion: maximum 2130 mm (84 in.)	
8.1.6	Height of touch screen monitor. Acceptance criteria: maximum 1470 mm (58 in.), measured from floor to uppermost active pad on screen minimum 910 mm (36 in.), measured from floor to lowest active pad on the screen. See §9 for horizontal reach criteria. NOTE: Touch screen design recommendations also apply to light pen operated systems.	
8.1.7	Tilt angle of touch screen monitor between 41 and 48 inches in height to top of screen. Acceptance criterion: upward minimum 30 degrees NOTE A: Angle adjustment is recommended to accommodate users of varying heights and to reduce glare under different lighting conditions. NOTE B: The angle of visibility for flat panel display touch screens varies depending upon which display technology is used (e.g., passive vs. active matrix) so providing angle adjustment will allow users to set the display angle for maximum visibility and comfort.	
8.1.8	Tilt angle of touch screen monitor less than 41 inches in height to top of screen. Acceptance criterion: upward minimum 45 degrees	
8.2	Location for operator primary interface, seated station (Note: A seated station where a short cylinder office-style chair is used.)	

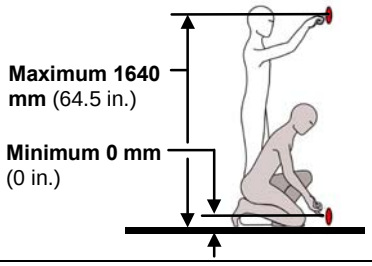
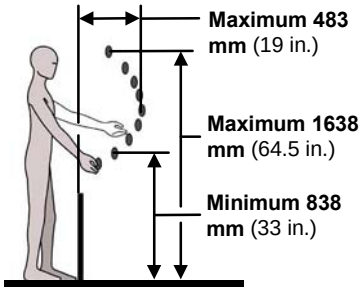
Section 8: Display Location

Section	*Indicator*	*Figure*
8.2.1	Height of video display terminal (single monitor). Does not include touchscreens, measured from floor to centerline of monitor. Acceptance criteria: maximum 1190 mm (47 in.) minimum 940 mm (37 in.) NOTE A: The display user should be able to view a display while maintaining a near-neutral posture.	
8.2.2	Height of video display terminal (stacked monitors), does not include touchscreens, measured from floor to top line of top monitor. Acceptance criteria: maximum 1400 mm (55 in.) minimum 940 mm (37 in.) The primary monitor in a stacked configuration is the bottom monitor.	
8.2.3	Tilt angle of video display terminal greater than 55 inches in height to top of screen. This line item becomes significant in the event that the maximum height criteria cannot be met. Acceptance criterion: downward minimum 15 degrees	
8.2.4	Height of touch screen monitor Acceptance criteria: maximum 1070 mm (42 in.) measured from floor to highest active pad on the screen minimum 760 mm (30 in.) measured from floor to lowest active pad on the screen See §9 for horizontal reach criteria. NOTE: Touch screen design recommendations also apply to light pen operated systems.	
8.3	Display characteristics	
8.3.1	Lateral distance from the centerline of the display to the centerline of the input device(s). Acceptance criterion: maximum 320 mm (12.6 in.) NOTE: If several input devices are used (i.e. keyboard and mouse) the centerline of the input device farthest from the display should be measured.	
8.3.2	Character height (Specific to Chinese, Korean and Japanese characters.) Acceptance criterion: character height is greater than or equal to the viewing distance divided by 143 Recommended viewing distance is between 457 mm (18 in.) and 762 mm (30 in.).	

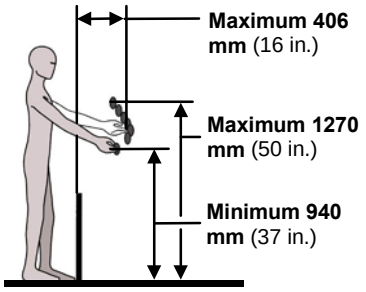
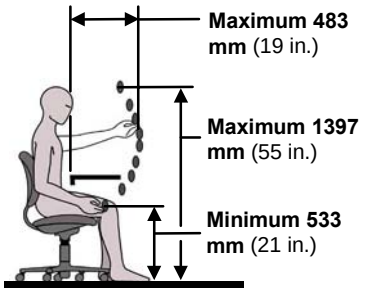
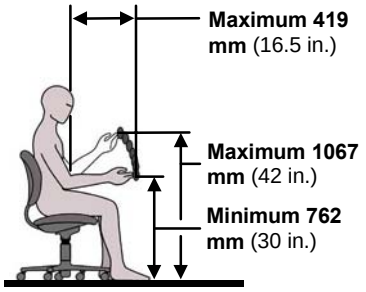
Section 8: Display Location

Section	*Indicator*	*Figure*
8.3.3	Character height (All characters other than Chinese, Korean and Japanese.) Acceptance criterion: character height is greater than or equal to the viewing distance divided by 215 Recommended viewing distance is between 457 mm (18 in.) and 762 mm (30 in.).	

Section 9: Hand Control Location

Section	*Indicator*	*Figure*
9.0	Hand Control Location (These criteria only apply to controls, tools, and materials accessed for routine production operation and maintenance.)	
9.1	Standing station NOTE: A standing station is one where the machine operator can assume a standing posture or a seated posture in a tall stool, which places the operator at approximately the same stature.	
9.1.1	Vertical location of very infrequently used controls (controls used less often than once every 24 hours) measured from the standing surface to the centerline of the control. Acceptance criteria: maximum 1640 mm (64.5 in.). minimum 0 mm (0 in.).	
9.1.2	Location of infrequently used and/or critical controls. Maximum reaches are indicated for various heights. Reaches are measured from the leading edge of the equipment or obstacle. Acceptance criteria: controls should not be located above 1638 mm (64.5 in.) or below 838 mm (33 in.). NOTE A: Interpolate for intermediate values. NOTE B: Reach distances should be measured from the leading edge of the machine housing or obstructions between the machine operator and the control. Obstructions include keyboard trays, drip trays, machine anti-vibration pads and load-bearing pads. NOTE C: See Figure 9.1.2 for maximum recommended reaches.	

Section 9: Hand Control Location

Section	*Indicator*	*Figure*
9.1.3	Location of frequently used controls. Maximum reaches are indicated for various heights. Reaches are measured from the leading edge of the equipment or obstacle. Acceptance criteria: controls should not be located above 1270 mm (50 in.) or below 940 mm (37 in.). NOTE A: Interpolate for intermediate values. NOTE B: Reach distances should be measured from the leading edge of the machine housing or obstructions to the center of the control. Obstructions include keyboard trays, drip trays, machine load bearing pads and anti-vibration pads. NOTE C: See Figure 9.1.3 for maximum recommended reaches.	
9.2	Seated station (Note: A seated station is one where a short cylinder office-style chair is used).	
9.2.1	Location of infrequently used and/or critical controls. Maximum reaches are indicated for various heights. Reaches are measured from the leading edge of the work surface or obstacle. Acceptance criteria: Controls should not be located above 1397 mm (55 in.) or below 533 mm (21 in.). NOTE A: Interpolate for intermediate values. NOTE B: See Figure 9.2.1 for maximum recommended reaches.	
9.2.2	Location of frequently used controls. Maximum reaches are indicated for various heights. Reaches are measured from the leading edge of the work surface or obstacle. Acceptance criteria: controls should not be located above 1067 mm (42 in.) or below 762 mm (30 in.). NOTE A: Interpolate for intermediate values. NOTE B: See Figure 9.2.2 for maximum recommended reaches.	

Section 9: Hand Control Location Figures

Coordinates given for hand control locations. Height (vertical measurement from standing surface to center of control), Depth (horizontal measurement from leading edge of work surface to the center of control)

Height and depth of controls

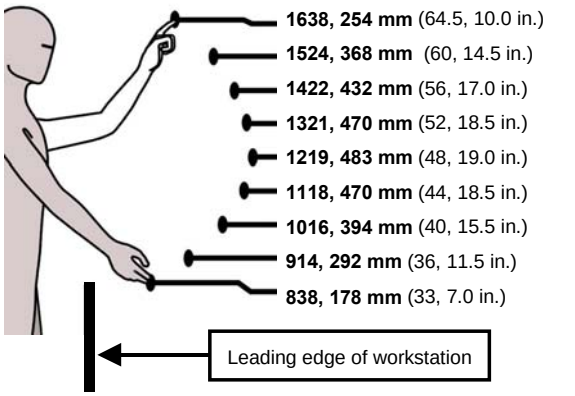


Figure 9.1.2 Infrequently used standing control reaches

Height and depth of controls

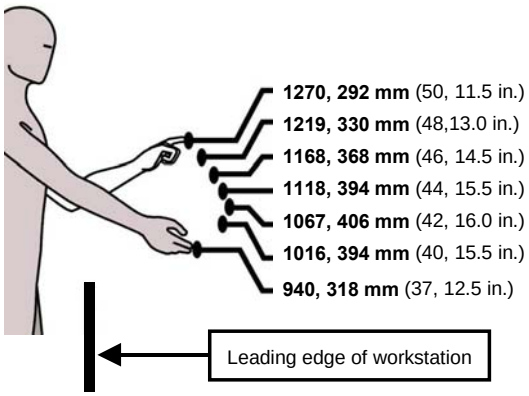


Figure 9.1.3 Frequently used standing control reaches

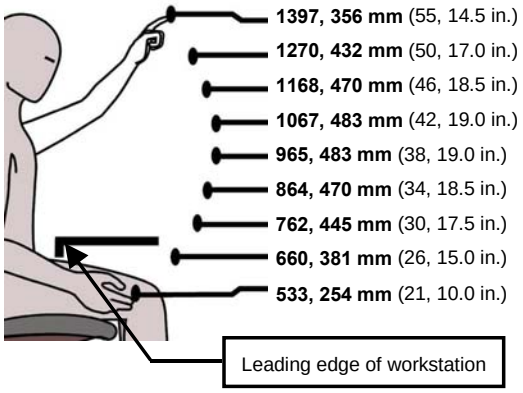


Figure 9.2.1 Infrequently used seated control reaches

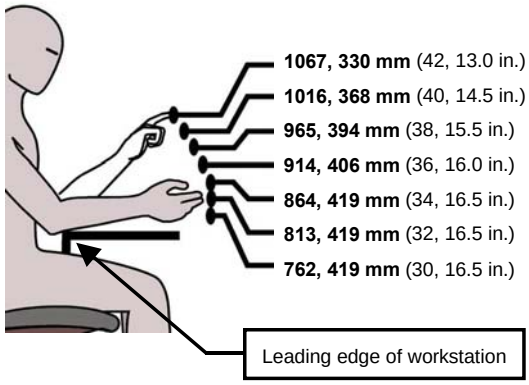
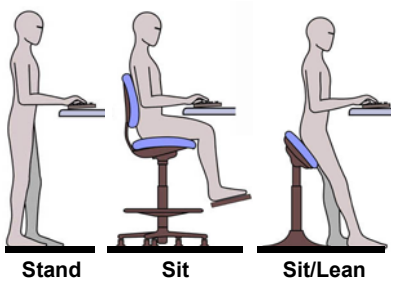
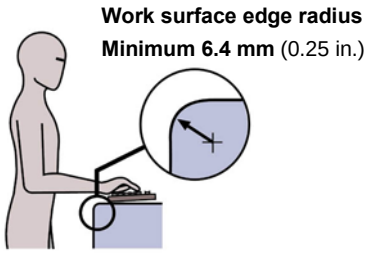
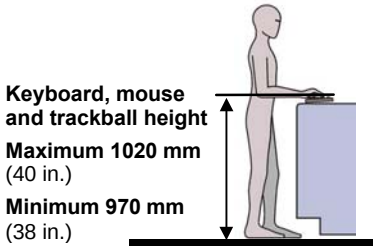
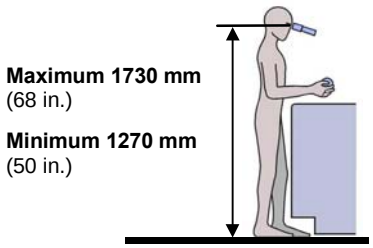
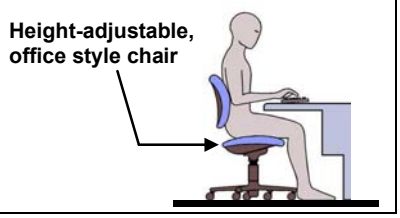
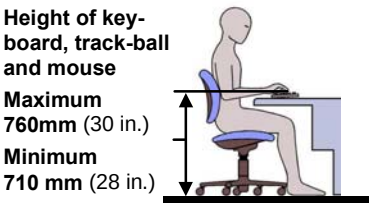
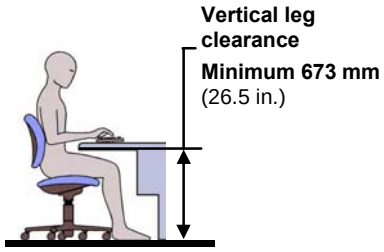
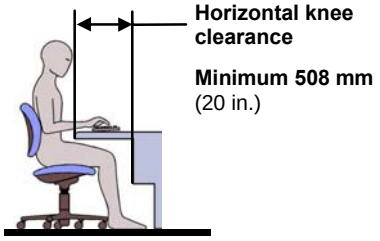
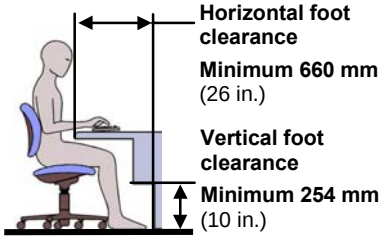
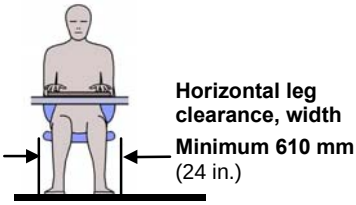


Figure 9.2.2 Frequently used seated control reaches

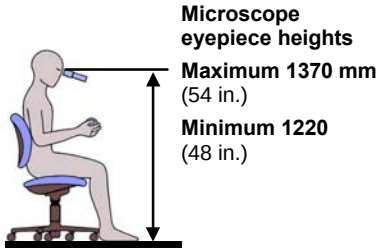
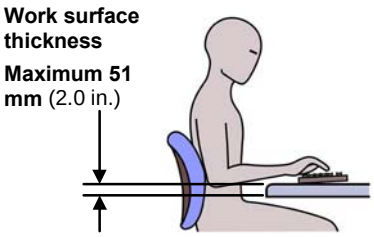
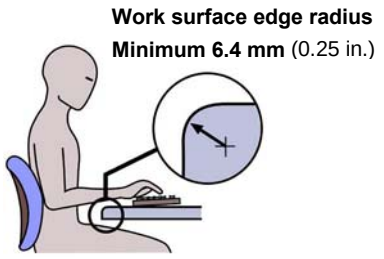
Section 10: Workstation Design

Section	*Indicator*	*Figure*
10.1	Standing station (Note A standing station is one where the operator can assume a standing posture or a seated posture in a tall stool, which places the operator at approximately the same stature.) NOTE: If a tall stool, chair or sit/lean stool is used, it is assumed that the seat is user height-adjustable.	
10.1.1	Work surface edge radius where the operator can assume a static posture in contact with the edge. Acceptance criterion: minimum 6.4 mm (0.25 in.) radius NOTE: This recommendation applies to both horizontal and vertical surfaces where the equipment operator can assume a static posture.	
10.1.2	Height of keyboard, trackball, or mouse (to home row, top of ball/mouse). NOTE: In applications where input devices (keyboard, trackball, or mouse) are used more like machine controls (intermittent one finger entry on the keyboard, intermittent short term use of the mouse or trackball) than for standard typing (continuous use of keyboard for entry of long character strings, extended use of trackball or mouse in graphical environment), it is appropriate to use the height and reach locations described in Section 9, Hand Control Location (standing station). Acceptance criteria: maximum 1020 mm (40 in.) minimum 970 mm (38 in.) NOTE: The home row of a keyboard is the row with the “F” and “J” typing home keys.	
10.1.3	Height of microscope eyepieces. Must be adjustable. Acceptance criterion: Range includes 1270 mm (50 in.) to 1730 mm (68 in.) NOTE A: Measured from standing surface to center of the eyepiece. NOTE B: Both height-adjustable eyepieces and adjustable tables may be used to meet this recommendation. If a height-adjustable table is used, the SESC checklist should be used to determine the appropriate machine load port heights and locations for displays and controls at the maximum and minimum table heights.	
10.2	Seated station (A seated station where a short cylinder office-style chair is used.) NOTE: A height-adjustable chair is assumed.	

Section 10: Workstation Design

Section	*Indicator*	*Figure*
10.2.1	Height of keyboard, trackball, or mouse. (measured to home row and top of ball/mouse). NOTE: In applications where input devices (keyboard, trackball, or mouse) are used more like machine controls (intermittent one finger entry on the keyboard, intermittent short term use of the mouse or trackball) than for standard typing (continuous use of keyboard for entry of long character strings, extended use of trackball or mouse in graphical environment), it is appropriate to use the height and reach locations described in Section 9, Hand Control Location (seated station). Acceptance criteria: maximum 760 mm (30 in.) minimum 710 mm (28 in.) NOTE: The home row of a keyboard is the row with the "F" and "J" keys.	
10.2.2	Vertical leg clearance. Acceptance criterion: minimum 673 mm (26.5 in.)	
10.2.3	Horizontal leg clearance, depth at knee level. Acceptance criterion: minimum 508 mm (20 in.)	
10.2.4	Horizontal leg clearance, depth at foot level. Acceptance criteria: minimum 660 mm (26 in.) depth × 254 mm (10 in.) vertical foot clearance.	
10.2.5	Horizontal leg clearance: width. Acceptance criterion: minimum 610 mm (24 in.)	

Section 10: Workstation Design

Section	*Indicator*	*Figure*
10.2.6	Height of microscope eyepiece. Must be adjustable. Acceptance criterion: Range includes 1220 mm (48 in.) to 1370 mm (54 in.) NOTE A: Measure from the standing surface to center of the eyepiece. NOTE B: Both height-adjustable eyepieces and adjustable tables may be used to meet this recommendation. If a height-adjustable table is used, the SESC checklist should be used to determine the appropriate machine load port heights, leg clearances, and the location of controls and displays for the maximum and minimum table heights.	
10.2.7	Thickness of work surface. Acceptance criterion: maximum 51 mm (2.0 in.)	
10.2.8	Work surface edge radius where the operator can assume a static posture in contact with the edge. Acceptance criterion: minimum 6 mm (0.25 in.) radius NOTE: This recommendation applies to both horizontal and vertical surfaces where the equipment operator can assume a static posture.	

SEMI S9-1101
SAFETY GUIDELINE FOR ELECTRICAL DESIGN VERIFICATION TESTS FOR SEMICONDUCTOR MANUFACTURING EQUIPMENT

This guideline was technically approved by the Global Environmental Health and Safety Committee and is the direct responsibility of the North American Environmental Health and Safety Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001. Originally published in 1995.

NOTICE: This document as balloted is intended to replace SEMI S9-95 in its entirety.

NOTICE: Paragraphs entitled "NOTE" are not an official part of this document and are not intended to modify or supercede the official guideline. The task force has supplied them to clarify and to enhance usage of the guideline by equipment designers.

1 Purpose

1.1 The purpose of this document is to provide electrical design verification tests, test methods, and acceptance criteria for semiconductor manufacturing equipment. Some of these tests are used as part of the electrical safety evaluation in SEMI S2.

2 Scope

2.1 This safety guideline should be applied to one or more representative samples of the equipment (or parts of the equipment) used for the manufacturing, measurement, assembly, and testing of semiconductor products.

2.2 The following tests are discussed in this document:

- Leakage Current Test (Section 9.1)
- Grounding Continuity Test (Section 9.2)
- Starting Current Test (Section 9.3)
- Input Test (Section 9.4)
- Dielectric Test (Section 9.5)
- Strain Relief Test (Section 9.6)
- Transformer Output Short Circuit Test (Section 9.7)
- Power Supply Output Short Circuit Test (Section 9.8)
- Safety Circuit Function Test (Section 9.9)
- Safety Circuits Conductor Disconnection Test (Section 9.10)
- Capacitor Stored Energy Discharge Test (Section 9.11)
- Temperature Test (Section 9.12)

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

3 Limitations

3.1 This document is not intended to be a comprehensive compilation of electrical tests specified in product safety standards. This document is also not intended to replace any test methods described in any appropriate national or international product safety standards.

3.2 It is not the intent of this guideline to require repetition of tests where the equipment has been certified or tested to other relevant electrical product safety standards. Any applicable test from this guideline that has been previously completed under an applicable product standard and which satisfies the intent of that test should be accepted, even if there are differences in test methods.

3.3 Engineering analysis, when based on sound engineering principles, may serve as an alternative to conducting a test.

3.4 If it is evident from the design and construction of the equipment that a particular test is not safety-relevant, the test need not be performed.

3.5 This document is not intended to address production line or routine testing.

4 Referenced Standards

4.1 *SEMI Standards*

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

4.2 *IEC Standard* [1]

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

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *1500 ohm impedance network* — a network consisting of a 1500 ohm resistor in parallel with a 0.15 μF capacitor.

5.2 *accessible* — capable of being contacted by an IEC accessibility probe (IEC standard test finger, as described in IEC 61010).

NOTE 2: The test finger is also known, in various IEC documents, as the "jointed test finger" and "jointed standard test finger".

5.3 *full load current* — current when the equipment is operated at the maximum manufacturer's specified operating conditions including all motors and heaters designed to operate simultaneously.

5.4 *hazardous energy* — energy of 20 J (Joules) or more, or an available power level of 240 V*A or more.

5.5 *least favorable condition* — the condition which is most likely to result in a test failure.

5.6 *permanently connected equipment* — Equipment that is intended to be electrically connected to a supply by means of connection which can be detached only by the use of tools.

5.7 *primary circuit* — an internal circuit which is directly connected to the external supply mains or other equivalent source (such as a motor-generator set) which supplies the electric power. It includes the primary windings of transformers, motors, other load devices and the means of connection to the supply mains.

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

5.9 *PE Terminal* — a terminal which is bonded to conductive parts of a piece of equipment for safety purposes and is intended to be connected to an external protective earthing system.

5.10 *standby condition* — condition in which equipment is energized and in its idle state.

5.11 *tool* — an external device used to aid a person in performing a mechanical function. As used in this document, *tool* includes devices such as keys.

5.12 *V*A* — Volt-ampere.

6 Safety Precautions

6.1 The tests outlined in this document are to be performed by trained and qualified personnel who have knowledge of the techniques and the test apparatus described herein.

7 Calibration and Standardization

7.1 All test equipment should be calibrated and traceable to a calibration standards organization (e.g., National Institute of Standards and Technology (NIST) in the United States or the National Metrology Institute in Japan).

7.2 The calibration interval for test equipment should not exceed one year.

8 Test Conditions

8.1 Except where noted otherwise, the equipment should be tested under the least favorable conditions within the manufacturer's operating specifications. These conditions include:

- supply potential
- supply frequency
- position of movable parts
- operating mode (e.g. full temperature conditions, motors in operation)
- adjustment of thermostats, regulating devices, or similar controls in operator-accessible areas

8.2 *Test Supply Potential* — To determine the least favorable supply potential for a test, consider:

- multiple-nominal rated potentials (e.g., 120/240 V)
- extremes of nominal rated potential ranges (e.g., 208–240 V)

8.2.1 Consideration of the tolerance on a nominal rated potential (e.g., 120 ± 5%) is not necessary.

NOTE 3: Some standards (e.g., IEC 61010-1 and IEC 60950) may specify 90% and 110% of any rated supply voltage.

8.3 *Test Supply Frequency* — To determine the least favorable supply frequency for a test, consider the nominal frequencies as specified (e.g., 50 Hz, 60 Hz, or 50/60 Hz).

1 International Electrotechnical Commission, 1, rue de Varembé, Case Postale 131, CH-1211 Geneva 20, Switzerland. Website: www.iec.ch

NOTE 4: Consideration of the tolerance on a nominal rated frequency (e.g., 50 ± 0.5 Hz) is not usually necessary.

8.4 As an alternative to carrying out tests on the complete equipment, tests may be conducted on circuits, components and sub-assemblies independent of the equipment, provided that the results of the tests would be representative of those performed as part of the assembled equipment.

EXCEPTION: The leakage current and grounding continuity tests identified in Sections 9.1 and 9.2 should be completed only on fully assembled equipment.

9 Electrical Tests

9.1 *Leakage Current Test for Cord-and-Plug Equipment*

9.1.1 *Test Equipment* — A 1500 ohm impedance network and a true RMS voltmeter with an accuracy of 1.0%. The impedance network can be a separate assembly or incorporated within a leakage current measuring instrument.

9.1.2 *Procedure* — For equipment connected to the facility branch circuit with a cord-and-plug (plug/socket combination), ensure that the equipment is isolated (e.g., by placing the equipment on a wooden or other isolating surface). Connect the equipment to its rated source of supply with the equipment grounding (PE) conductor disconnected and operate it at the least favorable conditions specified by the manufacturer. Connect the 1500 ohm impedance network between each accessible metal part and the supply equipment grounding (PE) conductor. In determining accessibility of live parts, remove all doors, panels, etc. that are to be removed by the operator during normal operation. Using a true RMS voltmeter, measure the voltage drop across the impedance network. Calculate the leakage current using the formula:

$$I_{leakage} = \frac{Voltage_{measured}}{1500\ ohms}$$

9.1.3 *Acceptable Results* — The maximum calculated leakage current does not exceed 3.5 mA.

9.2 Grounding Continuity Test

9.2.1 *Test Equipment* — Low range ohmmeter with a range to measure 0.10 ohm with an accuracy of 1.0%.

9.2.2 *Procedure* — Disconnect the equipment from the supply. For equipment installed with fixed wiring methods, disconnect the supply equipment grounding conductor (protective earthing conductor) from the main equipment grounding terminal (PE Terminal). Measure the resistance between the power supply equipment grounding terminal (PE Terminal) and each accessible metal part (handle, monitor, doors, etc.) on the equipment using a low-range ohm-meter. Upon test completion, reconnect the supply equipment grounding conductor (protective earthing conductor).

EXCEPTION: Grounding Continuity Test is not required to be measured where accessible metal surfaces are not likely to become energized in a single fault condition.

NOTE 5: Some standards (e.g., IEC 60204-1, IEC 61010-1) may specify this test to be performed using a current injection method.

9.2.3 *Acceptable Results* — The resistance between the grounding conductor terminal and each accessible part shall not exceed 0.1 ohm.

9.3 *Starting Current Test*

9.3.1 *Test Equipment* — None.

9.3.2 *Procedure* — Start the equipment in accordance with manufacturer's instructions three times from a completely stopped condition. Ensure that the time interval between successive starts is sufficient to allow the equipment return to ambient conditions.

9.3.3 *Acceptable Results* — None of the equipment's overload or overcurrent protections activates during this test.

NOTE 6: It is recommended that the peak inrush starting current be measured using an appropriate current measuring device and recorded in the test report.

9.4 *Input Test*

9.4.1 *Test Equipment* — True RMS current measuring equipment, with accuracy of 3.0%.

9.4.2 *Procedure* — Measure the input current to the equipment under the maximum normal operating load conditions (i.e., with all motors, heaters, etc. running at manufacturer's specified maximum loading conditions).

9.4.3 *Acceptable Results* — The measured current does not exceed 110% of the rated full load current value specified on the equipment nameplate.

9.5 *Dielectric Test*

9.5.1 *Test Equipment* — Timer with accuracy of ± 5 seconds. Dielectric Withstand Tester with means of indicating test potential, as well as an audible or visual indicator of electrical breakdown, or an automatic-reject feature for any unacceptable unit. In an alternating current test, the test equipment should include a transformer having sinusoidal output. This transformer should have a rating of 500 VA or greater unless it is provided with a voltmeter that directly measures the applied output potential.

9.5.2 *Procedure* — With the equipment disconnected from its supply, apply a dielectric withstand potential of 1500 Volts AC or 2121 Volts DC between live metal parts of primary circuit(s) and dead metal parts. Surge suppression components and devices, and electronic components certified by an accredited testing laboratory that may be damaged may be disconnected from the circuit for this test. For this test, the following conditions need to be set:

- The equipment should be at its maximum operating temperature
- Switches should be placed in the "on" position
- Circuits through contactors be completed by manually engaging the contacts or bypassing the contactor terminals.

9.5.2.1 Achieve the test potential gradually, starting from zero and holding at the maximum value for a period of one minute.

NOTE 7: A grounded circuit (neutral) conductor, if used in the circuit, is considered a live part.

NOTE 8: Where line-to-ground filter components are installed in the equipment, the DC dielectric potential specified above may be used as an equivalent.

9.5.3 *Acceptable Results* — The equipment does not have a dielectric breakdown as indicated by a puncture, flashover or sparkover.

NOTE 9: Breakdown is often indicated by an abrupt decrease or nonlinear advance of voltage as the voltage is increased. Similarly, a breakdown is often indicated by an abrupt increase in current. Partial discharge (corona) and similar phenomena are disregarded during application of the test voltage.

9.6 *Strain Relief Test*

9.6.1 *Test Equipment* — Timer with accuracy of ± 5 seconds. A calibrated weight to apply a force of 156 Newtons (35 lb) ± 1.56 Newtons (0.35 lb). A supporting surface to secure the equipment.

9.6.2 *Procedure* — For cord-and-plug connected equipment, strain relief is provided to prevent mechanical stress such as a pull or twist being transmitted to terminals, splices or interior wiring. Support the equipment on a surface so it will not move when the force is applied to the cord. Apply a direct pull of 156 N (35 pounds) to the equipment supply cord from the least favorable angle. If necessary use pulleys or other means to adjust the angle of force applied to the strain relief on the equipment. Apply the force gradually by slowly suspending the weight on the cord and maintain the applied force for a period of one minute.

9.6.3 *Acceptable Results* — The equipment supply cord does not displace to the extent that stress could be applied to the internal connections.

9.7 *Transformer Output Short Circuit Test*

9.7.1 *Test Equipment* — Timer with accuracy of ± 5 minutes. A substantial conductor suitable for carrying the short circuit current.

9.7.2 *Procedure* — With the equipment in its standby condition, short circuit the output of each power transformer.

NOTE 10: If overcurrent protection is connected to the output of the transformer under test, connect the short-circuit jumper after this protective device.

EXCEPTION 1: Where the overcurrent protective devices on the input or output of the transformer are rated at not more than 125% of the rated current of the transformer respectively and the overcurrent protective devices are certified by an accredited testing laboratory, the transformer need not be subjected to this test.

EXCEPTION 2: A thermally-protected or impedance-protected transformer that is certified by an accredited testing laboratory need not be subjected to this test.

9.7.3 *Acceptable Results* — A hazardous condition (e.g., smoke, fire, or molten material) does not exist within 8 hours or before activation of overcurrent protection, thermal protection, or other protective circuit/device whichever occurs first.

9.8 *Power Supply Output Short Circuit Test*

9.8.1 *Test Equipment* — Timer with accuracy of ± 5 minutes. A substantial conductor suitable for carrying the short circuit current.

9.8.2 *Procedure* — With the equipment in its standby condition, short circuit the output of each power supply, one at a time.

NOTE 11: If overcurrent protection is connected to the output of the power supply under test, connect the short circuit jumper after this protective device.

EXCEPTION: A power supply that is certified by an accredited testing laboratory and used in accordance with its certification and the manufacturer's instructions need not be subjected to this test.

9.8.3 *Acceptable Results* — A hazardous condition (e.g., smoke, fire, or molten material) does not exist within 8 hours or before activation of overcurrent protection, thermal protection, or other protective circuit/device whichever occurs first.

9.9 *Safety Circuit Function Test*

9.9.1 *Test Equipment* — Depends on safety devices being tested.

9.9.2 *Procedure* — Functionally test each safety circuit (e.g., EMO, Emergency Stop, End-of-travel sensors, loss of exhaust sensors, light curtains, and safety interlocks) by actuation and resetting.

9.9.3 *Acceptable Results* — The following sections provide the acceptable results for the applicable safety systems.

9.9.3.1 When the EMO is actuated, all hazardous voltage and all power greater than 240 volt-amps in the equipment beyond the main power enclosure should be de-energized, except where permitted by SEMI S2.

9.9.3.2 Actuation of the emergency stop and safety interlocks causes the equipment, or relevant parts of the equipment, to be automatically brought to a safe condition.

9.9.3.3 Resetting of the safety circuit should not cause the system to resume operation.

NOTE 12: This test documents the electrical functionality of the safety circuit(s). It is not intended to determine or document the appropriateness of the shutdown actions taken.

9.10 *Safety Circuit Conductor Disconnection Test*

9.10.1 Test Equipment — None.

9.10.2 *Procedure* — For each independent safety interlock (such as door interlock), EMO, and safety sensor (e.g., exhaust sensor, low fluid level sensor), disconnect each conductor, in turn, and each connector, in turn.

9.10.3 *Acceptable Results* — The following sections provide the acceptable results for the applicable safety circuits.

9.10.3.1 The opening of the safety circuit causes the equipment to be placed in a safe condition as if the safety device had been actuated

9.10.3.2 Reconnecting the conductor should not cause the system to resume operation.

9.11 *Capacitor Stored Energy Discharge Test*

9.11.1 *Test Equipment* — Timer with accuracy of ± 1 seconds. DC voltmeter with sensitivity of 1.0%.

9.11.2 *Procedure* — Test each capacitor which stores a hazardous energy (20 J or more). Monitor the voltage across the capacitor terminals continuously. Disconnect the equipment from the supply. Record the voltage across the capacitor terminals after 10 seconds.

9.11.3 *Acceptable Results* — The capacitor is discharged to less than 20 J within 10 seconds of equipment disconnection from the supply.

NOTE 13: The following formula is provided to calculate the energy.

$$J = \frac{1}{2} C V^2$$

where J is the energy in joules,

C is the capacitance in farads and

V is the potential in volts.

EXCEPTION: This criterion does not apply if a tool is necessary to remove a panel to reach the capacitor and the equipment is marked specifying the discharge time—5 minutes maximum—that is required for the capacitor to discharge to less than 20 J.

9.12 *Temperature Test*

9.12.1 *Test Equipment*— Timer with accuracy of ± 5 seconds. A thermometer with a full range resolution of 0.1°C.

9.12.2 *Procedure* — The equipment is to be operated at the manufacturer's maximum design load for 8 hours or until thermal equilibrium is reached (whichever occurs first). Measure and record the ambient room temperature. Measure and record the temperatures of the various components and devices for comparison with Table 1.

NOTE 14: Thermal equilibrium is considered to be attained when three successive readings taken at five minutes intervals indicate that there is no temperature change of the part exceeding 1.0 °C.

9.12.3 *Acceptable Results* — The measured temperatures do not exceed the values listed in Table 1.

Table 1 Maximum Temperature Limit

Parts of the Equipment	*Temperature Limit (°C)*
Knife switch blade and contact jaws	55
Fuse and fuse clip	110
Rubber and thermoplastic insulated conductors	See Note 1.
Field wiring terminals	--
Equipment marked for 60°C or 60/75°C supply wires	75
Equipment marked for 75°C supply wires	90
Buses and connecting straps or bars	125
Capacitors	See Note 2.
Power switching semiconductors	See Note 3.
Printed wiring boards	See Note 4.
Motors and Transformers	See Note 5.

NOTE 1: The temperature as marked on the conductor.
NOTE 2: The temperature marked on the capacitor.
NOTE 3: The case temperature for the applied power dissipation recommended by the semiconductor manufacturer.
NOTE 4: The operating temperature of the board as specified by the board manufacturer.
NOTE 5: The rated temperature of the motor or transformer as specified by the manufacturer, if provided. When not provided, use appropriate standards such as IEC 61010-1 for guidance.

10 Reporting Test Results

10.1 Include the following information on the test data form:

- Name, model, and serial number of the equipment
- Date of tests
- Name(s)/signature(s) of tester(s)
- Complete test methods and conditions
- Complete test results
- Complete test equipment information (type of test equipment, manufacturers' names, model numbers, serial numbers, and calibration information).

10.2 The general configuration and actual operating mode that was used for the test should be clearly documented. Where components are tested separately or only parts of the overall system are operational, this should be documented as a condition for the test results reported. This information can be on the test data form(s), or incorporated in the test report.

10.3 See Table 2 for a sample blank test data form.

Table 2 Sample Blank Test Data Form

Manufacturer:		Tester's Name:	
Name of Equipment:		Model No.:	
Serial No.:		Date:	
Location of Test Performed:			
(Test Name)			
Test Method:			
Test Result:			
Tester:		Reviewed:	
Equipment Used:	Model No.:	Serial No.:	Last Date Calibrated:

11 Related Documents

11.1 *SEMI Standards*

SEMI S1 — Safety Guidelines for Equipment Safety Labels

11.2 *IEC Documents*

IEC 60204 — Safety of Machinery – Electrical equipment of Machines, Part 1: General Requirements

IEC 60950 — Safety of Information Technology Equipment

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

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SEMI S10-1103
SAFETY GUIDELINE FOR RISK ASSESSMENT AND RISK EVALUATION PROCESS

This safety guideline was technically approved by the Environmental, Health, & Safety Committee and is the direct responsibility of the European Environmental, Health, & Safety Committee. Current edition approved by the European Regional Standards Committee on July 1, 2003. Initially available at www.semi.org October 2003; to be published November 2003. Originally published December 1996.

NOTICE: This document was completely rewritten in 2003.

NOTICE: Paragraphs entitled "NOTE:" are not an official part of this document and are not intended to modify or supersede the official guideline.

1 Purpose

1.1 The purpose of this guideline is to establish general principles for risk assessment to enable identification of hazards, risk estimation and risk evaluation in a consistent and practical manner. The document provides a framework for carrying out risk assessments on equipment in the semiconductor and similar industries and is intended for use by supplier and purchaser as a reference for EHS considerations.

1.2 Use of this safety guideline is intended to assist in the development of a strategy to prioritize and control risks.

2 Scope

2.1 This guideline is intended to apply to the assessment of risks considering the lifecycle of the equipment.

NOTE 1: It can also be applied to processes or facilities.

2.2 This guideline outlines a hazard identification, risk estimation, and risk evaluation process.

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

3 Limitations

3.1 This guideline is not intended to be used to verify compliance with local regulatory requirements.

3.2 This guideline does not cover risk reduction, mitigation, avoidance or transfer techniques.

3.3 This guideline is not intended to explain specific risk assessment techniques, such as Fault Tree Analysis (FTA), Event Tree Analysis (ETA), Hazard and Operability Studies (HAZOP) and Failure Mode Effect Analysis (FMEA). However, it recognizes that these techniques exist and that they are adequately covered elsewhere.

NOTE 2: Related Information 2 provides summary information and references for applicable techniques**.**

3.4 Use SEMI S14 for fire risk assessment criteria for equipment.

4 Referenced Standards

4.1 *SEMI Standards*

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

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

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

5 Terminolgy

5.1 *Definitions*

5.1.1 *controls* — means to prevent or avoid a hazard from causing loss.

5.1.2 *exposure to a hazard* — situation in which a hazard is present which may (but does not necessarily) result in harm.

5.1.3 *frequency of exposure* — how often personnel or equipment are exposed to a hazard.

5.1.4 *harm* — physical injury or damage to health of people, or damage to equipment, buildings or environment.

5.1.5 *hazard* — condition that has the potential to cause harm.

5.1.6 *lifecycle* — the entire life of an item of equipment, from conceptual design through to disposal.

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

NOTE 3: Likelihood groups are defined in Appendix 1.

5.1.8 *maintenance* — planned or unplanned activities intended to keep equipment in good working order.

5.1.9 *modification* — change of the equipment that may introduce new hazards and risks.

5.1.10 *residual risk* — risk remaining after engineering, administrative, and work practice controls have been implemented.

5.1.11 *risk* — the expected magnitude of losses from a hazard, expressed in terms of severity and likelihood.

5.1.12 *risk assessment* — a procedure through which knowledge and experience of design, use, incidents and accidents and harm are brought together to measure the risks for specified scenarios of the equipment being assessed. Risk assessment includes determining the use and limits of the machinery, hazard identification, and risk estimation.

5.1.13 *risk estimation* — derivation of the risk associated with a particular situation from a combination of the severity and the likelihood.

5.1.14 *risk evaluation* — the process of deciding if risk reduction is required.

5.1.15 *risk reduction* — the process by which the risk is reduced to a lower level.

5.1.16 *service* — unplanned activities intended to return equipment that has failed back in good working order.

5.1.17 *severity* — the extent of potential credible harm.

NOTE 4: Severity groups are defined in Appendix 1.

6 Procedures

6.1 *General Guidelines*

6.1.1 Figure 1 shows the essential steps of the risk assessment and control process.

6.1.2 A risk assessment should be performed to identify and evaluate potential hazards in the equipment being assessed. Risk assessment should be initiated early in the design phase and updated as the design matures.

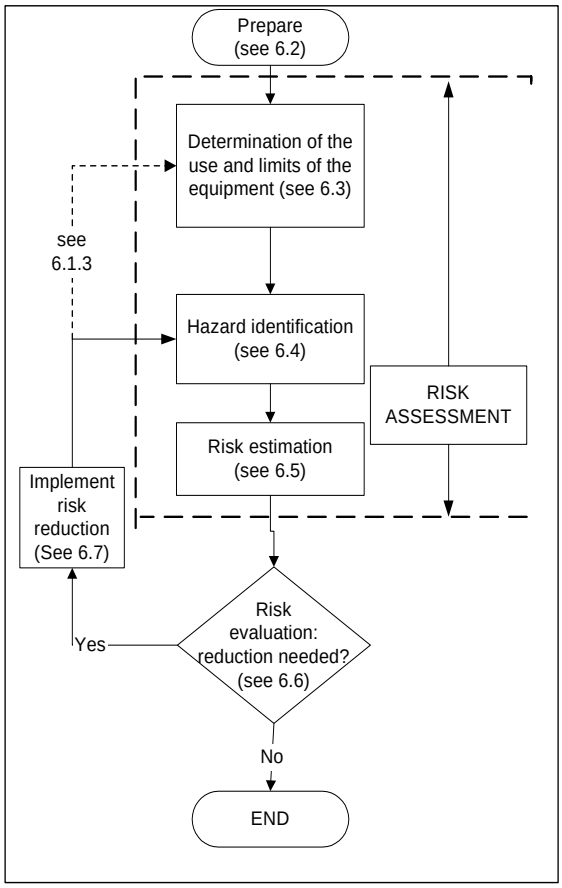


Figure 1
Risk Assessment Flowchart

6.1.3 After a significant modification (i.e. one that can introduce new hazards and/or risks in the design), reconsideration of use and limits of the equipment may be necessary (see Figure 1).

6.2 *Preparations for Hazard Identification and Risk Estimation Process*

6.2.1 The assessment should be carried out by those with the necessary knowledge and experience of the task, equipment, or process being assessed.

NOTE 5: To have an effective process, good preparation is essential.

6.2.2 Select the reviewers (e.g., designers, equipment manufacturers, field engineers, end-users, third party evaluators, a risk assessment leader and someone with experience in hazard identification).

6.2.3 Select the risk assessment technique.

6.2.4 Collect information on the design (e.g., drawings, mock-up, and hardware).

6.2.5 Determine the scope of the assessment.

6.3 *Define Use and Limits of the Equipment* — Consider at least the following aspects:

- Lifecycle stages,
- Person(s) involved,
- Areas in which equipment is used,
- Support equipment intended to be used with the equipment, and
- Chemicals or family of chemicals to be used in the equipment.

6.3.1 All lifecycle stages should be considered during the hazard identification e.g.:

- Design & development
- Equipment manufacturing
- Transportation
- Install
- Maintenance & Service
- Use
- Modification
- Decommissioning
- Disposal (include reuse, recycling)

6.4 *Hazard Identification* — Identify anticipated hazards that could result, in a reasonably foreseeable scenario, in harm at each lifecycle stage by using an appropriate technique. Hazards can be identified under those headings defined in SEMI S2.

NOTE 6: See Related Information 1 for an example of a checklist to assist in identifying hazards and Related Information 2 for examples of hazard analysis techniques.

6.5 *Risk Estimation*

6.5.1 There are numerous ways of estimating the risk associated with a hazard. Some risk estimates are based on identifying the observed and reasonably foreseeable outcomes from a hazard and assigning an expected frequency to each (see Section 6.5.2). Other risk estimates are obtained by comparing the equipment qualitatively to similar equipment (see Section 6.5.3).

6.5.2 The risk estimation using outcome and frequency consists of several parts:

6.5.2.1 Identification of each observed or reasonably foreseeable outcome of a hazard.

6.5.2.2 Assignment of a severity group to each outcome. The preferred severity groups are given in Table A1-1.

6.5.2.3 Assignment of a likelihood group to an outcome representing each severity group. The preferred likelihood groups are given in Table A1-2. The likelihood, also called the Probability of Occurrence of Harm can be a function of:

- Frequency and duration of exposure to the hazard,
- Probability of the occurrence of harm during exposure, and
- Probability of avoiding harm during exposure, based on the presence, the extent, or the lack of controls.

6.5.2.4 Identification of the overall risk associated with the hazard, using a suitable table. The preferred risk category assignments are given in Table A1-3.

6.5.2.4.1 The risk for each severity/likelihood combination should be determined.

6.5.2.4.2 The greatest risk from all of the combinations should be considered the overall risk for the hazard.

6.5.3 *Benchmark Method* — Benchmarks an anticipated or observed hazardous situation against a similar situation. Based on the circumstances in which the hazard occurs, a risk category (Very High to Very Low) is assigned to the risk.

NOTE 7: Benchmarking method should only be used if sufficient adequate and reliable information is available on a similar model or situation.

6.6 *Risk Evaluation*

6.6.1 Each hazard or set of hazards is evaluated to decide if risk reduction is needed.

6.6.2 Risk evaluation can be an individual internal process for the equipment manufacturer or the equipment user, or a joint effort by all involved parties.

NOTE 8: This document does not establish a level of risk for which reduction is required. In the evaluation of risk reduction, various aspects may be taken into account, including:

- Customer expectations,
- Social expectations,
- Feasibility (e.g., Costs, technical possibility),
- Legal requirements,
- Industry accident history,
- International industry standards, and
- Good engineering and manufacturing practices.

6.7 *Risk Reduction*

6.7.1 The risk assessment may be used to assist in the identification and selection of control measures to

reduce the risk. Following risk reduction measures, the assessment may need to be reviewed.

NOTE 9: This document does not specify risk reduction measures that may be necessary following risk assessment. SEMI S2 suggests that the following should be considered in the design and construction of equipment:

- Regulatory requirements,
- SEMI guidelines,
- International industry standards, and
- Good engineering and manufacturing practices.

7 Documentation

7.1 The risk assessment, evaluation, and reduction should be documented and the documentation should contain at least the following:

- risk assessment technique used,
- reviewers,
- date,
- identification of the equipment considered,
- hazards identified,
- risk estimation,
- the criteria used to determine if risk reduction is required,
- risk evaluation, and
- control measures implemented to reduce the risk from identified hazards.

NOTE 10: The risk assessment documentation can be used as input for safety reviews, e.g., SEMI S2, S8 or S14 report.

8 Related Documents

8.1 *SEMI Standards*

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

8.2 *US Military Standards*[1]

MIL STD 1629A — Failure Modes, Effects and Criticality Analysis

MIL STD 882D — Standard Practice for System Safety

8.3 *International Electrotechnical Commission Standards*[2]

IEC 60812 — Analysis Techniques for System Reliability - Procedure for Failure Mode and Effects Analysis (FMEA)

IEC 61025 — Fault Tree Analysis (FTA)

IEC 61508-5: (1999-04) — Functional Safety of Electrical/Electronic/Programmable Electronic Safety Related Systems - Part 5: Examples of Methods for the Determination of Safety Integrity Levels

IEC 61508-5:(1998-12) — Related Systems - Part 5: Examples of Methods for the Determination of Safety Integrity Levels

8.4 *ANSI Standards*[3]

ANSI/RIA R15.06: 1999 — Industrial Robots and Robot Systems — Safety Requirements

ANSI B11 TR3-2000 — Risk Assessment and Risk Reduction – A Guide to Estimate, Evaluate and Reduce Risks Associated with Machine Tools

8.5 *ISO Standards*[4]

ISO 14121: 1999 — Safety of machinery - Principles for risk assessment

ISO/TR 13849-1:1999/EN 954-1: — Safety of machinery - Safety-related parts of control systems. Part 1: General principles for design

ISO/TR 12100-1:1992/EN 292-1: — Safety of machinery - Basic concepts, general principles for design. Part 1: Basic terminology, methodology

ISO/TR 12100-2:1992/EN 292-2: — Safety of machinery - Basic concepts, general principles for design. Part 2: Technical principles and specifications

8.6 *Other Documents*

SEMATECH[5] #9202963A-ENG; — Failure Mode and Effects Analysis (FMEA): A Guide for Continuous Improvement for the Semiconductor Equipment Industry

1 Available through the Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120-5099, USA. Telephone: 215.697.3321

2 Available through the 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

3 Available through the 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

4 Available through the 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

5 Available through International SEMATECH, 2706 Montopolis Drive, Austin, TX, USA website: http://www.sematech.org

AIChE[6] — Several standards covering risk assessment, evaluation and specific topic, focused on chemical products.

BS[7] 5760–5:1991 — Reliability of systems, equipment and components. Guide to failure modes, effects and criticality analysis (FMEA and FMECA)

[6] Available through the American Institute of Chemical Engineers, 3 Park Ave, New York, N.Y., 10016-5991, USA. http://www.aiche.org

[7] Available through the British Standards institute, 389 Chiswick High Road, London W4 4AL, United Kingdom www.bsi-global.com

APPENDIX 1
RISK RANKING TABLES

NOTICE : The material in this appendix is an official part of SEMI S10 and was approved by full letter ballot procedures on April 2, 2003.

NOTE A1-1: The following Tables A1-1 and A1-2 give the groups of severity and likelihood. Other examples can be found in Related Information 3 (Risk Ranking Number) and Related Information 4 (more detailed numerical Severity and Likelihood).

Table A1-1 Severity Groups

Severity Group	*People (See Note A1-2.)*	*Equipment/Facility (See Note A1-3.)*	*Property*
1 – Catastrophic	One or more fatalities.	System or facility loss.	Chemical release with lasting environmental or public health impact.
2 – Severe	Disabling injury/illness.	Major subsystem loss or facility damage.	Chemical release with temporary environmental or public health impact.
3 – Moderate	Medical treatment or restricted work activity (OSHA recordable).	Minor subsystem loss or facility damage.	Chemical release triggering external reporting requirements.
4 – Minor	First aid only.	Non-serious equipment or facility damage.	Chemical release requiring only routine cleanup without reporting.

NOTE A1-2: This number is if 1-2 people are exposed to the risk. The severity group should be reconsidered to a more severe severity group when 3 or more people are involved.

NOTE A1-3: Although it is not a safety risk it adds value to take in account product (e.g. wafers, reticles) damage. No descriptions are given due to the fact of the value and number of products on a equipment can vary. Possible descriptions can be: Rework of a wafer, Rework of a batch, Loss of a batch.

Table A1-2 Likelihood Groups

Likelihood Group	*Expected Frequency (% of Units- Year) (See Note 1.)*
A – Frequent	More than 1%
B – Likely	More than 0.2% but not more than 1%
C – Possible	More than 0.04%, but not more than 0.2%
D – Rare	More than 0.02%, but not more than 0.04%
E – Unlikely	Not more than 0.02%

Note 1: The frequency (in percent) is calculated by dividing the number of (observed or expected) occurrences by the number of unit-years that the hazard has existed or is anticipated to exist, then multiplying the quotient by 100.

NOTE A1-4: If data are available, they should be used. If data are not available, the frequencies should be estimated.

NOTE A1-5: The following two example calculations are added for clarification of Table A1-2 only:

Example 1:

If something expected to happen 1 time in 5 units operated for 6 years the frequency will become:

(1 time/(5 units × 6 year of operation)) × 100% = 3.3% (= A – Frequent)

Example 2:

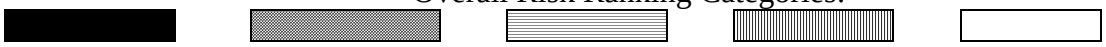
If something expected to happen 2 times on 50 units with 30 are operated for 6 years and 20 are operated for 7 years the frequency will become

(2 times/(30 units × 6 year of operation + 20 units × 7 year of operation)) × 100% = 0.625% (= C – Possible)

Table A1-3 Risk Ranking Matrix

RISK RANKING MATRIX		LIKELIHOOD				
		FREQUENT A	LIKELY B	POSSIBLE C	RARE D	UNLIKELY E
SEVERITY	CATASTROPHIC 1					
	SEVERE 2					
	MODERATE 3					
	MINOR 4					

Overall Risk Ranking Categories:



VERY HIGH | HIGH | MEDIUM | LOW | VERY LOW

NOTE A1-6: The Risk Categories of “Very High” and “Very Low” correspond identically with the Risk Categories, used in previous SEMI documents (e.g., S10-12-96, S2, and S14) of “Critical” and “Slight”. The terms were changed to facilitate translation from English.

RELATED INFORMATION 1
HAZARD IDENTIFICATION CHECKLIST

NOTICE: This related information is not an official part of SEMI S10 and was derived from EN 1050. Figure 1 from BS EN 1050: 1997 is reproduced with the permission of BSI under license number 2003DH0150. British Standards can be obtained from reproduced with the permission of BSI Customer Services, 389 Chiswick High Road, London, W4 4AL, United Kingdom, Tel + 44 (0)20 8996 9001.

R1-1 Hazard Identification Checklist

R1-1.1 This checklist is produced to assist the assessor in identifying potential hazards. Other SEMI safety guidelines may also be used.

Table R1-1 List of Hazards (copied from EN 1050)

1	*Mechanical hazards*
1.1	Crushing hazard
1.2	Shearing hazard
1.3	Cutting or severing hazard
1.4	Entanglement hazard
1.5	Drawing-in or trapping hazard
1.6	Impact hazard
1.7	Stabbing or puncture hazard
1.8	Friction or abrasion hazard
1.9	High pressure fluid injection or ejection hazard
2	*Electrical hazards*
2.1	Contact of persons with live parts (direct contact)
2.2	Contact of persons with parts which have become live under faulty conditions (indirect contact
2.3	Approach to live parts under high voltage
2.4	Electrostatic phenomena
2.5	Thermal radiation or other phenomena such as the projection of molten particles and chemical effects from short circuits, overloads, etc.
3	*Thermal hazards*, resulting in:
3.1	Burns, scalds and other injuries by a possible contact of persons with objects or materials with an extreme high or low temperature, by flames or explosions and also by the radiation of heat sources
3.2	Damage to health by hot or cold working environment
4	*Hazards generated by noise***,** resulting in:
4.1	Hearing loss (deafness), other physiological disorders (e.g., loss of balance, loss of awareness)
4.2	Interference with speech communication, acoustic signals, etc.
5	*Hazards generated by vibration*
5.1	Use of hand-held machines resulting in a variety of neurological and vascular disorders
5.2	Whole body vibration, particularly when combined with poor postures
6	*Hazards generated by radiation*
6.1	Low frequency, radio frequency radiation, micro waves
6.2	Infrared, visible and ultraviolet light
6.3	X and gamma rays
6.4	Alpha, beta rays, electron or ion beams, neutrons
6.5	Lasers
7	*Hazards generated by materials and substances* (and their constituent elements) processed or used by the machinery
7.1	Hazards from contact with or inhalation/ ingestion and subcutaneous injection of harmful fluids, gases, mists, fumes, and dusts
7.2	Fire or explosion hazard
7.3	Biological or microbiological (viral or bacterial) hazards
8	*Hazards generated by neglecting ergonomic principles in machinery design* as, e.g., hazards from:
8.1	Unhealthy postures or excessive effort
8.2	Inadequate consideration of hand-arm or foot-leg anatomy
8.3	Neglected use of personal protection equipment
8.4	Inadequate local lighting
8.5	Mental overload and underload, stress
8.6	Human error, human behavior (e.g.:due to improper training, selection, …)
8.7	Inadequate design, location or identification of manual controls

8.8	Inadequate design or location of visual display units
9	*Combination of Hazards*
10	*Unexpected start-up unexpected over-run/over-speed* (or any similar malfunction) from:
10.1	Failure/disorder of the control system
10.2	Restoration of energy supply after an interruption
10.3	External influences on electrical equipment
10.4	Other external influences (gravity, wind, etc.)
10.5	Errors in the software
10.6	Errors made by the operator (due to mismatch of machinery with human characteristics and abilities, see 8.6)
11	*Impossibility of stopping the machine in the best possible conditions*
12	*Variations in the rotational speed of tools*
13	*Failure of the power supply*
14	*Failure of the control circuits*
15	*Errors of fitting*
16	*Break-up during operation*
17	*Falling or ejected objects or fluids*
18	*Loss of stability / overturning of machinery*
19	*Slip, trip and fall of persons* (related to machinery)
Additional hazards, hazardous situation and hazardous events due to mobility	
20	*Relating to the traveling function*
20.1	Movement when starting the engine
20.2	Movement without a driver at the driving position
20.3	Movement without all parts in safe position
20.4	Excessive speed of pedestrian controlled machinery
20.5	Excessive oscillations when moving
20.6	Insufficient ability of machinery to be slowed down, stopped and immobilized
21	*Linked to the work position* (including driving station) on the machine
21.1	Fall of persons during access to (or at/from) the work position
21.2	Exhaust gases/lack of oxygen at the work position
21.3	Fire (flammability of the cab, lack of extinguishing means)
21.4	Mechanical hazards at the work position: contact with the wheels rollover fall of objects, penetration by objects break-up of parts rotating at high speed contact of persons with machine parts or tools (pedestrian controlled machines)
21.5	Insufficient visibility from the work positions
21.6	Inadequate lighting
21.7	Inadequate seating
21.8	Noise at the work position
21.9	Vibration at the work position
21.10	Insufficient means for evacuation/emergency exit)
22	*Due to the control system*
22.1	Inadequate location of manual controls
22.2	Inadequate design of manual controls and their mode of operation
22.3	Inadequate explanation of the use of the controls
23	*From handling the machine* (lack of stability)
24	*Due to the power source and to the transmission of power*
24.1	Hazards from the engine and the batteries
24.2	Hazards from transmission of power between machines
24.3	Hazards from coupling and towing
25	*From/to third persons*
25.1	Unauthorized start-up/use
25.2	Drift of a part away from its stopping position
25.3	Lack or inadequacy of visual or acoustic warning means
26	*Insufficient instructions for the driver/operator*
Additional hazards, hazardous situations and hazardous events due to lifting	
27	*Mechanical hazards and hazardous events*
27.1	from load falls, collisions, machine topping caused by:
27.1.1	lack of stability
27.1.2	uncontrolled loading – overloading – overturning moments exceeded
27.1.3	uncontrolled amplitude of movements
27.1.4	unexpected/unintended movement of loads

27.1.5	inadequate holding devices/accessories
27.1.6	collision of more than one machine
27.2	from access of persons to load support
27.3	from derailment
27.4	from insufficient mechanical strength of parts
27.5	from inadequate design of pulleys, drums
27.6	from inadequate selection of chains, ropes, lifting and accessories and their inadequate integration into the machine
27.7	from lowering of the load under the control of friction brake
27.8	from abnormal conditions of assembly/testing/use/maintenance
27.9	from the effect of load on persons (impact by load or counterweight)
28	*Electrical hazards*
28.1	from lightning
29	*Hazards generated by neglecting ergonomic principles*
29.1	insufficient visibility from the driving position
Additional hazards, hazardous situations and hazardous events due to underground work	
30	*Mechanical hazards and hazardous events due to:*
30.1	Lack of stability of powered roof supports
30.2	Failing accelerator or brake control of machinery running on rails
30.3	Failing or lack of deadman's control of machinery running on rails
31	*Restricted movement of persons*
32	*Fire and explosion*
33	*Emission of dust, gases etc.*
Additional hazards, hazardous situations and hazardous events due to the lifting or moving of persons	
34	*Mechanical hazards and hazardous events* due to:
34.1	Inadequate mechanical strength – inadequate working coefficients
34.2	Failing of loading control
34.3	Failing of controls in person carrier (function, priority)
34.4	Overspeed of person carrier
35	*Falling of person from person carrier*
36	*Falling or overturning of person carrier*
37	*Human error, human behavior*
38	*Seismic hazards*
39	*Inadequate hazard warnings*

RELATED INFORMATION 2
HAZARD ANALYSIS TECHNIQUES

NOTICE: This related information is not an official part of SEMI S10 and is not intended to modify or supersede the official guideline. It has been derived from practical application by the task force members. Publication is authorized by the vote of the responsible committee April 2, 2003.

R2-1 Hazard Analysis Techniques

R2-1.1 *Introduction*

R2-1.1.1 This related information gives an overview of several hazard analysis techniques that can be used. Each technique has its own limitation or is developed for a special type of risk assessment. For each technique a short description of the technique and a reference, if available, is given. Of course, it is not possible to list all techniques in this overview.

R2-1.1.2 Analysis techniques: the choice of analysis technique depends upon the goal of the analysis. Two basic types of techniques exist:

R2-1.1.2.1 Top-down (deductive) techniques are suitable for determining the initiating events that can lead to identify top events, and calculating the probability of top events from the probability of the initiating events. They can also be used to investigate the consequences of identified multiple failures. An Example of top-down techniques is Fault Tree Analysis (FTA, see IEC 61025).

R2-1.1.2.2 Bottom-up (inductive) techniques are suitable for investigating the consequence of identified single failures. Examples of bottom-up techniques are Failure Modes and Effects Analysis (FMEA, see IEC 812) and Failure Modes, Effects and Criticality Analysis (FMECA, see MIL-STD-1629A).

Table R2-1 Overview of Analysis Techniques and Area of Use

Technique	*When to use*		*Where to Use*			
	Before malfunction	*After malfunction*	*Process*	*Work place*	*Machine*	*Organization*
Work Safety analysis	X	-	-	X	-	-
What-If	X	-	X	X	X	-
MORT	X	X	-	-	-	X
Checklists	X	X	X	X	X	X
Action Error Analysis	X	-	-	-	X	-
HAZOP	X	-	X	-	X	-
FMEA	X	-	X	-	X	-
Event Tree Analysis	X	-	X	X	X	-
Fault Tree Analysis	X	X	X	X	X	-
Circuit Logic Analysis	X	X	X	-	-	-
Interface Analysis	X	-	X	-	X	-
Mapping	X	-	-	-	X	-
Procedure Analysis	X	X	-	X	-	X
Contingency Analysis	X	-	-	X	-	X
Mathematical Malfunction analysis	X	-	X	X	X	-
Work Space analysis	X		-	X	-	X
Task Analysis	X	X	-	X	X	-

R2-2 Summary of Risk Assessment Techniques

R2-2.1 *Work Safety Analysis* — A checklist is used to check the working place on criteria such as environment, ergonomics, and organization. On all the criteria of the checklist a rating is given. The overview of the ratings gives the "comfort" of the working place.

R2-2.2 *MORT: Modified Fault Tree Analysis* — Used for detection of organization and policy errors being the root causes of incidents. MORT uses a systematic control list. MORT was developed as a safety management program.

R2-2.3 *Checklists* — List of questions which is used as guidance for the assessment. Almost every technique uses a checklist. Checklists can be developed for generic or specific situations (e.g., EN 1050 safety checklist).

R2-2.4 *Action Error Analysis* — The consequences of correct and incorrect actions are evaluated. Very much based on handling of the person and the controls used.

R2-2.5 *HAZOP* — Hazard and Operability study: Small team of experts of the machine/process which, using a systematic checklist, checks for realistic failures.

R2-2.6 *FMEA* — Failure Modes, Effects Analysis (FMEA) is a tabulation of the system/plant equipment, failure modes, and each failure mode' s effect on the system/plant equipment. The failure mode is a description of how equipment fails (e.g., open, closed, on, off, leaks). The effect of the failure mode is the system response or accident resulting from the equipment failure. FMEA identifies single failure modes that either directly result in or contribute significantly to an important accident. Human/operator errors are generally not examined in FMEA, although the effects of a mis-operation are usually described by an equipment failure mode. FMEA is not efficient for identifying combinations of equipment failures that lead to accidents. The FMEA can be performed by two analysts or a multi-disciplinary team of professionals. A Failure Modes, Effects and Criticality Analysis (FMECA) is an FMEA with criticality rankings (Based on MIL-STD-1629A).

R2-2.7 *What-if* — Possible failures are checked on possible consequences. A checklist, suited for the equipment to evaluate, may be used.

R2-2.8 *Event Tree Analysis* — Event tree analysis is a technique for evaluating potential accident outcomes resulting from a specific equipment failure or human error known as an initiating event. Event tree analysis considers operator response or safety system response to the initiating event in determining the potential accident outcomes. The results of the event tree analysis are accident sequences, a chronological set of failures or errors that define an accident. These results describe the possible accident outcomes in terms of the sequence of events (successes or failures of safety functions) that follow an initiating event. Event tree analysis is well suited for operations that have safety systems or emergency procedures in place to respond to specific initiating events.

NOTE R2-1: This technique is also known as Fault Hazard Analysis.

R2-2.9 *Fault Tree Analysis* — Fault Tree Analysis (FTA) focuses on one particular accident event and provides a method for determining causes of that accident event. The fault tree itself is a graphic model that displays the various combinations of equipment faults and failures that can result in the accident event. The solution of the fault tree is a list of the sets of equipment failures that are sufficient to result in the accident event of interest. The strength of FTA as a qualitative tool is its ability to break down an accident into basic failures. This allows the safety analyst to focus preventive measures on these basic causes to reduce the probability of an accident.

R2-2.10 *Circuit Logic Analysis* — Logic of an electrical circuit is checked by making a logic diagram. Possible errors are reviewed for their consequences.

R2-2.11 *Interface Analysis* — Check how process, equipment and systems are connected to each other. Identify the risks of each connection.

R2-2.12 *Mapping* — The first step in determining a risk profile is to develop a checklist of the areas of risk. These factors can be evaluated quantitatively (as accurate measurements) or qualitatively (as levels or descriptive states). The second step is carrying out sensitivity analyses for the quantitatively assessed factors.

R2-2.13 *Procedure Analysis* — Procedures are reviewed and checked if hazards occur in the steps or sequence of steps.

R2-2.14 *Contingency Analysis* — Contingency analysis is a method of treating uncertainty that explores the effect on the alternatives of change in the environment in which the alternatives are to function. This is a "what-if" type of analysis, with the what-ifs being external to the alternative.

R2-2.15 *Mathematical Malfunction Analysis* — Identification of malfunctions, deviations in design are made and the effect calculated. This technique is widely used for rotating equipment.

R2-2.16 *Work Space Analysis* — In this technique, the position of the person performing a task is evaluated. All external and task related circumstances are evaluated and their risks are identified.

R2-2.17 *Task Analysis* — Task analysis is the systematic examination of a task to identify all loss exposures related to the task. A task will be reviewed in the step-by step manner. Task Analysis should be done during design and on final design. Task analysis is also known as Job Safety Analysis (JSA). Verification of the task analysis should be done by a Task Observation or Job Safety Observation (JSO).

RELATED INFORMATION 3
EXAMPLE OF RISK RANKING METHOD

NOTICE: This related information is not an official part of SEMI S10 and is not intended to modify or supersede the official guideline. It has been derived from practical application by the task force members. Publication is authorized by the vote of the responsible committee April 2, 2003.

R3-1 Example of Risk Ranking Method

R3-1.1 One method for risk analysis is the risk ranking number (RRN) system. Numerical values are assigned to descriptive phrases. A RRN is calculated, thus indicating the risk.

R3-1.2 The RRN is a function of severity (S) and probability of occurrence (PO).

R3-1.3 To get the RRN, use function (1) **or** (2), depending on which data and experiences are available.

$$RRN = S \times PO \quad (1)$$

$$RRN = S \times FE \times POH \times PA \quad (2)$$

Where: $PO = FE \times POH \times PA$

R3-1.4 *Severity (S)* — when assessing the severity of harm, the following factors should be taken into account:

- degree of possible harm/injury
- number of people at risk
- amount of property loss
- harm to environment

R3-1.5 *Probability of Occurrence of Harm (PO)* — The probability of occurrence taken into account the factors described in Sections R3-1.6-R3-1.8.

R3-1.6 *Frequency and Duration of Exposure (FE)* — need for access to the danger zone, e.g., operator, maintenance, service personnel

- number of persons exposed to hazard
- time spent of exposure to the danger zone, e.g., seconds, minutes
- frequency of access, e.g., annually, monthly, daily

R3-1.7 *Probability of Occurrence of Hazardous Situations (POH)* —

- accident history
- history of damage to heath, property and/or environment
- risk comparisons to other industries with similarities, e.g., chemical industry, petroleum industry
- statistical data

R3-1.8 *Possibility to Avoid the Harm (PA)*

R3-1.8.1 This is a number between 1 (not possible) to 0 (avoiding always possible)

- nature of persons, e.g., skilled or unskilled persons, unmanned operation
- the speed of appearance of the hazards, e.g., slow, fast
- awareness of critical situations, e.g., warning signs, direct observation, information
- possibility to avoid the hazardous situations, e.g., reflex, possibility of escape
- knowledge and experience about the equipment

R3-1.9 *Risk Ranking Number*

R3-1.9.1 The risk-ranking number is a function of severity (S) and probability of occurrence (PO).

R3-1.9.2 For these criteria, specific numbers need to be defined. Based on the risk ranking appropriate actions should be carried out according to the control strategy.

RELATED INFORMATION 4
EXAMPLE OF NUMERICAL RISK RATING METHODS

NOTICE: This related information is not an official part of SEMI S10 and is not intended to modify or supersede the official guideline. It has been derived from practical application by the task force members. Publication is authorized by the vote of the responsible committee April 2, 2003.

R4-1 Example of Numerical Risk Rating Methods

R4-1.1 *Background* — For practical reasons numerical descriptions are preferred during many risk assessments. The tables below are an example how the descriptive categories are changed to numerical. The data in the following tables are not based on statistical data.

Table R4-1 Likelihood and Frequency: Based on Number of Occurrence Per Year

		Frequency of exposure – based on number of occurrence per year						
		Infrequent	Annually	Monthly	Weekly	Daily	Hourly	Constant
% of time	*Likelihood of occurrence*	0.333	1	12	52	365	8760	525600
0%	Impossible, Cannot happen	0	0	0	0	0	0	0
0.25%	Almost unlikely, possible in extreme circumstances	0.001	0.003	0.03	0.13	0.91	21.9	1,314
1%	Highly unlikely, Though conceivable	0.003	0.01	0.12	0.52	3.65	87.6	5,256
5%	Unlikely, but could occur	0.017	0.05	0.6	2.6	18.25	438	26,280
15%	Possible, but unusual	0.05	0.15	1.8	7.8	64.76	1,314	78,840
50%	Even chance of occurance, can happen	0.167	0.5	6	26	182.6	4,380	262,800
75%	Probable, not surprised	0.25	0.75	9	39	273.8	5,570	394,200
90%	Likely, to be expected	0.3	0.9	10.8	46.8	328.5	7,884	473,040
100%	Certain, No doubt	0.33	1	12	52	365	8,760	525,600

Table R4-2 Likelihood and Frequency: Related to Example Likelihood Table in SEMI S10-1296

Likelihood of occurrence	*Range*	*Number of times per year (based on 500 installed tools)*
Frequent	X > 5	Greater than 5 times a year
Likely	1 < X < 5	More once a year, but no more than 5 times a year
Possible	0.2 < X < 1	More once in 5 years, but no more than once a year
Rare	0.1 < X < 0.2	More than once in 10 years, but no more than once in 5 years
Unlikely	0 < X < 0.1	No more than once in 10 years

Table R4-3 Severity numbers (more quantitative)

Severity number		*People (See Note R4-1)*	*Equipment/Facility*	*Property*
	0	No injury	No damage	No damage
Minor	1 (minor)	Scratch/bruise	Non-serious equipment (< 1 hour) or facility damage.	Minor Chemical release requiring only routine cleanup without reporting.
	2	First aid only.	Non-serious equipment (< 8 hour) Facility damage (< 1 hour).	Chemical release requiring only routine cleanup without reporting.
Moderate	4	Minor Medical treatment or restricted work activity (OSHA recordable) (< 1 week) Beginning Repetitive strain injury.	Minor subsystem loss (< 1 day) Facility damage (< 1 shift).	Chemical release triggering external reporting requirements.
	8	Medical treatment or restricted work activity (OSHA recordable). Repetitive strain injury (intensive treatment required).	Subsystem loss (< 1 month) Facility damage (< 1 shift).	
Severe	16	Disabling injury/illness. Repetitive strain injury (permanent restricted work activity).	Major-system loss (between 1 month and 1 Year) Facility damage (1-4 Weeks).	Chemical release with temporary environmental or public health impact.
	32	Disabling injury/illness. (Loss of Limbs/ serious illness)	Total System loss; (> 1 Year) Facility loss (between 1 month and 1 Year).	
Catastrophic	64	One or more fatalities.	Total Facility loss (> 1 year).	Chemical release with lasting environmental or public health impact.

Note R4-1: This number is if 1-2 people are exposed to the risk. The number must be doubled when there are 3 or more people involved.

Table R4-4 Table R4-1 to Table R4-3 related to Appendix 1 Table A3

RISK ASSESSMENT MATRIX		**LIKELIHOOD**				
		FREQUENT (X >5)	LIKELY (1 < X < 5)	POSSIBLE (0.2 < X < 1)	RARE (0.1 < X < 0.2)	UNLIKELY (0 < X < 0.1)
SEVERITY	CATASTROPHIC (≥ 64)					
	SEVERE (8 ≤ x < 64)					
	MODERATE (4 ≤ x < 8)					
	MINOR (1 ≤ x < 4)					

Overall Risk Ranking Categories:

VERY HIGH | HIGH | MEDIUM | LOW | VERY LOW

NOTE 1: The Risk Categories of “Very High” and “Very Low” correspond identically with the Risk Categories, used in previous SEMI documents (e.g., S10-12-96, S2, and S14) of “Critical” and “Slight”. The terms were changed to facilitate translation from English.

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

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SEMI S11-1296
ENVIRONMENTAL, SAFETY, AND HEALTH GUIDELINES FOR SEMICONDUCTOR MANUFACTURING EQUIPMENT MINIENVIRONMENTS

1 Purpose

1.1 These guidelines are intended as a minimum set of performance-based environmental, health, and safety considerations for minienvironments used in semiconductor manufacturing.

1.2 These guidelines are intended to be a supplement to SEMI S2 (see Section 3.1).

2 Scope

2.1 These guidelines apply to minienvironments used in the manufacturing, metrology, assembly, and testing of semiconductor products.

2.2 Equipment enclosed by, or used in conjunction with, the minienvironments is addressed separately by SEMI S2 (see Section 3.1). Examples are process tools and exhaust emissions abatement devices.

2.3 For "integrated minienvironments," only the minienvironment enclosure portion is addressed by these guidelines.

3 Referenced Documents

NOTE: Documents as listed or referenced shall be the latest available.

3.1 *SEMI Documents*

SEMI S2 — Safety Guidelines for Semiconductor Manufacturing Equipment

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

3.2 *NFPA Documents*[1]

NFPA 255 — Standard Method of Test of Surface Burning Characteristics of Building Materials

NFPA 318 — Standard for the Protection of Cleanrooms

3.3 *Other Documents*

ACGIH — Industrial Ventilation - A Manual of Recommended Practice[2]

UL 181 — Standard for Safety Factory-Made Air Ducts and Air Connectors[3]

4 Terminology

4.1 *closed loop air supply* — A system in which air is recirculated from the minienvironment and returned to the minienvironment with minimal make-up air.

4.2 *emergency off (EMO)* — Control circuit which when activated, places the equipment into a safe shut down condition.

4.3 *integrated minienvironment* — The minienvironment that is an integral part of the tool.

4.4 *minienvironment* — A localized environment created by an enclosure to isolate the product from contamination and people.

4.5 *minienvironment end user* — The facility which uses a minienvironment for semiconductor fabrication.

4.6 *minienvironment supplier* — The party that builds, sells, or otherwise provides minienvironment enclosures.

4.7 *tool supplier* — The party that builds, sells, or otherwise provides the tools that are used together with the minienvironments.

5 General Requirements

5.1 *Safety and Health Design Requirements* — Minienvironment manufacturers should consider site-specific design requirements but must not compromise compliance with applicable regulatory requirements. The requirements covered in these guidelines are not all-inclusive. The minienvironment supplier should employ any additional applicable regulatory and industry standards that govern associated components. It is the minienvironment supplier's responsibility to work with the user and tool supplier to understand the local codes and variances.

1 National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269-9101

2 American Conference of Governmental Industrial Hygienists, 6500 Glenway, Building D-7, Cincinnati, OH 45211-4438

3 Underwriters Laboratories Inc., 33 Pfingsten Road, North Brook, IL 60062

5.2 *Environmental Design Requirements*

5.2.1 In order to assess the environmental impact of minienvironments, the minienvironment supplier should provide a listing of materials of construction showing the compatibility with chemical and process materials typically used in the given minienvironment. In the case of "non-typical" chemical and process chemicals, the minienvironment supplier and minienvironment end-user will evaluate the particular materials involved to ensure compatibility. "Nonprocess" chemical wastes (i.e., wastes not in contact with the product such as oil filters, pump oils, etc.) that are generated by routine preventative maintenance should be included.

5.3 Materials of construction should be in conformance with SEMI S2, Section 19.

6 Enclosure Interlocks

6.1 Not all enclosure panels, doors, and hatches require interlocks. There may be cases where the customer requires ports for manual access for product load/unload or tool adjustment without process tool interrupt. The need for interlocks should be assessed. If the overall level of safety is not compromised, interlocks need not be provided.

6.2 Interlocks are required when the minienvironment replaces an interlocked door or panel on the process tool or where the minienvironment provides the primary barrier to operator exposure to chemical, electrical, mechanical, thermal, radiation or other recognized hazards.

7 Chemical and Physical Hazards

7.1 The addition of the minienvironment and its associated components should not compromise equipment safety and health considerations required for conformance with SEMI S2.

7.2 *Shut-off Valves* — Manual shut-off valves for hazardous materials should be clearly visible, labeled, and easily accessible. Access to these valves should not be restricted by any part of the minienvironment.

8 Noise

The addition of a minienvironment system should not cause the noise level to exceed conformance with SEMI S2, Section 9 (see Section 3.1).

9 Ventilation & Exhaust

9.1 Recirculating air ducts, connectors, and ventilation components within the minienvironment, should be constructed of noncombustible material of Class 0 or Class 1 materials as tested in accordance with UL 181, Standard for Safety Factory-Made Air Ducts and Air Connectors.

9.2 Recirculating air duct materials should be compatible with chemical processes used in the given minienvironment; the minienvironment supplier should provide a listing of materials of construction showing the compatibility with chemical and process materials typically used in the given minienvironment. In the case of "non-typical" chemical and process materials, the minienvironment supplier and minienvironment end-user will evaluate the particular materials involved to ensure compatibility.

9.3 Exhaust should not be altered in any fashion to accommodate a process where flammable liquids are used or flammable vapors present. Dampers, where required for balancing or control of the exhaust system, should be of the locking type.

9.4 Primary exhaust and monitoring of the equipment/process enclosed should be incorporated as defined in SEMI S2 (see Section 3.1).

9.5 Minienvironments with a closed loop air supply should control fugitive emissions in accordance with SEMI S2, to prevent the buildup of gases and vapors within the enclosure.

9.6 Ventilation of tools and areas in which hazardous materials are used, should comply with the ACGIH reference in Section 3.2.

10 Electrical

The addition of the minienvironment and associated equipment should be in compliance with SEMI S2 (see Section 3.1).

11 Emergency Shutdown

Emergency off (EMO) buttons should be relocated, or additional EMO buttons installed, if the original EMOs are out of reach or obstructed due to mini-environment installation.

12 Ergonomics/Human Factors

12.1 Ergonomics/human factors should comply with SEMI S8 (see Section 3.1).

12.2 Areas of particular concern for minienvironments include load/unload ports and maintenance accesses. The design should discourage extended reaching, lifting, pulling, and manual orientation of product and/or containers.

13 Seismic Event Design

Minienvironments and associated equipment should be designed in conformance with SEMI S2, Section 17 (see Section 3.1).

14 Fire Suppression

14.1 Whenever possible, non-combustible materials should be used in minienvironment design and construction. Fire detection/suppression should be incorporated based on evaluation of the minienvironment size, materials of construction, the process, equipment enclosed, the facility design, and interaction with the facility fire detection/suppression systems.

14.2 If fire sprinklers are used, they should be the "quick response" (QR) type.

14.3 If the minienvironment prevents personnel exposure to the tool and process, an automatic gaseous fire suppression system may be used as an alternative to sprinklers. Gaseous extinguishing systems should be actuated by optical detectors.

15 Maintenance & Servicing

15.1 *Maintenance and Service Preparation of Minienvironments with Chemical Process Tools* — Exhaust design at the tool should be adequate to prevent the concentration buildup of fugitive vapor emissions in the tool and minienvironment. The exhaust should be maintained during maintenance and service operations even though the enclosure doors are open.

15.2 Hazardous materials should be avoided for service and maintenance requirements.

15.3 Minienvironment panels, doors, and access ports removed for service or maintenance, should be stored in a secure manner that will not permit these parts to fall, obstruct passage ways, or otherwise cause tripping or handling hazards.

SEMI S12-0298
GUIDELINES FOR EQUIPMENT DECONTAMINATION

1 Purpose

1.1 This document establishes guidelines for decontaminating equipment which has been exposed to hazardous materials and which is intended for further productive use. Equipment intended for further productive use may include, but is not limited to, that being offered for reuse, resale, repair, refurbishment, or relocation.

1.2 These guidelines should be adapted at each site with proper consideration given to local, state, national, and international regulations and organization policies.

2 Scope

2.1 These guidelines apply to the preparation for transfer or relocation of equipment which has been exposed to hazardous or toxic materials and may pose a threat to human health or the environment. These activities may include, but are not limited to, shutdown, dismantling, removing, labeling, and packaging prior to transport.

2.2 These guidelines describe minimum requirements for documentation of decontamination and notification of residual hazards associated with decontamination.

2.3 The level of decontamination required for equipment designated for reuse in the same service in the same location may be assessed on a case-by-case basis by the site Environmental, Health, and Safety organization.

2.4 These guidelines are intended to be used to ensure that decontamination prior to transport occurs to the greatest extent possible, while acknowledging practical limitations which may exist in individual circumstances.

3 Referenced Documents

None.

4 Limitations

4.1 These guidelines are not intended to address decontamination requirements for the preparation of equipment for final “end-of-life” disposal.

4.2 These guidelines are not intended to supersede applicable international, governmental, site, or original equipment manufacturer requirements.

5 Terminology

5.1 *decontamination* — The removal of materials in or on equipment.

5.2 *equipment* — Process tools, chemical (liquid or gas) controls and delivery systems, ancillary support systems, structures, piping, ductwork, parts, and subassemblies (e.g., vacuum pumps, pump packages, effluent/exhaust treatment systems).

5.3 *hazardous material* — Any chemical, substance, or compound which is defined or interpreted to pose risks or hazards to human health or the environment by applicable international, national, regional, or local laws or regulations.

5.4 *health hazard* — A chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed persons. Health hazards include chemicals which are carcinogens, toxic or highly toxic materials, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, neurotoxins, agents which act on the hematopoietic system, and agents which damage the lungs, skin, eyes, or mucous membranes.

5.5 *transferor* — The party with physical custody of the equipment and responsibility for transfer.

5.6 *transferee* — The party who will receive physical custody of the equipment.

6 Responsibility

6.1 It is the responsibility of the equipment transferor to ensure the removal or minimization of all hazardous materials associated with the subject equipment prior to transfer or relocation. Hazards not addressed in the guideline may exist, including undissipated electrical charges or mechanical energy. It is recognized that, in many cases, complete chemical decontamination cannot be achieved without destruction of the equipment. The equipment transferor should ensure that *all* known remaining potential hazards are clearly identified to the transferee.

6.2 It is the responsibility of the equipment transferor to ensure residues, waste materials, and scrap parts/ equipment that are generated as part of the equipment decontamination process are safely handled and appropriately disposed of as per local, state, national, and international regulations or standards.

7 Personnel Safety

7.1 Assessment and decontamination procedures should be performed only by properly trained and equipped personnel.

7.2 Any specific procedures used to follow these guidelines should be pre-approved by the site environmental, health, and safety organization prior to decontamination activities.

7.3 Assessment and decontamination procedures should include requirements for appropriate personal protective equipment.

8 Equipment Assessment Prior to Decontamination

8.1 An assessment should be performed on all equipment prior to transfer. Assessment of equipment should initially consider history of the equipment and visual inspection. If initial assessment shows a potential for equipment to have contacted hazardous materials during the life of the equipment, further assessment needs to be performed. (See the flowchart in Figure 1.)

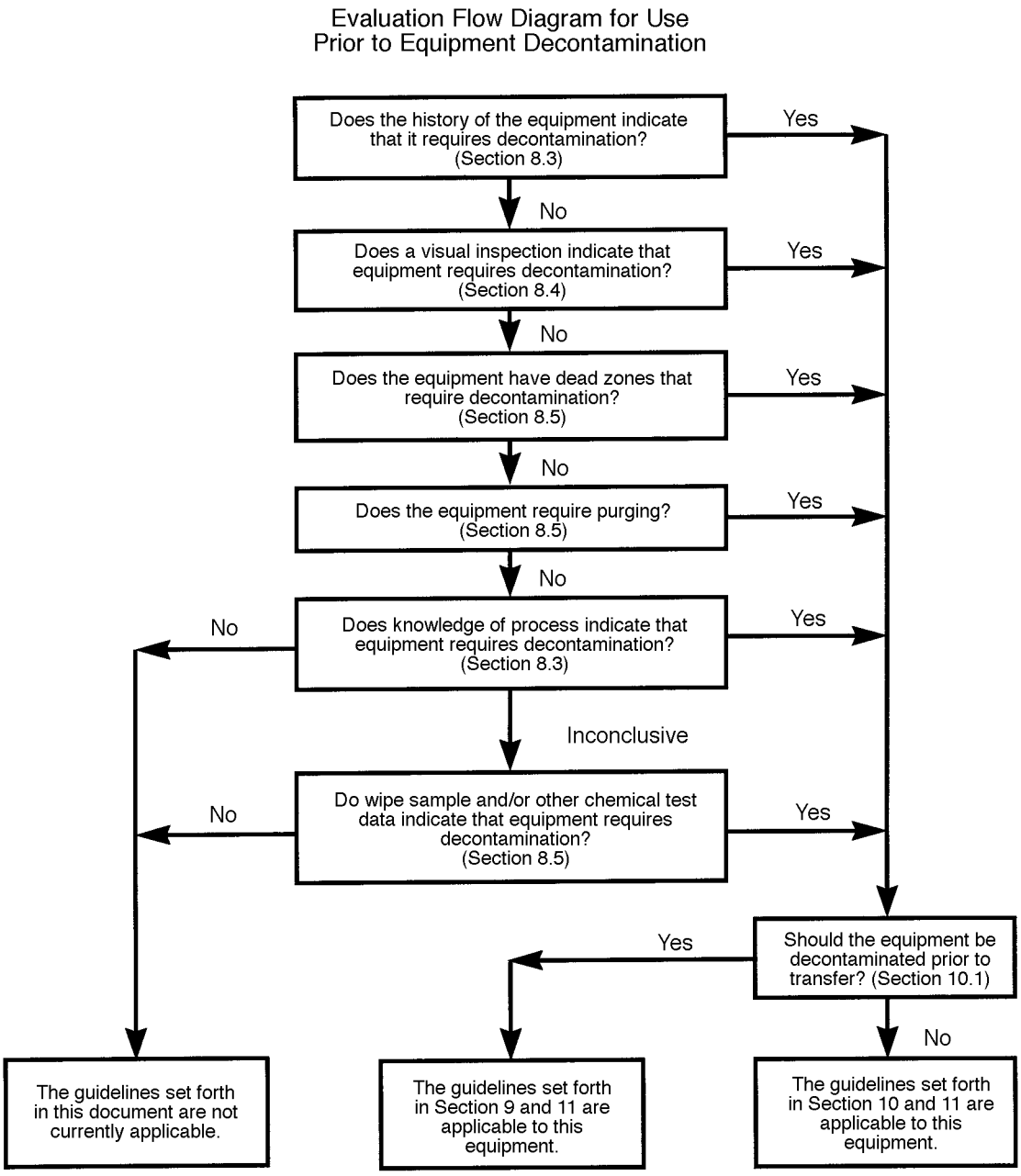

Figure 1
Equipment Assessment Flowchart

8.2 Prior to decontamination, the equipment should be evaluated for abnormalities or non-functionality that may affect the evaluation and decontamination efforts.

8.3 Decontamination should be performed on all areas of equipment which had potentially contacted hazardous materials during the life of the equipment, unless the areas are judged non-hazardous by the criteria set forth in this section. The areas to be decontaminated include external surfaces, internal areas which are accessible without disassembly, and areas accessible during normal operations. Normally inaccessible areas should be addressed on a case-by-case basis by the site Environmental, Health, and Safety organization. Normally removable parts may also require cleaning.

8.4 Visible residues on equipment surfaces, including liquids, powders, flakes, or films, potentially indicate the presence of hazardous materials. All visible indicators of hazardous materials should be assumed to be hazardous unless otherwise determined and documented by appropriate test, analysis, or evaluation.

8.5 Wipe sampling and chemical testing verifying the absence of materials posing physical and health hazards is recommended for all equipment that has been exposed to hazardous materials (regardless of the presence of visible residues).

8.5.1 It is recommended that professional guidance be used to determine the number, type, and location of samples that should be taken. *General guidance is available through air sampling strategy methodologies developed by NIOSH (Occupational Exposures Sampling Strategies) and through surface sampling strategies developed by the Nuclear Regulatory Commission (Manual for Conducting Radiological Surveys in Support of License Termination).*

8.6 If results of activities in Sections 8.2–8.5 indicate that equipment should be decontaminated prior to transfer, refer to Section 9 of this document. If results of activities in Sections 8.2–8.5 indicate that equipment requires decontamination but will not or cannot be decontaminated prior to transfer, see Section 10. If results of activities in Sections 8.2–8.5 indicate that equipment does not require decontamination prior to transfer, this guideline is not currently applicable to the equipment in its present state.

9 General Guidelines for Decontamination

9.1 All activity-specific safety and health procedures, including, but not limited to, hazardous energy control procedures, must be followed.

9.2 Equipment should be decontaminated before movement. If movement of the equipment is required prior to decontamination, precautions should be taken to remove potential sources of leakage, spillage, offgassing, or hazardous material emissions. These precautions may include draining, purging, and then the use of appropriate barriers, covers, or containment devices.

9.3 Chemical supply sources should be made safe prior to disconnecting or removal from the equipment and capped prior to the beginning of the cleaning process. Exhaust ventilation to control exposures to, and the spread of, airborne particulate should remain in service during equipment decontamination, or alternate exhaust provisions should be made.

9.4 Where equipment parts are routinely removed from the equipment for cleaning, such as those used in ion implanters, photoresist spinners/developers, and metal deposition chambers, these parts should be cleaned prior to equipment transfer.

9.5 Where equipment parts are routinely removed and replaced, such as filters, O-rings, or oil traps, these parts should be removed and replaced with clean parts or appropriate blanking device prior to equipment transfer. If any such parts are removed but not replaced, this fact should be noted on decontamination documentation (see Section 12 of this guideline).

9.6 All liquid and gas lines on the equipment should be appropriately purged, drained, protected against corrosion and process contamination, and securely sealed with blanking plugs, caps, or similar devices.

9.7 Thorough decontamination may not be achieved within component systems or equipment due to inaccessibility (i.e., “dead zone”) or to physical characteristics of materials. Equipment with such zones require additional cycle purges and/or disassembly for access and proper cleaning. If complete decontamination cannot be achieved, follow the guidelines outlined in Section 11.

9.8 While disconnecting equipment or removing components, gas leak monitoring and pH levels should be measured.

10 Requirements for Equipment Transfers without Complete Decontamination

10.1 It is recognized that, in some cases, complete chemical decontamination cannot or will not be desired or achieved for various reasons (e.g., it will destroy the equipment (i.e., pumps), there is a need for failure analysis). This section establishes guidelines for the transfer of equipment intended for further productive use which cannot or will not be completely decontaminated prior to transfer.

10.2 If the contaminated equipment is a sub-component or subassembly of a larger piece of equipment which will not be otherwise decontaminated, the contaminated sub-component or subassembly should be removed and transferred separately under the requirements of this section.

10.3 Prior to transfer, the transferor must ensure that any remaining potential hazards are clearly identified to persons handling, transporting, and receiving this equipment, as specified in Section 11. All requirements in Section 11 must be followed, with the exception of Section 11.3.2.

10.4 Prior approval must be obtained before transfer of contaminated equipment. Prior approval should consist of receipt of all documentation and certifications specified in Section 11 before shipment

and a signed authorization from the receiver to accept the equipment.

10.5 Equipment which is not completely decontaminated is potentially a hazardous material. Transfer of this equipment, including transportation, must be in accordance with all applicable local, state, national, and international regulations and organization policies.

11 Documentation and Certifications

11.1 The documentation recommended by this guideline is in addition to that required by local, state, national, and international regulations.

11.2 Documentation and certifications should be securely attached in a clear, weatherproof bag and transported with the equipment.

11.3 The following documentation and certifications should be prepared prior to transfer of equipment:

11.3.1 A history of all hazardous materials used in the equipment and potential by-products, including concentrations, if known. At a minimum, list the hazardous materials used in the tool just prior to decontamination or transfer.

11.3.2 Documentation of the procedure used for decontaminating the equipment, including:

11.3.2.1 the cleaning procedures used (including chemicals used for cleaning),

11.3.2.2 liquid or gas purge procedure used,

11.3.2.3 testing procedure used to determine adequacy of decontamination,

11.3.2.4 results of tests, and

11.3.2.5 other significant information pertinent to the decontamination activities, including parts removed for separate decontamination.

11.3.3 When it is likely that hazardous material residues remain in or on the equipment, a warning must accompany the equipment. The warning should identify suspected hazards, state appropriate personal protective equipment that should be worn, and precautions that should be taken when handling the equipment.

11.3.4 Documentation should include the name and phone number of the responsible/knowledgeable parties in case of emergency or requirements for additional information.

11.3.5 A certification by a responsible site environmental, health, and safety representative that states the equipment has been prepared for transfer according to this guideline.

12 Related Documents

12.1 *SEMI Documents*

SEMI S2 — Safety Guidelines for Semiconductor Manufacturing Equipment

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

SEMI S9 — Electrical Test Methods for Semiconductor Manufacturing Equipment

12.2 *EPA Documents*

US EPA (Environmental Protection Agency) — EPA's "Guide for Decontaminating Buildings, Structures, and Equipment at Superfund Sites," EPA/600/2-85/028, March 1985, Superintendent of Documents, US Government Printing Office, Washington, D.C. 20402

US EPA — "Chain of Custody Procedures," EPA/SW-846, Superintendent of Documents, US Government Printing Office, Washington, D.C. 20402

US EPA — Asbestos in Air Sampling, 40 CFR 763, Subpart E, Appendix A, Federal Register

US EPA — TEST METHODS FOR EVALUATING SOLID WASTES, EPA SW-846, Superintendent of Documents, US Government Printing Office, Washington, D.C. 20402

US EPA — INTEGRATED RISK INFORMATION SYSTEM, 1994, Superintendent of Documents, US Government Printing Office, Washington, D.C. 20402

US EPA — EXPOSURE FACTORS HANDBOOK, 1989, Superintendent of Documents, US Government Printing Office, Washington, D.C. 20402

12.3 *OSHA Documents*

CFR 1910.1200 — Hazard Communication Standard – Title 29, Federal Register, US Government Printing Office, Washington, D.C. 20402

OSHA (Occupational Safety and Health Administration), U.S. Department of Labor — OSHA TECHNICAL MANUAL, CPL 2 - 2.20B, Chapter 2, Sampling for Surface Contamination, February 5, 1990, Superintendent of Documents, US Government Printing Office, Washington, D.C. 20402

OSHA (Occupational Safety and Health Administration), U.S. Department of Labor — OSHA's CHEMICAL SAMPLING INFORMATION, Directorate of Technical Support, Salt Lake City Technical Center, Superintendent of Documents, US Government Printing Office, Washington, D.C. 20402

12.4 *Other Related Documents*

BOCA — National Fire Prevention Code published by Building Officials and Code Administration

CCR 5215(c)(2)(C) — Cal/OSHA's 4,4' — methylenebis (2-chloroaniline), MBOCAA, Barclays Law Publications, P.O. Box 3066, South San Francisco, CA 94083-3066

NIOSH (National Institute of Occupational Safety and Health), U.S. Department of Health and Human Services, CDC, Public Health Service — NIOSH's STATISTICAL SAMPLING STRATEGIES, Document #77-173, NTIS - PB 274792, Superintendent of Documents, US Government Printing Office, Washington, D.C. 20402

NIOSH (National Institute of Occupational Safety and Health), U.S. Department of Health and Human Services, CDC, Public Health Service — NIOSH's MANUAL OF ANALYTICAL METHODS, 3rd Ed., Superintendent of Documents, US Government Printing Office, Washington, D.C. 20402

SBCCI — Standard Fire Prevention Code published by Southern Building Code Conference International, Inc.

UFC (Uniform Fire Code) — Uniform Fire Code published by International Conference of Building Officials and Western Fire Chiefs Association, 5360 South Workman Mill Road, Whittier, CA 90601

US Nuclear Regulatory Commission — MANUAL FOR CONDUCTING RADIOLOGICAL SURVEYS IN SUPPORT OF LICENSE TERMINATION, NUREG/CR-5849, ORAU-92/C57, June 1992

RELATED INFORMATION 1
EXAMPLES OF WIPE SAMPLING PROCEDURES

NOTE: This related information is not an official part of SEMI S12 and is not intended to modify or supersede the official standard. It has been derived from the work of the originating task force. Publication was authorized by full ballot procedures. Determination of the suitability of the material is solely the responsibility of the user.

Wipe sampling should be conducted primarily on nonporous surfaces. "Wet" (swab or filter paper with solvent) or "dry" (swab or filter paper without solvent) wipe sampling techniques may be used. These procedures are based on those contained in the US EPA's "Guide for Decontaminating Buildings, Structures, and Equipment at Superfund Sites," EPA/600/2-85/028, March, 1985. The sample area has been decreased in the wet wipe sampling procedure from 0.25 m^2 to 100 cm^2 (0.01 m^2) due to the size of equipment and surfaces anticipated to be sampled for this SEMI Guideline. *Another relevant document on sampling for surface contamination is contained in the OSHA - Occupational Safety and Health Administration, U.S. Department of Labor, OSHA TECHNICAL MANUAL, CPL 2 - 2.20B, Chapter 2, Sampling for Surface Contamination, February 5, 1990*. Chemical-resistant gloves should be worn while performing these procedures. Gloves should be clean to avoid tainting the samples obtained and should be changed between the securing of samples to avoid cross-contamination.

R1-1 General Recommendations

R1-1.1 Assure that the marking method for the sample container and area to be wiped will not interfere with the intended analysis.

R1-1.2 Assure that the container will not absorb the material being sampled or add interfering material that will be detected during analyses.

R1-1.3 Assure that the wetting agent will not react with the material being sampled, interfere with the analysis, or degrade the shipping container.

R1-1.4 Should it become necessary to swipe an area other than 100 cm^2 (e.g., a lever or knob or other part of a tool), then record the estimated or, preferably, measured swipe area.

R1-1.5 Submit a blank with each batch of swipe samples. The blank is a sampling device (such as a swipe tab) of the same type and from the same batch as that used for the sampling and which is wetted and handled just like the samples, but which is not rubbed on a surface.

R1-1.6 Use appropriate personal protective equipment during sampling.

R1-1.7 Samples should be analyzed by a competent and appropriately certified laboratory for the hazardous materials being evaluated.

R1-1.8 The *sampling* and *analytical* methods used should be *appropriate for the agent in question, with the NIOSH Manual of Analytical Methods, EPA's Test Methods for Evaluation of Solid Wastes (EPA SW-846), and OSHA's Sampling and Analytical Methods being established methodologies*. *If new methods are to be* developed or reviewed, *they should be* approved by an industrial hygienist certified by the American Board of Industrial Hygiene or by another appropriately certified or registered professional.

R1-2 Wet Wipe Sampling Procedure

R1-2.1 Mark off a square area of approximately 100 cm^2 on the surface to be wiped, using a template which is cleaned between each sampling event. If a template is unavailable or the area to be wiped is less than 100 cm^2, note the exact dimensions and establish markings on the four outer corners of the area to be wiped.

R1-2.2 Label the appropriate wet sample container with the information listed in R1-1.5.

R1-2.3 Hold a filter paper with a clean, *impervious*, gloved hand or metal clamp, and saturate the wipe with either deionized water, isopropyl alcohol, *or other wetting* agent, depending on the *hazardous material* to be sampled.

R1-2.4 Wipe the sampling area starting at the outside edge and progressing toward the center, making concentric circles of decreasing size, applying moderate pressure. Fold the wipe sample with the exposed side in, and fold it over again.

R1-2.5 Carefully place the completed wipe sample in the container for storage and transportation, without allowing the sample to contact any other surfaces.

R1-3 Dry Wipe Sampling Procedure

R1-3.1 Label the appropriate dry sample container with the information listed in R1-1.5.

R1-3.2 Hold a filter paper wipe with a clean, impervious, gloved hand.

R1-3.3 Wipe the sampling area, starting at the outside edge and progressing toward the center, making concentric circles of decreasing size, applying

maximum pressure. Fold the wipe sample with the exposed side in, and fold it over again.

R1-3.4 Label a glass-stoppered jar or zipper-closure plastic bag with the information listed in R1-1.5.

R1-3.5 Carefully place the completed wipe sample in the container for storage and transportation without allowing the sample to contact any other surfaces.

R1-4 Scrape and Bulk Sampling

NOTE: A scrape sample is one made by abrading material and collecting it in a container which is sent to a laboratory for analysis. Scrape sampling might be done to assure lead and hexavalent chromium are not present in paint on the exterior of a tool. Bulk sampling requires the collection of *adequate amounts of the suspected material to allow for meeting minimum detection limits of the sampling and analytical techniques being used. Close consultation is needed with the accredited laboratory performing the analysis.*

R1-5 Sample Control

R1-5.1 Label each sample container with the following information before sampling:

- Sample Number
- Sample Location (where was sample taken from)
- Sample Type *and Media Used*
- Date of Sample
- Name of Person Performing Sampling
- Areas Sampled (in cm^2)

R1-5.2 Record each sampling event in a log book. Include a rough sketch of the equipment, associated areas of concern, and exact sampling locations. Also include any other pertinent notes or details which may affect the interpretation of sample results.

R1-5.3 Follow the chain of custody procedures outlined in EPA SW-846.

R1-5.4 Analyze samples using standard methods, such as those specified by *NIOSH*, *OSHA* or *EPA* SW-846, whenever possible. (See Section R1-1.8 for additional details.)

RELATED INFORMATION 2
EXAMPLE OF METHOD FOR ESTABLISHING "NON-HAZARDOUS" LEVELS

NOTE: This related information is not an official part of SEMI S12 and is not intended to modify or supersede the official standard. It has been derived from the work of the originating task force. Publication was authorized by full ballot procedures. Determination of the suitability of the material is solely the responsibility of the user.

This method was compiled from various sources. The applicability of this method and the validity of its assumptions in the application for which it is considered must be determined by an appropriate professional.

R2-1 Method 1

This method is designed to be protective of the health and safety of untrained and unprotected individuals. In this method, "non-hazardous" level is determined by assessment of the risk posed by potential exposure to the contaminant(s). (This method is based on the assumptions that 1) the exposed portions of a worker's body collect a single layer of the contaminant, with a density half that of the layer on the contaminated surface, in the course of a day and that 2) this contaminant is then incorporated, at the end of the day, into the body by either absorption or ingestion.) This method is, therefore, probably inappropriate for contaminants which are absorbed rapidly throughout the day.

R2-1.1 Toxicity criteria are determined for each of the chemicals identified as potentially leaving a residue. As an example, toxicity criteria used are reference doses (RfDs) for human uptake of chemicals (US EPA's Integrated Risk Information System, 1996), and no significant risk levels (NSRLs) defined under California's Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65). Daily exposures to the RfD (expressed in mg/kg-day) over a lifetime are not expected to cause adverse health effects (non-cancer effects). Daily exposure to the NSRL (µg/day) over a lifetime are considered to pose an insignificant (less than 1 in 100,000) increased cancer or reproductive risk.

R2-1.2 Oral and dermal exposures are considered. Dermal exposure is assumed to occur through direct contact with contaminated work *surfaces* (i.e., hands, arms, and face). Oral exposure is assumed to occur though *direct* contact with *contaminated work surfaces and* hands, and subsequent contact between hand and mouth.

R2-1.3 The equations used in this method to calculate the oral and dermal "Health-Based Cleanup Levels (HBCL's)" are:

$$HBCL_{oral} = \frac{RfD \times BW}{SA_O \times MF \times CE \times AF_O \times EF}$$

$$HBCL_{dermal} = \frac{RfD \times BW \times ED}{SA_d \times CE \times AF_d \times EF}$$

Where :

RfD = EPA RfD [mg/kg – day]

BW = Body weight [70 kg]

ED = Exposure duration [0.5 days]

SA_O = Surface area of exposed hands [0.084 m^2]

SA_d = Surface area of exposed hands, forearms, and head [0.316 m^2]

MF = Fraction of exposed dermal are contacted by mouth [0.5/day]

CE = Skin contact efficiency [0.5]

AF_O = Gastro - intestinal absorption factor [1.0] (conservative)

AF_d = Dermal absorption factor [0.01]

EF = Exposure factor [12 hours/24 hours; 250 days/365 days; 40 years/70 years = 0.20]

Body weight and surface area factors are as suggested by EPA's *Exposure Factors Handbook* (1989). The fraction of skin contaminant that will be ingested orally (MF) is conservatively assumed to be 50%. This is approximately equivalent to a person ingesting all of the chemical that contacts the palms of the hands, but not the backs. Contact efficiency (CE) refers to the fraction of chemical that is removed from the contaminated surface through contact with the skin. It is assumed that no more than 50% of the chemical contamination from equipment will rub off the surface and adhere to the skin. Oral and dermal absorption factors are chosen as the most conservative numbers due to limited available data.

The exposure factor (EF) represents the fraction of time that a person could be expected to be in contact with chemical contamination from exposed surfaces. Exposure to surfaces is assumed to follow an occupational exposure scenario. This scenario includes the following conservative assumptions:

- A person works at the facility for 40 years of a 70-year lifetime;
- Exposure occurs 250 days per year (365 days);
- The skin is in contact with the chemicals for 12 hours per day. This assumes that the chemicals are not removed from the skin until washed, and the skin is washed only once per day.

R2-1.4 The final HBCL for each chemical is then the lower of the levels for oral or dermal exposure routes.

NOTE: These HBCLs represent levels that are considered to be health-protective for a person who contacts equipment with residual contamination on a daily basis. These values are based on extremely conservative assumptions and are likely to provide an overestimate of a health-protective clean-up level.