SEMI S26-0308
ENVIRONMENTAL, HEALTH, AND SAFETY GUIDELINE FOR FPD MANUFACTURING SYSTEM

This standard was technically approved by the global Environmental, Health & Safety Committee. This edition was approved for publication by the global Audits and Reviews Subcommittee on December 20, 2007. It was available at www.semi.org in February 2008 and on CD-ROM in March 2008.

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

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1 Purpose

1.1 This safety guideline is intended as a set of performance-based environmental, health and safety (EHS) considerations for FPD manufacturing system (FPDMS) including their subsystems.

2 Scope

2.1 *Applicability* — This guideline applies to FPDMS used to manufacture, measure, assemble, and test FPD products, and their subsystems

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

1. Purpose

2. Scope

3. Limitations

4. Referenced Standards and Documents

5. Terminology

6. Safety Philosophy

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8. Evaluation for Design Review and Inspection

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18. Mechanical Design

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21. Exhaust Ventilation

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23. Chemicals

24. Ionizing Radiation

25. Non-Ionizing Radiation and Fields

26. Lasers

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Appendix 1 — Integration Issues for FPDMS

Appendix 2 — Enclosure Openings

Appendix 3 — Design Principles and Test Methods for Evaluating Exhaust Ventilation of FPDMS or Subsystem of FPDMS

Appendix 4 — Design Guidelines for Subsystem of FPDMS Using Liquid Chemicals

Appendix 5 — Fire Protection: Flowchart for Selecting Materials of Construction

Appendix 6 — Ionizing Radiation Test Validation

Appendix 7 — Non-Ionizing Radiation (Other Than Laser) and Fields Test Validation

Appendix 8 — Laser Data Sheet

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

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

3 Limitations

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

3.2 This guideline is not intended to replace or supersede any provisions of regulatory requirements.

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

3.4 Subsystems of FPDMS that meet the provisions of SEMI S2 may continue to meet SEMI S2. This guideline is not intended to be applied retroactively.

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

4 Referenced Standards and Documents

4.1 *SEMI Standards*

SEMI E6 — Guide for Semiconductor Equipment Installation Documentation

SEMI F5 — Guide for Gaseous Effluent Handling

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

SEMI S1 — Safety Guideline for Equipment Safety Labels

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

SEMI S3 — Safety Guideline for Process Liquid Heating System

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SEMI S6 — EHS Guidelines for Exhaust Ventilation of Semiconductor Manufacturing Equipment

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

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

SEMI S10 — Safety Guideline for Risk Assessment and Risk Evaluation Process

SEMI S13 — Environmental, Health and Safety Guideline for Documents Provided to the Equipment User for Use with Semiconductor Manufacturing Equipment

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

SEMI S21 — Safety Guideline for Worker Protection

SEMI S22 — Safety Guideline for the Electrical Design of Semiconductor Manufacturing Equipment

4.2 *ANSI Standards*[1]

ANSI/ASME B18.15M — Metric Lifting Eyes

ANSI/ASME B30.20 — Below-the-Hook Lifting Devices

ANSI/AWS D14.1 — Specification for Welding of Industrial and Mill Cranes and Other Material Handling Equipment

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

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

ANSI/ISA SP84.01 — Application of Safety Instrumented Systems for the Process Industry

4.3 *CEN/CENELEC Standards*[2]

EN 775 — Manipulating industrial robots — Safety

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

EN 1492 — Textile slings – Safety – Lifting slings for general service made from natural and man-made fibre ropes

4.4 *IEC Standards*[3]

IEC 60204-1 — Safety of Machinery – Electrical Equipment of Machines

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

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

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

IEC 62040-1-1 — Uninterruptible power systems (UPS) Part 1-1: General and safety requirements for UPS used in operator access areas

IEC 651 — Electro acoustics – Sound Level Meters

1 American National Standards Institute, Headquarters: 1819 L Street, NW, Washington, DC 20036, USA. Telephone: 202.293.8020; Fax: 202.293.9287. New York Office: 11 West 42nd Street, New York, NY 10036, USA. Telephone: 212.642.4900; Fax: 212.398.0023; http://www.ansi.org

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

3 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; http://www.iec.ch

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4.5 *ISO Standards*[4]

ISO 2415 — Forged shackles for general lifting purposes – Dee shackles and bow shackles

ISO 10218 — Manipulating industrial robots – Safety

ISO 11200 — Acoustics – Noise emitted by machinery and equipment – Guidelines for the use of basic standards for the determination of emission sound pressure levels at a work station and at other specified positions

ISO 13849-1 — Safety of machinery – Safety-Related Parts of Control Systems

ISO 14121 — Safety of machinery – Principles of risk assessment

ISO 14122 — Safety of machinery – Permanent means of access to machinery

4.6 *NFPA Standards*[5]

NFPA 12 — Standard on Carbon Dioxide Extinguishing Systems

NFPA 70 — National Electrical Code

NFPA 72 — National Fire Alarm Code

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

NFPA 704 — Identification of the Fire Hazards of Materials

4.7 *Underwriters Laboratories Standard*[6]

UL 508A — Industrial Control Panel

UL 1778 — Uninterruptible Power Systems

4.8 *US Code of Federal Regulations*[7]

21CFR Parts 1000-1050 — Food and Drug Administration/Center for Devices and Radiological Health (FDA/CDRH), Performance Standards for Electronic Products, Title 21 Code of Federal Regulations, Parts 1000-1050

4.9 *Council of the European Union Directives*

Directive 98/37/EC of the European Parliament and of the Council on 22 June 1998 on the approximation of the laws of the Member States relating to machinery

NOTE 1: This standard is commonly known as the Machinery Directive.

4.10 *Other Standards and Documents*

ACGIH, Industrial Ventilation Manual[8]

ASHRAE Standard 110 — Method of Testing Performance of Laboratory Fume Hoods[9]

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

MIL-STD-1365B — General Design Criteria for Handling Equipment Associated with Weapons and Related Items

Uniform Building Code (UBC)

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

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4 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; http://www.iso.ch

5 National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269, USA. Telephone: 617.770.3000; Fax: 617.770.0700; http://www.nfpa.org

6 Underwriters Laboratory, 333 Pfingsten Rd, Northbrook, IL 60062, USA. Telephone: 877.854.3577; Fax: 847.407.1395; http://www.ul.com

7 United States Food and Drug Administration/ Center for Devices and Radiological Health (FDA/CDRH). Available from FDA/CDRH; http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/cfrsearch.cfm

8 ACGIH, 1330 Kemper Meadow Road, Cincinnati, Ohio 45240, USA. http://www.acgih.org

9 ASHRAE, 1791 Tullie Circle, NE, Atlanta, Georgia 30329, USA. http://www.ashrae.org

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5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *AMHS* — Automated Material Handling System

5.1.2 *EMO* — Emergency Off

5.1.3 *FECS* — Fail-to-safe Equipment Control System

5.1.4 *FPD* — Flat Panel Display

5.1.5 *FPDMS* — FPD Manufacturing System

5.1.6 *HEI* — Hazardous Energy Isolation

5.1.7 *LEL* — Lower Explosive Limit

5.1.8 *LFL* — Lower Flammable Limit

5.1.9 *MMI* — Man Machine Interface

5.1.10 *MPE* — Maximum Permissible Exposure

5.1.11 *NOHD* — Nominal Ocular Hazard Distance

5.1.12 *PES* — Programmable Electronic System

5.1.13 *PPE* — Personal Protective Equipment

5.1.14 *SOC* — Substance of Concern

5.2 *Definitions*

5.2.1 *abort switch* — a switch that, when activated, interrupts the activation sequence of a fire detection or fire suppression system. [SEMI S2]

5.2.2 *adjusting* — as applied to AMHS: (1) the act of tuning positioning devices such as sensors or mechanical limiters in order to define the operating zone for an AMHS, or (2) entering data (e.g., calibration values) into the memory of an automation device so that the device is able to use data points to determine the status of the device (e.g., location, presence of substrate) automatically.

5.2.3 *accredited testing laboratory* — an independent organization dedicated to the testing of components, devices, or systems; competent to perform evaluations based on established safety standards; and recognized by a governmental or regulatory body. [SEMI S2, SEMI S3, SEMI S14, SEMI S22]

5.2.4 *automated material handling system* — subsystem of FPDMS that moves substrates or cassettes within the FPDMS automatically by means of a robot, a vehicle, or a conveyor, etc., without being touched by someone's hand.

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

5.2.6 *breathing zone* — imaginary globe, of 600 mm (two foot) radius, surrounding the head. [SEMI S2]

5.2.7 *capture velocity* — the air velocity that at any point in front of the exhausted hood or at the exhausted hood opening is necessary to overcome opposing air currents and to capture the contaminated air at that point by causing it to flow into the exhausted hood. [SEMI S2]

5.2.8 *carcinogen* — confirmed or suspected human cancer-causing agent as defined by the International Agency for Research on Cancer (IARC) or other recognized entities. [SEMI S2]

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

5.2.10 *cleanroom* — a room in which the concentration of airborne particles is controlled to specific limits. [SEMI S2]

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5.2.11 *coefficient of entry (C_e)* — the ratio of actual airflow into the exhausted hood to the theoretical airflow if all hood static pressure could be converted into velocity, as would be the case if the hood entry loss factor (K or F_h) were zero. $C_e = (VP/|SP_h|)^{0.5}$ where VP = duct velocity pressure and SP_h = hood static pressure. [SEMI S2]

5.2.12 *combustible material* — for the purpose of this guideline, a combustible material is any material that does propagate flame (beyond the ignition zone with or without the continued application of the ignition source) and does not meet the definition in this section for noncombustible material. (See also the definition for *noncombustible material*.) [SEMI S2]

5.2.13 *confined space* — a space that: (1) is large enough and so configured that employee can bodily enter and perform assigned work; and (2) has limited or restricted means for entry or exit (e.g., chambers, stockers, and space in enclosures, are spaces that may have limited means of entry); and (3) is not designed for continuous employee occupancy. [SEMI S21]

5.2.14 *EMO* — function to place the FPDMS into a safe shutdown condition without generating any additional hazard to personnel or the facility when an EMO actuator (e.g., button) is activated.

5.2.15 *enabling device* — an additional manually operated control device on the AMHS' manual operation box used in conjunction with a start control and which, when continuously actuated allow an AMHS to function. [IEC 60204]

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

5.2.17 *E-stop* — a circuit for halting motion (as of an AMHS) stopping all moving parts but not necessarily isolating or controlling all energy sources.

5.2.18 *evaluating party* — an in-house body, independent laboratory, or product safety consulting firm ("third party") meeting the provisions of SEMI S7 that may be used to supply testing or evaluation of conformance to this document.

5.2.19 *face velocity* — velocity at the cross-sectional entrance to the exhausted hood. [SEMI S2]

5.2.20 *fail-safe* — designed so that a failure does not result in an increased risk. [SEMI S2]

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

NOTE 2: An FECS is a subsystem to a Programmable Electronic System (PES) as defined in IEC 61508-4 Definitions.

5.2.22 *failure* — the termination of the ability of an item to perform a required function. Failure is an event, as distinguished from "fault," which is a state. [SEMI S2, SEMI S22]

5.2.23 *fault* — the state of an item characterized by inability to perform a required function, excluding the inability during preventive maintenance or other planned actions, or due to lack of external resources. [SEMI S2]

5.2.24 *fault-tolerant* — designed so that a reasonably foreseeable single point failure does not result in an unsafe condition. [SEMI S2, SEMI S17, SEMI S22]

5.2.25 *flammable gas* — any gas that forms an ignitable mixture in air at 20°C (68°F) and 101.3 kPa (14.7 psia). [SEMI S2, SEMI S4, SEMI S18]

5.2.26 *flammable liquid* — a liquid having a flash point below 37.8°C (100°F). [SEMI S2, SEMI S3, SEMI S14]

5.2.27 *flash point* — the minimum temperature at which a liquid gives off sufficient vapor to form an ignitable mixture with air near the surface of the liquid, or within the test vessel used. [SEMI S2, SEMI S3]

5.2.28 *FPD manufacturing system* — system used to manufacture, assemble, or test FPD products. The FPDMS is constructed by integration of equipment that processes substrates (e.g., glass substrates, reticules), its component parts and its auxiliary, support, or peripheral equipment (e.g., chemical controllers, chemical distribution systems,

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vacuum pumps) and AMHS. Each piece of equipment or AMHS is the subsystem of the FPDMS. FPDMS also includes other items (e.g., structures, piping, ductwork, effluent/exhaust treatment systems, valve manifold boxes, filtration, and heaters) specific to the aforementioned system, but may not include such an item if the item is part of a facility and can support more than one piece of FPD manufacturing system.

5.2.29 *gas cylinder cabinet* — cabinet used for housing gas cylinders, and connected to gas distribution piping or to system using the gas. Synonym: gas cabinet. [SEMI S2]

5.2.30 *gas panel* — an arrangement of fluid handling components (e.g., valves, filters, mass flow controllers) that regulates the flow of fluids into the process. Synonyms: gas jungle, jungle, gas control valves, valve manifold. [SEMI S2]

5.2.31 *gas panel enclosure* — an enclosure designed to contain leaks from gas panel(s) within itself. Synonyms: jungle enclosure, gas box, valve manifold box. [SEMI S2]

5.2.32 *harm* — physical injury or damage to health of people, or damage to equipment, buildings, or environment. [SEMI S2, SEMI S10]

5.2.33 *hazard* — condition that has the potential to cause harm. [SEMI S2, SEMI S10]

5.2.34 *hazardous non-ionizing radiation emissions* — for the purposes of this guideline, non-ionizing radiation emissions outside the limits shown in Appendix 7 are considered hazardous.

5.2.35 *hazardous production material (HPM)* — a solid, liquid, or gas that has a degree-of-hazard rating in health, flammability, or reactivity of class 3 or 4 as ranked by NFPA 704 and which is used directly in research, laboratory, or production processes that have as their end product materials that are not hazardous . [SEMI S2]

5.2.36 *hazardous voltage* — unless otherwise defined by an appropriate international standard applicable to the system, voltages greater than 30 volts rms, 42.4 volts peak, 60 volts dc are defined in this document as hazardous voltage. [SEMI S2, SEMI S22]

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

5.2.37 *hood* — in the context of § 21 and Appendix 3 of this guideline, "hood" means a shaped inlet designed to capture contaminated air and conduct it into an exhaust duct system. [SEMI S2]

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

$$Q = 12.65\mathrm{A}[(SP_h/d)/(1+F_h)]^{0.5} \quad (1)$$

where:

Q = volumetric flow rate in m^3/sec

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

SP_h = hood static pressure in Pa

d = density correction factor (unitless)

$$Q = 4.043\mathrm{A}[(SP_h/d)/(1+F_h)]^{0.5} \quad (2)$$

where:

Q = volumetric flow rate in m^3/sec

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

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

d = density correction factor (unitless)

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$$\text{US units: } Q = 4005A[(SP_h/d)/(1+F_h)]^{0.5} \quad (3)$$

where:

Q = volumetric flow rate in cfm

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

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

d = density correction factor (unitless)

5.2.39 *incompatible* — as applied to chemicals: in the context of § 23 of this guideline, describes chemicals that, when combined unintentionally, may react violently or in an uncontrolled manner, releasing energy that may create a hazardous condition. [SEMI S2]

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

5.2.41 *interlock* — a mechanical, electrical or other type of device or system, the purpose of which is to prevent or interrupt the operation of specified machine elements under specified conditions. [SEMI S2]

5.2.42 *ionizing radiation* — alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions in human tissue. [SEMI S2]

5.2.43 *laser* — any device that can be made to produce or amplify electromagnetic radiation in the wavelength range from 180 nm to 1 mm primarily by the process of controlled stimulated emission. [SEMI S2]

5.2.44 *laser product* — any product or assembly of components that constitutes, incorporates, or is intended to incorporate a laser or laser system (including laser diode), and that is not sold to another manufacturer for use as a component (or replacement for such component) of an electronic product. [SEMI S2]

5.2.45 *laser source* — any device intended for use in conjunction with a laser to supply energy for the excitation of electrons, ions, or molecules. General energy sources, such as electrical supply mains, should not be considered to be laser energy sources. [SEMI S2]

5.2.46 *laser system* — a laser in combination with an appropriate laser energy source, with or without additional incorporated components. [SEMI S2]

5.2.47 *lifting accessory* — a component (e.g., eyehook, shackle, hoist ring, wire rope, chain, or eyebolt) which is part of a lifting fixture or is attached directly between the lifting device and the load in order to lift it. [SEMI S2]

5.2.48 *lifting device* — a mechanical or electro-mechanical structure that *is* provided for the purpose of raising and lowering a load during operation, maintenance or service tasks, and *may be* capable of moving the load in one or more horizontal directions.

5.2.49 *lifting equipment* — lifting devices, lifting fixtures and lifting accessories. [SEMI S2]

5.2.50 *lifting fixture* — a mechanical device or an assembly of lifting accessories (e.g., hoisting yoke, wire rope sling, webbing sling, or chain assembly) placed between the lifting device (but not permanently attached to it) and the load, in order to attach them to each other. [SEMI S2]

5.2.51 *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). [SEMI S2, SEMI S10]

5.2.52 *local exhaust ventilation* — local exhaust ventilation systems operate on the principle of capturing a contaminant at or near its source and moving the contaminant to the external environment, usually through an air cleaning or a destructive device. It is not to be confused with laminar flow ventilation. Synonyms: LEV, local exhaust, main exhaust, extraction system, module exhaust, individual exhaust. [SEMI S2]

5.2.53 *lower flammable limit* — the minimum concentration of a flammable substance in air through which a flame will propagate. [SEMI S6]

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NOTE 4: The following pairs of terms are commonly used interchangeably:

- "lower explosive limit (LEL)" and "lower flammable limit (LFL) ";
- "upper explosive limit (UEL) " and "upper flammable limit (UFL) "; and
- "explosive range" and "flammable range".

SEMI S2 uses "LEL" as a synonym of LFL. However, "LEL", "UEL", or "explosive range" is sometimes used to designate concentrations to which a more specific criterion (e.g., a certain pressure rise or flame front speed) than the ability to propagate flame pertains.

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

5.2.55 *manual operation box* — a handheld device connected by cable to an AMHS controller with which an AMHS can be programmed or moved.

NOTE 5: A manual operation box which has programming function may be called "a teach pendant" or "a teaching pendant".

5.2.56 *manuals* — documents which describe necessary procedures and information for use with the FPD manufacturing system.

5.2.57 *mass balance* — a qualitative, and where possible, quantitative, specification of mass flow of input and output streams (including chemicals, gases, water, de-ionized water, compressed air, nitrogen, and by-products), in sufficient detail to determine the effluent characteristics and potential treatment options. [SEMI S2]

5.2.58 *material safety data sheet (MSDS)* — written or printed material concerning chemical elements and compounds, including hazardous materials, prepared in accordance with applicable standards. [SEMI S2]

5.2.59 *maximum permissible exposure (MPE)* — level of laser radiation to which, under normal circumstances, persons may be exposed without suffering adverse effects. [SEMI S2]

5.2.60 *nominal ocular hazard distance (NOHD)* — distance at which the beam irradiance or radiant exposure equals the appropriate corneal maximum permissible exposure (MPE). [SEMI S2]

5.2.61 *noncombustible material* — a material that, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat. Typical noncombustible materials are metals, ceramics, and silica materials (e.g., glass and quartz). (See also the definition for *combustible material*.) [SEMI S2]

5.2.62 *non-ionizing radiation* — forms of electro-magnetic energy that do not possess sufficient energy to ionize human tissue by means of the interaction of a single photon of any given frequency with human tissue. Non-ionizing radiation is customarily identified by frequencies from zero hertz to 3×10^{15} hertz (wavelengths ranging from infinite to 100 nm). This includes: static fields (frequencies of 0 hertz and infinite wavelengths); extremely low frequency fields (ELF), which includes power frequencies; subradio-frequencies; radiofrequency/microwave energy; and infrared, visible, and ultraviolet energies. [SEMI S2]

5.2.63 *non-recycling, deadman-type abort switch* — a type of abort switch that must be constantly held closed for the abort of the fire detection or suppression system. In addition, it does not restart or interrupt any time delay sequence for the detection or suppression system when it is activated. [SEMI S2]

5.2.64 *occupational exposure limits (OELs)* — for the purpose of this document, OELs are generally established on the basis of an eight hour workday. Various terms are used to refer to OELs, such as permissible exposure levels, Threshold Limit Values®, maximum acceptable concentrations, maximum exposure limits, and occupational exposure standards. However, the criteria used in determining OELs can differ among the various countries that have established values. Refer to the national bodies responsible for the establishment of OELs. (Threshold Limit Value is a registered trademark of the American Conference of Governmental Industrial Hygienists.) [SEMI S2, SEMI F5]

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

5.2.66 *parts-cleaning hood* — exhausted hood used for the purpose of cleaning parts.

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5.2.67 *placed on the market* — made physically available, regardless of the legal aspects of the act of transfer (loan, gift, sale, hire). [SEMI S2]

5.2.68 *platform* — a working space for persons, elevated above the surrounding floor or ground, such as a balcony for the operation or maintenance of machinery and FPDMS or its subsystem.

NOTE 6: The top of FPDMS or subsystem of FPDMS may be considered platform in some instances.

5.2.69 *positive-opening* — as applied to electromechanical control devices: the achievement of contact separation as a direct result of a specified movement of the switch actuator through non-resilient members (i.e., contact separation is not dependent upon springs). [SEMI S2]

5.2.70 *pyrophoric material* — a chemical that will spontaneously ignite in air at or below a temperature of 54.4°C (130°F). [SEMI S2, SEMI S14]

5.2.71 *radio frequency (rf)* — electromagnetic energy with frequencies ranging from 3 kHz to 300 GHz. Microwaves are a portion of rf extending from 300 MHz to 300 GHz. [SEMI S2]

5.2.72 *readily accessible* — capable of being reached quickly for operation or inspection, without requiring climbing over or removing obstacles, or using portable ladders, chairs, etc. [SEMI S2]

5.2.73 *recognized* — as applied to standards; agreed to, accepted, and practiced by a substantial international consensus. [SEMI S2]

5.2.74 *rem* — unit of dose equivalent. Most instruments used to measure ionizing radiation read in dose equivalent (rems or sieverts). 1 rem = 0.01 sievert. [SEMI S2]

5.2.75 *repair* — return the FPDMS or part of the FPDMS to a condition where it can perform its intended function through service.

5.2.76 *reproductive toxicants* — chemicals that are confirmed or suspected to cause statistically significant increased risk for teratogenicity, developmental effects, or adverse effects on embryo viability or on male or female reproductive function at doses that are not considered otherwise maternally or paternally toxic. [SEMI S2]

5.2.77 *residual* — as applied to risks or hazards: that which remains after engineering, administrative, and work practice controls have been implemented. [SEMI S2]

5.2.78 *risk* — the expected magnitude of losses from a hazard, expressed in terms of severity and likelihood. [SEMI S2]

5.2.79 *safe shutdown condition* — a condition in which all hazardous energy sources are removed or suitably contained and hazardous production materials are removed or contained, unless this results in additional hazardous conditions. [SEMI S2]

5.2.80 *safety critical part* — discrete device or component, such as used in a power or safety circuit, whose proper operation is necessary to the safe performance of the system or circuit. [SEMI S2]

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

5.2.82 *severity* — the extent of potential credible harm. [SEMI S2, SEMI S10]

5.2.83 *short circuit current rating* — the maximum available current to which the system supply circuit is intended, by the system manufacturer, to be connected.

NOTE 7: Short circuit current rating for an electrical system is typically based on the analysis of short circuit current ratings of the components within the system. See UL 508A for a method of determining short circuit rating.

5.2.84 *sievert (Sv)* — unit of dose equivalent. Most instruments used to measure ionizing radiation read in dose equivalent (rems or sieverts). 1 Sv = 100 rems. [SEMI S2]

5.2.85 *substance of concern (SOC), n.* — a substance for which the equipment relies on exhaust ventilation to protect personnel from exposure above the limits established in SEMI S2 or to prevent formation of a mixture with air at above 25% of the LFL of the substance during normal operation, during maintenance, or in the case of failure. This includes substances meeting the criteria in the definition that are to be used in processes, those that are products or byproducts of intended or foreseeable reactions, those that are not intended to be directly involved in the

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processes (e.g., coolants) and those that are used only in maintenance or service (e.g., solutions used to clean process chambers). [SEMI S6]

5.2.86 *supervisory alarm* — as applied to fire detection or suppression systems: an alarm indicating a supervisory condition. [SEMI S2]

5.2.87 *supervisory condition* — as applied to fire detection or suppression systems: condition in which action or maintenance is needed to restore or continue proper function. [SEMI S2]

5.2.88 *supplemental exhaust* — local exhaust ventilation that is used intermittently for a specific task of finite duration. [SEMI S2]

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

NOTE 8: A supplier can be supplier of some, or all of the subsystems of an FPDMS. A supplier can also be the system integrator.

5.2.90 *system integrator* — party that integrates various components (e.g., equipment, AMHS, etc.) and functional aspects into a system so that the integrated system (i.e., FPDMS) can perform its intended function. A system integrator can be the user of the FPDMS, or a supplier who is appointed to be the system integrator by contract.

5.2.91 *testing* — the term "testing" is used to describe measurements or observations used to validate and document conformance to designated criteria. [SEMI S2, SEMI S22]

5.2.92 *toeboard* — a vertical barrier at floor level erected along exposed edges of a floor opening, wall opening, platform, runway, or ramp to prevent falls of materials

5.2.93 *trouble alarm* — as applied to fire detection or suppression systems: an alarm indicating a trouble condition. [SEMI S2]

5.2.94 *trouble condition* — as applied to fire detection or suppression systems: a condition in which there is a fault in a system, subsystem, or component that may interfere with proper function. [SEMI S2]

5.2.95 *user* — party that acquires FPDMS for the purpose of using it to manufacture FPDs. (See also the definition for *supplier*.)

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

$$VP = (V/12.65)^2 \tag{4}$$

where:

V = air velocity in m/s

VP = velocity pressure in Pa

$$VP = (V/4.043)^2 \tag{5}$$

where:

V = air velocity in m/s

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

$$\text{U.S. units: } VP = (V/4005)^2 \tag{6}$$

where:

V = velocity in feet per second

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

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5.2.97 *volumetric flow rate (Q)* — in the context of § 21 and Appendix 3 of this guideline, Q = the volume of air exhausted per unit time. Associated equation: $Q = VA$, where V = air flow velocity, and A = the cross-sectional area of the duct or opening through which the air is flowing at standard conditions. [SEMI S2]

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

5.2.99 *yield strength* — the stress at which a material exhibits a specified permanent deformation or set. This is the stress at which, the strain departs from the linear portion of the stress-strain curve by an offset unit strain of 0.002. [SEMI S2]

6 Safety Philosophy

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

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

6.3 The following should be considered in the design and construction of FPDMS or a subsystem of FPDMS:

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

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

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

NOTE 9: The intent is to control single fault conditions that result in significant risks (i.e., Very High, High, or Medium risks based on the risk ranking matrix in SEMI S10).

6.6 Safety features of FPDMS and subsystem of FPDMS should be fail-safe or of a fault-tolerant design and construction.

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

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

6.8.1 The hazard analysis should include consideration of:

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

NOTE 10: ISO 14121 contains examples of hazard analysis methods.

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

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

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

NOTE 11: It is recommended that the supplier continue to work to eliminate identified hazards.

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

NOTE 12: It is recommended that provisions be made for periodic functional checks of safety devices, when applicable.

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

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

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

6.9.6 A combination of these approaches may be needed.

7 General Provisions

7.1 This guideline should be incorporated by reference in purchase specifications of FPDMS or subsystem of FPDMS. The user and supplier should agree on deviations from this guideline.

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

NOTE 13: It is recommended that the supplier request from the user information regarding local laws and regulations.

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

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

7.4 Each supplier should review acceptability of each risk level of a component or an assembly provided by its supplier.

7.5 Model-specific tools and accessories necessary to operate, maintain, and service subsystem of FPDMS safely should be provided with the subsystem of FPDMS or specified by the supplier.

NOTE 14: The official values in this guideline are expressed in The International System of Units (SI). Values that:

- are enclosed in parentheses, and
- directly follow values expressed in SI units.
- are not official, are provided for reference only, and might not be exact conversions of the SI values.

7.6 The user is responsible for appointing a system integrator. The system integrator should ensure preparation of appropriate interlocks and EMOs for the integrated FPDMS.

7.7 If a safety interlock of any subsystem comprising an FPDMS needs to be overridden to perform any routine tasks, risk assessment should be performed for the FPDMS and risk reduction should be implemented as appropriate.

7.8 The system integrator should be responsible for FPDMS safety integration.

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7.9 The system integrator should conduct a documented risk assessment and mitigate unacceptable risks generated by integration of FPDMS. Risk mitigating measures including administrative controls recommended for the user should be documented by the system integrator.

7.10 The system integrator should conduct risk assessment for AMHS incorporated in the FPDMS.

7.10.1 The system integrator should perform a risk assessment to determine the safety measures required for the final assembly of robot, load port, and associated system.

7.11 The system integrator should identify tools and accessories that become necessary by integration of the FPDMS to operate, maintain, and service FPDMS in addition to those provided or specified by the each supplier of subsystem. Specification for such tools and accessories should be communicated to the user by the system integrator.

8 Evaluation for Design Review and Inspection

NOTE 15: Texts originated in SEMI S2-0706[E] and texts original to this safety guideline are differentiated by indicating the latter by underline.

8.1 This section describes evaluation of FPDMS or subsystem of FPDMS (e.g., equipment, AMHS etc.) to this guideline, and supporting information needed to perform the evaluation.

8.2 *General* — The integrated FPDMS and each subsystem of the FPDMS should be evaluated by one or more evaluating parties according to this guideline. Each evaluating party should create a written evaluation report.

NOTE 16: The intent is that the "should" provisions of this guideline be used as the basis for evaluating conformance. The intent is also that the "may," "suggested," "preferred," "recommended," and "NOTE" provisions of this guideline not be used for evaluating conformance.

8.3 Conformance to specific sections of SEMI S26 may be achieved by instructions included in the supplier's installation instructions or other documentation of FPDMS or subsystem of FPDMS.

NOTE 17: SEMI E6 contains types of information typically included in installation instructions.

8.4 Evaluation Report Contents: General — The evaluation report for each subsystem of the FPDMS should include the manuals (§ 9.4) and the design-specific sections (§§ 10–27), except criteria that are only applicable to the integrated FPDMS. Appendices 2–8 should be used in the evaluation, and referenced in the report, only as they pertain to the specific application. The evaluation report for the integrated FPDMS, should cover integration issues in accordance with Appendix 1 in addition to applicable criteria in the design-specific sections (§§ 10–27).

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

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

8.4.1.1 The results of a risk assessment indicating no significant risk may be used in determining that the FPDMS or each subsystem of the FPDMS conforms to the intent of a section.

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

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

8.6 *Evaluation of Subsystem of FPDMS*

NOTE 18: It is recommended that the manufacturer's typical configuration and process be used for evaluation purposes. Alternatively, a process agreed upon between the user and the supplier may be used.

NOTE 19: Special options or configurations that may pose additional hazards and are not included in the initial evaluation may need a separate review. It is recommended that upgrades, retrofits, and other changes that affect the safety design of the subsystem of the FPDMS be evaluated for conformance, but generating a new or updated report may not be necessary for insignificant changes.

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

8.6.1.1 *General Information*

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

8.6.1.2 Industrial Hygiene Information which should include, as applicable:

- ventilation assessment (see § 21);
- chemical inventory and hazard analysis (see § 23);
- ionizing radiation assessment (see § 24);
- non-ionizing radiation assessment (see § 25);
- laser assessment (see § 26); and
- audio sound pressure level assessment (see § 27).

8.6.1.3 *Environmental Information* (see § 22)

- consideration of features that would promote reuse or refurbishing, or material recycling of the subsystem of the FPDMS and its components upon decommissioning;
- chemical selection methods and criteria (see§ 22.2);
- consideration of integrating effluent and emission controls into the subsystem of the FPDMS; and
- efforts to reduce wastes, effluents, emissions, and by-products.

8.6.2 *Evaluation Report Contents: Other Information* — The evaluation report for the subsystem of the FPDMS should also include:

- manufacturer's model number;
- serial number of unit(s) evaluated;
- the date(s) that the subsystem was evaluated;
- subsystem description including configuration, options,
- essential diagrams; and
- a statement of the qualifications of the evaluating party.

8.7 *Evaluation of Integrated FPDMS*

NOTE 20: Full system evaluation of the FPDMS may become possible only after the FPDMS is installed at the user's fab. It is recommended that scope (e.g., which parts of the FPDMS or which parts of this guideline) of evaluation is mutually agreed upon among concerned parties (e.g., user ,suppliers, evaluating party, system integrator).

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

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- Risk assessment information after integration
- System integrator's name and affiliation
- Evaluation place, date, evaluator's name and affiliation
- Integration schematic
- Integrated EMO circuit schematic
- Integrated interlock circuits schematic
- Schematic of operator control system for the FPDMS
- Alarm system schematic after integration
- Maintenance and service accessibility information

8.7.2 If a third party evaluation is performed for the integrated FPDMS, system integrator should be available to the third party during evaluation of the FPDMS to provide detail information regarding the documentation in ¶ 8.7.1.

9 Documents Provided to User

NOTE 21: Texts originated in SEMI S2-0706[E] and texts original to this safety guideline are differentiated by indicating the latter by underline.

9.1 *Evaluation Report* — Upon request by the user, each supplier should provide the user with a summary of the SEMI S26 evaluation report or the full report.

9.2 *Fire Protection Report* — Upon request by the user, each supplier should provide the user with a summary of the fire protection report or the full report.

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

9.3.1 Information regarding routes of unintended release (of effluents, wastes, emissions, and by-products) and methods and devices to monitor and control such releases. This should include information on features to monitor, prevent, and control unintended releases (see § 22.2.2).

9.3.2 Information regarding routes of intended release (of effluents, wastes, and emissions) and features to monitor and control such releases (see§ 22.2.3).

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

9.4 *Manuals*

9.4.1 Each supplier should provide the user with manuals based on the originally intended use as a subsystem of the FPDMS. The manuals should describe the scope and normal use of the subsystem of the FPDMS, and provide information to enable safe installation, operation, and maintenance of the subsystem of the FPDMS.

9.4.2 The system integrator should provide the user with manuals based on intended use of the FPDMS. The manuals should describe the scope and normal use of the FPDMS, and provide information to enable safe installation, integration, operation, and maintenance of the FPDMS.

9.4.2.1 The system integrator should ensure that information on energy isolation criteria and safety features for hazards shared between subsystems be easily identifiable and available so that service and maintenance personnel of any subsystem supplier can obtain such information from the user of the FPDMS.

NOTE 22: The assumption is that the user makes such information available to service and maintenance personnel of any subsystem supplier upon request.

9.4.3 The manuals should conform to SEMI S13.

9.4.4 Manuals should include technical descriptions in accordance with the provisions of each section of this document.

9.4.5 *Seismic Information* — Refer to § 19 of this document.

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9.4.6 *Industrial Hygiene Information* — Refer to § 21 and §§ 23–27 of this document.

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

- specific written instructions on routine Type 4 tasks, excluding troubleshooting (refer to ¶ 13.3);
- instructions for hazardous energy isolation (HEI, "lockout/tagout") (refer to § 17.2);
- descriptions of the emergency off (EMO) and safety interlock functions;
- a list of locations where work in confined space takes place;
- a list of maintenance tasks performed at confined space, such as inside of a chamber, design features ensuring safety of personnel during such tasks and recommended administrative controls;
- a list of locations where maintenance personnel could be exposed to asphyxiation hazards and recommended administrative measures to control risks associated with such hazards;
- a list of hazardous materials (e.g., lubricants, cleaners, coolants) required for maintenance, ancillary system or peripheral operations, including anticipated change-out frequency, quantity, and potential for contamination from the process;
- a list of items that become solid waste as a result of the operation, maintenance, and servicing of the FPDMS or subsystem of the FPDMS, and that are constructed of or contain substances whose disposal might be regulated (e.g., beryllium-containing parts, vapor lamps, mercury switches, batteries, contaminated parts, maintenance wastes);
- maintenance and troubleshooting procedures needed to maintain the effectiveness of safety design features or devices (i.e., engineering controls);
- information regarding potential routes of unintended releases (see § 22.2.2);
- residual hazardous materials, or parts likely to become contaminated with hazardous materials, that may be in the equipment at the time of end of use;
- instructions for proper use, maintenance, and inspection of lifting equipment supplied by the supplier of the subsystem of the FPDMS, including any guidance on specific inspection intervals. For lifting equipment specified or recommended, but not supplied, by the system integrator of the FPDMS or by the supplier of the subsystem of FPDMS, the documentation provided by the system integrator of the FPDMS or the supplier of the subsystem of FPDMS should specify that such instructions be obtained by the user from its lifting equipment supplier.

10 Hazard Alert Labels

NOTE 23: Texts originated in SEMI S2-0706[E] and texts original to this safety guideline are differentiated by indicating the latter by underline.

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

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

10.3 Labels should conform to SEMI S1.

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

11 Safety Interlock Systems

NOTE 24: Texts originated in SEMI S2-0706[E] and texts original to this safety guideline are differentiated by indicating the latter by underline.

11.1 This section covers safety interlocks and safety interlock systems.

NOTE 25: If a fire detection or suppression system is provided with the FPDMS or subsystem of the FPDMS, see § 14 for additional information.

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

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NOTE 26: Safety critical parts whose primary function is to protect the FPDMS (e.g., circuit breakers, fuses) are typically not considered to be safety interlocks.

11.3 Each FPDMS subsystem should be provided with interlock interfaces that allow for mitigation of foreseeable risks associated with hazards shared with other FPDMS subsystems.

11.3.1 The system integrator should verify that all safety interlocks provided for system integration are connected and operational prior to the FPDMS being used.

11.4 Safety interlock systems should be designed such that, upon activation of the interlock, the FPDMS, subsystem of the FPDMS or relevant parts of the subsystem, are automatically brought to a safe condition.

NOTE 27: A safe condition may be achieved by bringing the FPDMS or subsystem of the FPDMS into appropriate category of stop function as indicated by the risk assessment and the functional requirement. The definition of three categories of stop function can be found in IEC 60204-1.

NOTE 28: It is recommended that a safety interlock system is designed to provide safety performance appropriate for the risk level. ISO/FDIS 13849-1 may be used to decide necessary level of safety performance for the interlock system in relation to a risk level.

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

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

NOTE 29: An explanation of the cause is preferred upon activation of a safety interlock.

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

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

NOTE 30: This section does not address the defeatability of safety interlocks. See § 11.8 for additional information.

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

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

NOTE 31: Where a safety interlock is provided to safeguard personnel from severe or catastrophic harm as categorized by SEMI S10, consideration of positive-opening type switches is recommended

NOTE 32: Evaluation for suitability for use may also include reliability, self-monitoring, and redundancy as addressed under standards such as NEMA ICS 1.1 and UL 991.

NOTE 33: Solid-state devices include operational amplifiers, transistors, and integrated circuits.

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

NOTE 34: ¶ 13.4.3 states additional assessment criteria for safety-related components and assemblies.

NOTE 35: A FECS is a subsystem of a Programmable Electronic System (PES). IEC 61508 is the preferred standard for complex PES.

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

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11.8.1 Safety interlocks that safeguard personnel during normal operation tasks should not be defeatable without the use of a tool.

11.8.2 When maintenance access is necessary to areas protected by interlocks, defeatable safety interlocks may be used, provided that they require an intentional operation to bypass. Where practical, automatic activation of alternative risk mitigation means upon disabling of the interlocks may be considered.

11.8.2.1 In case of AMHS or robot, automatic activation of velocity limitation or hold to run upon defeating of safety interlock is recommended.

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

EXCEPTION: Manual restoration of safety interlocks may be acceptable provided exiting service mode becomes possible only after restoration of safety interlocks.

11.8.2.3 If a safety interlock is defeated, the related maintenance or service instructions should identify residual risks associated with the task, the administrative controls necessary to safeguard the personnel for whom access is necessary, and other personnel who may also be endangered by the defeating of the safety interlock.

11.8.2.4 If a safety interlock is defeated at some subsystem of FPDMS, maintenance and service manuals should describe how to control hazard to workers who are working on other subsystem that links, connects, or shares a part with the subsystem of FPDMS.

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

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

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

NOTE 36: Where the removal of a cover exposes a hazard, consider additional labels. See § 10 for guidance.

12 Emergency Shutdown

NOTE 37: Texts originated in SEMI S2-0706[E] and texts original to this safety guideline are differentiated by indicating the latter by underline.

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

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

NOTE 38: It is recommended that the emergency off function not reduce the effectiveness of safety devices or of devices with safety-related functions (e.g., magnetic chucks or braking devices) necessary to bring the FPDMS to a safe shutdown condition effectively.

NOTE 39: If a fire detection or suppression system is provided with the FPDMS or subsystem of the FPDMS, see § 14 for additional information.

12.1.1 Each subsystem of FPDMS should be provided with an EMO circuit, EMO actuator (e.g., button), and external EMO interface.

12.1.2 Each supplier should provide the system integrator with instructions for connecting the FPDMS' subsystem external EMO interface to the EMO circuit of the FPDMS.

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12.1.3 The system integrator should integrate EMO circuit of every subsystem comprising the FPDMS so that any EMO actuator of any subsystems of the FPDMS can place the FPDMS into a safe shutdown condition as described in § 12.1.

12.1.4 The system integrator should provide external EMO interface on the FPDMS with necessary instructions for connecting to the interface.

12.2 Activation of the emergency off circuit should de-energize all hazardous voltage and all power greater than 240 volt-amps in every system contained in the FPDMS beyond the main power enclosure.

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

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

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

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

12.2.2 The EMO circuit should consist of electromechanical components.

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

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

NOTE 40: ¶ 13.4.3 states additional assessment criteria for safety-related components and assemblies.

NOTE 41: An FECS is a subsystem of a Programmable Electronic System (PES). IEC 61508 is the preferred standard for complex PES.

12.2.3 All EMO circuits should be fault-tolerant.

12.2.4 Resetting an EMO actuator should not re-energize circuits or FPDMS.

12.2.5 The EMO circuit should shut down the FPDMS by de-energizing rather than energizing control components.

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

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

NOTE 42: Non-lockable self-latching (i.e., twist- or pull-to-release) EMO buttons may be required by regulations.

12.3.1 Any other activator that has only local or partial shut down function but not shut off FPDMS, should not use combination of red button with yellow background.

EXCEPTION: Red buttons with yellow background may be used on AMHS, provided such buttons are differentiated from EMO button by appearance.

12.4 All emergency off buttons should be clearly labeled as "EMO," "Emergency Off," or the equivalent text in local language should be clearly legible from the viewing location. The label may appear on the button or on the yellow background.

12.4.1 Any other activator that has only local or partial shut down function but not shut off FPDMS, should not be labeled as "EMO," "Emergency Off," or the equivalent.

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NOTE 43: When several pieces of equipment or AMHS comprise of an FPDMS, removal of EMO label may be necessary if initial EMO button, which is capable of shutting down individual equipment or AMHS, is not able to shut down FPDMS.

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

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

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

EXCEPTION: EMO button pendant may be provided for easy access from a location where incorporation of fixed EMO buttons is not practical for equipment operation but travel distance from periodic maintenance position exceeds 3 m or access to fixed EMO buttons can create other hazards.

NOTE 44: Maintenance position in a vacuum chamber is an example of such location.

NOTE 45: Provisions for EMO circuits described in § 12.2 and its subordinate sections are applied to EMO button pendant.

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

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

13 Electrical Design

NOTE 46: Texts originated in SEMI S2-0706[E] and texts original to this safety guideline are differentiated by indicating the latter by underline.

13.1 This section covers electrical and electronic systems in the FPDMS that uses hazardous voltages.

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

- *Type 1* — System is fully de-energized.
- *Type 2* — System is energized. Energized circuits are covered or insulated.

NOTE 47: Type 2 work includes tasks where the energized circuits are or can be measured by placing probes through suitable openings in the covers or insulators.

- *Type 3* — System is energized. Energized circuits are exposed and inadvertent contact with uninsulated energized parts is possible. Potential exposures are no greater than 30 volts rms, 42.4 volts peak, 60 volts dc or 240 volt-amps in dry locations.
- *Type 4* — System is energized. Energized circuits are exposed and inadvertent contact with uninsulated energized parts is possible. Potential exposures are greater than 30 volts rms, 42.4 volts peak, 60 volts dc, or 240 volt-amps in dry locations. Potential exposures to radio-frequency currents, whether induced or via contact, exceed the limits in § A7-1 of Appendix 7.

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

13.4 *Electrical Design* — FPDMS and their subsystems should conform to appropriate international, regional, national or industry product safety requirements.

NOTE 48: Examples of such standards/requirement are IEC 60204-1 and SEMI S22.

13.4.1 Nonconductive or grounded conductive physical barriers should be provided:

- Where it is necessary to reach over, under, or around, or in close proximity to hazards.
- Where dropped objects could cause shorts or arcing.

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- Where failure of liquid fittings from any part of the subsystem of the FPDMS would result in the introduction of liquid into electrical parts.
- Over the line side of the main disconnect.
- Where maintenance or service tasks on the subsystem of the FPDMS in dry locations are likely to allow inadvertent contact with uninsulated energized parts containing either: potentials greater than 30 volts rms, 42.4 volts peak, or 60 volts dc; or power greater than 240 volt-amps.

NOTE 49: A dry location can be considered to be one that is not normally subject to dampness or wetness.

NOTE 50: Removable nonconductive and noncombustible covers are preferred.

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

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

13.4.3.1 When supplier-specified components or subassemblies are necessary for proper functioning of the safety features of the FPDMS' subsystem, the necessity of using the specified components or subassemblies should be described in the maintenance manual.

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

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

EXCEPTION 2: Flexible cords.

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

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

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

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

13.4.7 Enclosure openings should safeguard against personnel access to uninsulated energized parts. (Refer to Appendix 2 for examples of openings for protection against access from operators.)

13.4.8 Top covers of electrical enclosures should be designed and constructed to prevent objects from falling into the enclosures. (Refer to Appendix 2 for examples of acceptable top enclosure openings.)

13.4.9 The short circuit current rating of the subsystems of the FPDMS or their industrial control panels, for each supply circuit from the facility to the system, should be identified in the installation instructions.

13.4.10 Subsystems of the FPDMS should be provided with main overcurrent protection devices and main disconnect devices rated with an interrupting capacity of at least 10,000 rms symmetrical amperes interrupting capacity (AIC) for circuits rated 240VAC or less, and at least 14,000 rms symmetrical amperes interrupting capacity (AIC) for circuits more than 240VAC.

NOTE 51: Some facilities may require higher AIC ratings due to electrical distribution system design.

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

13.4.11 Each subsystem of the FPDMS should be designed to receive incoming electrical power from the facility to a single feed location that terminates at the main disconnect specified in ¶ 13.4.10. This disconnect, when opened,

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should remove all incoming electrical power from the load side of the disconnect. The disconnect should also have the hazardous energy isolation (HEI, "lockout") capabilities specified in § 17.

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

EXCEPTION 2: Multiple units mounted separately with no shared hazards and without interconnecting circuits with hazardous voltages, energy levels or other hazardous conditions may have separate sources of power and separate supply circuit disconnect means, if they are clearly identified;

13.4.12 When a subsystem of the FPDMS can be controlled both from FPDMS controller and from local controls (e.g., by the controls of the subsystem itself, or by a local manual operation box), a lockable hardware-based device should be provided on or adjacent to the subsystem in order for selecting control sources.

EXCEPTION: The control source selection hardware-based device on the manual operation box of the AMHS is not required to be lockable if the manual operation box satisfies ¶ 20.3.1.2.1.

13.4.13 A permanent nameplate listing the manufacturer's name, machine serial number, supply voltage, number of phases, frequency, short circuit current rating of the subsystem of the FPDMS or its industrial control panel, and full-load current should be attached to the subsystem of the FPDMS where plainly visible after installation. Where more than one incoming supply circuit is to be provided, the nameplate(s) should state the above information for each circuit.

NOTE 52: Additional nameplate information may be required depending on the location of use.

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

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

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

- the emergency off actuator (button) is pushed; or
- the main system disconnect is opened; or
- the main circuit breaker is opened.

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

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

13.5.4 The UPS should be certified by an accredited testing laboratory and be suitable for its intended environment (e.g., damp location, exposure to corrosives) or otherwise evaluated to the applicable standard(s) for UPS. Examples of recognized UPS standards include IEC 62040 part 1-1 and UL1778.

13.5.4.1 Nationally approved UPS may be used if country where the place of use is located adopts national approval system, provided suitability for intended use of the UPS was tested and confirmed.

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

13.6 *Electrical Safety Tests*

13.6.1 Each subsystem of the FPDMS connected to the facility branch circuit with a cord and plug should not exhibit surface leakage current greater than 3.5 milliampere (mA) as determined by testing completed in accordance with "Leakage Current Test for Cord-and-Plug Equipment" in SEMI S22, Testing section.

EXCEPTION: Subsystem of the FPDMS with leakage current exceeding 3.5 mA is acceptable if documentation is provided to substantiate that the system or the component is fully compliant with an applicable product safety standard that explicitly permits a higher leakage current.

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13.6.2 All protective grounding circuits should have a measured resistance of one-tenth (0.1) ohm or less as determined by testing in accordance with "Earthing Continuity and Continuity of the Protective Bonding Circuit Test" in SEMI S22.

EXCEPTION: Alternatively, continuity of the protective bonding circuit may be verified by test specified in IEC 60204-1 or other applicable electrical safety standards.

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

NOTE 53: NFPA 497 and EN 1127-1 provide methods for making this assessment.

13.8 *Earth Leakage Protection Devices* — Earth leakage protection may be considered only as a secondary protection means.

NOTE 54: In some location of use, incorporation of leakage protection devices is regulatory requirement.

NOTE 55: Related Information 2 provides additional information on applications of Earth Leakage Protection Devices design.

14 Fire Protection

NOTE 56: Texts originated in SEMI S2-0706[E] and texts original to this safety guideline are differentiated by indicating the latter by underline.

14.1 *Overview* — This section provides minimum EHS considerations for protection from fire involving FPDMS or any subsystem of the FPDMS arising from the hazards contained within the FPDMS or any subsystem of the FPDMS.

14.1.1 This section provides minimum EHS considerations for fire protection designs and controls on the FPDMS or any subsystem of the FPDMS.

14.1.2 This section also provides minimum considerations for fire detection and suppression systems when provided with the FPDMS or subsystem of the FPDMS.

14.2 *Risk Assessment*

14.2.1 Each subsystem of the FPDMS should be subject to a fire risk assessment following the guidelines in SEMI S14.

14.2.2 For all fire risk assessments for life safety, SEMI S10 should be applied. For all other fire risk assessments, SEMI S14 should be applied.

14.2.3 The fire risk assessment should be carried out by, or supervised by, someone who is qualified to conduct such an assessment. SEMI S7 defines the qualifications of the evaluator.

14.2.4 In addition to the above, a documented fire risk assessment following the guidelines in SEMI S14 on integrated FPDMS should be performed by the system integrator and accepted by a party qualified to determine and evaluate fire hazards and the potential need for controls. If it is feasible, the qualified party may perform the risk assessment. Scope of this risk assessment should include hazards created by integration of subsystems and influence of residual fire risks in one of subsystems to the others.

14.3 *Reporting*

14.3.1 Reporting of fire risk assessment should be performed in accordance with the guidelines in SEMI S14.

14.3.2 A summary report should be provided to the user. The summary should include the following characterizations for each residual fire hazard identified.

- the assigned Severity;
- the assigned Likelihood; and
- the resulting Risk Category per SEMI S10 for life safety; or
- the resulting Risk Category per SEMI S14 for property or environment damage.

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