7 Information Provided by the Supplier

7.1 The supplier should provide the equipment owner with operation and/or maintenance manuals or similar documents drafted according to SEMI S13, which include the following information on the materials used in equipment, subassemblies and components upon the delivery of the equipment:

NOTE 2: The supplier may gather appropriate information at the time of design in conjunction with a disposal party.

7.1.1 Primary materials of appropriate disassemble-able unit in consideration with reuse, refurbishing, recycling and disposal of each component such as, chemicals (e.g., mercury), metals (e.g., stainless steel, steel, or copper), plastics (e.g., ABS - i.e., Acrylonitorile Butadiene Styrene plastics - or non-combustible ABS), glass, or ceramics.

7.1.2 Describe opportunities for reuse, refurbishing or material recycling of every component or recyclable subassembly. If there are no opportunities, a waste disposal method should be recommended based on assumption of usage with baseline process by the supplier. (e.g., ABS can be recycled after decontamination as class X plastic and mercury requires reclaim or hazardous waste disposal.)

7.1.3 *Disassembly Procedure*

7.1.3.1 A disassembly procedure should be recommended by the supplier to the level required to facilitate complete decontamination and material separation for waste disposal.

7.1.3.2 The disassembly procedure should include procedures to remove all hazardous energies.

7.1.3.3 The disassembly procedure should prevent the mixture of incompatible chemicals. If it is not feasible, administrative control procedures should be included.

7.1.3.4 If the chemicals/materials described from Sections 7.1.3.4.1 to 7.1.3.4.4 are hazardous, the disassembly procedure should prevent the release of them to the environment. The chemicals include:

7.1.3.4.1 Chemicals used to maintain the equipment (e.g., lubricant and coolant).

7.1.3.4.2 Other potentially hazardous items which are parts of the equipment, such as capacitors, batteries, lamps or mercury, which require special disposal procedures.

7.1.3.4.3 Chemicals used in the baseline process of the equipment manufacturer.

7.1.3.4.4 Anticipated byproducts of the baseline process.

NOTE 3: Byproducts are changeable according to several kinds of conditions such as exhaust diameter/length/volume, chamber volume/pressure/configuration, maintenance method/cycle, and evacuation frequency.

7.1.3.4.5 The disassembly procedure should address any hazards of ionizing radiation sources, if they are present, and address safe removal and storage procedures.

7.1.4 Disposal procedure should be a safer way based on the result of risk assessment such as SEMI S10 or EN 1050 and job hazard analysis.

8 Information Provided by the Equipment Owner

8.1 Prior to disposal, the equipment owner should provide the following information to the disposal party in order to reflect all residual waste hazards. This information should be provided to any party handling the waste regardless of intention to dispose or recycle the equipment unless the component in question is fully decontaminated.

8.1.1 Relevant information provided by the supplier per Section 7 of this document.

8.1.2 Chemicals used in the equipment owner specific process other than the baseline process and its byproducts.

8.1.3 Decontamination and waste disposal method for parts contaminated by an equipment owner specific process other than the baseline process.

8.1.4 The minimal information of necessary personal protective equipment (PPE) based on the equipment usage history.

NOTE 4: PPE and necessary training are to be specified by the employer of those personnel to be protected.

8.1.5 The details of the decontamination procedure and any remaining chemicals and their locations after the equipment owner has completed initial decontamination of the equipment.

9 Selection of the Disposal Party

9.1 The disposal party must comply with regional/national codes and regulations related to the receipt, transfer and disposal of equipment.

NOTE 5: A specially controlled industrial waste disposal license as well as a specially controlled waste collection and transfer license may be typically required by the relevant country's government.

9.2 The incident and compliance record of the waste disposal party should be considered at the time when a selection of the disposal party is made.

10 Equipment Disposal Procedure

10.1 The possibility of refurbishing the entire piece of equipment should be considered before disassembly and disposal is selected.

10.1.1 When refurbishing of the entire equipment is chosen, only the disposal parts which are not able to be refurbished at the time should be decontaminated or considered for disposal. This results in a significant reduction in waste.

10.2 *Equipment Decontamination and Packaging for Transfer* — Equipment being transferred should comply with SEMI S12 and all applicable hazardous materials shipping regulations. If the equipment has to be transported prior to decontamination, it should be ensured, that no contaminants may be released (e.g., by appropriate packaging).

10.3 *Disassembly and Decontamination* — The equipment owner or disposal party should follow all local regulations regarding disassembly and disposal.

10.3.1 If there is an equipment owner specific process, the specifics of that process and its hazards should be provided to the disposal party by the equipment owner.

10.4 *Material Separation* — Only materials that cannot be refurbished, recycled or reused should be categorized for other disposal methods (e.g., incineration and landfill) under this disposal assessment procedure.

10.4.1 First decontaminate any contaminated material which is capable of further decontamination.

10.4.2 Discard any materials incapable of decontamination by appropriate contaminated waste disposal categories or process (e.g., incineration, hazardous landfill, etc.).

10.4.3 Further separate materials into reusable components (e.g., pumps, motors, electronics, etc.).

10.4.3.1 This includes any components with a potential for refurbishing.

10.4.4 Separate recyclable materials by categories (e.g., metals, class of plastics, etc.).

10.4.5 Separate into reclamation categories (e.g., mercury recovery from lamps, lead recovery from batteries, etc.).

10.5 The equipment owner should confirm that the disposal party follows the procedures required by this document through checking manifest and/or implementing practical inspection periodically as well as applicable regional codes and regulations.

10.6 Ionizing radiation sources, if present, should be disposed of in accordance with each applicable country, state and local regulations. All applicable licensing and reporting requirements should be met.

11 Documentation and Records

11.1 Documentation should be prepared and maintained by the equipment owner according to applicable codes and regulations for the region or locality where disposal occurs.

11.2 Documentation showing final disposition of each class of material should be returned to the equipment owner by the disposal party.

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

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SEMI S17-0701
SAFETY GUIDELINE FOR UNMANNED TRANSPORT VEHICLE (UTV) SYSTEMS

This safety guideline was technically approved by the Global Environmental Health and Safety Committee and is the direct responsibility of the Japanese Environmental Health and Safety Committee. Current edition approved by the Japanese Regional Standards Committee on February 1, 2001. Initially available at www.semi.org April 2001; to be published July 2001.

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

1 Purpose

1.1 These guidelines are intended as a set of environmental, safety, and health considerations for unmanned transport vehicle (UTV) systems. UTV systems are used to automate the movement of material within semiconductor factories. Unmanned transport vehicle systems include both floor-traveling vehicle systems and space-traveling vehicle systems.

2 Scope

2.1 This guideline applies to UTV systems used in semiconductor manufacturing.

2.2 This guideline addresses both floor-traveling and space-traveling UTV systems. Floor-traveling vehicle systems include automatic guided vehicle (AGV) systems and rail guided vehicle (RGV) systems. Space-traveling vehicle systems include interbay overhead transport vehicle systems and intrabay overhead hoist transport vehicle (OHT) systems.

2.3 Evaluations for conformance to this document should include all equipment that is provided by the UTV system supplier including separate items such as rails, control panels, power panels, and any other type of equipment necessary for operation of the unmanned transport vehicles.

2.4 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 guideline to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2.5 This document contains the following sections:

- Purpose
- Scope
- Limitations
- Referenced Standards
- Terminology
- Equipment Evaluation
- Clearances and Interfaces
- Emergency Shutdown
- Manual Operation
- Vehicle Travel
- Material Protection
- Load/Unload Operation
- Hazard Indicators
- Hazardous Materials
- Related Documents

3 Limitations

3.1 This safety guideline may have only limited application to vehicles without on-board power (direct or induced) such as primary-grounded linear–motor-driven overhead transport vehicle systems used for interbay transport. Determinations of applicability should be made by section when evaluating such systems.

3.2 This safety guideline does not address rail-guided or robotic mechanisms included as part of semiconductor processing equipment. This type of equipment should be evaluated as part of the processing equipment per SEMI S2.

3.3 Person Guided Vehicles (PGVs) are not unmanned vehicles, therefore PGVs are not addressed by this standard.

3.4 This document does not supersede international, national or local codes, regulations and laws, which may impose separate requirements for assessing the safety of installations.

NOTE 1: Users should provide information to UTV suppliers about regulations for the location of use.

4 Referenced Standards

NOTE 2: Unless otherwise indicated, all documents cited shall be the latest published versions.

4.1 *SEMI Standards*

SEMI E15.1 — Specification for 300 mm Tool Load Port

SEMI E23 — Specification for Cassette Transfer Parallel I/O Interface

SEMI E84 — Specification for Enhanced Carrier Handoff Parallel I/O Interface

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

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

4.2 *ANSI Standard*[1]

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

4.3 *CENELEC Standards*[1]

EN775 — Manipulating Industrial Robots – Safety

4.4 *ISO Standards*[2]

ISO 10218 — Manipulating Industrial Robots – Safety

5 Terminology

5.1 *automated operation* — system operation under full pre-programmed control of the computer controller.

5.2 *automatic guided vehicle (AGV)* — a floor based vehicle, with or without robotic manipulators, used for transporting loads and operating without the need for assistance by factory personnel. AGVs travel without mechanical guidance.

5.3 *bumper* — a shock absorber for a UTV. A bumper is typically equipped with a contact switch or sensor on it. And if the bumper switch or sensor is activated, the UTV will stop immediately.

5.4 *EMO* — an actuator (e.g., button) which, when activated, places the equipment into a safe shutdown condition, without generating any additional hazard to personnel or the facility.

5.5 *E-Stop* — emergency stop feature provided to stop all moving parts but not necessarily isolating or controlling all energy sources.

5.6 *end user customer* — as related to UTVs, the company operating the factory in which the UTVs are installed.

5.7 *fault-tolerant* — designed so that a reasonably foreseeable single point failure does not result in an unsafe condition.

5.8 *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).

5.9 *hoist* — the assembly on a space-traveling vehicle that performs the load/unload operation by transferring a load [e.g., carrier(s), pod(s)] to and from an overhead vehicle.

5.10 *interbay transport* — movement of loads [e.g., carrier(s), cassette(s), reticle(s)] between functional work areas or bays.

5.11 *intrabay transport* — movement of loads [e.g., carrier(s), cassette(s), reticle pod(s)] within a functional work area or bay.

5.12 *load* — load is the object to be transported by UTV. Load includes a carrier (cassette, box, pod, etc.) and its contents.

5.13 *load/unload operation* — the action necessary to move a load [e.g., carrier(s), cassette(s) reticle pod(s)] to and from a vehicle. This operation may involve hoisting, manual, or robotic manipulation to transfer loads between a vehicle and semiconductor manufacturing equipment (such as process equipment or stockers). See Figure 1.

5.14 *manual operation* — defined as any control outside of automated operation.

5.15 *overhead hoist transport (OHT)* — a rail guided vehicle and hoist used to transport material above the factory floor over the heads of factory personnel.

5.16 *rail guided vehicle (RGV)* — a floor-based vehicle, with or without robotic manipulators, used to transport loads and operating on a guide rail without the need for assistance by factory personnel.

5.17 *space-traveling vehicle* — a vehicle that automatically travels through space, such as in the region just below a factory ceiling, to a specified station where a load/unload operation is performed automatically or manually. Space-traveling vehicles include interbay overhead transport vehicles and intrabay overhead hoist transport vehicles (OHT).

1 American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036

2 International Organization for Standardization (ISO), 1 rue de Varembe, Case postale 56, CH-1211 Geneve 20, Switzerland

5.18 *station* — the destination point where an unmanned transport vehicle is programmed to stop for load/unload operation (also known as a control point).

5.19 *travel* — the automated motion of a vehicle along a rail or programmed path from one station to another station. Travel does not include load/unload operation. See Figure 1.

5.20 *unmanned transport vehicle (UTV)* — a vehicle used to automate the movement of production material within semiconductor factories. There are two types of UTVs, floor-traveling vehicles and space-traveling vehicles.

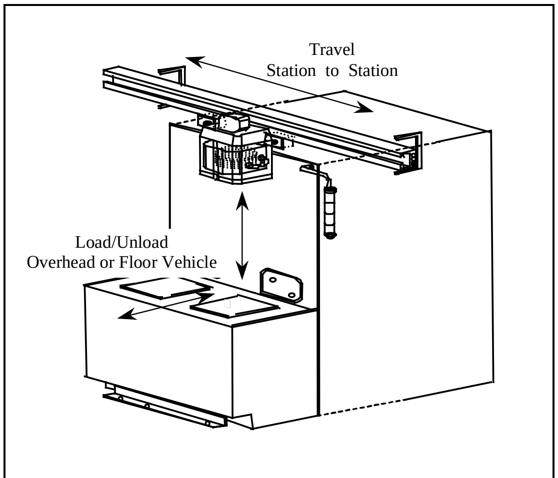

Figure 1
Delineation of Travel vs. Load/Unload

6 Equipment Evaluation

6.1 *Equipment Evaluation for both Floor-Traveling and Space-Traveling Vehicles* — All UTV equipment should be evaluated against the following referenced provisions.

6.2 All UTV equipment should be evaluated against appropriate sections of SEMI S2 for environmental, safety, and health considerations.

6.2.1 Evaluations to the provisions in the following sections of SEMI S2 are applicable to declare conformance to this document.

a) Electrical Design

b) Emergency Shutdown

c) Automated material handlers (This Automated material handlers section only applies to the robotics portion of UTV equipment, when provided.)

d) Hazard Warning Labels

e) Seismic Protection

f) Documents provided to User

6.2.2 At the discretion of the evaluator, additional provisions in SEMI S2 may be considered for evaluation based on the functionality of the UTV equipment.

6.3 All UTV equipment should be evaluated against SEMI S8 for ergonomic considerations.

6.4 All UTV equipment should be evaluated against the applicable Electro Magnetic Compatibility (EMC) regulations of the proposed installation site.

6.5 In addition to the provisions referenced in Section 6.1, UTV equipment should also be evaluated to the provisions contained in the following sections of this document.

7 Clearances and Interfaces

7.1 *Body Shape of both Floor-Traveling and Space-Traveling Vehicles* — The body of a UTV should be free of any dangerous parts such as sharp edges and protrusions. The UTV body surface should have a smooth finish.

7.2 *Minimum Clearance for Floor-Traveling Vehicles* — Where passageways are used for emergency egress, they should be provided on at least one side of the UTV. International, national or local codes, regulations, and laws should be used to determine passageway width.

7.3 *Minimum Clearance for Space-Traveling Vehicles* — The lowest part of the space-traveling vehicle, including the load, should maintain a minimum clearance of 2135 mm (7 feet) above the walking floor.

NOTE 3: Some end user customers may request a higher minimum clearance, or a minimum clearance between the space-traveling vehicle and the top of other equipment, to accommodate clearances specified by SEMI E15.1.

7.4 *Interfaces with Building Structures for both Floor-Traveling and Space-Traveling Vehicles* — UTV suppliers should provide for optional vehicle interfaces with building structures like doors, elevators, and walls.

7.4.1 If UTVs are required to operate in conjunction with building structures, such as automatic doors or elevators, UTVs should be capable of communicating with the facility to assure safe door opening/closing.

7.4.2 If it is necessary for a UTV to travel through a building firewall, the firewall pass through should be specified and/or designed to maintain the fire rating of the wall in the event of a fire.

8 Emergency Shutdown

8.1 *Emergency Shutdown for both Space-Traveling and Floor-Traveling Vehicles* — In addition to the emergency shutdown provisions of SEMI S2, UTV equipment should also conform to the following provisions.

8.1.1 The UTV should be equipped with an emergency off (EMO) circuit that, when activated, immediately stops the operation and motion of the UTV, including both travel and load/unload operation. The EMO circuit should be activated whenever the following actions occurs:

a) An EMO button on the UTV is pressed.

b) An EMO at a fixed floor location is pressed.

NOTE 4: See Section 9.2 for handheld remote control.

8.1.2 Once an EMO circuit has been activated, the UTV should not move under its own power until the cause of the emergency condition has been resolved and the system has been reset by a human operation. The system should not reset or restart automatically.

8.2 *Position of EMO Buttons on Floor-Traveling Vehicles* — Structure-mounted EMO buttons should be located for easy accessibility by factory personnel.

8.2.1 Vehicle-mounted EMO Buttons should be accessible and visible from all sides of the vehicle, typically on the four-corners of a floor-traveling vehicle.

8.3 *Position of EMO Buttons for Space-Traveling Vehicle Systems* — EMO buttons should be located for easy accessibility by factory personnel, for example:

- Near control panels or operator terminals including handheld vehicle remote controls.
- Near process equipment load ports or stations.
- On walls or other fixed locations in the factory area where space-traveling vehicles operate.

NOTE 5: Some end user customers may request EMO buttons included on the space-traveling vehicle.

8.3.1 Since space-traveling vehicle EMO buttons are typically remote from the vehicles, space-traveling systems should provide a method of determining the location of the activated EMO button. This will ensure that the emergency condition can be identified and resolved prior to resetting the system per Section 8.1.2.

9 Manual Operation

9.1 *Manual Movement of both Space Traveling and Floor-Traveling Vehicles* — When the EMO is activated, the UTV should be capable of brake release to allow for release of a potentially trapped person.

9.1.1 The UTV should be equipped with a manual movement function that permits a human operator to maneuver the vehicle in the event of a problem. In the event of a problem, manual movement of all vehicle functions including travel and load/unload should be allowed.

9.2 *Manual/Remote Operation of both Space-Traveling and Floor-Traveling Vehicles* — Except for EMO and E-Stop, any control of a vehicle outside of automated operation should be exclusive. Other devices should not override vehicle control or cause movement of more than one vehicle at a time.

EXCEPTION: Those controls that do not cause motion.

9.2.1 Manual control of a vehicle motion that could present a hazard if control is lost should be controlled with an enabling type switch, such that movement is enabled only when a switch is continuously held (pressed) by an operator.

9.2.1.1 Handheld remote controls should have an E-Stop or EMO function to allow operators to stop movement that could cause risk to themselves or others. If remote control is wireless, this function should not be marked or labeled as an EMO.

9.2.1.2 During handheld remote control operation, the UTV should stop any vehicle motion that could create a hazard if power or the communication signal is lost.

10 Vehicle Travel

10.1 *Collision Avoidance for both Space-Traveling and Floor-Traveling Vehicles* — UTVs should provide for protection of persons in the same traveling space from injury. Damage to property or equipment from traveling vehicles should also be prevented.

10.1.1 The UTV system supplier should provide documentation specifying safe practices for working within traveling space of the UTVs, to include documented administrative procedures necessary to work safely while performing maintenance on or near operating UTV systems.

10.1.2 UTVs should be equipped with non-contact approach sensing system so those vehicles do not inadvertently contact people or other obstacles during the traveling motion of the UTV. Non-contact approach sensing systems should consist of either electromechanical (preferred) or solid-state devices and components and be designed to be fault-tolerant.

10.1.2.1 If an overhead vehicle is provided with a fault-tolerant contact sensing system (such as a bumper switch), as primary safety protection for people, the circuitry of the secondary non-contact system is not limited to electromechanical or solid state devices and components.

10.1.2.2 Where solid-state devices and components are used in an approach sensing system circuit, the system and relevant parts of the system should be evaluated for suitability for use. Abnormal conditions such as overvoltage, undervoltage, power supply interruption, transient overvoltage, ramp voltage, electromagnetic susceptibility, electrostatic discharge, thermal cycling, humidity, dust, vibration, and jarring should be considered.

EXCEPTION: When the severity of a reasonably foreseeable mishap is deemed to be Minor per SEMI S10, a software based control may be considered suitable.

10.1.2.3 Upon request by the user customer, suppliers should provide a test piece or set of test pieces (appropriate to the sensor device provided) along with procedures for testing and calibration.

10.1.3 When a UTV detects a vehicle or obstacle, the UTV should decelerate and stop automatically before it touches that vehicle or obstacle. If the non-contact approach sensing device should be disabled (for example because the UTV is negotiating a sharp turn), the UTV should decelerate and issue a warning (see Hazard Alarms and Displays section of this document) to indicate that the sensing device has been disabled.

10.1.4 In an area where multiple UTVs are operating, the capability to prevent the collision of one vehicle with another should be provided and to satisfy Section 10.1.3, should consider the following conditions:

a) The distance between a given vehicle and the vehicle that follows it.

b) The timing at which one stream of vehicles merges with another.

c) The timing at which a vehicle branches out from a stream of vehicles to pass another vehicle moving toward it.

d) The distance that separates two vehicles when they pass each other.

10.2 *Collision Detection for Floor-Traveling Vehicles* — In addition to Section 10.1, floor-traveling vehicles should also be equipped with a contact sensing device (such as a bumper switch) capable of detecting collision in the direction in which motion can create a hazard.

10.2.1 The bumpers should have a shape and structure that does not pose a risk to personnel or to objects around the floor-traveling vehicle.

10.2.2 The bumpers should be equal to or larger than the width of the floor-traveling vehicle body, as measured perpendicular to the direction of its traveling motion.

10.2.3 The maximum allowable distance between a bumper and the floor is 15 mm (0.6 inch).

EXCEPTION: If this provision cannot be maintained, (such as when the floor-traveling vehicle enters an elevator, or changes in floor height) the distance should be explicitly stated in the operation manuals (and the specifications) as an alert or warning notice to appropriate personnel.

10.2.4 If an obstacle contacts a bumper, the floor-traveling vehicle should be able to stop within the bumper stroke, irrespective of the speed at which the vehicle is traveling. If this provision cannot be met for technical reasons, the floor-traveling vehicle supplier should clearly indicate the maximum speed at which the vehicle can stop within the bumper stroke.

10.2.5 There should not be any device that disables the functionality of the bumper switch or sensor on floor-traveling vehicles.

10.2.6 If a bumper switch or sensor has been activated by contact, a floor-traveling vehicle should not restart until the system has been reset by a human operation.

NOTE 6: Since space-traveling vehicles travel in dedicated space above the heads of factory personnel, criteria for space-traveling vehicle bumpers are not included.

10.3 *Protective Zones for Space-Traveling Vehicles* — Written administrative procedures for creating a protective zone around personnel, required to work overhead in the path of space-traveling vehicles, should be included in documentation provided by the UTV system supplier.

NOTE 7: Implementation of these administrative procedures is the responsibility of the end user customer.

10.4 *Travel Speed of Floor-Traveling Vehicles* — Floor-traveling vehicles, intended for use in areas where there are both operating vehicles and personnel present, should be equipped with a variable speed-setting mechanism.

10.4.1 The variable speed settings designed for use in areas with both operating vehicles and personnel should not exceed 60 meters/minute (196 feet/minute). Any variable speed settings exceeding 60 meters/minute (196 feet/minute) should be reserved for use in dedicated and unmanned areas for which personnel safety can be assured.

10.4.2 The variable speed setting mechanism of a floor-traveling vehicle should be designed so that only authorized personnel, following access control procedures, can change the vehicle’s speed setting.

NOTE 8: Criteria for traveling speeds of space-traveling vehicles are not included in this sub-section.

11 Material Protection

11.1 *Material Protection for both Floor Traveling and Space-Traveling Vehicles* — UTVs should provide for protection of the load when the UTV is traveling and during load/unload operations until safe transfer has been confirmed. UTV's should have an appropriate communication interface (For example SEMI standards such as SEMI E23 or SEMI E84). The UTV system supplier should document the exact method of confirmation.

11.1.1 UTVs should be designed so a single point of failure of the UTV system does not allow a load to fall.

11.1.2 Vehicles should be designed to prevent any load/unload movement when in traveling mode.

11.1.3 UTV load holding mechanisms should have load-shift prevention mechanism (such as stoppers), so that if the vehicle stops suddenly, the load is securely held in place.

11.2 *Material Protection for Floor-Traveling Vehicles* — In addition to the load protection provisions in Section 11.1, the following should also be provided on floor-traveling vehicles.

11.2.1 The floor-traveling vehicle should be designed to prevent loads from being placed on the vehicle so that the load overhangs any edge (length or width) of the vehicle.

11.3 *Material Protection for Space-Traveling Vehicles* — In addition to the load protection provisions in Section 11.1, the following should also be provided on space-traveling vehicles:

11.3.1 If secondary protection is required to meet Section 11.1.2 or to prevent loads from falling, covers or shields should be provided along rails to protect personnel from injury from falling loads.

11.3.2 Inadvertent lowering or uncontrolled drops of the vehicles' hoist mechanisms or loads should also be prevented.

12 Load/Unload Operation

12.1 *Protection from Load/Unload Motion of both Floor-Traveling and Space-Traveling Vehicles* — UTVs should have protection functions during load/unload operation to insure safety of the vehicle, the load and the equipment, until load/unload is completed.

12.1.1 Safety of personnel entering the load/unload area should be provided by a method agreed upon by the UTV supplier and the user.

12.1.2 UTVs should have an appropriate communication interface in order to provide the following functions. Examples for such interfaces are SEMI E84 or E23.

- confirm safe transfer of a load
- prevent transfer of loads prior to load port readiness
- notify affected factory personnel of abnormal load/unload conditions
- prevent transfer of loads when equipment is in manual delivery mode (PGV mode)
- prevent transfer of loads when equipment is at risk.

12.1.3 The UTV system supplier should provide to the end user customer documentation to ensure the UTV system interfaces properly with manufacturing equipment shields (if required), communications protocols, or other method necessary to prevent transfer of loads when equipment is at risk.

12.2 *Protection from Load/Unload Motion of Floor-Traveling Vehicles* — In addition to the load/unload provisions in Section 12.1, the following should also be provided on floor-traveling vehicles:

12.2.1 Load/unload mechanisms (transfer robots) on floor-based vehicles should be isolated or shielded as necessary to restrict contact with factory personnel. Measures should also be taken to prevent inadvertent motion of load/unload mechanisms.

12.2.2 If robotic manipulators are used on floor-traveling vehicles for load/unload operations, the robotic manipulator should meet requirements of the appropriate international or national standard (e.g., ISO 10218, EN775, or ANSI/RIA 15.06). If there are deviations from these general industry standards because of unique semiconductor applications, these deviations should be documented by the evaluator and assigned a risk factor according to a risk assessment.

13 Hazard Indicators

NOTE 9: The integrated design of any hazard indicator system or other safety system requires a coordinated effort among the UTV system supplier, the process equipment supplier, and the end user customer. The following are the minimum hazard indicators to be designed into UTV system equipment.

13.1 *Hazard Alarms and Lamps for both Floor-Traveling and Space-Traveling Vehicles* — The following indicators should be provided on all UTVs, but should be able to be configured to be compatible with the overall factory design for safety.

13.1.1 UTV suppliers should provide documentation of available configurations.

13.1.2 *Malfunction Alarm* — In the event of a malfunction, the UTV should both light a lamp(s) and generate an alarm sound to alert personnel.

NOTE 10: Malfunction alarms typically require the system to be reset by a human operation.

13.1.3 *Manual Operation Indicator* — The UTV should indicate if it is under manual operation, defined as any control of a vehicle outside of automated operation.

13.1.4 *Sensor Disabled Lamp* — The UTV should light a lamp(s) to indicate when the non-contact approach sensing device is disabled (for example, because the UTV is negotiating a sharp turn).

13.2 *Hazard Alarms and Lamps for Floor-Traveling Vehicles* — In addition to the indicators in Section 13.1, the following indicators should also be provided on floor-traveling vehicles:

13.2.1 *Startup Alarm* — When a floor-traveling vehicle restarts after stopping for 5 seconds or more, the vehicle should set off an audible alarm sound at least one second before it begins to move.

13.2.2 *Traveling Alarm* — When the floor-traveling vehicle is traveling, the vehicle should generate audible alarm sounds either continuously or intermittently as appropriate for the area in which the vehicle is operating.

13.2.3 *Turn Signal Lamps* — To indicate a floor-traveling vehicle is preparing to turn/spin-turn (right or left) and during the turn cycle, the vehicle should light turn signal lamp(s). Turn signal lamps should be clearly visible from the side in the direction of the turn.

13.2.4 *Automated Operation Indicator* — The floor-traveling vehicle should light lamp(s) to indicate it is in automated operation.

13.3 *Hazard Alarms and Lights for Space-Traveling Vehicles* — In addition to the indicators in Section 13.1, the following indicator should also be provided on space-traveling vehicles.

13.3.1 *Hoist Alarm* — The space-traveling vehicle and/or hoist should generate audible alarm sounds indicating that the hoisting mechanism is moving (raising or lowering).

NOTE 11: The same audible alarm device can be used to generate startup, traveling, hoist, or malfunction alarms, provided that different sounds are used to indicate each condition.

13.4 *Visual Hazard Alerts for both Floor-Traveling and Space-Traveling Vehicle Areas* — To assure personnel safety in the UTV operation area, information about the recommended system of safety measures should be provided by the UTV system supplier (including items such as alerts, signs, color coding, and safety poles for the vehicle operating area).

13.4.1 The UTV system supplier should provide information about style and placement of road signs, for posting along floor traveling vehicle paths and at load/unload or maintenance stations.

NOTE 12: End user customers may need to provide additional visual hazard alerts for posting on building structures (such as walls, columns, and doors) and/or equipment surrounding the UTV operation area.

13.5 *Visual Hazard Alerts on Floor-Traveling Vehicles* — In addition to the information about operational area visual hazard alerts (noted in Section 13.4), the floor-traveling vehicle supplier should provide all visual hazard alerts required for the floor-traveling vehicle. These visual hazard alerts should be clearly visible from all sides of the UTV.

13.6 *Visual Hazard Alerts for Space-Traveling Vehicles* — In addition to the operational area visual hazard alerts noted in Section 13.4, the following visual hazard alerts should also be provided by space-traveling vehicle suppliers.

13.6.1 The UTV system supplier should provide marking of maintenance station areas and their hazards, as well as a method of marking the floor location where maintenance descent occurs.

NOTE 13: End user customers may need to mark load/unload stations to identify the existence of the hazard. UTV system suppliers should suggest a method of marking these areas.

14 Hazardous Materials

14.1 *Batteries for Floor-Traveling and Space-Traveling Vehicles* — If the UTV requires the use of batteries, the following should be included in the documentation provided by the UTV supplier.

14.1.1 Specifications provided by the UTV system supplier for battery recharging, battery maintenance and battery storage areas should specify the following. This provision can be waived only if the batteries used are sealed with no possibility of gas emission.

- Requirements for eye-washing equipment.
- Requirements for ventilation.
- Restrictions on smoking and other sources of ignition.
- Personnel splash protection requirements during electrolyte handling.

14.1.2 The UTV system supplier should provide disposal requirements for batteries that constitute hazardous waste (such as lead, nickel cadmium or lithium).

NOTE 14: Disposal requirements should comply with national or local codes, regulations, and laws.

NOTE 15: Per SEMI S2 environmental guidelines, the UTV system supplier should provide information on the nature, volume, and risks of potential hazardous waste (such as lead or lithium).

NOTE 16: Battery charging stations may have to meet international, national, or local regulations (such as EU Directives or U. S. Department of Labor, Occupational, Safety and Health Act Regulations).

14.2 *Spill Prevention for Floor-Traveling and Space-Traveling Vehicles* — If the UTV requires the use of lubricants, the UTV supplier should meet the following spill and slip hazard provisions.

14.2.1 Any UTV with an internal oil-reservoir (such as a gearbox) should be structurally designed to prevent any oil from dripping out of the vehicle.

14.2.2 Space-traveling vehicle track lubricants should be restricted to those lubricant types and quantities that will not drip from the vehicle or create a slip hazard.

14.2.3 Rail guided vehicle or track lubricants should be restricted to those lubricant types and quantities that will not drip (e.g., onto sub-Fab floors). Neither should they create a slip hazard on the walking surfaces beside the rail or on the top of the rail itself.

15 Related Documents

15.1 *SEMI Standards*

SEMI E33 — Specification for Semiconductor Manufacturing Facility Electromagnetic Compatibility

SEMI E64 — Provisional Specification for 300-mm Cart to SEMI E15.1 Docking Interface Port

SEMI S1 — Safety Guideline for Visual Hazard Alerts

15.2 *ANSI Standard*[3]

ANSI/ASME B56.5 — Safety Standard for Guided Industrial Vehicles and Automated Functions of Manned Industrial Vehicles

15.3 *CEN Standards*[4]

EN 1525 — Safety of Industrial Trucks – Driverless Trucks and their Systems

15.4 *U.S. Government Regulations* [5]

29 CFR 1910 — U. S. Department of Labor, Occupational, Safety and Health Act Regulations

15.5 *JIS Standards* [6]

JIS D 6801 — Glossary of Terms Relating to Automatic Guided Vehicle Systems

JIS D 6802 — General Rules on the Safety of Automatic Guided Vehicle Systems

JIS D 6803 — General Rules on the Design of Automatic Guided Vehicles

JIS D 6804 — General Rules on the Design of Automatic Guided Vehicle Systems

JIS D 6805 — Testing Method of Characteristics and Functions of Automatic Guided Vehicles

15.6 *VDI Standards* [7]

VDI 2510 — Automated Guided Vehicle Systems (AGVS)

VDI-3643 — Self-Powered Trolley System – Load 500kg

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

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3 American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036

4 European Committee For Standardization, 36, rue de Stassart, B-1050 Brussels, Belgium

5 Code of Federal Regulations, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

6 Japanese Industrial Standards available in Japanese language only through Japanese Standards Association, 1-24, Akasaka 4-chome, Minato-ku, Tokyo, Japan 107-8440

7 Verein Deutscher Ingenieure (VDI), Postfach 101139, D-40002 Düsseldorf, Germany

RELATED INFORMATION 1
PROTECTIVE DEVICE OPTION CONSIDERATION FOR LOAD/UNLOAD OPERATIONS AT SEMICONDUCTOR MANUFACTURING EQUIPMENT LOAD STATIONS

NOTE: This Related Information is not an official balloted part of SEMI S17. It is included to assist the user of the document in making decisions about possible options.

R1-1 Purpose

R1-1.1 This Related Information should act as an application note for consideration and selection of safety devices that may be provided to protect load/unload operations where risks are generated by space traveling vehicles.

R1-1.2 Space traveling vehicle suppliers are not required to provide such devices, except as necessary to comply with local jurisdictional requirements.

NOTE R1-1: Refer to the main document for devices recommended for protecting equipment.

R1-2 Scope

R1-2.1 *Protective Devices* — As related to UTV equipment, devices designed to protect personnel or equipment from injury or damage during raising or lowering of loads into position.

R1-2.2 Protective devices should be considered when space-traveling vehicles with hoisting mechanisms are present.

R1-2.3 Protective devices function to warn of, or prevent transfer of, loads when personnel or equipment are at risk.

R1-2.3.1 This application note covers the following types of devices:

- Sensors
- Shields
- Alarms
- Signs and visual alerts
- Communication protocol

NOTE R1-2: This should not be considered a complete list there could be many other solutions.

R1-3 Limitations

R1-3.1 This Related Information is not intended to apply to situations where load ports are installed only in locations inaccessible to personnel walking on the factory floor (such as SEMI E15.1 Option 2 load ports).

R1-3.2 This Related Information does not apply to factories using only floor-traveling vehicles or PGVs.

R1-4 Considerations

R1-4.1 Protective devices should be considered for preventing transfer of loads when personnel or equipment are at risk.

R1-4.2 Protective device integration should be considered a coordinated effort between UTV supplier, manufacturing equipment supplier and the end user customer.

R1-5 Lookdown Sensors

R1-5.1 *Lookdown Sensors* — Such sensors surround the hoisting mechanism and look down to the loadport to determine if anything is within the path of descent.

R1-5.2 Lookdown sensors are one type of protective device that allows for the overhead vehicle to “see” if there is anything in the expected path of descent.

R1-5.3 Lookdown sensors can serve the function of protecting equipment from impact.

R1-5.4 Lookdown sensors should be capable of communicating the need for operator intervention back to a location that can notify the proper personnel.

R1-6 Shield Options

R1-6.1 *Shield Device* — Shield devices are physical shielding which is placed to block access to a hazard area.

R1-6.2 Shield devices, when selected, should be capable of fitting within the dimensional limitations of the load ports. (See SEMI E15.1 for dimensional requirements and exclusion zones for 300 mm load ports.)

R1-6.3 Shield device types include:

- Curtain Sensor
- Safety Guard
- Automatic Doors

R1-6.4 Shield devices, when chosen, should prevent simultaneous load/unload operation by a floor-traveling vehicle or person and a space-traveling vehicle.

R1-6.5 *Protective Device Interlocks* — These confirmation signals from shield devices are used to interrupt the transfer process if a shield is breached.

R1-6.5.1 In the case of UTV systems, protective device interlocks should communicate to the UTV equipment either directly or through the manufacturing equipment.

R1-6.5.2 Communication should be via a protected-path communications protocol that is fail safe.

R1-7 Alarms

R1-7.1 A*larms* — Alarms consist of audible and visual notices of hazards that may be approaching.

R1-7.2 Alarms may also be selected as protective devices.

R1-7.3 Alarms may be field configurable to allow for selection of type of audible or visual allowed, or to allow for selection of either audible or visual and elimination of the other type.

R1-8 Signs and Visual Alerts

R1-8.1 Signs such as “Caution”, “Warning”, or other sign appropriate to the potential hazard may be selected as a method of protection.

R1-8.2 Signs should be compatible with SEMI S1, or should be approved by the local jurisdictional authority.

R1-8.3 *Visual Alerts* — an indicator applied to floors or vertical surfaces surrounding a potential are of delivery, which indicates to persons present that a potential hazard exists in the area.

R1-8.4 Visual alerts may include:

- Striped tape on the floor
- Warning barriers
- Railings

NOTE R1-3: This should not be considered a complete list there could be many other solutions.

R1-9 Communication Protocol

R1-9.1 *Communication Protocol* — A method of communicating the status of the equipment to a centrally monitored location. This may be direct or through the equipment communication path.

R1-9.2 Protective devices offered should be capable of communicating with floor-traveling and space-traveling UTVs through some type of interface.

R1-10 Providing Information

R1-10.1 If protective devices are offered, the UTV supplier should provide documentation to the end user customer about protective devices available.

R1-10.2 Information should be provided to the user to explain the function of any protective devices that may be offered.

R1-10.3 Information may also be needed by suppliers of other equipment to insure adequate communication between equipment types.

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SEMI S18-1102
ENVIRONMENTAL, HEALTH, AND SAFETY GUIDELINE FOR SILANE FAMILY GASES HANDLING

This guideline was technically approved by the Global Environmental, Health, and Safety Committee and is the direct responsibility of the Japan Environmental, Health, and Safety Committee. Current edition approved by the Japan Regional Standards Committee on July 19, 2002. Initially available at www.semi.org September 2002; to be published November 2002.

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

1 Purpose

1.1 This guideline is intended as a minimum set of safety and health criteria for silane family gases handling related to equipment and facilities used in semiconductor or Flat Panel Display (FPD) manufacturing.

2 Scope

2.1 Silane family gases which are described in this guideline are: monosilane (SiH_4), disilane (Si_2H_6), trisilane (Si_3H_8), dichlorosilane (SiH_2Cl_2) and trichlorosilane ($SiHCl_3$).

2.2 This guideline includes the following sections:

- Purpose
- Scope
- Limitations
- Referenced Standards
- Terminology
- General Principles
- Education and Training
- Leak Detection and Alarm Systems
- Fire Detection, Suppression and Alarm Systems
- Emergency Response
- Materials, Components, and Construction for Silane Family Gas Handling Equipment and Facilities.
- Pressurization and Leak Testing
- Storage
- Supply Systems
- Distribution Systems for Gas Supply
- Equipment Using Silane Family Gases
- Exhaust Systems and Plumbing
- Exhaust Treatment Systems
- Related Documents

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

3 Limitations

3.1 This document is not intended to impart requirements on any party.

3.2 This document is not intended to apply to gas manufacturers or distribution companies.

4 Referenced Standards

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4.1 *SEMI Standards*

SEMI F1 — Specification for Leak Integrity of High Purity Gas Piping Systems and Components

SEMI F3 — Guide for Welding Stainless Steel Tubing for Semiconductor Manufacturing Applications

SEMI F4 — Specification for Pneumatically Actuated Cylinder Valves

SEMI F5 — Guide for Gaseous Effluent Handling

SEMI F6 — Guide for Secondary Containment of Hazardous Gas Piping Systems

SEMI F13 — Guide for Gas Source Control Equipment

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

SEMI F15 — Test Method for Enclosures Using Sulfur Hexafluoride Tracer Gas and Gas Chromatography

SEMI S1 — Safety Guideline for Equipment Safety Labels

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

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

SEMI S5 — Safety Guideline for Flow Limiting Devices

SEMI S6 — Safety Guideline for Ventilation

SEMI S10 — Safety Guideline for Risk Assessment

SEMI S13 — Safety Guideline for Operation and Maintenance Manuals Used with Semiconductor Manufacturing Equipment

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

4.2 *NFPA[1] Standards*

NFPA 13 — Installation of Sprinkler Systems

NFPA 70 — National Electrical Code

NFPA 318 — Standard for the Protection of Cleanrooms

4.3 *Compressed Gas Association[2]*

CGA P-20 — Standard for the Classification of Toxic Gas Mixtures

CGA P-23 — Standard for Categorizing Gas Mixtures Containing Flammable and Nonflammable Components

4.4 *Other Documents*

High Pressure Gas Safety Law[3]

The High Pressure Gas Safety Institute of Japan (KHK), Application Guide for the High Pressure Gas Safety Law[4]

Santa Clara County Toxic Gas Ordinance No. NS-517.44[5]

SSA Journal[6], — Volume 11 No. 4, Winter 1997

4.5 *US Code of Federal Regulations*

Uniform Fire Code (UFC)[7] —Sections *51, 79 and 80* — Semiconductor Facility-Specific Sections

29CFR 1910.1200[8], — "Hazard Communication" (OSHA)

NIOSH Pocket Guide — available online at http://www.cdc.gov/niosh/topreq.html

4.6 *EU Directive*

The Safety Sheets Directive 93/112 EEC

5 Terminology

5.1 Terminology defined in SEMI S2 should be referred to except if otherwise specified below.

5.2 *Abbreviations and Acronyms*

5.2.1 *ACGIH®* — American Conference of Governmental Industrial Hygienists. (ACGIH is a registered trademark of the American Conference of Governmental Industrial Hygienists.)

5.2.2 *ESOV* — Emergency Shut Off Valve.

5.2.3 *IDLH* — Immediately Dangerous to Life and Health, concentration of airborne contaminants, normally expressed in parts per million or milligrams per cubic meter, which represents the maximum level from which one could escape within thirty minutes without any escape-impairing symptoms or irreversible health effects. This level is established by the National Institute of Occupational Safety and Health (NIOSH). [SEMI F6]

5.2.4 *MSDS* — Material Safety Data Sheet, a document that provides information on the properties of a chemical material in a format specified by a regulation such as OSHA 29 CFR 1910.1200, "Hazard Communication".

5.2.5 *PTFE* — Poly Tetra Fluoro Ethylene.

5.2.6 *SSCS* — silane safety control system. SSCSs are integrated systems of detection devices that, when monitored as a group, provide for an overall status of the safety of the hazardous gas handling system (e.g., pressure transducers linked to valve status monitors and valve cycle counting programs or excess-flow monitoring interlocked to shutdown the source).

5.2.7 *TLVs®* — Threshold Limit Values for chemical substances in the work environment adopted by ACGIH® (TLV® is a registered trademark of the

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

2 Compressed Gas Association, 1725 Jefferson Davis Highway, Suite 1004, Arlington, Virginia 22202-4102

3 KHK, Sumitomo-Tranomon Bldg., 4-3-9 Toranomon, Minatoku, Tokyo 105-8447

4 KHK, Sumitomo-Tranomon Bldg., 4-3-9 Toranomon, Minatoku, Tokyo 105-8447

5 Santa Clara County TGO

6 SSA Journal, SSA Journal Headquarters 1313 Dolly Madison Blvd. Suite402, McLean, VA22101

7 Uniform Fire Code, 5360 South Workman Mill Road, Whitter, CA 90601

8 Occupational Safety and Health Administration U.S. Department of Labor, http://www.osha.gov

American Conference of Governmental Industrial Hygienists.) [SEMI F6].

5.2.8 *TWA* — Time Weighted Average — As defined by the American Conference of Governmental Industrial Hygienists (ACGIH®) [SEMI F6].

5.2.9 *VMB* — Valve Manifold Box.

5.3 *Definitions*

5.3.1 *abatement system* — a system used to modify the effluent from a process in order to make it safe to emit from the facility or to reduce emissions of hazardous materials to safe levels.

5.3.2 *authorized personnel* — those persons trained and capable of performing activities involving the risks associated with the defined tasks.

5.3.3 *carriage* — a hand cart for carrying one or two gas cylinders.

5.3.4 *chlorosilane* — dichlorosilane or trichlorosilane.

5.3.5 *controlled condition* — when related to silane family gases, a condition in which the gas is controlled within the confines of an approved piping system with controls that can determine if the safe parameters of the piping system have failed.

5.3.6 *exhaust treatment system* — a system similar to an abatement system, except it handles only the airborne emissions from a process in order to make them safe to emit or to reduce the levels of hazardous materials to safe emission levels.

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

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

5.3.9 *Flow Limiting Device* — a device installed in a valve that is designed to reduce the maximum flow from the valve under full flow conditions [SEMI F5] [One such device is a Restricted Flow Orifice (RFO)].

5.3.10 *foolproof* — designed so that any single human error or misuse does not result in unacceptable risk.

5.3.11 *occupational exposure limits (OELs)* — 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. When OELs are used to specify work-area criteria in this document , OELs are generally established on the basis of an eight hour workday. When OELs are used to specify criteria in this document for alarm or warning in non-occupational area, OELs established on shorter exposure basis may be used. 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.)

5.3.12 *oxidizer gas* — a gas which will support combustion or increase the burning rate of a combustible material with which it may come in contact [SEMI S4].

5.3.13 *pyrophoric gas* — "a gas which upon contact with air will ignite spontaneously at or below a temperature of 54°C (130°F) [SEMI S4]" at a pressure of 101.3kPa (14.7psia).

5.3.14 *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.

5.3.15 *safe state* — a condition in which the equipment does not present any uncontrolled hazards to itself or to personnel. It does not allow hazardous production chemicals to flow. An acceptable safe state is determined by the designer of the equipment and is based on the hazards in the design.

5.3.16 *silane* — any of monosilane, disilane, or trisilane.

5.3.17 *unacceptable risks* — risks of a degree or type which are not acceptable to the person who approves a design or procedure.

5.3.18 *unsafe gas condition* — a condition in which the gas is not safely contained within the designed parameters of the equipment process, or which could lead to a gas emission or gas hazard.

6 General Principles

6.1 Since silane family gases have several hazardous properties, personnel should wear appropriate protective equipment when working with silane family gas sources.

6.1.1 Monosilane (SiH_4), disilane (Si_2H_6) and trisilane (Si_3H_8) are pyrophoric. If these gases are mixed with stronger oxidizing gases than air, combustion and explosion energies can radically increase.

6.1.2 Dichlorosilane (SiH_2Cl_2) is pyrophoric and trichlorosilane ($SiHCl_3$) is flammable. Dichlorosilane (SiH_2Cl_2) and trichlorosilane ($SiHCl_3$) are also corrosive gases. If these gases are mixed with moisture, corrosivity can radically increase and pyrophoric byproduct gases might also be produced.

NOTE 2: The most recent and best research on DCS puts the AIT (Auto Ignition Temperature) at 44 degrees C plus/minus 3 degrees C, or about 111 degrees F. It should be noted however, that unlike silane, DCS is not expected to autoignite in almost all ambient conditions where we would find it in use. For fire protection purposes it can be treated as a highly flammable gas.

6.2 *Risk Management Strategies* — Fundamental concepts of safety and accident prevention are:

6.2.1 An understanding of facilities, piping and equipment, from storage to gas abatement, is essential for safe handling of silane family gases in semiconductor or FPD manufacturing facilities.

6.2.2 The safety of facilities can be enhanced by implementation of designs for sources, piping and equipment that use devices with fail-safe, foolproof, self-diagnostic and predictive functions.

6.2.3 Safety systems should detect current safety status and generate notices that indicate conditions of elevated risk, through computer self-diagnosis and dedicated SSCS devices. If the SSCSs cannot confirm normal operation of assigned silane family gas handling system or unit, the silane family gas supply should automatically be shut off.

6.2.3.1 SSCSs can determine if a safe status has been achieved before proceeding to the next step in a silane family gas handling process.

6.2.3.2 SSCSs should be provided in distribution facilities, cylinder cabinets, process equipment, gas treatment systems, and the like.

6.2.4 Safe design depends on equipment designers' and facilities designers' understanding of silane family gas properties and hazards. Design methods for controlling these hazards require full integration of measures from all portions of the delivery and use systems.

NOTE 3: Information on silane family gases' hazards is available from various sources, including: regulations, MSDSs, Factory Mutual Loss Prevention Data Sheets, NFPA Standards, consensus Building Codes, and various research papers.

6.2.4.1 The supplier should complete, prior to use, a hazard identification and risk assessment [such as Process Hazard Analysis (PHA), Hazard and Operability Analysis (Haz-Op), Failure Mode Effects Analysis (FMEA)], for all silane family gas systems.

6.2.4.2 The results of the analysis should be reported using the SEMI S10 risk matrix.

6.2.5 *Minimization of Quantity* — The quantity of any silane family gas online and in use should be limited to the smallest amount necessary for effective production.

NOTE 4: Separation and setback considerations for silane family gas storage and dispensing areas must be in accordance with jurisdictional requirements.

6.2.6 Periodic accident prevention assessments should be performed to assist in minimizing incident frequency.

6.3 *Isolation (Lockout/Tagout)* — Isolation ("lock out/tag out") capability should be provided for all silane sources at all levels necessary to perform service or maintenance safely on silane family gas systems.

6.3.1 Energy isolation of all other energy sources (e.g., electrical, mechanical) should be performed, as appropriate, to provide safety for personnel working on energy systems associated with silane family gases.

NOTE 5: Maintenance on energized non-hazardous electrical systems may not be safe when a silane family gas is present in the system.

6.4 *Access Control*

6.4.1 Multiple level access control, to each point where any hazard may exist in a normal or failure state, should be provided for all silane family gas systems.

6.5 All personnel concerned in silane family gas handling should be trained for the jobs they are to perform and hazards to which they will be exposed. All such training should be formally documented and if regulations apply then the documentation should be in accordance with the regulations.

6.5.1 Audits of system status and equipment condition should be performed and documented on a periodic basis.

6.5.2 The operator or technician should be capable of checking the current status and any abnormal condition before beginning work on any system or sub-system.

6.5.3 *Evacuation and Purging*

6.5.3.1 When connecting silane family gas piping to equipment, the air in the piping should be purged out with inert gas such as nitrogen into a safe location to prevent reaction with silane family gases.

6.5.3.2 To enable purging without venting into unsafe locations, a purge port should be installed at locations where sealed systems require purging. Purge ports should have a stop valve and, if not connected to the purge gas, should be sealed with a cap or plug.

6.5.3.3 The user should introduce silane family gases only after purging oxidizing gases and other incompatible gases, materials or substances from the system.

6.5.3.4 Silane family gas systems should have procedures based on calculated minimum purge cycles, minimum purge-gas pressures, and necessary vacuum levels to insure the system has been adequately purged before being opened to atmosphere. Calculations are needed to define minimum number of cycles. Process purges typically far exceed this number of cycles, therefore testing is usually not necessary.

6.5.3.5 An adequate means should be provided to avoid a cross contamination of purge gases and the process gases by accidental backflow.

6.5.3.6 Separation of purge gas and silane family gases should not solely depend on check valves. A control valve, such as a pneumatic valve placed before or after the check valve, is preferred for isolating silane family gases from other gases during procedures that might allow reverse flow.

6.5.4 The purge gas for silane family gases should be supplied from dedicated source containers.

NOTE 6: Some regional codes (e.g., Japan's High Pressure Gas Safety Law) require a purge gas source which is totally separated from the purge gas source for oxidizer gas lines.

6.5.4.1 Purge lines from dedicated bulk supplies (where allowed at all by the jurisdiction) should have multi-level back-flow and pressure differential protection to prevent potential back-flow of pyrophoric gases into bulk systems.

NOTE 7: Back-flow into these bulk purge systems has been known to generate ignitable mixtures when the inert gas is exposed to atmosphere far from the source of contamination.

7 Education and Training

NOTE 8: It is important for managers as well as employees to deepen their understanding of the characteristics of gases that they handle, so as to ensure safe work practices. If employees do not handle gases, this section is not applied.

7.1 Everyone who handles silane family gases should be specially educated about the hazardous properties and safe handling methods of these gases.

NOTE 9: Some jurisdictions (such as Japan) require that users of "specialty high-pressure gases" provide special safety education to their employees.

7.1.1 In regard to safety education and training, each organization should create the curricula or obtain approved curricula for education and training, assign a person responsible for education and training, and implement a periodic training plan.

7.1.2 Instructors should be persons who have sufficient knowledge and experience about the hazards, use and safe control of silane family gases.

NOTE 10: It may be necessary to request the assistance of outside experts, depending on an organization's capabilities.

7.1.3 Training should include safe use, handling, hazardous properties and by-products and emergency procedures of process gases as well as case studies of past accidents.

7.1.4 Training should be performed periodically and the training results documented.

7.2 Equipment and facilities suppliers, maintenance service providers and users should establish education curricula for job specific environmental, safety, and health (ES&H) education programs, train their personnel, and keep records or issue certificates.

7.3 Maintenance personnel should be fully trained in their own areas of responsibility.

7.3.1 Maintenance personnel should understand the overall design of facilities and equipment for silane family gases.

7.3.2 Energy isolation ("lock out/tag out") training should be provided to all employees who are expected to perform service or maintenance on silane family gas systems.

7.4 Training curricula, should be requested from the responsible party (constructor, facility manager, or equipment manufacturer) as part of the purchase specifications.

7.4.1 Each party should have qualified persons to train personnel working in their facility.

NOTE 11: It may be necessary to request the assistance of outside experts to perform training, depending on an organization's capabilities.

NOTE 12: Responsible persons for each party must be trained as required by regulation.

7.5 Training of persons performing periodic inspections should be provided to ensure the inspections are performed and documented properly.

NOTE 13: Ideally, information on safe design practices and accident investigation summaries should be freely shared across the industry, so the information can be provided, as part of education and training, to all personnel who could potentially be exposed.

8 Leak Detection and Alarm Systems

8.1 *General*

8.1.1 Audible and visual alarms should be provided at a location where they can be seen and heard by workers.

8.1.2 Remote audible and visual alarms should be provided at a constantly attended location so that appropriate actions can be taken.

8.2 *Silane Family Gas Leak Detection Practice*

8.2.1 Leak can be detected directly with leak sensors (gas detectors) or indirectly with heat or fire detectors.

NOTE 14: Sensor types include electrochemical, chemically treated tape, chemiluminescence, ionization detection, and UV/IR.

8.2.1.1 Gas detection should be capable of detecting the silane family gas down to a level at least one-half of the TLV® level.

8.2.1.2 Ultraviolet/Infrared (UV/IR) detectors may be allowed in some jurisdictions.

8.2.1.3 If UV/IR detection is used, it should be designed to focus its detection beam across all areas within the silane family gas exhausted enclosure where leaks may occur.

8.2.1.3.1 UV/IR detection may be able to detect the heat signature at levels lower than detectable limits for gas detectors in some situations.

8.3 *Leak Detection Installation*

8.3.1 The location of detection points should be determined by considering airflow patterns, specific gravity of the gas, surrounding conditions or barriers, and equipment height.

8.3.2 A leak detection system should be installed with detection points at intervals appropriate to the detection technology, or as required by regulation, for exhaust ducts or cylinder storage.

8.3.3 Leak detectors should also be placed:

- in gas cabinets at locations that will detect leaks from the piping system or the cylinder,
- in gas manifold boxes for silane family gas distribution systems, and
- to detect leaks within equipment gas boxes for equipment using silane family gases.

8.3.4 Leak detectors should be provided or specified for locations where potential exposure is anticipated during maintenance or service, when the normal detection points might not detect a release.

8.3.5 The number and location of detection points should be determined from detector capabilities, and the area (or volume) to be monitored by each detector.

NOTE 15: A detection point is a collection opening for a suction type gas leak detection system or a detector for a diffusion-type gas-leak detection system.

8.3.5.1 The coverage should be tested after installation to verify performance.

8.4 *Leak Detection Systems Characteristics*

8.4.1 Leak detection systems should be fail safe.

8.4.2 Effective detection that can generate warnings and alarms when a given concentration of gas is detected.

8.4.3 Warnings, which may not activate the audible and visual alarms, should be generated at a concentration level equal to or below OEL or as specified in an applicable regulation of the country of use. Alarms, which do activate notifications and audible and visual alarms, should be activated at OEL concentration level. If the OEL value is not available for a silane family gas, or if the value is impractical for the system, the lowest detectable concentration technically practical or the concentration set by an applicable regulation should be used.

8.4.4 The system should be capable of detecting the target gas beginning at a level at least ½ of the OEL, and continuing to at least ½ IDLH (Immediately Dangerous to Life and Health) levels.

8.4.5 A 10% voltage variation should not produce more than a 30% change in the indicated concentration.

8.4.6 Detection should be capable of detecting a release, within one minute of exposure of the detection point, to a leak, which has a concentration above the concentration of the warning or alarm level.

8.4.7 The alarm should continue, even if the concentration varies after detection, until it is manually reset.

8.4.8 Activation of the leak detection system in a gas cabinet should close the automatic cylinder shut off valve referenced in Section 14.3.5.

8.5 *Maintenance*

8.5.1 Gas leak detection and alarm systems should be periodically inspected and maintained following the procedures provided by the gas detection system manufacturer.

8.5.1.1 Inspection and maintenance should be recorded.

8.5.2 The system should be calibrated at intervals specified by the detection system manufacturer.

8.5.3 Calibration should be performed frequently enough to meet the accuracy criteria.

8.6 The gas leak detection system should have back up power (e.g., UPS, emergency power, etc.) to maintain its function during short-term power interruption or be fail-safe. The back up power should be periodically tested or inspected and the test or inspection documented.

NOTE 16: The testing, the inspection, and the documentation must be in accordance with any applicable regulations.

8.7 There may be a need for gas detection in some exhaust treatment systems to detect breakthrough. See the Exhaust Treatment System section for details.

NOTE 17: Gas detector monitoring in ducts may be required by regulation or permits.

9 Fire Detection, Suppression, and Alarm Systems

9.1 Alarms should connect to the facility under the guidelines of SEMI S2.

9.2 Fire Detection and suppression system(s) where used should be operational at all times, including when equipment or facilities are shut down or in maintenance modes. See SEMI S14 for guidelines for determining whether such systems are appropriate and for designing them.

EXCEPTION 1: Maintenance of the fire detection system.

EXCEPTION 2: Activation of the fire detection system should not remove power from fire detection system and safety systems.

9.3 *Fire Detection and Suppression for Bulk Silane Systems*

9.3.1 An automatic fixed water spray system should be provided for any bulk silane system for purposes of cooling the system only.

9.3.1.1 The regulator station and control panel areas should also be protected by a water spray system for purposes of cooling the system only.

NOTE 18: Design density, area and duration should be calculated appropriate to the surface area of the container using a method such as the one provided in NFPA 318.

9.3.2 Activation of the optical flame detectors, manual activation, or heat-link activators should initiate the water spray system and should close emergency shutoff valves (ESOVs). ESOVs should be located directly on the source or on the piping, as close to the container as possible.

9.4 *Fire Detection and Suppression*

9.4.1 Fires within valve manifold boxes (VMBs) may impinge on other lines within the VMBs. If this is assessed as an unacceptable risk, there may be a need for fire protection.

9.4.2 When fire protection is installed, it should remain active during all conditions such as maintenance and service.

EXCEPTION: Maintenance of the fire protection system.

10 Emergency Response

10.1 Exhaust and abatement systems should be left running during any emergency event, including fire in the facility.

10.2 *Evacuation of Personnel*

10.2.1 Procedures for evacuation, as a result of a gas leak, should be developed based on a hazard analysis and should be appropriate to the level of hazard.

10.2.2 After an evacuation, no one should re-enter the area until the exposure risk has been reduced to an acceptable level.

10.2.3 All personnel in the facility should be trained regarding proper evacuation procedures.

10.3 *Leak Identification and Isolation*

10.3.1 If the appropriate method of achieving a safe situation is for a response team to enter, only authorized and trained response personnel may enter to locate and fix the leak.

10.3.2 If the leak location can be accurately determined, the specific source supplying silane family gases to the leak location should be automatically shut down.

10.3.3 If the leak location cannot be accurately determined, all of the systems supplying the area where the leak was detected should be shut down.

10.3.4 Do not enclose a silane installation where adequate exhaust flow can not remain during a leak. This could lead to an explosion.

10.4 *Recovery from Leaks*

10.4.1 Trained personnel should investigate the incident until the original or root cause is determined. Systems should not be restarted until the safety of the entire system is confirmed.

10.4.2 Sufficiently purge all affected systems with an inert gas.

10.4.3 Perform appropriate leak tests to confirm that the affected system is safe before allowing silane family gas back into the system.

10.4.4 Check the reliability of installed detectors. Change the detectors if necessary.

10.4.5 Confirm that the system (from the silane family gas, source systems to the gas abatement systems) is not damaged. Perform corrective actions if necessary.

10.5 *Fire and Explosion*

10.5.1 The only safe way to extinguish a gas fire is to shut off the source.

NOTE 19: Do not attempt to extinguish any gas fire except by shutting off the source. Many countries require fire extinguishers at gas storage areas, but these should be used for extinguishing things other than the gas, or for escape.

10.5.2 Water spray or deluge systems should be used only to cool the container or adjacent containers to prevent other cylinders from heating or over-pressurizing.

10.5.3 Accidental extinguishing of a gas fire without shutting off the gas presents an unacceptable risk of explosion.

10.5.4 When fire is suspected, contact the emergency responders.

NOTE 20: Local fire departments may not be trained in silane family gas fires. The emergency responders should include plant emergency response teams or public hazard response teams, as well as fire departments.

10.5.5 Only trained personnel should enter an area affected by a silane family gas fire.

10.5.5.1 Trained responders to a fire event should be wearing appropriate protective equipment before entering the area.

10.5.5.2 After a fire event, check the reliability of installed fire detectors. Change the detectors if necessary.

11 Materials, Components, and Constructions for Silane Family Gas Handling Equipment and Facilities

11.1 *Material* — Material used for piping and components for silane family gas should be suitable for maintaining structural integrity.

11.1.1 Combustible materials (as defined in SEMI S2) should not be used in constructing assemblies that contact, support or make up structural components of silane family gas handling equipment, unless specifically designed as safety devices.

11.1.2 Materials such as SUS304, SUS316, SUS316L, Monel, Hastelloy or XM-27 may be needed to provide adequate protection from corrosion related to chlorosilanes.

11.1.3 Dust caps for chlorosilanes, plastic gaskets or O-rings for secondary seals should be made of chemically stable and heat-resistive materials (e.g., PTFE) of a suitable size to fit the cap.

11.2 *Components*

11.2.1 Components should be nationally approved, conform to national standards, or be accompanied by data that demonstrates safety and compatibility.

11.2.2 When cylinder connection gaskets are used they should be single-use metal-surface compression gaskets (unless incompatible) that do not provide a source of additional fuel.

11.2.3 Components used in the piping should be selected with structures that minimize dead leg sections.

11.2.4 Gas cabinet or equipment suppliers should provide the user with reliability data for repeated operations, so the user can schedule replacement of the components within their expected lifetimes.

11.2.5 If a pneumatic valve is used, the operating gas should be nitrogen (N_2) or another inert gas.

11.3 *Construction*

11.3.1 Equipment, facilities and piping should be protected from electrostatic discharge.

11.3.2 Assembly of stainless steel components should be by welding wherever possible to reduce the need for exhausted enclosures.

11.3.3 *Fittings* — Fittings should be welded, (preferably orbital-butt-welded) wherever possible. Mechanical joints (metal-gasket face-seal fittings) should be used when disassembly will be required.

NOTE 21: Compression fittings lead to increased risk of leaks, especially when subjected to expansion and contraction by temperature changes.

11.3.4 Only cylinder connections approved by a recognized authority such as the Compressed Gas Association (CGA) should be used on gas cylinders, to prevent connection of a cylinder containing an incompatible gas.

NOTE 22: Special style connections such as CGA-DISS can provide added protection by their use of “keyed” differentiation between gas types.

12 Pressurization and Leak Testing

12.1 Each supply piping system should be both pressure-tested and leak tested.

NOTE 23: Leak testing alone (as in SEMI F1 purity testing) will not detect potential increased-pressure failures.

12.2 *Pressurization Testing*

12.2.1 Pressurization testing should be performed to determine the integrity of the assembled piping.

12.2.2 Pressurization testing should be performed at 150% of the pressure to which the piping section can be exposed if a single component fails.

NOTE 24: There may be pressure requirements to higher levels under some regulations.

12.2.3 *Procedure* — Seal the test target with the test gas and pressurize to the test pressure. Maintain the test condition for 24 hours. Read the pressure gauge and confirm that the pressure deviation (with temperature correction) is within the error of the gauge.

12.3 *Leak Testing*

12.3.1 Use one of the following two methods:

NOTE 25: Leak testing should be performed with a gas such as Helium or Helium/balance Nitrogen.

12.3.2 *Inboard Leak Testing*

12.3.2.1 Generate a vacuum within the test section with a leak check system. Expose the exterior of the piping, its joints and fittings to a tracer gas source. While exposing the exterior of the piping to the tracer gas watch the leak detection system for detection of the tracer gas.

12.3.2.2 Detection of any tracer gas indicates a leak.

12.3.3 *Outboard Leak Testing*

12.3.3.1 Pressurize the test section with the test gas to 150% of the pressure expected during normal operation at room temperature. Use a leak detection system to search the exterior of the piping for presence of the tracer gas.

NOTE 26: Authorities Having Jurisdiction (AHJs) may require higher pressures.

12.3.4 *Corrective Actions* — If any pressure or tracer gas gauge change is detected, repair the leak and retest.

12.4 *Exhaust Piping*

NOTE 27: Pressurized exhaust piping does not include facility exhaust ducts.

12.4.1 *Pressurized Exhaust Pipe Leak Testing* — Exhaust and treatment system piping should be pressure tested to 100% of what could be the expected pressure within the piping during a catastrophic reaction within the piping. The expected pressure is determined by evaluation of the foreseen operating pressure and exhaust piping contents.

13 Storage

13.1 *General Considerations*

13.1.1 Storage area construction materials should be non-combustible and compatible with the hazards presented by the silane family gases present.

NOTE 28: For certain gases, it may be necessary to consider multiple hazards, such as in the case of dichlorosilane, which is both pyrophoric and corrosive.

13.1.2 Silane family gases should be separated from other gases per SEMI S4.

13.1.3 The recommended storage temperature is less than 40°C.

13.1.4 A water deluge or sprinkler system should be installed over storage area for silane family gases to cool the gas containers during a fire event and reduce the effect of impingement of flame from one container on another.

EXCEPTION: Cylinders of volume of 1 liter or less may be exempt from this criterion.

NOTE 29: Many jurisdictions require sensors, detectors, and lighting fixtures all to be of electrical construction meeting hazardous location requirements (e.g., not less than NEC Class 1 Div. 2.) in rooms classified as flammable rooms.

13.1.4.1 Access to a source of fire protection water should be provided.

13.2 *Cylinder Storage*

13.2.1 Cylinders of silane family gases in storage should maintain cylinder valve plug securely tightened and cylinder valve protective cap in-place.

13.2.2 Cylinders should be stored in an area adequately designed to protect the building from reasonably foreseeable incidents in the cylinder storage area.

13.2.2.1 Cylinders not located in bunkers should be provided with a security open chain-link fence. The cylinders should be separated from adjacent structures and the fence by a minimum distance of 2.7m (9ft) as shown in Figure 2. [NFPA 318]

13.2.2.2 If cylinders which contain silane family gases are stored in a structure independent from occupied building, mechanical or natural ventilation at a minimum of 0.005 meter/second (about 1cfm/square foot) should be provided for the structure in which the cylinders are stored.

NOTE 30: Refer to standards such as NFPA 318 or High Pressure Gas Safety Law for more details.

13.2.3 The construction or location of the cylinder storage should not inhibit safe cylinder transfer.

13.2.4 A cylinder should be secured to the structure (directly or indirectly) with at least two non-combustible securing devices positioned to prevent cylinders from falling sideways as might be experienced when only a single device is installed.

NOTE 31: Jurisdictions may impose additional requirements.

14 Supply Systems

14.1 *Bulk Silane* — Bulk silane supply systems should incorporate the following features:

14.1.1 *Location and Construction*

14.1.1.1 The container and its peripherals should be constructed outside of buildings with set back from buildings and property lines as required by NFPA 318 or regulation. An example of the recommended layout is shown in Figure 1.

NOTE 32: There may be some jurisdictions that require more separation than NFPA 318.

NOTE 33: Additional protective barriers may be required to shield nearby structures or activities from potential flying objects.

14.1.1.2 A full risk assessment should be performed to determine if there are other risks with the location such as vehicular traffic and sabotage.

14.1.1.3 The storage configuration should be of open construction and have natural ventilation that does not allow for pocketing of silane that could result in explosion, unless regulations require enclosures.

14.1.1.4 Bulk silane systems should be separated from each other and from the regulator station by 2-hour-rated firewalls.

14.1.2 Access control should be installed to protect from unnecessary approach of persons.

14.1.2.1 The storage area should have at least two exits.

14.1.2.2 Workers from the gas supplier and trained site personnel should be the only persons authorized to work in a bulk silane gas area.

14.1.3 *Controls and Safeguards*

14.1.3.1 The arrangement of piping, valving, controls, and valve manifold boxes as recommended for liquefied silane Gas Bulk system should be considered.

14.1.4 *Flow Components*

14.1.4.1 The Flow Limiting Device [e.g., restricted flow orifice (RFO)] size used in bulk systems should be as small as possible to meet combined process needs.

NOTE 34: Combined process needs include the influences of the length of the delivery line.

14.1.4.2 A Flow Limiting Device should be placed in the outlet valve of the delivery manifold from the tube trailer.

14.2 *Liquefied Silane Family Gas Bulk Systems*

14.2.1 Liquefied silane family gas bulk systems should be equipped with the following controls and safeguards:

a) Excess flow protection,

b) Secondary containment for spills,

c) A manual shutdown valve at both the point of supply and the point of use and dispensing,

d) Overpressure monitors with pressure relief and automatic gas shut off, and

e) A system to prevent overfilling for automated delivery systems.

14.2.2 If heating mechanisms for liquefied gas containers are required, over-temperature interlocks should be provided. Indirect heating is recommended.

14.3 *Gas Cylinder (Rack) Systems*

14.3.1 Open dispensing racks for silane should not be located in rooms inside the building.

14.3.2 Exterior dispensing areas should be separated from structures in accordance with Figure 2. The dispensing area should be open on at least three sides with cylinders secured to steel frames. Where a canopy is provided, the height should be a minimum of 3.7 m (12 ft). [NFPA318].

14.3.3 The construction or location of the on-line cylinder system should not inhibit safe cylinder transfer.

NOTE 35: Jurisdictions may impose additional requirements.

14.3.4 A system of controls regarding how many and which cylinders are on-line should be implemented. This includes how many cylinders can be connected in any given bundle as well as the size and capacity of cylinders.

14.3.5 Cylinders should be equipped with normally closed automatic pneumatic shutoff valves and restricted flow orifices.

NOTE 36: The industry has moved almost exclusively to this condition.

NOTE 37: For cylinder pack systems, a gas detection system may be required by some jurisdictions. The detection should close all cylinders ESOVs upon activation.

NOTE 38: An example of the recommended arrangement in a cylinder gas supply system is shown in Related Information 3.

14.3.6 If multiple cylinders are used, in parallel, for continuous supply during a cylinder replacement, an automated switching system should be employed for the system.

14.3.7 Flow Limiting Devices should be only as large as necessary to meet process flow requirements.

NOTE 39: UFC 80-1 requires maximum 0.010-inch orifice for cylinders in silane service.

14.3.8 *Cylinder Systems Using Gas Cabinets*

14.3.8.1 *Exhaust Requirements*

14.3.8.1.1 A forced exhaust system should be provided for cabinets. Air flow should be directed across potential leak points to prevent pocketing.

NOTE 40: Recommendations for cabinet exhaust are provided in RI-2.

14.3.8.1.1.1 The forced exhaust system for silane family gas should have capability of treating worst case leak. The treatment may be accomplished by either an abatement system or dilution of silane family gas to below 25% of the lower flammable limit.

14.3.8.1.1.1.1 A worst case leak is typically a full-flow release rate from the largest cylinder installed through the Flow Limiting Device at full cylinder pressure.

14.3.8.1.2 The exhaust system should be provided with automatic emergency source of backup power.

NOTE 41: Jurisdictional requirements may define backup power.

NOTE 42: Many jurisdictions require sensors, detectors, and lighting fixtures all to be of electrical construction meeting hazardous location requirements (e.g., not less than NEC Class 1 Div. 2.) in rooms classified as flammable rooms.

NOTE 43: In some jurisdictions, the exhaust and abatement system may not be required to operate continuously, provided when a leak is detected, the forced exhaust and abatement system be activated to abate the leak.

14.3.8.2 Mechanical ventilation should be provided for the gas cabinet to keep inner pressure of the cabinet negative to atmosphere. The effectiveness of the ventilation should be monitored.

14.3.8.3 Vent lines of the high pressure side of the regulator of silane family gas cylinders should be routed to an abatement system when applicable to meet jurisdictional requirements. The system should have the capability to abate the largest possible flow through the cylinder flow restrictor.

14.3.8.4 Excess flow switches should be provided upstream of the regulator, either in conjunction with high pressure process valves or on the pigtail immediately downstream of the cylinder valve. This is to limit the maximum flow of gas to the regulator.

14.3.9 *Special Cylinder Issues*

14.3.9.1 *Cylinder Change Procedures*

14.3.9.1.1 A well defined method of leak checking should be performed after a new cylinder is installed and prior to final pigtail purging to insure cylinder connection leak-tight integrity.

14.3.9.1.2 Appropriate personal protective equipment (PPE) should be worn during cylinder handling and changing.

14.3.9.1.3 Before opening the cabinet door to replace a cylinder, a visual inspection for silicon dioxide (SiO_2) powder should be performed. If SiO_2 is present, it is evidence of a leak in the system, and the door should not be opened until the gas supply is shut off and, if possible, purged remotely. Adequate precautions should be taken as trapped pockets of silane may ignite.

14.3.9.2 Cylinder should be transported with the cylinder valve plug securely tightened and the cylinder valve protective cap in-place.

14.3.9.3 Cylinder replacement should be performed by two persons. Each should have received appropriate training to perform their tasks safely.

14.3.9.4 Cylinders should be transported on appropriate carriages with adequate means for fixing the cylinder to the carriage.

14.4 *Changing Sources*

14.4.1 To prevent air from entering a silane family gas system during container change, a constant purge of the connection should be operating during the entire time the supply is not connected.

14.4.1.1 To prevent accidental intake of air into the source container, the source container pressure should be maintained above atmospheric pressure and replaced by new one before the pressure drops to atmospheric pressure.

14.4.1.2 At a certain minimum pressure, a warning should be provided to an attended location and the gas shut down.

14.4.2 *Auto-sequence Controllers* — Auto-sequence controllers are recommended whenever possible to reduce the potential for human error in supply change-out.

14.4.2.1 When an auto sequence controller is used, the leak test after replacement of the cylinder should be designed to monitor the pressures continuously within the purging supply system. Interrupted monitoring may not capture a pressure change that indicates ineffective purging.

14.4.2.1.1 The design of automatic-sequence control systems for cylinder cabinets should incorporate the following features:

a) Fault-tolerant design,

b) The ability to perform a leak check of the container by measuring pressure rise in the system, with the container valve closed, under the condition that the container has been connected and the purge gas eliminated,

c) Continuous pressure monitoring of the system during all purges and operating conditions, and

d) Written procedures for safe source container replacement including verification requirements for the leak testing and verification of the sensing system function.

NOTE 44: All tasks assessed as high risk (from the risk assessment) should minimize human interaction as much as possible.

15 Distribution Systems for Gas Supply

15.1 *General Considerations*

15.1.1 To enable purging without venting into unsafe locations, a purge port should be installed at locations where sealed systems require purging. Purge ports should have a stop valve, if not connected to the purge gas, should be sealed with a cap or plug.

15.1.2 Dead leg sections (internal piping which can trap silane family gases) should be minimized to the smallest volume possible.

15.1.3 An excess flow control valve should be installed on every silane family gas piping system as close as practical to the source. The excess flow control valve should be sized to deliver only as much gas as necessary to the process requirements.

NOTE 45: See Related Information 3 for an example.

15.1.3.1 Silane family gas delivery systems should be equipped with the following controls and safeguards:

a) Excess flow protection,

b) A manual shutdown valve at both the point of dispensing and in the distribution line near or in the equipment gas box, and

c) Over-pressure monitors with pressure relief and automatic gas shutoff when pressure is detected above the designed limit.

15.2 *Location and Construction*

15.2.1 *Piping General*

15.2.1.1 Piping should be welded throughout or contained within an exhausted enclosure.

EXCEPTION: Non-welded piping, outdoors, may not require an enclosure.

15.2.1.2 Piping should be labeled with the gas name and flow direction.

15.2.1.3 If the piping diverges into two or more lines, each line should be provided with a shut off valve.

NOTE 46: Some jurisdictions require both manual and automatic shut off valves.

15.2.1.3.1 These valves should enable cycle purging of each line.

15.2.1.3.2 These valves should be provided with an exhausted enclosure.

15.2.1.3.3 The enclosure should be monitored with detectors for the silane family gases present.

15.2.1.4 The ventilated enclosures should have exhaust monitoring per SEMI S2.

15.2.1.5 The piping of oxidizer gases should be isolated from the piping of silane family gases. The isolation should also be applied to silane family gas purge lines.

15.2.2 *Coaxial Piping*

NOTE 47: Some jurisdictions require building-runs of silane family gas piping to be of secondarily contained (coaxial) construction. Some believe there is little evidence that coaxial piping for these gases is appropriate, as long as non-welded fittings are within secondary enclosures. Coaxial piping may add substantial costs and other hazards which should then be addressed. However, pressurized, monitored, and interlocked coax lines provide a local warning to persons who accidentally damage the jacket. The sound of the escaping inert gas used to pressurize the jacket alerts the worker. The interlock alerts the facility of the breach, and reduces the total amount of process gas lost if the inner line is damaged.

15.2.2.1 When coaxial piping is installed, the annular space should be pressurized with helium or other inert gas, purged, or maintained at a vacuum.

15.2.2.2 If a purge method is used, the purge gases from the coaxial piping should be monitored with detectors for the specific silane family gas.

15.2.2.2.1 This detector should shut down the source when a leak is detected.

15.2.2.3 If a pressure or vacuum method is used, the pressure or vacuum in this annular space should be monitored and should alarm at a constantly attended location when a change occurs.

15.2.2.3.1 The alarm should also shut off the silane family gas at the nearest up-stream valve.

15.2.2.4 A procedure for responding to an annular space alarm, and determining the nature of the hazard condition, should be created.

15.3 *Flow Components*

15.3.1 The state of a valve (open or closed) should be indicated through display or on the valve itself. The supplier should provide the user with reliability data for repeated operations, and the user should replace the valve within its expected lifetime.

15.4 *Heaters and Heat Insulation Materials* — External heating of piping and regulators may be required in outside locations or long distance lines to prevent re-liquification. In such cases, the following should be considered:

15.4.1 If electrical resistance heating is used with insulation, the insulation should be visually inspected periodically for degradation or exposed wiring to avoid electrical arcing and damage to the piping.

15.4.1.1 Electrical resistance piping heating systems should not be placed in wet areas because of the increased possibility of damage from corrosion.

15.4.2 Electrical resistance piping heating systems should be monitored. Monitors should alarm in the event of over temperature, an open circuit or a short circuit and should shut off the power supply and gas supply.

15.4.2.1 Gas supply shutdown may be required by some jurisdictions.

NOTE 48: Heaters must conform to jurisdictional requirements for the device type.

16 Equipment Using Silane Family Gases

16.1 *Design*

16.1.1 Coaxial piping within process equipment is not usually practical, but piping between equipment gas box and process chambers should be coaxial piping if the piping is both pressurized and outside of exhausted and leak-monitored enclosures.

16.1.2 *Safe State* — Equipment should be designed so that detection of a silane release immediately sends the equipment into a safe state. Safe shutdown of the equipment itself or silane family gas sources may be appropriate.

16.1.2.1 Any silane process vacuum pump, when used, should be maintained and monitored for its ability to safely remove potentially hazardous silane family gases from equipment for maintenance and repair.

NOTE 49: For fire detection, suppression, and alarm criteria see Section 9.

16.1.3 Fire detection system activation should shut off flammable and pyrophoric gases supplying the equipment being monitored, as this is the only safe method of extinguishing gas fires.

16.1.4 Equipment using silane family gases should be capable of performing a purge/vacuum sequence to purge the silane family gas to prevent chemical reaction damage before service or maintenance.

16.1.4.1 The minimum number of purge/vacuum cycles should be decided according to the results of tests that evaluate the sequence effectiveness.

16.1.4.2 The equipment supplier should provide the minimum safe number of cycles to the user based upon the baseline process.

16.1.4.3 If adjustable, this minimum number of cycles should be controlled in such a way that the user is aware of the consequences of changing the cycle count, and access to the means of changing the cycle count is limited to maintenance or service personnel, but not operators.

16.1.5 When the appropriate number of purge cycles for the user's own process are determined by the user, the number should not be less than the minimum number of cycles recommended by the equipment supplier.

16.1.5.1 If unusual circumstances appear to reduce the number of cycles needed, the supplier should be consulted for a recommendation specific to the circumstances.

16.1.6 If a system is designed to supply a silane family gas and a gas with which the silane family gas can react, to a chamber simultaneously, the flows should be controlled to avoid concentrations and pressures of those gases that would pose unacceptable risks.

16.1.6.1 The equipment should be designed so that it will not initiate the next process step if a gas mixture condition that would pose unacceptable risks exists.

16.1.6.2 The equipment should not allow additional gas to flow until any unsafe gas condition alarm has been manually reset.

16.1.6.3 Silane family gases and incompatible gases should have separate piping up to the point where a system EMO or a safe-state function can shut them off.

16.1.6.4 A hazard analysis of the system, beyond the safe-state shut off, should be used to determine adequate protection.

16.1.6.5 No single component failure should allow for incompatible gases to mix, in manifolds or other areas, in pressures and concentrations that would pose unacceptable risks.

16.2 *Construction*

16.2.1 Equipment interface points for the gas supply piping should be designed with seismic bracing as needed to achieve the seismic protection detailed in SEMI S2.

16.2.1.1 The external force on the bending point should be minimized by use of reverse bending or other methods.

16.2.1.2 The tensile strength of joints should be compliant with the appropriate piping standard for the jurisdiction (such as ASTM/ANSI, ISO, or JIS).

16.2.2 Dead leg sections (internal piping which can trap silane family gases) should be minimized to the smallest volume possible.

16.2.3 Chambers intended for silane family gas processes should be evaluated for their ability to withstand reasonably foreseeable events related to the silane family gases such as fire or explosion that arise from single point failures.

16.2.3.1 If viewing ports are used they should be designed to the same capability as the chamber, or be provided with safety devices to capture any potential flying debris before it affects personnel or other equipment.

16.2.3.1.1 If viewing ports are intended to be user replaceable, the user documentation should specify the part and the change procedure and warn the user of the possible consequences of using an alternate part.

16.2.3.2 If an enclosure is required to contain chamber rupture, such an enclosure should be ventilated and evaluated per SEMI S2 and SEMI S6.

16.2.3.2.1 If the chamber rupture protection is an enclosure, the enclosure panels should be interlocked to prevent process initiation or continuance if the enclosure is open.

16.2.4 Flame sensors or leak detectors should be installed in all areas that may accumulate silane family gases from a leak.

16.2.5 The results of the tracer gas tests specified in SEMI S2 and SEMI F15, should indicate that ambient concentration of silane family gases will be less than the level specified in SEMI S2 during maintenance activities or delivery system failure.

16.3 *Vacuum Pump Systems*

16.3.1 Materials of construction for vacuum pumps that are exposed to the gas stream should be compatible with the gas stream.

16.3.2 Vacuum pumps that are exposed to the gas stream should be dry type or use inert (non-hydrocarbon) oil.

16.3.3 Purge gases for vacuum pumps should be nitrogen (N_2) or other inert gas. The flow rate of the purge gas should be sufficient to dilute the silane family gas to below the lower explosive limit until the gas has safely passed into the burn box or abatement system. If a combined pump/abatement system is used, this criterion is not applicable.

16.3.3.1 The flow rate of purge gas flow should be interlocked to shut off the silane family gases if the purge gas flow drops below the amount needed to insure adequate dilution.

16.4 *Protection*

16.4.1 *Fire Detection and Suppression*

16.4.1.1 Use the results of the risk assessment described in SEMI S14 to determine the need for fire detection and suppression.

16.4.1.2 Fire detection and suppression system(s) should be operational at all times, including when equipment or facilities are shut down or in maintenance mode.

EXCEPTION: Maintenance of the fire detection system.

16.4.2 As for any other safety design consideration aspect of process equipment, SEMI S2 provides criteria for assessing and managing safety risks.

16.5 *Information on Exhaust*

16.5.1 The equipment supplier should provide exhaust information to the user. The information should be based on the baseline process including:

- the chemicals and their composition,
- compatibility requirements and type of connection expected at outlet of the vacuum pump,
- the potential hazards expected if duct is open to air during the maintenance,
- recommended maintenance procedures when the equipment is connected to a point-of-use gas treatment system,

- recommended duct size and flow volumes, based on the suppliers recommended base process,
- information on potential maintenance issues associated with the process (such as silicate deposits and reactive by-product generation),
- The probable hazards that would be generated by exposure of open ducts to air during maintenance activities,
- maximum distance from the reaction chamber to the vacuum pump, and
- maximum distance from the pump to the exhaust connection or the point-of-use abatement.

16.5.2 The need to route the residual gas and by-products to the proper gas treatment system may require consideration of separate pump systems for incompatible gases.

16.6 *Other Information*

16.6.1 Manuals as defined in SEMI S13, should include information and training requirement on silane family gases, their hazards, and recommended protective measures.

16.6.2 Hazard warning labels should be designed in conformance to SEMI S1. Where such labels are to be placed should be decided per SEMI S2.

17 Exhaust Systems and Plumbing

17.1 *Design*

17.1.1 *Enclosure Exhaust System* — Exhaust piping for the gas panel enclosure or the pump enclosure may be required to be separated from heat exhaust line to prevent the possibility for mixing of incompatible chemistries before dilution.

NOTE 50: Separation of exhaust systems may be required by certain jurisdictions.

17.1.1.1 Air velocity for an enclosure should be calculated to minimize collection of silane family gases into pockets.

NOTE 51: Information to decide what amount of air velocity should be needed is provided through Related Information 2. Document such as CGA P32-2000 and NFPA318-2000 provides similar information.

NOTE 52: Some regulations may require minimum velocities until new research (SSA Journal, Spring and Winter 1998) can be incorporated into the regulations. This minimum velocity is not less than 1.0 m/sec for the overall enclosure, and air velocity across any potential leakage point is not less than 0.5 m/sec.

NOTE 53: Recommendations for gas cylinder cabinet exhaust provided in Related Information 2 can also be used for enclosures within process equipment. For the purpose of enclosure exhaust calculations, gas delivery pressure to the enclosure should be used as the "source pressure" in Figure 3 of Related Information 2.

17.1.2 *Process Exhaust Systems*

17.1.2.1 Materials of construction should be compatible with the hazards presented by the silane family gases present.

17.1.2.2 Materials for exhaust piping containing silane family gases should be compatible with the byproducts and should provide protection from heat and reactions, which may be present when silane family gases exit a reaction chamber.

17.1.2.3 No combustible joint compound (including adhesive or tape) should be used to seal joints.

17.1.2.4 Process exhaust piping should withstand the maximum potential pressure generated by the reaction of respective silane family gases in a reasonably foreseeable worst case, single-point failure at the process equipment.

17.1.3 Metal-gasket face-seal fittings should be used wherever possible. Compression fittings lead to increased risk of leaks, especially when subjected to expansion and contraction by internally burning and extinguishing silane family gases.

17.2 *Protective Devices*

17.2.1 Mechanical fittings in pressurized exhaust or treatment system should be enclosed in exhausted enclosures, like any supply piping. Leaking can be caused by the result of assembly and disassembly during pump and treatment system maintenance.

17.3 *Maintainability*

17.3.1 Maintenance personnel should inspect for liquids and solids collecting in exhaust ducts to prevent accidents resulting from the build-up of reaction products.

17.3.2 Ports for chemical sampling should be provided in order to enable inspection of deposits and sampling of gas composition and concentration in the exhaust duct.

17.3.2.1 Ports, if not connected to a sampling device, should have a stop valve and should be sealed with a cap or plug.

17.3.2.2 This monitoring should be performed periodically to insure gas composition and quantities have not generated new hazards and to characterize gas deposits and ensure they are being removed.

17.3.2.3 View ports also require periodic cleaning to provide for adequate viewing capability. If the gas is corrosive, these ports should be compatible with the hazards presented.

17.3.3 Due to the hazards associated with silane family gas deposits, only maintenance workers trained to handle the potential for reactions, small fires or explosions should be allowed to perform maintenance on exhaust ducts for silane family gases.

17.3.3.1 Maintenance management should investigate the thickness and composition of the deposits and establish the proper method of maintenance.

17.3.3.2 If the investigation indicates the deposit is reactive or unstable, a procedure to stabilize or neutralize the deposit before opening the duct to air should be implemented.

17.3.3.3 Equipment suppliers should also notify users that stabilizing or neutralizing procedures provided in the maintenance manuals might not work for exhaust lines with multiple silane family gas-using systems attached.

17.3.4 The exhaust piping should be designed to have a means of monitoring the exhaust line for determining if the exhaust line is blocked.

18 Exhaust Treatment Systems

18.1 *Selection*

18.1.1 Refer to SEMI F5 for techniques and information to determine the appropriate abatement (exhaust treatment) system.

18.1.2 The user should determine the composition, concentration, absolute amount per minute and possible phases (solid, liquid or gas) of all chemicals, to be treated, before requesting quotations on abatement systems. This information is very important to design an appropriate abatement system.

18.1.3 The information should be provided for normal operation and all reasonable foreseeable failures.

18.2 *Absorbent Systems* — Gas leak detection may also be needed as breakthrough detection for absorbent systems. To ensure that each gas treatment system functions properly, it should have a gas detection and alarm system that detects breakthrough of absorbent. The location of sample points should be appropriate to detect breakthrough of the absorbent according to the treatment system instructions.

18.2.1 When breakthrough is detected, the gas source which supplies silane family gas or other hazardous gas to the equipment connected to the failed abatement system should be shut off. Absorbent in the failed abatement system should be replaced immediately. Alternatively a switching system can be employed to switch to a back-up absorbent bed or redundant treatment system.

18.3 *Design*

18.3.1 Point-of-use gas abatement systems are described in SEMI F5.

18.3.2 A gas abatement system should be selected with consideration for both equipment and facilities.

18.3.3 Some gas abatement systems need enclosures. Such enclosures should be monitored for leaks. Upon leak detection, an alarm should be activated and the gas source should be shut down.

18.3.4 When abnormal status of an abatement system is detected, the gas source(s) which supply gas to the equipment connected to the gas abatement system should be stopped.

18.3.5 In a combustion-type gas treatment system, a flame detector, an airflow rate sensor, an exhaust temperature monitor and a gas concentration monitor at the outlet could be used for detecting abnormal status of those parameters.

18.3.6 If a wet-type gas abatement system is used downstream of an adsorbent or combustion gas treatment system, it should be designed to prevent reverse flow of water into the upstream system. Monitoring to determine any abnormal operating condition of the wet-type system should be provided.

18.3.6.1 The system should also be equipped with a water leak sensor.

18.4 *Operation*

NOTE 54: The concentrations of exhaust gas at the outlet of a gas abatement system must not exceed the maximum allowable concentrations established by laws and regulations of the region where the system is used, even in an emergency situation.

18.4.1 Adequate performance of the abatement system should be ensured at all times.

NOTE 55: Constant monitoring of the concentration at the outlet may be required by some jurisdictions. The source gas may also have to be shut down if the emissions reach the maximum allowable amount.

NOTE 56: It may not be necessary for abatement systems to be constantly “on-line” in some jurisdictions when gas is “stored” and not “dispensed”. In such a situation, the abatement system may be allowed to start when a leak is detected.

18.5 *Maintenance*

18.5.1 The gas abatement system manufacturer should provide the user with recommended maintenance procedures considering the characteristics of silane family gases and by-products in written form, even if the manufacturer maintains the system. Maintenance workers should be provided training as specified by the manufacturer.

18.5.2 Interlocks or bypasses should be provided at appropriate locations to stop the flow of process effluent to the exhaust treatment system during maintenance or malfunction.

18.5.3 After a malfunction alarm is activated, the abatement system should not be automatically restarted. The cause of the alarm should be carefully inspected and maintenance or service of system should be performed if necessary.

19 Related Documents

NOTE 57: As listed or revised, all documents cited shall be the latest publications of adopted standards.

19.1 *Compressed Gas Association*

CGA P-32 — Safe Storage and Handling of Silane and Silane Mixtures

19.2 *SEMATECH, Inc. / International SEMATECH, Inc*[9].

96083168A-ENG — Effects of Leak Size and Geometry on Releases of 100% Silane (ESHB001)

96013067A-ENG — Ignition Characteristics of Releases of 100% Silane (ESHB001)

95092976A-ENG — Comparative Analysis of a Silane Cylinder Delivery System and a Bulk Silane Installation (ESHB001)

94062405A-ENG — Silane Safety Improvement Project S71 Final Report

19.3 *Factory Mutual Property Loss Prevention Data Sheet, 7-7*[10] — Semiconductor Fabrication Facilities

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9 SEMATECH Inc./International SEMATECH Inc., 2706 Montopolis Drive, Austin, TX 78741-6499 (or www.sematech.org)

10 Factory Mutual Engineering, 1151 Boston-Providence Turnpike (PO Box 9102) Norwood, MA, 02062 or http://www.fmglobal.com; (877) 364-6726 (toll free for U.S. & Canada) or (781) 255-4681, or print out an order formand fax it to us at (781) 255-4359.

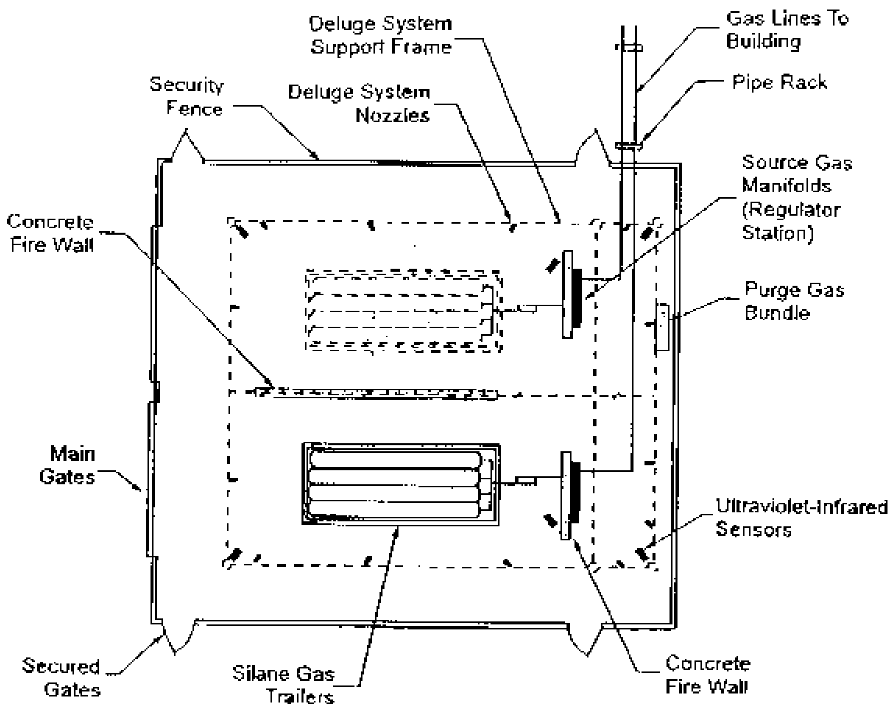

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Figure 1
Bulk Silane Storage/Dispensing Facility

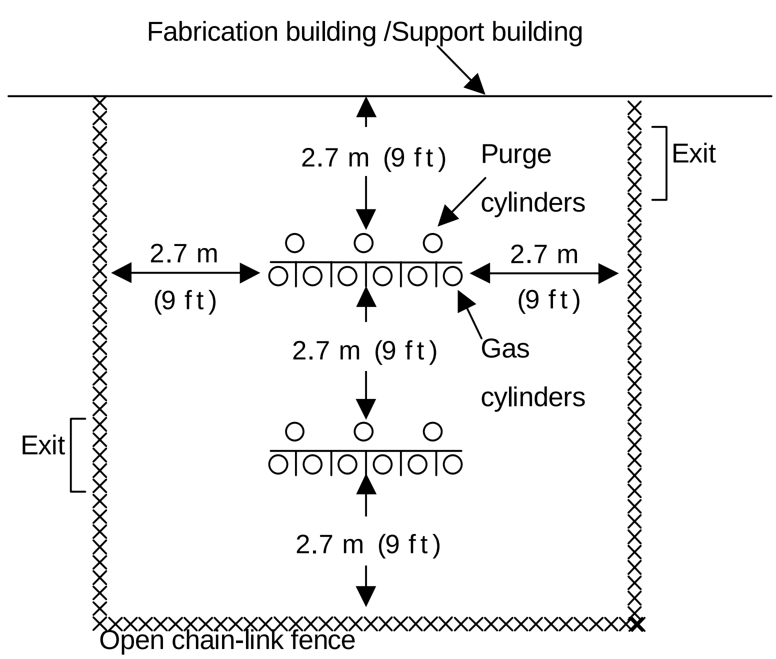

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Figure 2
Exterior Dispensing Areas for Cylinder Rack System

RELATED INFORMATION 1
SILANE SAFETY CONTROL SYSTEMS

NOTICE: This Related Information is not an official balloted part of SEMI S18. It is included to assist the user of the document in understanding effective control systems. Publication is authorized by vote of the responsible committee.

R1-1 Silane Safety Control Systems

R1-1.1 These systems should be fail-safe and fault-tolerant in order to perform effectively.

R1-1.2 In order for Silane Safety Control Systems to continually monitor the status of the gas delivery system that they control, they should be connected to devices that provide real-time information on the parameters of the system being monitored.

R1-1.3 Devices such as pressure transducers, and cycle counters should operate in conjunction with the software that ensures the parameters (pressure, counts, etc.) are within the safe operating limits for the silane family gas controlled.

R1.3.1 Software (firmware) that monitors the data from such devices should have the following features:

a) Protected from access by unauthorized personnel,

b) Require version testing before the version can be installed in active controller systems,

c) Have tolerance to accidental keystroke errors (such as asking if you really want to make a change), and

d) Require review and approval by a supervisory entity before it can be placed on line.

R1-1.4 In locations where ignitable mixtures of air and flammable gas can form in normal operation or as the result of a single, credible failure, the control devices should not be capable of igniting the mixture.

R1-1.4.1 This criterion applies to ALL types of controls, including fire protection, leak detection, and process safety monitoring.

RELATED INFORMATION 2
EXAMPLES OF CALCULATIONS FOR MAXIMUM POTENTIALS FOR SILANE FAMILY GASES

NOTICE: This Related Information is not an official balloted part of SEMI S18. It is included to assist the user of the document in understanding effective control systems. Publication is authorized by vote of the responsible committee.

R2-1 Release Potentials

R2-1.1 In gas cabinets, size the ventilation system to limit the maximum concentration of silane inside the cabinet to 0.4 percent by volume. Base the maximum concentration of silane inside the gas cabinet on the continuous release of SiH_4 at a standard volumetric flow rate given by the size of the RFO in the discharge line and the maximum SiH_4 gas cylinder storage pressure (see Table R2-1). For a 0.4 percent concentration, the required ventilation airflow rate can be estimated from Figure R2-1.

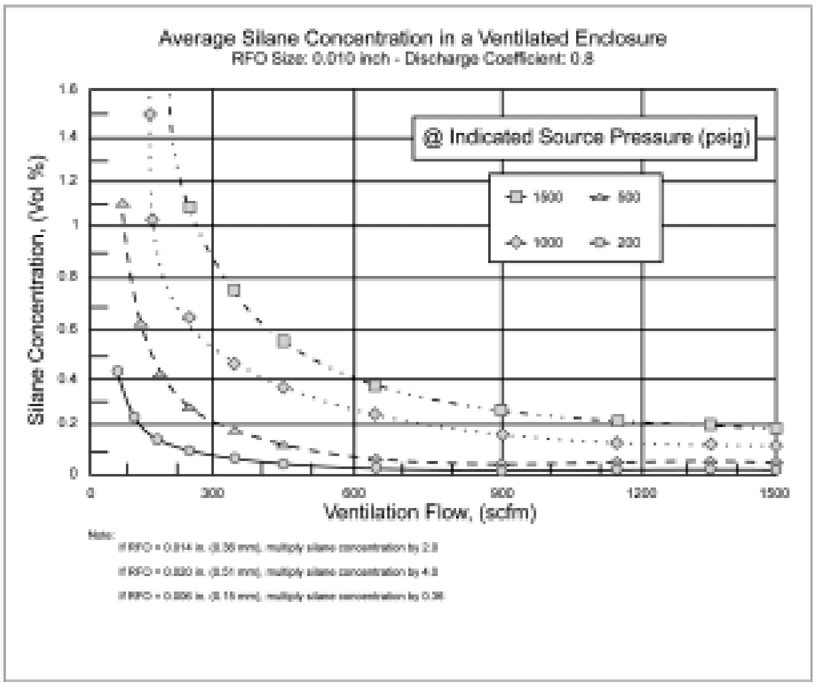

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Figure R2-1
Average Silane Concentration in a Ventilated Enclosure

Table R2-1 Silane Flow Rates Through Restricted Flow Orifices Based on the Predictionsfrom the Factory Mutual Research Model

Silane Flow Rate [scfm] (Source Temperature: 77°F; Downstream Pressure: 0 psig; Discharge Coefficient: 0.8)									
RFO Dia. in. (mm)	*Source Pressure [psig]*								
	1500	1200	1000	800	600	400	200	100	50
0.020 (0.51)	10.0	7.88	6.04	4.34	3.02	1.92	0.949	0.497	0.288
0.014 (0.36)	4.91	3.86	2.96	2.13	1.48	0.941	0.465	0.243	0.136
0.010 (0.25)	2.50	1.97	1.51	1.08	0.755	0.480	0.237	0.124	0.069

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R2-2 Explosion Potentials

R2-2.1 *Silane Ventilated Enclosure Example*

R2-2.1.1 Consider the case of a ventilated enclosure of 25.9 ft (0.73 m) volume, swept by a ventilation flow of 450 scfm (12,744 lpm). Silane is supplied to the enclosure by a 1/4-in. (6.3 mm) (OD) line at a regulated pressure of 50 psig (3.4 bar). This line is in turn fed from a source at 1450 psig (100 bar), through a 10-mil restricted flow orifice (RFO), located at a distance of 80 ft (24.4 m) from the ventilated enclosure. Safe operation of the system is determined by the evaluation of two conditions:

- the magnitude of the initial silane inventory in the 1/4-in. (6.3 mm) line relative to the size of the enclosure, and
- the magnitude of the RFO-controlled flow relative to the ventilation in the enclosure. The first condition determines the severity of a potential ignition transient at flow start-up. The second provides a measure of the pressure development at flow shut-off.

R2-2.2 The standard silane inventory in the line is calculated by first determining the volume of the line [assume 0.035 in. (0.9 mm) wall thickness]:

$$V_{line} = \pi / 4\ (0.25\text{-}2\times0.035)^2 \times 80 \times 12 = 24.43\ \text{in}^3$$

The silane volume, when expanded to standard conditions, is given by (cf. Eq. 1):

$$\Delta Vstd\ = 24.43 \times 0.0708 \times 50\ (1 + 8.19\ 10^{-7} \times 50^{2}) = 86.66\ \text{in}^{3} = 0.05\ \text{ft}^{3}$$

The ratio of the volume of the enclosure to the standard volume of silane is:

$$Vencl / \Delta Vstd = 25.9 / 0.05 = 518$$

R2-2.3 Since this value is greater than 100, the situation is acceptable from the point of view of potential pressure transients caused by ignition of the release at flow startup.

R2-2.4 Verifying the second condition requires calculating the RFO-controlled flow. By interpolation of the data in Table 2, the flow through a 10-mil orifice from a source at 1450 psig (100 bar) is estimated to be equal to 2.41 scfm (68.25 lpm). Since the maximum silane flow rate that can be accepted for a ventilation of 450 scfm (12,744 lpm) is 1.8 scfm (51 lpm) (450/250, see recommendation 3 above), this situation is not acceptable. It would become acceptable if the ventilation flow was increased to 600 scfm (16,992 lpm) (2.41 ´ 250) or if the explosion venting conditions shown in Figures R2-2a and R2-2b were to be satisfied.

R2-2.5 Provide explosion venting for gas cabinets and enclosures to limit overpressure inside gas cabinets and enclosures to 0.25 psig (1.7 kPag). Explosion venting can be provided by door panels, windows, louvers or exhaust duct openings. Size explosion venting to satisfy both the requirements for line inventory pressure (Figure R2-2a) and for the volume of the enclosure (or cabinet) (Figure R2-2b).

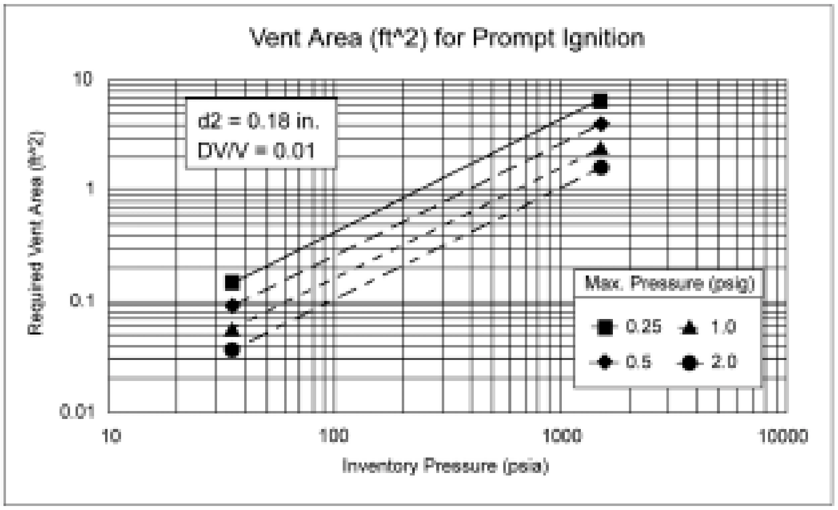

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Figure R2-2a
Vent Area Requirement for Prompt Ignition of Silane Releases as a Function of Initial Line Pressure

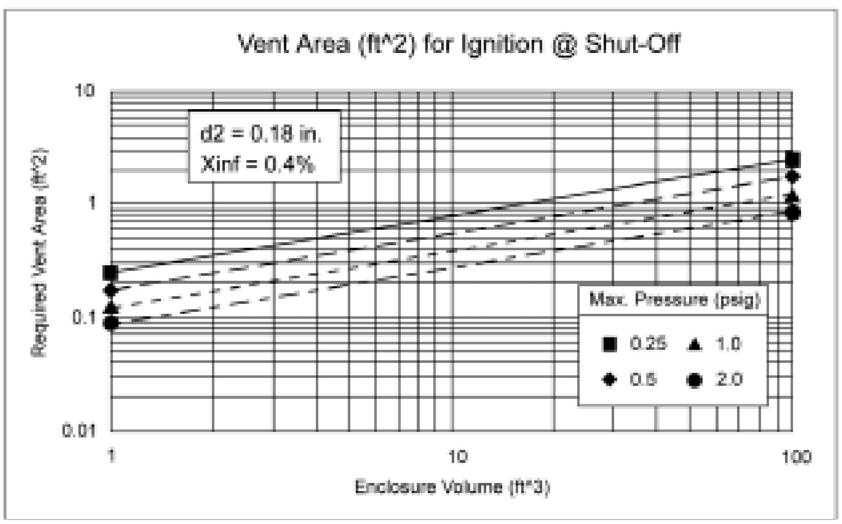

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Figure R2-2b
Vent Area Requirements for Ignition of Silane Releases at Shut-Off as a Function of Enclosure Volume

RELATED INFORMATION 3
EXAMPLES OF SIMPLIFIED VALVE AND PIPING DIAGRAM FOR GAS SUPPLY

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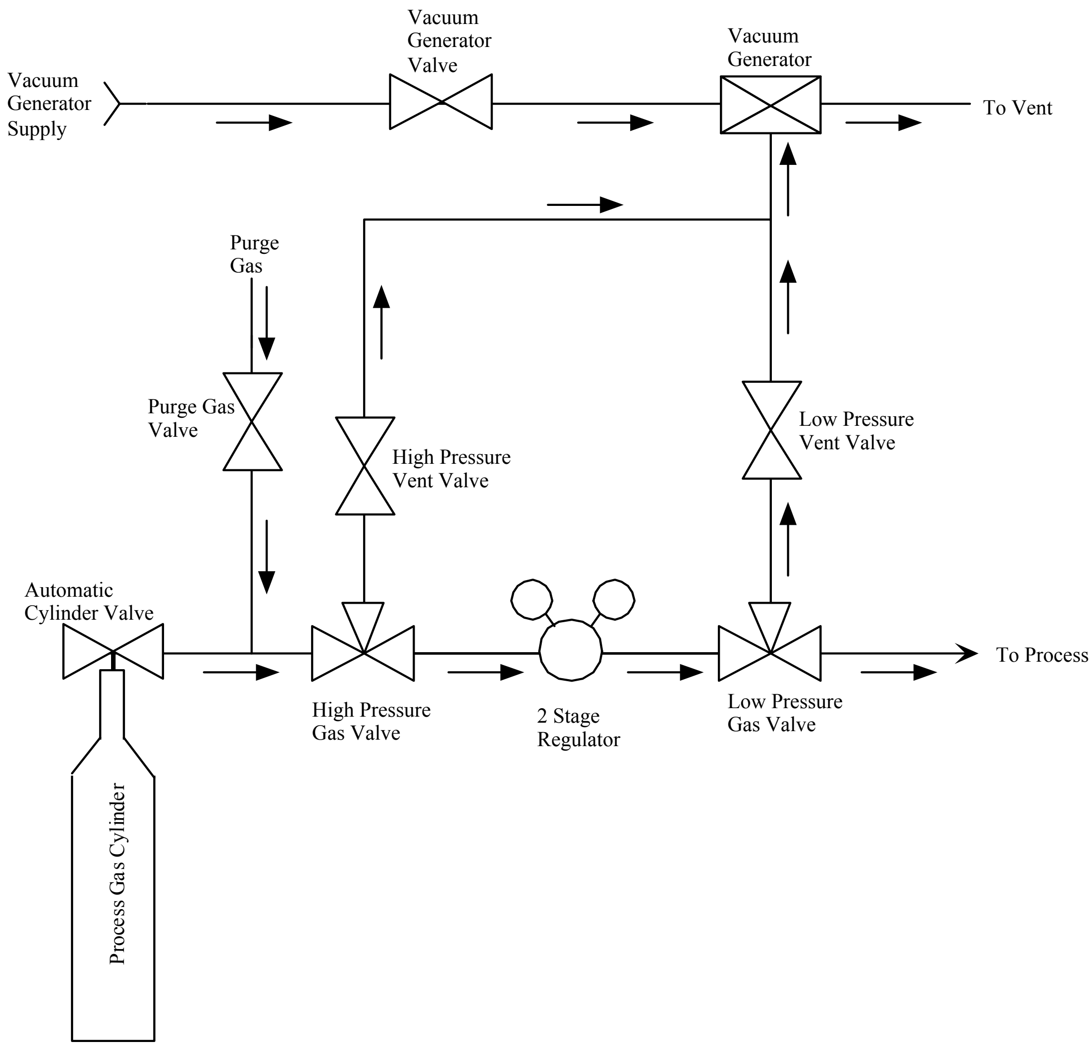

Figure R3-1
Gas Supply System

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SEMI S19-1102
SAFETY GUIDELINE FOR TRAINING OF SEMICONDUCTOR MANUFACTURING EQUIPMENT INSTALLATION, MAINTENANCE AND SERVICE PERSONNEL

This safety guideline was technically approved by the Global Environmental, Health, and Safety Committee and is the direct responsibility of the North American Environmental, Health, and Safety Committee. Current edition approved by the North American Regional Standards Committee on August 29, 2002. Initially available at www.semi.org September 2002; to be published November 2002.

1 Purpose

1.1 Provide guidance to the employer for environmental, health and safety proficiencies.

NOTE 1: The "*employer*" is determined by regulation or by contact.

1.2 Establish specific learning objectives which, when fulfilled, demonstrate a baseline level of environmental, health and safety (EHS) proficiency.

1.3 Identify quality control, documentation and record keeping criteria for the management of EHS training programs.

2 Scope

2.1 This document applies to the EHS training of personnel servicing, maintaining, installing or otherwise providing semiconductor equipment support.

2.2 All elements of this guideline are necessary for declaring conformance to the guideline.

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

3 Limitations

3.1 This guideline is not intended to apply to trades used in the facility construction and remodeling, or provision of building or facility services to semiconductor equipment.

3.2 The guideline provided herein is not intended to represent an all inclusive or exhaustive identification of the EHS training required for personnel within the scope of this guideline.

3.3 Depending on the hazards, additional training or certifications, specific to the task or the area hazards, may be required.

4 Referenced Standards

4.1 *ANSI Documents*[1]

ANSI Z490.1 — Criteria for Accepted Practices in Safety, Health and Environmental Training

NOTE 2: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *Definitions*

5.1.1 *authorized employee(s)* — persons trained and proficient in performing a hazardous energy isolation (lockout/tagout) procedure on an energy source ensuring that the energy isolating device and the equipment being controlled cannot be operated until the locking device is removed.

5.1.2 *instructor or facilitator* — an individual with appropriate technical expertise and experience, authorized by the employer to deliver, or facilitate the delivery of, a course module or set of modules and capable of addressing student questions in a timely manner.

5.1.3 *learning objective* — written statement of the desired knowledge, skill, or ability to be demonstrated.

5.1.4 *qualified employee(s)* — persons trained and proficient in the equipment and operation to be performed, including recognition of the hazards and necessary protective measures.

5.1.5 *training* — an activity which assists an individual in fulfilling the learning objectives.

6 Core Curriculum

6.1 The employer is responsible for ensuring that the employee's EHS training is based on a needs assessment or the results of hazards analyses. The subject matter in this section is considered the minimum basic curriculum for training personnel within the limitations of this guideline.

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

6.2 *Housekeeping* — General principles and concepts of hazard recognition and various techniques, procedures or practices for reducing or eliminating risks such as:

- Appropriate use of passageways, storerooms, and service rooms,
- Maintaining walking and working surfaces in a safe, clean, orderly and sanitary condition, and
- Establishing and maintaining aisle width and means of egress.

6.3 *Ergonomics* — General principles and concepts of Ergonomic and Musculoskeletal Disorders (MSD) as they relate to service activities, with special emphasis in the following areas:

- Repetitive motion injuries,
- Video display terminal usage,
- Material handling techniques,
- Recognition of MSD signs and symptoms,
- How to report MSD signs and symptoms and the importance of early reporting,
- Personal MSD risk factors including factors that contribute to MSD of the upper extremities, and back,
- MSD hazards in their jobs and measures for protection against MSD hazards,
- Proper selection and use of tools and equipment, and
- Job-specific controls implemented.

6.4 *Hand and Portable Power Tools*

- Recognition of the hazards associated with the use of hand and portable power tools, and
- Requirements for tool–specific training in the safe use of the tools to be used.

6.5 *Material Handling Equipment*

- Recognition of the hazards associated with operating or working around material handling equipment and mechanical lifting devices such as hoists, pallet jacks, forklifts, and overhead cranes, and
- Restrictions, including additional training and certification requirements, associated with their operation.

6.6 *Robotics*

- Recognition of the hazards associated with working near robots and associated components,
- Restrictions and requirements for robot service or repair, including additional training and certification of service personnel,
- An understanding of the operating envelope and the risks associated with entry, and
- Review of appropriate safe work practices.

6.7 *Confined Space*

- Ability to recognize a confined space,
- Recognition of the hazards associated with confined spaces, and
- Requirements and restrictions for confined space entry including sampling or additional training and certification of service personnel.

6.8 *Elevated Work*

6.8.1 *Fall Protection*

- Recognition of the hazards, both to the worker and other personnel, when performing work in an elevated position, and
- Identification of when additional fall protection measures including training are required.

6.8.2 *Portable Ladders*

- Recognition of the hazards associated with the use of portable ladders, and
- Proper selection, inspection, set–up and use of portable ladders and working platforms in the work area.

6.9 *Walking and Working Surfaces* — General principles and concepts of hazard recognition and various techniques, procedures or practices for reducing or eliminating risks involving:

- Walking and working surfaces, gratings, raised platforms, floor and wall openings,
- Guarding floor and wall openings and holes using covers, guardrails and warning barriers,
- Floor loading and protection, and
- Protection of open-sided floors, platforms, runways, and stairway railings and guards.

6.10 *Electrical Work* — General principles and concepts of performing work on or around electrical circuits as well as instruction in the following areas:

- General electrical safety requirements,
- Recognition of the hazards associated with electrical work,
- Importance of equipment grounding continuity, and
- Restrictions and requirements to qualify service personnel for performing energized electrical work (EEW) including additional procedures, training, and protective measures.

6.11 *Control of Hazardous Energy* — Authorized Employee — Requirements of the Hazardous Energy Control (Lockout/Tagout) Program including:

- Consequences (injury potential and disciplinary action) of failing to comply with the energy control requirements,
- Requirements to ascertain each of the various types and magnitudes of potentially hazardous energy sources, both potential and kinetic, in the system(s) or equipment involved,
- General procedures for performing hazardous energy isolation and the equipment necessary to isolate and control hazardous energies,
- General procedures for re–energizing after completion of work,
- The role and use of equipment–specific procedures,
- Methods of testing and or verifying energy isolation, and
- Periodic program inspection and auditing of program effectiveness.

6.12 *Radiation (Ionizing and Non-Ionizing)*

- Awareness of basic radiation hazards as associated with both ionizing and non-ionizing radiation (e.g., x-ray, ultraviolet, electromagnetic), and
- Restrictions, including additional requirements for training, to qualify service personnel for work with or around hazardous levels of radiation.

6.13 *Lasers*

- Recognition of the hazards associated when working with or around lasers, and
- Restrictions, including additional training to qualify service personnel, for working around specific classes of lasers.

6.14 *Workplace Environmental Hazards* — Recognition of the direct and indirect exposure hazards of workplace environmental factors such as lighting, noise, heat and cold.

6.15 *Mechanical Hazards*

- General principles and concepts of hazard recognition and the various techniques, procedures or practices for reducing or eliminating the risks when working around mechanical energies,
- Recognition of the various types of hazardous mechanical energies as associated with the points of operation, power transmission points, pinch points, and shear points (e.g.: automated material handling systems), and
- Requirements for, and the appropriate application of, guards and safeguards.

6.16 *Pressure and Vacuum* — Recognition of the hazards associated with the systems or equipment containing either pressure or vacuum.

6.17 *Chemical Hazards*

6.17.1 Requirements and obligations for the communication of chemical hazards, as required by applicable regulations.

6.17.2 Details of the employer' s chemical hazard communication program, including:

- Labeling requirements and commonly used labeling systems,
- How to access, interpret and apply the provided hazardous materials data including commonly used terms pertaining to occupational exposure limits and physical hazard data commonly found in Material Safety Data Sheets (MSDS),
- Methods the employer will use to inform employees of the hazards of non-routine tasks,
- Appropriate protective measures for protection against physical and health hazards including specific procedures such as work practices, emergency procedures, and the use of personal protective equipment,
- Location and availability of the written hazard communication program, including the required inventory list(s) of hazardous chemicals and MSDSs,
- Operations in the work area where hazardous chemicals are present,

- The general classes of hazardous materials (e.g., toxic, corrosive, flammable, reactive) and their associated physical and health hazards,
- Physical and health hazards of the specific chemicals in the work area,
- Methods and observations that may be used to detect the presence or release of a hazardous chemical such as monitoring devices, the visual appearance or odor of hazardous chemicals,
- Proper segregation and hazardous material storage requirements,
- General requirements and restrictions for the disposal of hazardous materials, and
- Emergency care for overexposure.

6.17.3 Employee responsibilities including:

- Access, review and apply hazard information and data, and
- Use reasonable care when working with hazardous materials.

6.18 *Personal Protective Equipment (PPE)*

- General principles and concepts of the hierarchy of protective measure selection (elimination-first, engineering controls-second, administrative controls-third, personal protection equipment – last),
- Use of specific factors within the hazard analyses, including identification of health and safety risks, potential routes of exposure, environmental factors, and individual or combinations of protective measures, to determine the need for and selection of PPE,
- General factors affecting PPE selection including physical restraints, applicable regulatory requirements and industry standards, and
- Training, based on the PPE expected to be worn, that includes information regarding:
    - When and what PPE is required,
    - Acquisition and replacement of PPE,
    - Limitations,
    - PPE inspection,
    - Proper donning, adjustment, use and removal,
    - How to monitor PPE when in use, and
    - Proper care, maintenance and useful life.

6.19 *Hazard Analysis* — Methods for properly conducting a hazard analysis for determining the hazards and associated risks, and identifying possible corrective measures associated with a job or work area, including:

- Methods for identification of basic job steps,
- Delineating the potential hazards associated with each step,
- Assessing the related risks of the identified hazards, and
- Identification and selection of appropriate control measures.

NOTE 3: Some locations require approval by an EHS professional before application of protection measure.

6.20 *Fire Safety*

- Recognition of the hazards associated with performing any work that could provide a reasonable source of ignition (hot work) and the potential of site–specific requirements,
- Restrictions, including additional training, for the use of fire extinguisher equipment, and
- Basic fire behavior and control.

6.21 *Emergency Procedures*

- Explanation of the responsibilities and obligations of personnel during an emergency, and
- Procedures to be followed during an evacuation or medical emergency.

6.22 *Accident/Incident Reporting*

- Explanation of the primary objective of incident reporting (prevent reoccurrence of incident),
- Procedures for reporting an accident or incident both within the employer’s facility and off-site, and
- Requirements for a complete and timely report of incident.

7 Site–Specific Training

7.1 The facility owner should provide site–specific information or training to the employer (if different than facility owner). If any element of the site–specific training is not provided, the employee has a right to request the information. Topics for site-specific training may include:

- Evacuation and emergency procedures,
- Monitoring and evacuation alarms,
- Incident and injury reporting,

- Site–specific elements of EHS programs identified elsewhere in this guideline (e.g., Energy Control Program, Confined Spaces, Fall Protection),
- Hazardous materials approval, handling and waste management procedures including identification of hazardous materials to which they may be exposed, MSDS location, labeling, storage and disposal,
- Selection, use and limitations of PPE expected to be used and made available at the facility,
- Use and use restrictions of facility emergency equipment (e.g., fire extinguishers, breathing apparatus), and
- Applicable site or local regulations, restrictions or requirements not addressed elsewhere in this guideline (e.g., radiation badges, use of recording equipment, site security).

8 Additional Exposure–Based Training

8.1 It is the employer's responsibility to ensure potential hazards are identified through hazard analyses and provide the appropriate EHS training. The following list of additional training programs is not intended to be all-inclusive but identifies some of the specialty programs that may be necessary based on the individual's potential exposure or risk.

- Respiratory Protection
- Arsenic Safety
- Confined Space – Entry
- Forklift Operations
- Hearing Conservation
- Laser Safety
- Radiation Safety
- Energized Electrical Work – Qualified Employee
- High Voltage (>600 V) Electrical Work
- Fire Extinguisher Use
- Fixed Extinguishing Systems
- Basic First Aid
- Cardiopulmonary Resuscitation (CPR)
- Bloodborne Pathogens

NOTE 4: The *employer* is obligated to provide immediate (within 4 minutes) emergency medical services until advanced medical support can arrive. Energized electrical work also requires having a person, qualified to perform CPR, immediately available (typically the back-up worker or "buddy"). The facility owner (if different from the employer) may provide this service if contractually agreed upon in advance. If not, the employer must ensure a sufficient number of employees are trained in Basic First Aid, CPR and Bloodborne Pathogens and immediately available in an emergency.

NOTE 5: Bloodborne Pathogen training is requirement of persons whose job requires First Aid or CPR training.

9 Quality Control

9.1 To ensure the quality of the training program, the elements of ANSI Z490.1 should be followed in the management of the training program as well as in the development and implementation of training courses.

9.2 Unless otherwise specified or required by regulation, retraining or a proficiency demonstration should occur:

- Every three years,
- When changes in the requirements or workplace, such as modifications to the process, procedures, or current protective measures, render training obsolete,
- If the employer becomes aware of new or previously unrecognized hazard, and
- Anytime an employee cannot demonstrate adequate knowledge of the subject and application of the skills.

9.3 Competency is to be demonstrated to a qualified individual other than the student.

10 Training Documentation & Record Maintenance

10.1 The employer should identify in its written training program a system for collecting and maintaining documentation pertaining to the development and implementation of EHS training, procedures for access, availability, and confidentiality of records. The system should address all pertinent records and documents to ensure that they:

- Are readily retrievable, identifiable, and maintained in an orderly manner,
- Are current, accurate, legible, and dated (including revision dates),
- Are retained for a specified period,
- Adequately fulfill applicable customer and regulatory requirements, and
- Are made available upon request for verification of conformance with this guideline.

10.2 *Records*

10.2.1 Course records should identify

- The target audience and stated learning objective(s),
- Sources, materials and references used for training development,
- Persons designing and developing the training and their qualifications,
- Training materials developed for the course,
- Regulations, standards or legislation for which the training is intended to comply,
- Methods for demonstrating competency, and
- Plans for evaluation and continuous improvement of the course.

10.2.2 Delivery records for each training event should identify:

- Name and description of the course,
- Date, location, and duration of the training,
- Name, identification number and employer of students participating in the training,
- Person(s) delivering the training,
- Students successfully completing the training and completion date (if training event spanned multiple days),
- Competency demonstration records, and
- The subject matter presented.

10.2.3 Trainer records should include the name, qualifications, contact information and employer of the trainer.

10.2.4 Program management records should include documented periodic evaluations of the training program and reevaluations of courses.

10.3 *Record Confidentiality and Availability*

10.3.1 Records should be maintained such that they meet applicable requirements for availability, disclosure, confidentiality, and protection of trade secrets.

10.3.2 The employer should ensure the student is provided confirmation of successful training completion within a reasonable time.

10.3.3 If the facility owner is different than the employer, documentation of training completion and contact for verification upon request should be made available to the facility owner in a language acceptable to the facility owner. Records, such as those identified within this guideline, are considered documentation that could be used for verification.

10.3.3.1 Suggested methods of providing documentation of training completion in the field include:

- A training passport that summarizes training received with course completion acknowledged by the instructor with signature, and
- Training certification cards that identify the courses and completion dates of training received.

10.3.3.2 When an individual holding a valid training certification issued by his/her previous employer changes employers, it is suggested that the new employer upon verification of the validity of the training “certification” and associated curriculum, re-certify its new employee by written examination and practical demonstration to the current training guidelines.

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SEMI S20-0303
SAFETY GUIDELINE FOR IDENTIFICATION AND DOCUMENTATION OF ENERGY ISOLATION DEVICES FOR HAZARDOUS ENERGY CONTROL

This safety guideline was technically approved by the Environmental, Health, and Safety Committee and is the direct responsibility of the North American Environmental, Health, and Safety Committee. Current edition approved by the North American Regional Standards Committee on November 22, 2002. Initially available at www.semi.org January 2003; to be published March 2003.

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

NOTICE: The intent of the task force that produced this document is that conformance to the "should" provisions of this guideline comprises conformance with this guideline.

1 Purpose

1.1 This guideline is intended to establish a method for the unique identification of energy isolation devices (EID) used for lockout/tagout (LOTO). This identification is intended to occur both at the devices and at those places in the supplier-provided manuals where the devices are referenced in tasks or procedures.

NOTE 1: Throughout this document, "LOTO EID" refers to these devices.

1.2 This document supplements the existing provisions in SEMI S2 (for Hazardous Energy Isolation) and SEMI S13 (for providing appropriate documentation) with a uniform graphical representation and identification system.

1.3 This document also provides guidance for developing instructions for operating LOTO EIDs.

2 Scope

2.1 This guideline applies to equipment used to manufacture, measure, assemble, and test semiconductor products, and the maintenance and service procedures associated with the equipment.

2.2 This guideline provides criteria for documentation and identification of all supplier-specified LOTO EIDs meeting the criteria of SEMI S2. This includes isolation devices that the supplier intends to be provided by the end user.

EXCEPTION: Equipment in which a cord and plug connection is the only LOTO EID is exempt from this guideline.

NOTE 2: Isolation devices with locking capability are not necessarily LOTO EIDs, unless the supplier specifies them as LOTO EIDs.

NOTE 3: In some jurisdictions, it is the responsibility of the supplier to specify the energy isolation points that must be locked out in conjunction with the manufacturer-specified maintenance procedures. However, the end user is responsible for the overall hazardous energy control program for the work site and for the installation of additionally required facility EIDs. The user is not responsible for EIDs that are required by regulation to be incorporated within the equipment.

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 document is not intended to provide guidelines for developing or replacing user-site energy isolation programs.

3.2 This document is not intended to be used in place of the need for adequate training of individuals who perform hazardous energy control.

3.3 This document is not intended to conflict with laws and regulations on Control of Hazardous Energy.

3.4 This guideline does not contain criteria or requirements for providing a particular LOTO EID to be used in a LOTO program.

NOTE 4: The requirements and criteria for providing a particular LOTO EID for use in a LOTO program may be found explicitly or implicitly in SEMI S2, equipment design standards, United States OSHA requirements, or in various good engineering practices.

3.5 This document is not intended to replace or supersede SEMI S2 or any other SEMI Safety Guideline.

3.6 This document is not intended to be applied retroactively, i.e., to designs already in the field.

3.7 This document does not apply to the labeling of hazards, which is the function of SEMI S1.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI S1 — Safety Guideline for Equipment Safety Labels

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

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

SEMI S13 — Safety Guidelines for Operation and Maintenance Manuals Used With Semiconductor Manufacturing Equipment

4.2 *ANSI Standards*[1]

ANSI Z535.1 — Color Coding for Labels

4.3 *Code of Federal Regulations* - *United States of America*[2]

29 CFR 1910.147 — The Control of Hazardous Energy (lockout/tagout)

29 CFR 1910.147 — *Appendix A* "Typical Minimal Lockout Procedure"

4.4 *ISO Standards*[3]

ISO 3864 — Safety Colours and Safety Signs

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

5 Terminology

5.1 *Abbrevitions and Accronyms*

5.1.1 *LOTO* — acronym for lockout/tagout.

NOTE 5: Also equivalent to the term Hazardous Energy Isolation (HEI), which may be used in some jurisdictions.

5.2 *Definitions*

5.2.1 *blocking (v)* — preventing flow of material as through piping or preventing energies (such as suspended weights or springs) held in a suspended state from movement.

5.2.2 *clean room compatible materials* — materials approved for use within a fabrication facility, including: laminated card stock or paper, clean room paper, electronic media or other approved media.

5.2.3 *Energy Isolation Device (EID)* — a mechanical device that physically prevents the transmission or release of energy, including but not limited to the following: a manually operated electrical circuit breaker; a disconnect switch; a manually operated switch by which the conductors of a circuit can be disconnected from all ungrounded supply conductors, and, in addition, no pole can be operated independently; a line valve; a block; and any similar device used to block or isolate energy. Push buttons, selector switches, and other control devices are not energy isolation devices. [OSHA 29 CFR 1910.147]

NOTE 6: Lockout devices (elsewhere defined in this document) are not energy isolation devices.

5.2.4 *graphical* — using an image or multiple image representation that reflects the equipment as assembled and is used for indicating the location of the individual LOTO EIDs in relation to the equipment being maintained. Images include labeled drawings, or photographs enhanced with labels.

5.2.5 *graphical reference guide* — the merger of text instructions and graphical representations of the equipment in a manner that provides a clear description of the task and a simple means of locating the correct devices.

5.2.6 *lockout* — the placement of a lockout device on an energy isolation device, in accordance with an established procedure, ensuring that the energy isolation device and the equipment being controlled cannot be operated until the lockout device is removed. [OSHA 29 CFR 1910.147]

5.2.7 *lockout device* — a lock and associated hardware used to secure an EID in the safe position and prevent energy flow.

NOTE 7: Energy isolation devices (elsewhere defined in this document) are not lockout devices.

5.2.8 *maintenance* — planned or unplanned activities intended to keep equipment in good working order. (See also definition for *service*.) [SEMI S2]

5.2.9 *marked* — identified by the use of a label, engraving, silk screening, etching, or other physical and durable indication; placed near components or on systems for the purpose of matching to identifying documentation.

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

2 Available from Occupational Safety and Health Administration, U.S. Department of Labor, http://www.osha.gov

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

5.2.10 *service* — unplanned activities intended to return equipment that has failed to good working order. (See also the definition for *maintenance*.) [SEMI S2]

5.2.11 *tagout* — the placement of a tagging device (such as a tag and a secure means of attachment) to an energy isolation device in accordance with an established procedure. The tagout indicates that the energy-isolation device may not be operated until the tagging device is removed.

6 Task Specific Information

6.1 For each task requiring hazardous energy isolation (i.e., LOTO), the following information should be provided in a combined format (including labels, maintenance manuals, and graphical reference guides as described in Sections 7, 8, and 9 of this document).

NOTE 8: In some jurisdictions the bulleted items below are required.

6.1.1 Identification of:

- type and magnitude of hazardous energies to be isolated,
- LOTO EIDs necessary for controlling sources of hazardous energy, and
- lockout devices necessary to secure the LOTO EIDs.

6.1.2 Instructions for the following:

- isolating each source of energy,
- blocking energy, or reducing the potential to a zero energy state (such as blocking chemical lines or blocking the suspended energy state in a spring or raised weight),
- dissipating any residual energy,
- isolating hazardous energy sources that are isolated by disconnection, but for which there are no lockable EIDs. These instructions should state that the protection depends on the means of disconnection remaining in the immediate control of the personnel performing the work,
- attempting to restart the equipment or re-energize the system(s) that is/are to be isolated from hazardous energy, and
- verification that there is no hazardous residual energy in the system.

NOTE 9: An example of minimum Hazardous Energy Control Procedures can be found in 29 CFR 1910.147 Appendix A.

NOTE 10: The intent of instructions is to meet the need for a valid verification method that energy is isolated and to ensure that proper procedures are provided. An instruction is not required if the condition is not present or possible or the method is not technically feasible.

7 Energy Isolation Device Identification

7.1 Each LOTO EID should be uniquely and consistently identified on the system, drawings, schematics, procedures, etc. to reduce confusion.

EXCEPTION*:* Equipment consisting of a grouping of functional modules (e.g., a “cluster tool”), where more than one module is used in the same grouping, may use the same identifying numbers in each module.

NOTE 11: Where there are multiple control devices such that one or more operating devices might be confused with the LOTO EID, a differentiation marking may be used to prevent confusion. One example of such a differentiation marking is shown in Related Information 3.

7.2 All LOTO EIDs integral to the equipment should be marked on the equipment.

7.2.1 LOTO EID markings should be located on the equipment adjacent to (not on) the EIDs they identify.

NOTE 12: Marking directly on the EID can mean that replacement of the EID will also remove the EID marking.

7.2.2 Where the LOTO EID marking is obscured (covered by wiring, tubing, installation hardware, etc.), an additional marking should also be placed on the EID itself.

7.3 For LOTO EIDs required by the supplier but provided and installed by the user, the supplier should specify the requirements for such devices.

7.3.1 When such devices are specified, users should provide lockable EIDs.

7.3.2 Users should provide to the supplier, if requested, the location of the device.

7.3.3 Utility connection points for which LOTO EIDs are located external to the equipment should be marked to indicate that a user-provided EID is the method of energy isolation. Space on the equipment should be provided for the user to indicate the location of the LOTO EID.

7.4 The style and size of letters and numbers on LOTO EID markings should meet the criteria of SEMI S8 in order to be readable from the normal viewpoint of access to the LOTO EID.

7.4.1 The LOTO EID marking (as it appears on the equipment) need not be colored according to Table 1 in Section 9.

8 Graphical Representations in Manuals, Documentation & Procedures

8.1 Supplier-provided instructions for lockout/tagout and graphical representations of LOTO EIDs should be included with each maintenance task or in a separate section of the manual referenced by each maintenance task to which they pertain.

8.2 The text instructions should refer to the equipment and all support equipment related to the task.

8.2.1 When the supplier does not provide the support equipment, a generic graphical-reference placeholder for the equipment should be used. Generic LOTO procedures should also be included where the supplier maintenance procedures require isolation of that equipment.

NOTE 13: A graphical reference placeholder can be provided by any method that allows space for the user to identify user-installed support equipment and its associated LOTO EIDS (e.g., a blank outlined space, a blank underlined space, a numbered line with space for inserting text).

8.3 The size of the LOTO EID identifiers on the graphical representation of the equipment should be large enough to indicate the EID in question, but not so large as to confuse location of the device in relation and orientation to the rest of the equipment.

8.4 Each of the LOTO EID physical locations on the equipment should be identified on a graphical representation of the equipment with an image similar in shape and text to the marking on the equipment.

8.5 LOTO EIDs that are not provided by the supplier but are necessary to complete the associated task safely, as defined by the supplier, should be graphically identified as a generic external device in the procedures. The procedure should mention that the end user provides these devices.

8.6 For each specific task, the graphical representation should illustrate at least the portion(s) of equipment involved in the specific maintenance task.

EXCEPTION: Graphical representation need not be duplicated for each task, but may be referenced by more than one instruction.

8.6.1 The representation should be easily capable of being associated with the LOTO procedure for the task being completed or include the procedure text in written form at the bottom of the graphical representation.

8.6.2 Task level instructions should identify those LOTO EIDs that are required for the specific task being completed and link them to the graphical representation.

8.7 Energy isolation instructions for equipment options or nonstandard procedures should be provided with the equipment option or nonstandard process change as purchased from the supplier.

NOTE 14: Nonstandard procedures include customer specific tasks such as chamber cleaning for unique chemistries, use of special lifting devices for single customers, and other tasks that are not part of the standard procedures for the normal supplier-delivered configuration.

8.7.1 The graphical representations should capture the option's LOTO EID in the representation for the overall task it affects (e.g., if a UPS is offered as an option, the LOTO procedures for the UPS option should be provided and the UPS LOTO EID included in the graphical representation).

9 Graphical Reference Guides for use at the Equipment

NOTE 15: Graphical reference guides are intended to make it easy for personnel to locate and isolate sources of hazardous energy associated with the tasks they are performing.

9.1 Graphical reference guides should be provided for each task where LOTO is used. LOTO EIDs should be graphically identified on these reference guides. Instructions for controlling each source of energy as outlined in Section 6.1.2 should also be provided on the reference guides. The reference guides should be task specific.

NOTE 16: See Related Information 1 for example.

EXCEPTION: A single graphical reference guide may be used for more than one task, provided it can be easily determined from the text instructions, which LOTO EIDs are used for each task.

9.2 It is recommended that the graphical reference guides include a color representation of the overall equipment, as well as individual task-specific representations, as they would be found in the maintenance manual.

EXCEPTION: If manuals are printed only in black and white, the color representation may be specified as "printed by the user" from the electronic copy.

9.3 If the supplier has no standard for coloring the indicators of the LOTO EID locations on graphical representations, they should be colored according to the type of energy being isolated. See Table 1, "Recommended Identifying Color Matrix".

NOTE 17: Supplier standard color coding may be any colors including black and white.

Table 1 Recommended Identifying Color Matrix

Type of Energy	*Text/Background*
Electrical	Black/Orange
Compressed Gases	White/Blue
Pressurized Liquids	White/Green
Chemical	Black/Yellow
Mechanical	White/Black
Thermal	Red/White
Ionizing Radiation	Purple/Yellow
Non-Ionizing Radiation (Laser, RF, UV, IR, etc.)	Black/Red

NOTE 18: Recommended color shades may be found in standards such as ANSI Z535.1, Colors for Safety Labels ISO 3864 Safety Colours & Safety Signs or other international equivalent for uniformity.

9.3.1 Colors (whether from the recommended list or from the suppliers' standard color coding) should be assigned depending on the type of energy being isolated, not the hazard being controlled. For example, a circuit breaker that removes power from a robot should have a unique identifier on the graphical representation color-coded as Electrical, not Mechanical energy.

9.4 Graphical reference guides should be either electronic media or made from clean room compatible materials that can be located at the equipment or can be carried there during the performance of the tasks.

9.4.1 The supplier may offer optional media as part of the purchase.

NOTE 19: Certain types of electronic devices (e.g., broadcasting handheld computers) may be restricted from use in clean rooms due to system interference issues.

9.4.1.1 If the reference guide is intended to be displayed electronically, the display device should be conveniently available to personnel while they perform the particular task.

9.4.1.2 The supplier may also specify that users have the option to convert the guides to clean room compatible, color printed versions.

9.5 Each graphical reference guide should be designed so that it is clearly cross-referenced with its related maintenance task(s).

9.5.1 Text instructions for operating and verifying the isolation of each LOTO EID should be in the same field of view as the graphical representation of that LOTO EID on the graphical reference guide.

EXCEPTION: In an electronic file, the field of view is controlled by the screen size and therefore text instructions and graphics may not be in the same field of view or may even be connected via hyperlink to each other.

NOTE 20: One possible design is where the graphical reference guides each consists of a card or page (perhaps in a bound collection of reference guides) that can be placed near the computer or manual and show the steps of the task. Another possibility is to provide the ability to produce a split screen display on a computer.

10 Related Documents

10.1 *SEMI Standards*

SEMI F34 — Guide for Liquid Chemical Pipe Labeling

10.2 *NFPA Standards*[4]

NFPA 70E — Standard for Electrical Safety Requirements for Employee Workplaces

NFPA 79 — Electrical Standard for Industrial Machinery

10.3 *ANSI Standards*[5]

ANSI Z244.1 — Personnel Protection, Lockout/Tagout of Energy Sources – Minimum Safety Requirements

10.4 *United States Code of Federal Regulations*[6]

29 CFR 1910.333b — Working on or Near Exposed De-energized Parts

OSHA STD 1-7.3 — 29 CFR 1910.147, the Control of Hazardous Energy (Lockout/Tagout) - Inspection Procedures and Interpretive Guidance

OSHA document 3120 — Control of Hazardous Energy (Lockout/Tagout) - 1997 (Revised)

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

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

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

6 Available from Occupational Safety and Health Administration, U.S. Department of Labor, http://www.osha.gov

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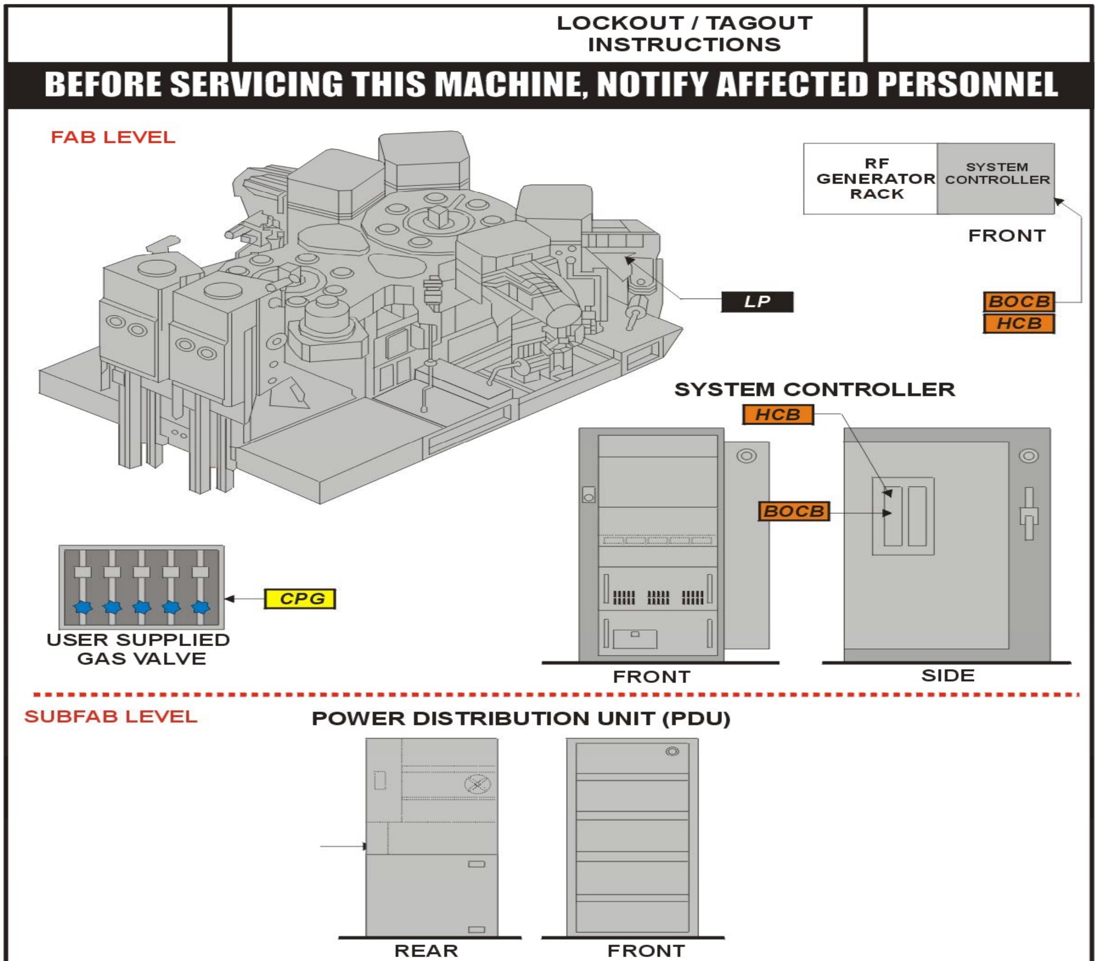
RELATED INFORMATION 1
EXAMPLES OF GRAPHICAL REPRESENTATIONS

NOTICE: This Related Information is not an official part of SEMI S20. It was derived from AMD activity, but is generic and not copyrighted. This related information was approved for publication by inclusion in the ballot and by vote of the SEMI Standards EHS Committee. It is included to assist the user of the document in understanding what the graphical representations should provide in the way of information and location identification.

R1-1 Drawings



LOTO INSTRUCTIONS FOR PM #5

ENERGY SOURCE		LOCATION	PERFORM ACTION	VERIFY
CPG	*CHAMBER PROCESS GAS VALVES*	*USER SUPPLIED GAS VALVE*	CLOSE GAS VALVES AND PURGE LINES FOR CHAMBER BEING SERVICED. ATTACH LOCKING DEVICE AND TAG.	ENSURE LINES HAVE BEEN PURGED. LINE GAUGES MUST READ ZERO (0).
BOCB	*BAKE OUT CIRCUIT BREAKER*	*SIDE OF CONTROL PANEL*	PLACE CIRCUIT BREAKER FOR CHAMBER BEING SERVICED IN THE OFF POSITION. ATTACH LOCKING DEVICE AND TAG.	CONFIRM ZERO (0) VOLTAGE AT CHAMBER.
HCB	*HEATER CIRCUIT BREAKER*	SIDE OF CONTROL PANEL	PLACE CIRCUIT BREAKER FOR CHAMBER BEING SERVICED IN THE OFF POSITION. ATTACH LOCKING DEVICE AND TAG.	CONFIRM ZERO (0) VOLTAGE AT CHAMBER.
LP	*LOCK PIN*	PROCESS CHAMBER LID	PLACE PIN IN HINGE HOLE FOR CHAMBER BEING SERVICED. ATTACH LOCKING DEVICE AND TAG.	INSPECT PIN FOR PROPER INSTALLATION.

RELATED INFORMATION 2
EXAMPLE FLOW FOR HAZARDOUS ENERGY CONTROL DESIGN

NOTICE: This Related Information is not an official part of SEMI S20 but was derived from task force activity. This related information was approved for publication by inclusion in the ballot and by vote of the SEMI Standards EHS Committee. It is included to assist the user of the document in understanding what the graphical representations should provide in the way of information and location identification.

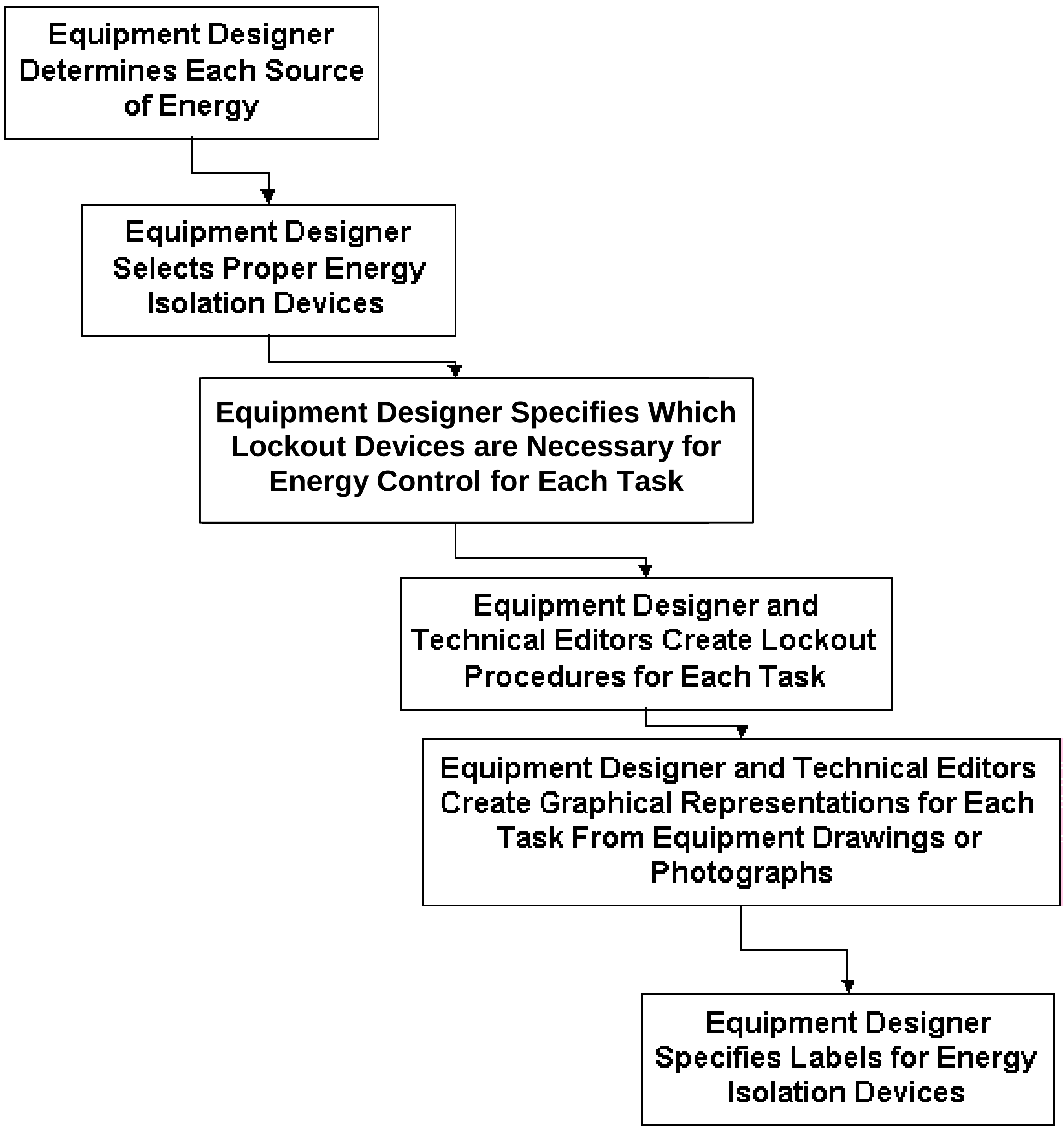


Figure R2-1
Flow Chart for HEC Design and Graphical Representation Generation

RELATED INFORMATION 3
EXAMPLE OF A LOTO EID DIFFERENTIATION MARKING

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R3-1 Differentiation Marking

R3-1.1 In addition to a unique identifier, it may be beneficial to differentiate LOTO EIDs from non-LOTO EIDs by using the following symbol. This symbol may be on or adjacent to, or combined with the unique identifier marking for that specific LOTO EID.

R3-1.2 SEMI S8 provides guidance for sizing of this differentiation symbol so it will be readable from the normal viewpoint of a person's access to the LOTO EID.

R3-1.3 Where LOTO EIDs are located behind a panel, it is useful to mark the exterior of the panel in order to indicate the path of access to the LOTO EID or approximately where the EID is hidden.

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