Background Statement for SEMI Draft Document #3560J

Note: This background statement is not part of the balloted item. It is provided solely to assist the recipient in reaching an informed decision based on the rationale of the activity that preceded the creation of this document.

Note: Recipients of this document are invited to submit, with their comments, notification of any relevant patented technology or copyrighted items of which they are aware and to provide supporting documentation. In this context, “patented technology” is defined as technology for which a patent has issued or has been applied for. In the latter case, only publicly available information on the contents of the patent application is to be provided.

This document was developed to fill the gaps concerning the integration of wafer handling robots and load ports into Semiconductor Manufacturing Equipment (SME). Integrators have found that they do not always receive the information and safety features needed to integrate robots and load ports to provide safe products. With the advent of larger, faster and more powerful robots, this has become more critical.

Some issues arise because wafer handling robots are not clearly subject to standards for industrial robots. Other issues arise because the information provided to the integrators is not sufficient to conduct risk assessments for the integrated product. In some cases experience has shown the need for features not anticipated even by the industrial robot standards.

The previous Document 3560I failed the letter ballot in the summer of 2008. Changes were made to the document in response to negatives and comments.

This ballot will be discussed further at a meeting of the AMHS Safety Task Force during SEMI Standards meetings November 3-6 in San Jose, California. Formal adjudication of this ballot is scheduled for the EHS Committee meeting November 6, 2008, in San Jose.

Please forward a courtesy copy of any comments or negatives against the ballot to Alan Crockett at Alan.Crockett@kla-tencor.com
Safety Checklist for SEMI Draft Document #3560J
Title: Safety Guideline for Robots and Load Ports Intended for Use in Semiconductor Manufacturing Equipment

Developing/Revising Body
Name/Type: Automated Material Handling Safety (AMHS) Task Force
Technical Committee: Environment Health & Safety (EHS)
Region: North America (NA)

Leadership

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Documents, Conflicts, and Consideration

Safety related codes, standards, and practices used in developing the safety guideline, and the manner in which each item was considered by the technical committee

<table>
<thead>
<tr>
<th># and Title</th>
<th>Manner of Consideration</th>
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<tr>
<td>SEMI S2 Environmental, Health, and Safety Guidelines for Semiconductor Manufacturing Equipment</td>
<td>Lack of specific requirements for wafer handling robot was a motive for drafting this document.</td>
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<tr>
<td>SEMI S17 Safety Guideline for Unmanned Transport Vehicle (UTV) Systems</td>
<td>Used to exclude Unmanned Transport Vehicles from this document</td>
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<tr>
<td>SEMI S22 Safety Guideline for the Electrical Design of Semiconductor Manufacturing Equipment</td>
<td>Used as an example of an electrical safety standard that might be used for evaluations.</td>
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<td>ANSI/RIA R15.06 Industrial Robots and Robot Systems – Safety Requirements</td>
<td>Reference for Industrial robots, this documents distinguishes between wafer handling robots and industrial robots</td>
</tr>
<tr>
<td>EN 775 Manipulating Industrial Robots - Safety</td>
<td>Reference for Industrial robots, this document distinguishes between wafer handling robots and industrial robots. This document is no longer in effect.</td>
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<tr>
<td>IEC 60204-1 Safety of Machinery – Electrical Equipment of Machines</td>
<td>Used as an example of an electrical safety standard that might be used for evaluations.</td>
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<td>IEC 61010-1 Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 1: General Requirements</td>
<td>Used as an example of an electrical safety standard that might be used for evaluations.</td>
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<tr>
<td>ISO 10218-1 Robots for Industrial Environments – Safety Requirements – Part 1: Robot</td>
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<td>ISO 12100-1 Safety of Machinery – Basic Concepts, General Principles for Design, Part 1: Basic Terminology, Methodology</td>
<td>Reference for basic principles of machinery safety.</td>
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</table>
ISO 12100-2 Safety of Machinery – Basic Concepts, General Principles for Design Part 2 – Technical Principles

ISO 13849-1 Safety of Machinery – Safety-Related Parts of Control Systems

NFPA79 — Electrical Safety of Industrial Machinery

UL 1740 Standard for Robots and Robotic Equipment

Reference for basic principles of machinery safety.

Referenced as a widely accepted guide for determining what types of safety circuits are needed based on risk assessment.

Used as an example of an electrical safety standard that might be used for evaluations.

Used as an example of an electrical safety standard that might be used for evaluations.

Known inconsistencies between the safety guideline and any other safety related codes, standards, and practices cited in the safety guideline

<table>
<thead>
<tr>
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<th>Inconsistency with This Safety Guideline</th>
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<tr>
<td>SEMI S2 Environmental, Health, and Safety Guidelines for Semiconductor Manufacturing Equipment</td>
<td>(¶11.5) states that interlock circuits should be fault tolerant. This document describes a risk assessment method that may select safety circuits that are not fault-tolerant.</td>
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<td>SEMI S2 Environmental, Health, and Safety Guidelines for Semiconductor Manufacturing Equipment</td>
<td>(Note 30) suggests using NEMA ICS 1.1 and UL991 for evaluating the suitability of components in safety circuits. This document refers to ISO 13849-1 and ANSI R15.06.</td>
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<tr>
<td>SEMI S2 Environmental, Health, and Safety Guidelines for Semiconductor Manufacturing Equipment</td>
<td>(Note 29) suggests that consideration of using positive-opening switches is suggested when there is a risk of severe or catastrophic harm. This document suggests using the risk assessment method of ISO 13849-1, which is based on frequency, severity and to what extent the harm is avoidable.</td>
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<td>IEC 61010-1 Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 1: General Requirements</td>
<td>The criteria of IEC 61010-1 for evaluating the suitability of components for use in safety circuits are not used. The criteria of ISO 13849-1 and ANSI R16.06 are used instead.</td>
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Other conflicts with known codes, standards, and practices or with commonly accepted safety and health principles to the extent practical

<table>
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Participants and Contributors

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The content requirements of this checklist are documented in Section 14.2 of the *Regulations Governing SEMI Standards Committees*. 
SEMI Draft Document #3560J

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

NOTICE: Conformance to the “should” provisions of this guideline is necessary to declare conformance to this document. Conformance to “may”, “suggested”, “preferred”, “recommended”, “NOTE”, or “Related Information” provisions is not necessary to declare conformance.

1 Purpose
1.1 This Safety Guideline is intended as a set of performance and design based safety considerations for load ports and wafer handling robots intended to be integrated into SME (semiconductor manufacturing equipment).
1.2 This Safety Guideline is intended to provide additional guidance to manufacturers of load ports and wafer handling robots beyond the general coverage of SEMI S2.
1.3 This Safety Guideline is intended to provide coverage of essential safety issues for load ports and wafer handling robots intended for integration into SME that might not be covered in other applicable safety guidelines and standards for industrial robots.
1.4 This Safety Guideline is intended to aid the evaluation of load ports and wafer handling robots before integration.
1.5 This Safety Guideline is intended to aid the designers of load ports wafer handling robots to anticipate safety considerations that will arise during integration into SME.
1.6 This Safety Guideline is intended to provide suppliers of load ports and wafer handling robots with guidance as to the documents needed by integrators for safety evaluations of their completed SME systems.

2 Scope
2.1 This Safety Guideline applies to atmospheric and vacuum wafer-handling robots that are manufactured with their supplier’s intention that they be integrated by a 2nd party (i.e., an integrator) into semiconductor manufacturing equipment.

NOTE 1: The second party is someone, other than the end user, who will sell the robot or load port integrated into a product either to an end user or to another integrator.

2.2 This Safety Guideline applies to load ports that interface with FOUPs (front-opening uniform pods), SMIF (standard mechanical interface) pods and cassettes and that are manufactured for integration into semiconductor manufacturing equipment.

2.3 This Safety Guideline includes safety considerations in addition to those of safety standards for industrial robots.
2.4 This Safety Guideline applies to wafer handling robots and load ports that are being evaluated independently of SME.
2.5 The provisions in § 8 apply to existing load port and wafer handling robot designs.
2.6 This document contains the following sections:
1. Purpose
2. Scope
3. Limitations
4. Referenced Standards and Documents
5. Terminology
6. General Considerations
7. Safety Features for Robots and Load Ports
8. Information to be Provided to the Integrator

**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 Safety Guideline is not intended to apply to unmanned transport vehicle (UTV) systems (floor-traveling vehicle systems and space-traveling vehicle systems), which move carriers between areas of the factory.

**NOTE 2:** UTV systems are the subject of SEMI S17, Safety Guidelines for Unmanned Transport Vehicle (UTV) Systems.

3.2 This Safety Guideline does not address design and manufacture of multipurpose industrial robots of any type (e.g., as defined by ANSI/RIA R15.06, ISO 10218-1, and UL 1740) used for moving structural, construction, or building maintenance loads around a factory.

3.2.1 This Safety Guideline is not intended to replace regulatory requirements for industrial robots (e.g., multipurpose industrial robots used to transport wafers).

3.3 This Safety Guideline does not apply to mechanisms that support and move wafers only while they are being processed, measured or inspected by the SME (e.g., an x-y stage).

3.4 This Safety Guideline is not intended to apply to flat panel substrate handling robots.

**NOTE 3:** Safety for flat panel display equipment is the subject of SEMI S26 — Environmental, Health, and Safety Guideline for FPD Manufacturing System.

3.5 This Safety Guideline is not intended to apply to equipment that handles reticle SMIF pods (see SEMI E100 and SEMI E117).

3.6 This Safety Guideline is not intended to be used for evaluating SME that has integrated robots or load ports.

**NOTE 4:** Once robots and load ports are integrated into SME or EFEMs, SEMI S2 may be used for evaluation.

3.7 This Safety Guideline is not intended to be used to verify compliance with ISO, IEC and other standards, nor is it intended that other standards would be an alternate means of satisfying the intent of this Safety Guideline.

**NOTE 5:** Certain IEC, ISO and other standards are referenced in this Safety Guideline because they can be helpful for the design of safety circuits.

3.8 This safety guideline is not intended to be applied to load port and wafer handling robot designs retroactively. The considerations contained in § 7 are not intended to be applied to robots and load ports developed before this safety guideline is published.

### 4 Referenced Standards and Documents

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

**4.1 SEMI Standards & Safety Guidelines**

SEMI E1.9 — Mechanical Specification for Cassette Used to Transport and Store 300 mm Wafers

SEMI E19.4 — Standard Mechanical Interface (SMIF)

SEMI E62 — Provisional Standard for 300 mm Front-Opening Interface Mechanical Standard (FIMS)

SEMI E63 — Mechanical Specification for 300 mm Box Opener/Loader to Tool Standard (BOLTS-M) Interface

SEMI E92 — Specification for 300 mm Light Weight and Compact Box Opener/Loader to Tool-Interoperability Standard (BOLTS/Light).

SEMI E100 — Specification for a Reticle SMIF Pod (RSP) Used to Transport and Store 6 inch or 230 mm Reticles

SEMI E117 — Specification for Reticle Load Port

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

SEMI S10 — Safety Guideline for Risk Assessment and Risk Evaluation Process
SEMI S17 — Safety Guideline for Unmanned Transport Vehicle (UTV) Systems
SEMI S22 — Safety Guideline for the Electrical Design of Semiconductor Manufacturing Equipment
SEMI S26 — Environmental, Health, and Safety Guideline for FPD Manufacturing System

4.2 ANSI Standard¹
ANSI/RIA R15.06 — Industrial Robots and Robot Systems - Safety Requirements

4.3 IEC Standards²
IEC 60204-1 — Safety of Machinery – Electrical Equipment of Machines
IEC 61010-1—Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 1: General Requirements

4.4 ISO Standards³
ISO 10218-1 — Robots for Industrial Environments – Safety Requirements – Part 1: Robot
NOTE 6: EN Standard⁴ EN775 (Manipulating Industrial Robots – Safety) has been withdrawn. It has been replaced by ISO 10218-1.
ISO 12100-1 — Safety of Machinery – Basic Concepts, General Principles for Design, Part 1: Basic Terminology, Methodology
ISO 12100-2 — Safety of Machinery – Basic Concepts, General Principles for Design Part 2 – Technical Principles
ISO 13849-1 — Safety of Machinery – Safety-Related Parts of Control Systems – Part 1: General Principles for Design
ISO 13849-2 — Safety of Machinery – Safety-Related Parts of Control Systems –Part 2: Validation

4.5 NFPA Standard⁵
NFPA79 — Electrical Safety of Industrial Machinery

4.6 UL Standard⁶
UL 1740 — Standard for Robots and Robotic Equipment

4.7 International SEMATECH⁷
99033693A-ENG — Integrated Mienviornment Design Best Practices

4.8 Council of the European Union⁸ Directives

¹ American National Standards Institute, 25 West 43rd Street, New York, NY 10036, USA. Telephone: 212.642.4900; Fax: 212.398.0023; http://www.ansi.org
² International Electrotechnical Commission, No. 3, Rue de Varembe, Case Postale 131, CH-1211 Geneve 20, Switzerland. Telephone: 41.22.919.02.11; Fax: 41.22.919.03.00; http://www.iec.ch
³ International Organization for Standardization (ISO), ISO Central Secretariat, 1, ch.de la Voie-Creuse, 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 02169, USA; http://www.nfpa.org
⁶ Underwriters Laboratories, Inc., 333 Pfingsten Road, Northbrook, Illinois 60062, USA; http://www.ul.com
⁷ International SEMATECH, 2706 Montopolis Drive, Austin, TX 78741, USA; http://www.sematech.org
⁸ Council of the European Union, Rue de la Loi / Wetstraat, 175, B-1048 Brussels, Belgium; http://europa.eu.int/comm/
5 Terminology

5.1 Abbreviations and Acronyms

5.1.1 EFEM — equipment front end module

5.1.2 EMO — emergency off

5.1.3 FIMS — front-opening interface mechanical standard (see SEMI E62 and SEMI E92))

5.1.4 FOUP — front-opening unified pod

5.1.5 FPD — flat panel display

5.1.6 IEC — International Electro-Technical Commission

5.1.7 ISO — International Organization for Standardization

5.1.8 ME — minienvironment

5.1.9 SEMI — Semiconductor Equipment and Materials International

5.1.10 SMIF — standard mechanical interface (see SEMI E19)

5.1.11 SME — semiconductor manufacturing equipment

5.1.12 UL — Underwriters Laboratories

5.1.13 UTV — unmanned transport vehicle

5.2 Definitions

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

5.2.2 definitions related to carriers

5.2.2.1 carrier — a device for holding wafers, dies, packaged integrated circuits, or reticles for various processing steps in semiconductor manufacturing. [SEMI E78, SEMI E129]

5.2.2.2 cassette — an open structure that holds one or more wafers. [SEMI E1.9]

5.2.2.3 front opening unified pod (FOUP) — a box (that complies with SEMI E47.1) with a non-removable cassette (so that its interior complies with SEMI E1.9) and with a front-opening interface (that mates with a FIMS port that complies with E62) [SEMI E47.1]

5.2.2.4 pod — a box having a standardized mechanical interface. [SEMI E19]

5.2.2.5 Reticle SMIF Pod (RSP) — a minienvironment compatible carrier capable of holding one 6 inch or one 230 mm reticle in a horizontal orientation during transport and storage and is compatible with a Standard Mechanical Interface (SMIF) per SEMI E19.4 [SEMI E100]

5.2.2.6 SMIF pod — a pod for controlling the transport environment of wafer cassettes for sizes up to 200mm as specified by SEMI E19.

NOTE 7: Pods include SMIF Pods (see SEMI E19.4), FOUPs, and Reticle SMIF Pods. Pods and cassettes are carriers.

NOTE 8: Pods are normally clamped in place while they are open, while cassettes are normally not clamped in place.

5.2.3 confined space — a space that: (1) is large enough and so configured that an employee can bodily enter and perform assigned work, and (2) has limited or restricted means for entry or exit, and (3) is not designed for continuous employee occupancy.

5.2.4 controlled stop — the stopping of moving parts with drive power on during the stopping process.

5.2.5 controller — a system that performs required operations when certain conditions occur or when interpreting and acting upon instructions and that communicates with a higher level manager. Controllers exist at all levels within a factory.
5.2.6 **defeat** — in the context of safety circuits or safety interlocks, to modify or block a control circuit or actuator so it cannot perform its safety function. Defeating might be authorized or unauthorized.

NOTE 9: SEMI S2 and SEMI S22 use the terms “defeat,” “bypass” and “override” apparently interchangeably but do not provide definitions.

5.2.7 **emergency stop** — a safety circuit that, when activated, provides a Category 0 or Category 1 Stop for hazardous moving parts but does not necessarily isolate or control all energy sources.

5.2.7.1 **Category 0 Stop** — provides an uncontrolled stop by removing drive power from all moving parts immediately.

5.2.7.2 **Category 1 Stop** — provides a controlled stop using drive power followed by removing the drive power.

NOTE 10: There is an overlap between terminology for stop categories and safety circuit categories. In particular, a Category 1 Stop is not the same as a Category 1 control circuit.

5.2.8 **emergency off** — a safety circuit that, when activated, places the equipment in a safe shutdown condition without generating any increased risk to personnel or the facility.

NOTE 11: Activation of the EMO circuit will cause a Category 0 or 1 stop, and will shutdown other parts of the equipment besides moving parts. See SEMI S2 or S22 for exceptions and conformance criteria.

5.2.9 **equipment front end module (EFEM)** — consists of the carrier handler that receives carriers from the factory material handling system on one or more load ports (as specified in SEMI E15.1), opens the carriers (if needed) and may include a substrate handler for unloading and loading wafers from the carrier to the process part of the equipment. [SEMI E63]

5.2.10 **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]

5.2.11 **fault** — the state of an item characterized by the 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]

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

5.2.13 **floor-traveling vehicle** — a vehicle that automatically travels on the factory floor to a specified station where a load/unload operation is performed automatically or manually. Floor-traveling vehicles include automatic guided vehicles (AGV) and rail guided vehicles (RGV). [SEMI S17]

5.2.14 **hazardous electrical power** — power levels equal to or greater than 240 VA. [SEMI S22]

5.2.15 **hazardous voltage** — voltages greater than 30 Volts RMS, 42.4 Volts peak, or 60 Volts DC. [SEMI S22]

5.2.16 **integrator** — an equipment supplier who integrates components such as load ports, robots, and EFEMs into semiconductor equipment.

5.2.17 **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]

5.2.18 **Definitions related to load ports:**

5.2.18.1 **load port** — the location on the equipment where carriers are loaded and unloaded. [SEMI E87]

5.2.18.2 **load port door** — the mechanism that opens between SME and a carrier to allow access to wafers.

5.2.18.3 **FIMS type load port** — a load port capable of opening and closing an E47.1 compliant FOUP using a mechanism that complies with E62.

5.2.18.4 **manual load port** — a load port without a mechanism for opening and closing wafer carriers. Load ports that handle cassettes, also called open cassette load ports, are also manual load ports unless they have a mechanism that opens and closes using drive power.

5.2.19 **maintenance** — planned activities intended to keep equipment in proper working order (see also the definition for service). [SEMI S22]
5.2.20 minienvironment — a localized environment created by an enclosure to isolate the product from contamination and people. [SEMI E45, E47.1, E62, E63, E70, E78, E92, E100, E106, E111, E112, E119, E129, M31, M51, S11]

5.2.21 normal operation — operation of SME to perform its intended function to modify, transfer, inspect or measure wafers under local or remote control.

5.2.22 operator — a person who interacts with the equipment only to the degree necessary for the equipment to perform its intended function. [SEMI S2, S21, S22]

5.2.23 pendant — a handheld device linked to the control system with which a robot can be programmed or moved.
NOTE 12: A pendant does not necessarily provide for teaching. See the definition for “teach pendant.”

5.2.24 program verification — the process of monitoring robot functions after teaching that may involve operation of a robot, with interlocks deactivated or barriers removed, at a speed greater than that used in teaching.

5.2.25 Definitions related to robots:

5.2.25.1 industrial robot — an automatically controlled, reprogrammable multipurpose manipulator programmable in three or more axes which may be either fixed in place or mobile for use in industrial automation applications.

5.2.25.2 robot — an automatically controlled, reprogrammable manipulator including the moving parts, their actuators, drivers and controller, that has an end effector which is used to hold an item or tool and maneuvers the item or tool through three or more axes of motion.

5.2.25.3 robot space — the three dimensional space encompassing the physically possible movements of all parts of the robot as defined by the manufacturer through their axes.

5.2.25.4 robot maximum space — the three dimensional space encompassing the movement of all parts of the robot as defined by the manufacturer plus the space which can be swept by the end effector and workpiece.

5.2.25.5 wafer handling robot — a robot that is designed for transfer of wafers, but not for movement during processing of wafers.

5.2.26 safety circuit — a circuit whose intended function is to make equipment safer. Safety interlocks, EMO circuits and other protective circuits are examples of safety circuits. [SEMI S22]

5.2.27 safety interlock output — an electromechanical or solid state switch or relay contact that is not connected to ground, power or other internal circuits.

5.2.28 semiconductor manufacturing equipment (SME) — equipment used to manufacture, measure, assemble, or test semiconductor products. It includes the equipment that processes substrates (e.g., silicon wafers, reticles), its component parts, and its auxiliary, support or peripheral equipment (e.g., chemical controllers, chemical delivery systems, vacuum pumps). SME also includes other items (e.g., structures, piping, ductwork, effluent treatment systems, valve manifold boxes, filtration, and heaters) specific to and provided with the aforementioned equipment, but does not include such an item if the item is part of a facility and can support more than one piece of SME. [SEMI S3]

5.2.29 service — unplanned activities intended to return equipment that has failed to proper working order.[SEMI S22]

5.2.30 single-point failure — a failure resulting from the malfunction of one individual device or component or from one improper human action.
NOTE 13: This definition is derived from the text of SEMI S2.

5.2.31 substrate — basic unit of material (e.g., wafer, lead frame, CD, die, flat panel substrate, circuit board, disk, mask plate, reticle, strip, tape) on which work is performed or which is used to perform work.
NOTE 14: This definition is derived from several definitions used in other SEMI Standards. See SEMI E90, E94, E98, E116, T13.

5.2.32 teach mode — a mode of robot operation for setting the trajectories and end-points of robot motion.
5.2.33 teach pendant (also called teaching pendant) — a wired or wireless device used to instruct a robot about its operating parameters.

5.2.34 teaching (robots) — the act of entering trajectory or endpoint data into the memory of a robot.

5.2.35 uncontrolled stop — the stopping of moving parts by immediately removing drive power to the drive actuators and activating all brakes and mechanical stopping devices.

5.2.36 wafer mapper — a subsystem that scans a carrier to determine which slots contain wafers and whether they are oriented correctly.

5.3 Symbols

5.3.1 ¶ — a character used to identify a particular paragraph of the document. The identified portion includes the numbered paragraph identified by the number following the symbol and the Exceptions and lists (bulleted or numbered) embedded therein. It does not, however, include the subordinate headers and paragraphs. When duplicated, as ¶¶, it refers to more than one paragraph. For example, ¶ 8.5.3 refers to the text immediately following that number, the bulletted list, and the Exception. Contrarily, ¶ 8.5.1 refers to only that paragraph, but not to ¶ 8.5.1.1, 8.5.1.2, or 8.5.1.2.1.

5.3.2 § — a character used to identify a particular section or subsection of the document. The identified portion includes the numbered paragraph or header identified by the number following the symbol and all subordinate headers and paragraphs as well as the Exceptions and lists (bulleted or numbered) embedded therein. When duplicated, as §§, it refers to more than one section or subsection. For example, § 8.5 refers to ¶¶ 8.5, 8.5.1, 8.5.1.1, 8.5.1.2, 8.5.1.2.1, 8.5.2, and 8.5.3 (including the bulletted items and the Exception).

6 General Considerations

6.1 This section may be helpful to suppliers of wafer handling robots and load ports, and to integrators of wafer handling robots and load ports. This section (§ 6) is not intended to be used for evaluations – § 7 and § 8 should be used for evaluations of wafer handling robots and load ports.

6.2 Wafer handling robots integrated into SME are often installed in the minienvironments of EFEMs. The space within an EFEM is usually more confined than the space around an industrial robot, and there are often other mechanisms and other risks from hazards within this space. As a result, some safety features not required by the safety standards for industrial robots may be needed for wafer handling robots used in SME.

6.2.1 The configuration of the robot or load port as likely to be installed in SME should be considered in design of robots and load ports intended for integration into an EFEM. A typical EFEM has a fan filter unit above the robot and load ports at the front. The EFEM is attached to the process part of the equipment. There may also be a tabletop (i.e., horizontal surface) below the wafer handling volume. The EFEM is often only wide enough to accommodate the load ports and a pre-aligner. The depth is limited by the need for the robot to move wafers into carriers in front and into the process part of the equipment in the rear. See also 99033693A-ENG — SEMATECH Integrated Minienvironment Design Best Practices.

6.2.1.1 The z-axis mechanism of wafer handling robots is usually more powerful than other axes because it usually carries the actuators for the other axes and consequently has greater weight. There is potential for a person to be trapped or crushed either above the robot between robot arm and air filter, or below the robot arm between the arm and the base of the robot. Other axes may also create hazards of trapping or crushing (e.g., scissor-like action of a robot arm).

6.2.2 A person teaching the robot may be exposed to hazards from load port doors and wafer mappers. Integrators may wish to combine the emergency stop controls for these devices into a single actuator.

6.2.3 The speed limit for industrial robots in the teach mode (250 mm/sec measured at the tip of the end effector) may not provide sufficient safety margin for a person teaching the robot within the confined space.

6.2.4 The provision in industrial robot safety standards for moving the robot without drive power may not provide a practical means of freeing a person who becomes trapped by the robot mechanism in SME.

6.3 Integrators need evaluations of wafer-handling robots and load ports (e.g., for conformance with SEMI S2, the Machinery Directive or the Low Voltage Directive) that will be sufficient to determine if the designs provide, to the integrators, the features and documentation needed for safe integration into SME.
6.3.1 The integrator can more easily implement the necessary interlocks when subsystems provide an emergency stop input.

6.3.2 Integrators need electrical test data for subsystems using hazardous voltage or hazardous electrical power.

6.3.3 Integrators need complete data about all the ranges of motion, drive forces, kinetic energy, and potential energy of moving parts, and failure mode behavior.

6.4 SME operators have been known to pull on a FOUP or on a load port door before it is released by a load port. In some cases a FOUP can be pulled out of the docked position while clamped to the load port. In other cases the clamp may fail to retain the FOUP when the FOUP is pulled.

6.5 A door on a FIMS type load port creates pinch points during up or down travel and while moving horizontally to close. Operators would be exposed to the hazard if the door were to operate without a FOUP being in place. Service personnel could be exposed to it while teaching and aligning the robot.

NOTE 15: E1.9 and E47.1 define a zone reserved within 300 mm carriers for end effectors. An edge-grip end effector must extend more then 85 mm (y4) and less than 152 mm (y6) beyond the facial datum plane. E63 specifies that the facial datum plane for a docked carrier is 173 mm (y70) in front of the equipment boundary. An edge-grip end effector will therefore extend between 258 and 323 mm in front of the equipment boundary.

6.6 The following standards, although not criteria for conformance with this Safety Guideline, may be helpful for suppliers and integrators of robots and load ports:

6.6.1 ISO 12100-1 and ISO 12100-2 cover basic concepts and principles for mechanical safety.

6.6.2 ISO 13849-1 provides a method for using risk assessment to select appropriate safety circuits.

6.6.3 IEC 60204-1 provides guidance for electrical safety for robots and load ports using hazardous voltages.

NOTE 16: The IEC is drafting a standard for semiconductor fabrication equipment under the Low Voltage Directive.

7 Safety Features for Robots and Load Ports

7.1 Teach Mode for Robots

7.1.1 If there is provision for a teach mode for a robot and this mode defeats any safety function, changing from the operational mode to the teach mode should require a manual operation or password.

7.1.2 While in the teach mode, the person teaching should have exclusive control over the robot.

7.1.3 If teaching the robot involves entry into the robot space, a teach pendant should be provided.

7.1.3.1 The teach pendant should have an emergency stop actuator which will override all other functions and operations in all modes and cause a Category 0 or Category 1 stop.

NOTE 17: An emergency off will cut off power to the robot controller, so an emergency stop cannot override the EMO.

7.1.3.2 The teach pendant should have one of the following types of enabling actuators:

7.1.3.2.1 A three-position actuator that must be held in the mid position continually in order for the robot to move. In either the released position or fully-pressed position, the actuator will cause a Category 0 or Category 1 stop.

7.1.3.2.2 A two-position actuator that must be pressed in order for the robot to move. In the released position, the actuator will cause a Category 0 or Category 1 stop.

7.1.3.2.3 A three-position actuator is preferred. Use of a two-position actuator should be based on a risk assessment.

NOTE 18: ANSI/RIA R15.06 and ISO 10218-1 require a three-position actuator. IEC 60204-1 requires either a two-position or three-position actuator.

NOTE 19: Teach pendants are frequently set down during teaching. People are likely to be tempted to defeat the actuator if resuming teaching is time-consuming or complicated (e.g., robot must move to a home position).

7.1.4 While the robot is being taught using a teach pendant, the teacher should have the option of selecting a speed lower than 250 mm/sec (measured at the tips of the end effector), but should not be able to select a higher speed, except as provided for program verification.
7.2 Program Verification for Robots — If a robot provides for program verification, it should comply with the provisions for program verification in ANSI/RIA R15.06 or ISO 10218-1.

7.3 Alternate Control Modes for Load Ports — If there is provision for a load port command interface separate from the host controller, and its mode can be changed from normal operation to an alternate control mode for maintenance or service, and this mode defeats any safety function, then:

7.3.1 Changing from the normal operation mode to the alternate control mode should require a manual operation or password, and

7.3.2 The load port should be configured so the person who changed the mode can retain exclusive control of the mode control.

NOTE 20: Load port suppliers may refer to the alternate mode as “maintenance mode” or “service mode”, but this is not consistent with how “service” and “maintenance” are used in SEMI Standards and Safety Guidelines.

7.4 Wafer Retention — The robot should retain wafers by vacuum or other means after the robot loses power, at least until the robot stops moving.

7.5 Emergency Stop Control

7.5.1 Robots should have an input, suitable for connection to a safety interlock output, that will stop and remove drive power from the robot’s moving parts (Category 0 or 1 stop). The safety circuit in the SME or EFEM will typically be an isolated contact that opens to stop the robot.

NOTE 21: ANSI R15.06 and ISO 10218-1 require robots to have separate inputs for an emergency stop and for a “safety stop” (ANSI R15.06) or a “protective stop” (ISO 10218-1).

7.5.2 Load ports should either provide inputs for an emergency stop similar to those for robots or rely on the safety circuit of the integrated system to cut off electrical power to the load port for an emergency stop. The removal of electrical power should result in a Category 0 or Category 1 stop.

NOTE 22: If a load port relies on cutting off electrical power for the emergency stop function, people are likely to be tempted to defeat the actuator if resuming operation is time-consuming or complicated (e.g., load port door must move).

7.6 Safety Interlocks

7.6.1 Robots may be provided with means of defeating safety interlocks only for teaching and program verification.

NOTE 23: Safety interlock circuits such as those for the enclosure provided by the integrator may have provision for defeating the interlock to conduct additional activities such as trouble shooting. These are considered to be outside of the scope of this document.

7.6.2 A robot with teach pendant should have a safety interlock output that closes when the controller is in the teach mode. The integrator can use the output to control the defeating of interlocks to support the teach mode. (e.g., maintain the power to a load port whose power would be cut off when an access door is opened during normal operation).

NOTE 24: Some robots may defeat safety interlocks when the teach mode is enabled, while others may need the safety interlocks to be defeated externally. In either case, the integrator may need to bypass other safety interlocks (e.g., load ports) during teaching.

7.6.3 A robot with a teach pendant should provide a safety interlock output that opens when the teach pendant emergency stop is activated that the integrator can use to activate the emergency stop on a load port or other mechanism if the integrator finds it to be necessary.

7.6.4 The FIMS load port should provide a safety interlock output that will be activated if,

- the load port door is open in such a way as to expose an operator to Very High, High, or Medium risk, determined in accordance with SEMI S10, from hazards from the robot (see ¶ 6.6) or load port door (see ¶ 6.5), and
- there is no FOUP properly placed on the load port

7.6.4.1 When activated, this safety interlock should stop the motion of the load port door.

7.6.4.2 When activated, this safety interlock should also open a safety interlock output.
NOTE 25: FOUPs have been known to fail and be dislodged from the load port when struck by a robot. In some cases a FOUP can be removed even though it is clamped to the load port either because the FOUP fails or the clamp fails.

7.6.5 A manual load port should provide a safety interlock output that will open if and when an operator would be able to contact the robot or its end effector, from a hazard from a robot (e.g., during loading and unloading of cassettes).

NOTE 26: The robot’s end effector must reach into a carrier to load or unload wafers. A FOUP is considered to block operator access to the interior of an EFEM. A cassette is not considered as blocking access. A manual load port may be constructed so the operator is protected from the robot by a physical barrier.

7.7 Release from Entrapment

7.7.1 Robots and load ports should provide a method that does not use drive power for freeing a person who may become trapped by the moving parts.

7.7.2 The method for freeing should be practical, given the space and accessibility limitations of SME and minienvironments. (see ¶ 6.2.1 for clarification).

7.7.3 The method should not rely on more than one person being able to assist the person who is trapped.

7.7.4 The means of release should not be blocked by the person who is trapped, or by the robot itself.

7.7.5 The documentation provided with the robot or load port should describe the method(s) to release an entangled person.

7.7.6 If the robot requires electrical power to release a brake, the robot should have provision for accepting a non-hazardous voltage power (usually 24 VDC) as allowed by SEMI S2 after an EMO activation so that the integrator can provide the brake release power regardless of the EMO activation status.

7.7.7 If a tool is required to release an entrapped person, the tool should be designed or selected by the supplier so that it can be kept readily available by the integrator.

7.8 Special Lifting Fixtures for Robots

7.8.1 If special lifting fixtures are needed for removal and replacement of robots, they should be provided.

7.9 Safety Circuits — Safety related parts of robots and load ports should be designed based on the anticipated Very High, High, or Medium risk, as determined in accordance with SEMI S10, from hazards they should protect against.

7.9.1 The degree of reliability and choice of features should be based on a risk assessment.

NOTE 27: The likelihood of a failure occurring is primarily determined by the selection of components, while the ability of the circuit to perform in spite of a fault is determined by the structure of the circuit.

NOTE 28: ISO 13849-1 provides a method to assess risk and select an appropriate safety circuit Performance Level. This method is based on the severity of the harm, the exposure to the hazard, and the probability of avoiding harm from the hazard.

NOTE 29: SEMI S2 says that safety interlock systems should be fault-tolerant. A Category B or Category 1 circuit may not be considered to be fault-tolerant.

7.9.2 Safety circuits should be designed following practices that minimize the likelihood of failure:

- Switches and other control device contacts used in safety circuits 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.
  - Exception: An additional circuit, used to increase reliability, may use contacts on its grounded side.

- Circuits should open to perform their safety function.

- Components should de-energize to perform their safety function.

- Components should be approved by an accredited testing laboratory.

- Components should be selected so that anticipated failure modes and times to failure provide adequate reliability.

• Potential mechanical failure modes for electromechanical parts should be considered and their negative effects minimized.

7.9.3 The structure of a safety circuit and the components used in a safety circuit should be appropriate to the application based on a risk assessment.

NOTE 31: See Related Information 1 for an introduction to the risk assessment method and discussion of component selection in ISO 13849-1.

7.10 Electrical Safety Tests — Robots and load ports using hazardous voltage or hazardous electrical power should be tested in accordance with SEMI S22 or a relevant standard such as NFPA79, IEC 60204-1, or UL 1740. The leakage current test and the dielectric test from S22 should also be performed for cord and plug connected equipment unless the standard being used has an equivalent test.

8 Information to be Provided to the Integrator

8.1 The robot or load port supplier should provide documents describing these products’ safety circuits including circuit diagrams and electrical ratings and critical safety parameters, including maximum temperature, pressure, flow, speed, or force for the critical components.

8.2 The safety evaluation for a robot or load port should describe the risk assessment used to determine the appropriate type of safety circuit.

8.3 The load port supplier should provide the integrator with data for the speed and drive force for those moving parts of the load port that can present a Very High, High, or Medium risk, determined in accordance with SEMI S10, of an injury.

8.4 The force needed to dislodge a FOUP while the load port door is open should be provided if the force is less than 106 N (24 lbs) applied to an empty FOUP.

NOTE 32: This force is roughly 125% of the weight of a fully loaded 300 mm FOUP (containing 25 wafers). The assumption is that this is not a sufficient force to cause the FOUP to fail.

8.5 The robot supplier should provide the integrator with documents showing either the robot space or the robot maximum space.

8.5.1 Data for the drive force, velocity and the mass of each axis as provided by the supplier should be provided, including the force to stop motion or break free from servos/stepper motors (if used).

8.5.2 Documents should describe the means of controlling the kinetic and potential energy of each axis in an emergency stop (e.g., what is done to control the tendency of the robot to drop or coast after an emergency stop).

8.5.3 The procedure for controlling the potential energy of all axes for purposes of hazardous energy isolation (lockout) should be provided.

8.6 Electrical test data for the leakage current and dielectric tests for subsystems using hazardous voltage or hazardous electrical power should be provided for cord and plug connected equipment. If over-voltage protective devices (e.g., surge arrestors) were removed in order to perform the dielectric test, this should be noted.

8.7 The robot supplier should provide specific lifting information for removal of robots either manually or by mechanical assist. If special lifting fixtures are needed they should be provided. The lifting details should be sufficient for an integrator to specify a commercially available mechanical assist for the end user when needed.
RELATED INFORMATION 1
TYPES OF SAFETY CIRCUITS

NOTICE: This related information is not an official part of SEMI [doc number] and was derived from practical application by task force members. This related information was approved by vote of the EHS Committee on [date of approval].

R1-1 Purpose
R1-1.1 This Related Information provides an introduction to the risk assessment method and types of safety circuits contained in ISO 13849-1.

R1-2 Risk Assessment
R1-2.1 The risk assessment method in ISO 13849-1 considers the severity of the harm, the exposure to the hazard, and the probability of avoiding harm from the hazard to determine the Performance Level needed to reduce the risk from that hazard to an acceptable level. These factors are rated either high or low, in contrast to the risk assessment method of SEMI S10.

R1-2.2 Based on the three factors, one can select the appropriate Performance Level of the safety circuit (see ANNEX A of ISO 13849-1).

R1-2.3 The Performance Level does not correspond directly to the category of the safety circuit, because the reliability of the components and the degree of diagnostic coverage of fault detection can raise or lower the Performance Level for the categories.

R1-3 Safety Circuit Categories
R1-3.1 The following list refers to categories of safety circuits described in ISO 13849-1 offering increasing levels of reliability:

R1-3.2 Category B: a control circuit using ordinary components.

R1-3.2.1 Category 1: a control circuit consisting of components of established suitability for safety use.

R1-3.2.2 Category 2: a control circuit that is monitored periodically. (A fault may or may not prevent operation when needed.) If a fault is detected, operation will be limited until the fault is cleared.

R1-3.2.3 Category 3: a control circuit that will perform its safety function in spite of a single fault, and will detect the fault when it operates.

R1-3.2.4 Category 4: a control circuit that will detect faults before operation and will operate in spite of more than one failure (i.e. some combinations of multiple faults).

NOTE 1: Categories 2, 3 and 4 have fault detection.

NOTE 2: There is an unfortunate overlap between terminology for stop categories and safety circuit categories. In particular, a Category 1 Stop is not the same as a Category 1 control circuit.

R1-4 Components in Safety Circuits
R1-4.1 Components of established suitability for use in a Category 1 circuit may be either:

- Components evaluated and approved by an accredited testing laboratory for use in safety controls (see “safety-rated” components in ANSI R15.06).

- Components with a history of successful use in safety controls. (e.g., positive-opening switches) (see “well-tried components” in ISO 13849-1 and ISO 13849-2).

R1-4.2 A component, such as a switch that relies on a spring to open its contact, may fail by having one or more contacts welded shut. So, while such a component may be used successfully in other contexts, it would not be suitable for use in a Category 1 safety circuit. A switch with positive-opening contacts is more reliable, because the applied force is very likely to open contacts, even if they are welded. A positive-opening switch with two contacts in
series may be configured so the force is applied to both contacts. As a result, one contact will open even if the other were solidly welded shut. Welding of two contacts in series is extremely improbable, so such a switch design has a history of successful use in safety controls.

R1-4.3 The level of reliability that components provide is related to their Mean Time to Dangerous Failure (MTTFd). This can be determined by using data provided by the component manufacturer or using default values provided in Annex C of ISO 13849-1 and determining the percentage of failures that increase risk of the safety circuit failing to perform its function.

NOTE 3: Single electronic devices, and switches or relays using a spring to open contacts are examples of components are not likely to be approved by an accredited testing laboratory for use in Category 1 safety circuits.

NOTE 4: Category 2, 3, & 4 safety circuits rely on the structure of the circuit to operate despite a single fault rather than the reliability of the components. Consequently, “safety-rated” or “well-tried” components are not always necessary, although their use will enhance the reliability of the safety circuit.

R1-5 Other factors effecting the performance of safety circuits

R1-5.1 A spring-operated switch can be configured to be positive opening. For example, if opening a door forces the contacts open and the spring is used to close the contact when the door is closed, the likelihood of contacts not opening when necessary is reduced.

R1-5.2 The mean time to dangerous failure of each safety circuit channel is determined by combining the MTTFd of all the components as shown in Annex D of ISO 13849-1. Adding more components to a channel results in a lower MTTFd.

R1-5.3 For category 2, 3 and 4 safety circuits the effectiveness of the fault detection will enhance or diminish the performance of the safety circuit. A method to evaluation this effectiveness is provided in Annex E of ISO 13849-1

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