



SEMI S2-93

SAFETY GUIDELINES FOR SEMICONDUCTOR MANUFACTURING EQUIPMENT

NOTICE: These safety guidelines do not purport to address all of the safety issues associated with their use. It is the responsibility of the users of these guidelines to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

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

NOTE: This entire document was revised in 1993.

1. Purpose

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

2. Scope

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

This document contains the following:

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3. Safety Philosophy

3.1 Few safety standards exist that specifically address the design and construction of process equipment used in

the manufacturing of semiconductors. Because of the expense and disruptive effects of safely retro-fitting equipment, these guidelines should be used, during design and construction of process equipment, to help eliminate known safety and health hazards inherent in operation and maintenance. Industry standards, building, electrical and fire codes, government regulatory requirements, and good practice should be considered in all equipment development programs.

3.2 The safety philosophy set forth in these guidelines is that potential hazards in the operation and maintenance of equipment be identified and engineered out of equipment during the design and construction phases. Where identified hazards cannot be eliminated, no single point failure or operational error should allow immediate exposure of personnel, facilities or community to hazards or directly result in injury, death or equipment loss. All equipment should be fail-safe or of a fault-tolerant design.

3.3 These guidelines define the minimum safety considerations for semiconductor manufacturing equipment. The areas of concern in the operation and maintenance of equipment are:

- Chemical hazards
- Radiation hazards
- Electrical hazards
- Physical hazards
- Mechanical hazards
- Environmental hazards
- Fire and explosions
- Seismic activity hazards
- Ventilation
- Ergonomics

4. General Guidelines

This section describes the general safety guidelines for all semiconductor manufacturing process and test equipment.



4.1 Equipment should meet these general safety criteria. These guidelines should be incorporated by reference in all standard equipment purchase specifications (rather than rewriting the guideline for each piece of equipment). The intent is for the end user to buy a safe design, not design the equipment. The user and supplier should document when it is necessary to deviate from these guidelines.

4.2 The design of the completed equipment and its options should be examined and a risk analysis performed and documented by a qualified product-safety professional or other qualified engineering/technical professional. The risk analysis and documentation should be issued in the form of a report no later than 30 days prior to system shipment. This report should state that the equipment, including its components and sub-assemblies, conforms to applicable laws, regulations, and codes in effect at the time of purchase, and to the guidelines presented here or other applicable product safety standards. An independent laboratory or product safety consulting firm may be commissioned to supply additional testing, listings, or evaluations of conformance to this document.

EXCEPTIONS: All hazards that cannot be engineered out of the product should be clearly identified and controlled to reduce personnel exposure and/or property damage. These hazards should be addressed specifically in the product operations and maintenance manual or in an accompanying notice. The manufacturer should continue to work to eliminate these hazards.

4.3 The equipment manufacturer should ensure that its equipment complies with laws and codes which are in effect at the time of purchase. All equipment requiring certification or approval by government agencies should have this certification or approval noted on the equipment or in the manuals as required by regulations.

4.4 The equipment manufacturer should maintain a program of quality assurance along with a safety, health and environmental program to identify, correct, and inform the end user of potential hazards. Notification should be directed to the end user's equipment engineer, environmental health and safety officer, and purchasing agent.

4.5 No single point failure or equipment operational error should allow exposure of personnel, facilities or community to hazards or directly result in injury, death or equipment loss.

4.6 The equipment manufacturer should consider the type and quantity of hazardous process materials that may be used in the operation and maintenance of its equipment. The manufacturer should strive to avoid or minimize hazardous material use. If the end user's specific

process chemistry is not defined, the equipment manufacturer's baseline process may be used for evaluation purposes.

4.7 Equipment manufacturers who do not have an established and active product safety program and a comprehensive understanding of safety standards should obtain the services of a product safety professional during the development of the equipment.

5. Safety-Related Interlocks

5.1 All equipment should use fail-safe hardware safety interlocks to protect against hazards inherent in the operation of the equipment. Hardware safety interlocks should back up the equipment's operating system to ensure that, upon activation, the equipment is brought to a safe standby condition automatically and the operator alerted immediately. The operator notification should provide an explanation of the cause.

5.2 The safety interlock scheme should be designed to minimize the need to override automatic fail-safe safety interlock systems during maintenance activities. Safety interlocks in conjunction with physical barriers that operate at the point of the hazard are preferred (for example, a safety interlocked cover over a laser beam). When access to hazards that cannot be eliminated is required during maintenance, defeatable safety interlocks should be provided. Upon exiting the maintenance mode all safety interlocks should be automatically restored.

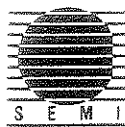
5.3 Each type of safety interlock and its operation should be fully explained in the operations and maintenance manuals.

5.4 Equipment using greater than 30 volts RMS or 42.2 volts peak, rf power, hazardous chemicals, lasers, and uv light, as well as radiation generating equipment should be provided with physical barriers (labeled as to the hazards they protect) or safety interlocks, at the point of hazard, which effectively protect from personnel exposure. If the physical barrier does not require a tool to obtain access, the interlock is mandatory.

5.5 All equipment using hazardous gas requiring detection should be able to interface with gas monitoring equipment. The output from gas monitoring equipment should initiate automatic shutdown of gas flows and place the equipment in a safe state.

5.6 When triggered, safety interlocks should place the point of hazard area in a safe state.

5.7 When triggered, each affected safety interlock should require individual manual reset or restart before the equipment function can be restored.



5.8 Computer hardware failure should automatically place the equipment in a safe standby mode. Software safety interlocks should be backed up by hardware safety interlocks in all cases.

6. Chemicals

6.1 Operation and maintenance manuals should contain descriptions or diagrams of potential key failure points and trouble spots in equipment that use hazardous process materials or contain hazardous by-products. Text should be highlighted with such words as CAUTION, WARNING or DANGER. (The use of these words should conform to the requirements of 29 CFR 1910.144-147 [OSHA] and ANSI Standard Z535.)

6.2 Equipment that uses hazardous production materials requiring detection based on regulations (such as federal, state, and local codes) should have sample points mounted in the equipment, or have recommended sampling points identified in the product literature. The equipment should be able to interface with an external monitoring device and shut down the supply of the hazardous process materials.

6.3 Equipment manufacturers should strive to use only compatible process chemicals in a single piece of equipment. If incompatible materials are present, a single device should not be the sole means of preventing their undesired mixing.

6.4 The equipment manufacturer should characterize process by-products and exhaust effluent and provide pertinent information necessary to address the best method of handling process by-products and exhaust effluent by the end user. This includes in line filtration, recirculation traps and pump oils which are part of the equipment. (For additional information, see SEMI F5.)

6.5 Components used in systems designed to contain hazardous production materials under pressure should be rated for the service in which they are used. Mechanical connections are to be enclosed in such a way as to prevent exposure of personnel should a leak occur. (For additional information, see UFC Article 51.)

6.6 If normal maintenance activities expose personnel to chemicals, or process by-products, typical exposure levels and compound types should be available to end user.

6.7 A warning label should be placed at all chemical enclosure maintenance openings that reads "Warning: Hazardous chemicals located within this enclosure."

7. Ionizing Radiation

7.1 Ionizing radiation emissions during operation and maintenance activities should be limited to the lowest practical level. Shielding, safety interlocks, and other

safeguards should be used to ensure the lowest practical leakage level. Under normal operating conditions the equipment should meet or exceed all requirements of OSHA, 29 CFR 1910, NRC, and the FDA, 21 CFR 1000 through 1050 or local regulations, whichever is most stringent.

7.2 Suppliers of radiation producing equipment should be registered with the NRC and the state (if an agreement state). If required by government regulations, documentation stating the type of ionizing radiation and levels of external radiation from the equipment at time of manufacture should be furnished to the user. (For additional information, see 29 CFR 1910.96.) Documentation that provides a performance guarantee may be submitted by the supplier, if based on established ratings for the same type of equipment and allowed by regulations.

7.3 Where supplemental administrative controls are needed to limit radiation exposures, these procedures should be described in detail in the supplier's operation and maintenance manuals.

7.4 All point-of-hazard panels and shields, when removed or accessed, should be safety interlocked to prevent operation of x-ray sources or exposures of personnel to sealed radioactive sources. These interlocks, by design, should not be defeatable.

7.5 Labeling of radiation-producing equipment should be provided by the equipment manufacturer or supplier in accordance with 21 CFR 1020.40, NRC Part 20, 29 CFR 1910 or state and local regulations, whichever is most stringent.

8. Non-ionizing Radiation

8.1 During operation or maintenance activities, exposure to non-ionizing radiation and fields (ranging from static electric and magnetic fields through ultra-violet radiation, including: ultraviolet, infrared, visible light, radio frequency, laser, and microwave), should be limited to the lowest practical level and should not exceed applicable standards or guidelines. Shielding, safety interlocks, and other safeguards should be used to ensure the lowest practical leakage level. The equipment design should minimize potential non-ionizing radiation exposure to persons performing routine operations, maintenance and service procedures. Under no circumstances should non-ionizing radiation levels exceed the maximum permissible exposure in the areas occupied by personnel. (For additional information, see ANSI Z-136.1 and C95.1 or OSHA 29 CFR 1046.10.)

8.2 Documentation showing the frequency/wavelength and the energy level of non-ionizing radiation from the equipment and its fields should be available to the user for all portions of the equipment that contains sources of



non-ionizing radiation. (For additional information, see ANSI Z-136.1 and C95.1.)

8.3 Where supplemental administrative controls are needed to limit the non-ionizing radiation exposures, these procedures should be described in detail in the supplier's operation and maintenance manuals. A description of supplemental monitoring and alarms should also be required.

8.4 All equipment should conform with requirements of the FDA-CDRH. (For additional information, see Center for Device and Radiological Health, 21 CFR 1000 through 1050.)

8.5 All point-of-hazard panels and shields should be rigidly affixed and require a tool for removal and be labeled as outlined by the preceding standards.

8.6 Removable shielding or filtering material (such as film shielding used on windows) should be designed or arranged to prevent reverse or faulty installation and labeled as outlined by ANSI Z-136.1, and C95.1, and Center for Device and Radiological Health, 21 CFR 1000 through 1050.

9. Audio Noise

9.1 The equipment should be designed to operate at the lowest practical dB(A) level but in no case greater than 80 dB(A). (For additional information, see 29 CFR 1910.95.) Test results indicating conformance to requirements should be available to the equipment user upon request.

9.2 Noise level tests, where required, should be conducted at the supplier's location or in an appropriate test room. The measurement technique should be ANSI S1.13 (R1976), Acoustical Society of America STD 4 (ANSI S3.17), or ANSI S1.4. The application should be checked with the ACGIH requirements.

EXCEPTION: In lieu of an actual noise-level test report on the equipment being quoted, an alternative performance guarantee may be submitted if based on established noise ratings for the same type of equipment.

10. Ventilation and Exhaust

10.1 Ventilation enclosures should be designed and test validated for efficient and safe control of chemical emissions during routine operation and maintenance, and during the failure of other control systems. These systems should optimize the use of air flow, as far as practical, directing escaping chemicals so they do not impinge on the equipment. These means should be based on application-specific design principles as specified in the ACGIH *Industrial Ventilation - A Manual of Recommended Practice*, OSHA regulations, 29 CFR 1910, SEMI S6 for

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ventilation, or the model mechanical codes applicable at the site of installation.

10.2 Equipment that uses hazardous materials or that generates hazardous chemical by-products should be designed to use local exhaust ventilation as the primary safety control. Exhaust loads that require continuous flow external treatment should be minimized. Supplementary exhaust to support maintenance should be used where appropriate to reduce the continuous exhaust requirements for the equipment.

10.3 Equipment that uses process materials with an NFPA 704 hazard rating in health, flammability or reactivity of 3 or 4, should place non-welded connections handling such materials in an exhausted enclosure. The equipment supplier should document when external exhaust is required and specify the requirements.

10.4 Secondary enclosure and exhaust systems for gas plumbing should be designed to ensure that a "realistic worst case" leak will be contained or captured.

10.5 During equipment development, the supplier should conduct testing to demonstrate conformance with these criteria. Documentation should be provided showing that the exhaust flow rates were determined by practical application testing. Tracer gas analysis, as described in SEMI F15, is the preferred testing method.

10.5.1 The goal is zero leakage, and under normal operating conditions should not exceed 1% of ACGIH recommended TLV, PEL, or the lower detectable limit.

10.5.2 The secondary containment should control emissions into the work room air to less than 25% of ACGIH recommended TLV or PEL during a delivery system failure.

10.5.3 Emissions from the equipment into the work area should not exceed 25% of TLV or PEL during maintenance activities.

10.5.4 Any measurements of airborne concentrations in the work areas should be made using recognized methods with documented sensitivities and accuracy established by NIOSH, or other nationally recognized standard or test procedures.

10.6 The size of the enclosure, the removable panels, and the openings should be minimized.

10.7 The equipment supplier should specify static pressure, volumetric flow rate, the location where exhaust measurements should be made, and the duct material requirements for the user's exhaust systems.

10.8 The equipment supplier should specify exhaust flow rates and differentiate among the types of exhaust re-



quired for various applications (heat, scrubbed, solvent, pyrophoric, etc.).

10.9 Exhaust flow interlocks should be provided by the equipment manufacturer (but the actual exhaust system is part of the facilities and its monitoring system should be supplied by the end user) on all equipment that use hazardous process materials. When the exhaust falls below the prescribed set point a visual and audible alarm should be provided in visual and audible range of the operator, and the process equipment should be placed in a safe stand-by mode.

11. Electrical

11.1 *Energized Electrical Work ("Hot Work")* - The supplier should design the equipment to minimize the need to conduct calibration, testing, or maintenance on equipments that may be energized and to minimize work that must be performed on components near exposed energized circuits. The supplier is expected to move as many tasks as possible from the "Hot Work" categories type 3, 4, and 5 to type 1 or 2. This can be accomplished through such hardware changes as remote safe testing points for high-voltage measurements. Work in types 3, 4, and 5 should have specific written instructions in the maintenance manuals.

The following are the five types of energized electrical work:

Type 1 - Equipment is fully de-energized (electrically "cold").

Type 2 - Equipment is energized. Live circuits are covered or insulated. Work is performed at a remote location to preclude accidental shock.

Type 3 - Equipment is energized. Live circuits are exposed and accidental contact is possible. Potential exposures are less than 30 volts RMS, 42.2 volts peak, 240 volt-amps, and 20 Joules. (See NFPA 79-14.3, IEC 204, UL 1950 & 1262, IEC 950.)

Type 4 - Equipment is energized. Live circuits are exposed and accidental contact is possible. Voltage potentials are greater than 30 volts RMS, 42.2 volts peak, 240 volt-amps, 20 Joules, or radio frequency (rf) is present.

Type 5 - Equipment is energized and measurements and adjustment require physical entry into the equipment, or equipment configuration will not allow the use of clamp-on probes.

The supplier should list type 3 or higher electrical hazard tasks by their type (as defined in Section 10.1) in its equipment operation and maintenance manuals.

11.2 Equipment should be provided with means to allow the user to comply with OSHA 29 CFR 1910.147 (Control of Hazardous Energies, Lockout/Tagout) and 29 CFR 1910.331-335 (Electrical Safety-Related Work Practices) as related to lockout/tagout. Recommended lockout/tagout procedures should be supplied and installation instructions for user supplied lockout devices provided as part of the maintenance/installation instructions.

11.3 *Electrical Design* - The supplier should meet the following electrical design guidelines. (See NFPA 79 for specific detail of design.)

11.3.1 The equipment manufacturer should provide non-conductive and/or grounded conductive physical barriers on all areas where exposed circuits are greater than 30 volts RMS or 42.4 volts peak. Barriers concealing hazards should be labeled identifying the hazards concealed. Visual hazard alerts should be in accordance with SEMI S1-90, ANSI Z535, or an equivalent.

11.3.2 The equipment design should minimize the probability of electrical shock during maintenance, repair, modification, calibration, or adjustment. Exposed energized circuits, components, and terminal strips should have removable non-conductive and non-combustible covers to protect personnel from incidental contact.

EXCEPTION: Covers are not required for enclosures which require a tool to open and are properly labeled and designed to minimize accidental contact with energized circuits.

11.3.3 The equipment should not exhibit surface leakage current greater than 3.5 milliamperes (mA) measured from any point on the surface of the equipment covers and associated controls to earth ground. Equipment grounding circuits within a machine must have a measured resistance of one tenth ohm or less between any measured points and the main equipment grounding conductor. Grounding conductors and connectors should be compatible in current rating to the associated ungrounded conductors and connectors as specified in the National Electrical Code.

11.3.4 All electrical components and wiring should be designed to conform with the most recent electrical code for the country of use at the time of the equipment's assembly.

- United States; NEC/NFPA 70, NFPA 79
- Japan; JIS
- Europe; IEC 950, IEC 204

Critical electrical/electronic components (whose failure could increase the risk of electrical shock, fire, or personnel injury) should be listed or recognized by a nationally recognized testing laboratory, or otherwise enclosed and



protected by a protection device which is listed or recognized by a nationally recognized testing laboratory.

11.3.5 Electrical wiring should be color coded or labeled for easy identification of the wiring's origin and termination according to international or appropriate (country of use) national standard.

11.3.6 Electrical enclosures should be constructed to National Electrical Manufacturers Association (NEMA) standards or equivalent.

11.3.7 The minimum over-current ratings for components used as main disconnects should be identified in the facility installation and maintenance manual. (For additional information, see NEC 110-9 and 110-10.) The end user should require the following as a minimum:

All 208/120 volt main circuit protection devices should be rated to withstand the available short circuit current of at least 10,000 rms symmetrical amperes at 208/120 volts at their incoming terminals. For all 480/277 volt circuits, protection devices should withstand a minimum of 14,000 rms symmetrical amperes.

EXCEPTION: Over current protection devices need not have 10,000 AIC (or 14,000 AIC) if they are located on the load side of another over current protection device, mentioned above, with the proper AIC rating. This over current protection device shall be mounted in close proximity to the equipment.

11.3.8 Incoming electrical power from the facility to the process equipment should come from a single feed location and should terminate at the main disconnect defined in 11.3.7. This disconnect should have the lockout capabilities specified in 11.2. (For additional information, see OSHA 29 CFR 1019.147.)

EXCEPTION 1: Internal power distribution to support modules and sub-panels is acceptable.

EXCEPTION 2: Equipment with more than one feed should be provided with provisions for lockout and be marked with the following text, "DANGER, RISK OF ELECTRIC SHOCK. DISCONNECT ALL (number of feed locations) SOURCES OF SUPPLY PRIOR TO SERVICING" at each disconnect.

EXCEPTION 3: A second power feed may be used when power is supplied from a facilities UPS system to maintain critical equipment system, but not the entire system. Power supplied from an external UPS will be removed when the emergency off circuit is activated or the main equipment breaker is opened.

11.3.9 All equipment should be provided with a nameplate, located adjacent to the input power connection, containing, as a minimum, the manufacturer's name,

model number, serial number, and electrical ratings (voltage, current, frequency, and, for multi-phase systems, the number of phases and number of wires. For more information, see NEC 670-3 and NFPA 79, Chapter 2-7.)

11.4 *UPS, Uninterrupted Power Supplies* - Applies to UPS with outputs greater than 30 volts ac or dc or energy level in the excess of 500 volt-amperes and integrated inside equipment footprint. (For additional information, see NFPA 110A.)

11.4.1 Output of the UPS should be removed when the emergency off circuit is activated or the main equipment breaker is opened. The emergency off circuit or the main equipment breaker should be a hardware-based fail-safe circuit.

11.4.2 UPS should be located within the main power enclosure. If not, it must be physically isolated from other equipment systems.

11.4.3 The UPS should be listed or recognized by a nationally recognized testing lab.

11.4.4 The UPS wiring shall be separate and identified at termination points as "UPS SUPPLY OUTPUT".

12. Emergency Shutdown

12.1 The equipment should have an "emergency off" (EMO) circuit which, when activated, places the equipment into a safe shutdown condition. A safe shutdown should not increase the level of hazard in the system.

EXCEPTION: Components which are not intended to be used as a stand alone equipment, but rather within an overall end-use system (and receive their power from the end-user system), need not be provided with an emergency off circuit. The component installation manual, however, should need to provide clear instruction to the end-user system manufacturing to connect the component to the end-user system's emergency off circuit.

12.2 The emergency off circuit (EMO) should be a fail safe circuit that shuts off all electrical power to the equipment so that only the safe voltage EMO circuit (typically 24 volts) and its supply may be energized. The EMO should be designed to ensure that it cannot be disabled without causing the main power circuit to open. The EMO should be hardwired to the equipment's operating system. The EMO circuit should require manual resetting so that power cannot be restored automatically. Resetting of the EMO switch should not re-energize the equipment.

NOTE: The EMO should perform its function by de-energizing rather than energizing control components.