

SEMI S18-0818

ENVIRONMENTAL, HEALTH, AND SAFETY GUIDELINE FOR FLAMMABLE SILICON COMPOUNDS

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1 Purpose

1.1 This Safety Guideline is intended as a minimum set of safety and health criteria for storage, handling, and use of flammable silicon compounds from supply to abatement.

1.2 This Safety Guideline is also intended as a minimum set of safety and health design criteria for semiconductor, FPD, PV manufacturing equipment and other equipment that uses flammable silicon compounds for processing.

2 Scope

2.1 Flammable silicon compounds that are within the scope of this Safety Guideline are shown in Table 1.

Table 1 Chemicals Within the Scope of this Safety Guideline

	<i>Compressed Gas</i>	<i>Liquefied Gas</i>	<i>Liquid</i>
Not Corrosive	monosilane	disilane monomethylsilane dimethylsilane trimethylsilane	trisilane tetramethylsilane
Corrosive		monochlorosilane dichlorosilane hexachlorodisilane	trichlorosilane methylchlorosilane methyldichlorosilane dimethyldichlorosilane methyltrichlorosilane

NOTE 1: The term ‘chemicals’ includes liquids and gases.

NOTE 2: ‘Silane’ without modifiers usually means silicon tetrahydride. The synonym ‘monosilane’ is also used for clarification.

2.2 Flammable mixtures containing flammable silicon compounds included in the Table 1 are also within the scope of this Safety Guideline.

NOTE 3: Silane is often mixed with highly toxic flammable gas such as phosphine. In such case additional requirements apply.

2.3 In some sections of this Safety Guideline, as well as in some of the included supplementary materials, the columns to the right of the text designate to which flammable silicon compounds the text applies. In the headers of those columns: “CG” designates ‘compressed gas,’ “LG” designates ‘liquefied compressed gas,’ and “L” designates ‘liquid.’ Where there are no such columns, the material applies to all of the flammable silicon compounds included in the scope of this Document.

NOTICE: SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the Documents 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 apply to facilities of gas manufacturers or distribution companies or to operations in those facilities.

4 Referenced Standards and Documents

4.1 SEMI Standards and Safety Guidelines

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

SEMI F5 — Guide for Gaseous Effluent Handling

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

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 Separation of Chemical Cylinders Contained in Dispensing Cabinets

SEMI S5 — Safety Guideline for Sizing and Identifying Flow Limiting Devices for Gas Cylinder Valves

SEMI S6 — Environmental, Health, and Safety Guideline for Exhaust Ventilation of Semiconductor Manufacturing Equipment

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

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

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

NOTE 4: A Safety Guideline named SAFETY GUIDELINE FOR USE OF ENERGETIC MATERIALS IN SEMICONDUCTOR R&D AND MANUFACTURING PROCESSES is under development. The document can be very informative when considering highly reactive nature of some flammable silicon compounds and their byproducts with other chemicals including water at the locations downstream from the process equipment (e.g., in process gas exhaust piping).

4.2 ASME Standard¹

ASME B31.3 — Standards for Pressure Piping – Process Piping

4.3 CGA Standards²

CGA G-13 — Storage and Handling of Silane and Silane Mixtures

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 ISO Standards³

ISO 10156 — Gases and Gas Mixtures – Determination of Fire Potential and Oxidizing Ability for the Selection of Cylinder Valve Outlets

ISO 10298 — Determination of Toxicity of a Gas or Gas Mixture

4.5 NFPA Standards⁴

NFPA 1 — Fire Code

NFPA 70 — National Electrical Code (NEC)

NFPA 318 — Standard for the Protection of Semiconductor Fabrication Facilities

4.6 US Code of Federal Regulations

29CFR 1910.1200 — Hazard Communication (OSHA)⁵

4.7 Other Documents

ASTM Manual, MNL33 “Manual on Chlorosilane Emergency Response Guidelines”

FM Global Property Loss Prevention Sheets 7-7R “Semiconductor Fabrication Facilities”⁶

¹ American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990, USA; Telephone: +1.973.882.1170, Fax: +1.973.882.1717, <https://www.asme.org>

² Compressed Gas Association, 4221 Walney Road, 5th Floor, Chantilly, VA 20151, USA; Telephone: +1.703.788.2700, Fax: +1.703.961.1831, <http://www.cganet.com>

³ International Organization for Standardization, ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland; Telephone: +41.22.749.01.11, <http://www.iso.org>

⁴ National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269, USA; Telephone: +1.617.770.3000, Fax: +1.617.770.0700, <http://www.nfpa.org>

⁵ Occupational Safety and Health Administration, Available from U.S. Department of Labor; <http://www.osha.gov>

⁶ FM Global, <http://www.fmglobal.com>

High Pressure Gas Safety Law⁷

Pressure Equipment Directive 97/23/EC

The High Pressure Gas Safety Institute of Japan (KHK), Application Guide for the High Pressure Gas Safety Law⁷

NIOSH Pocket Guide⁸

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

5 Terminology

5.1 Refer to the terminology defined in SEMI S2 except for terms specified below.

5.2 Abbreviations and Acronyms

5.2.1 *AEV* — additional exhaust ventilation

5.2.2 *ESOV* — emergency shut off valve

5.2.3 *IDLH* — immediately dangerous to life and health

5.2.4 *MAWP* — maximum allowable working pressure

5.2.5 *MOP* — maximum operating pressure

5.2.6 *MSDS* — material safety data sheet

5.2.7 *PEV* — primary exhaust ventilation

5.2.8 *PTFE* — polytetrafluoroethylene

5.2.9 *SEV* — secondary exhaust ventilation

5.2.10 *TLV*[®] — threshold limit value

5.2.11 *TWA* — time weighted average

5.2.12 *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 reduce emissions of hazardous materials to levels that do not present unacceptable risk.

5.3.2 *bulk* — able to contain 454 L (volume of 0.5 US tons of water) or more.

NOTE 5: The volume is of the container, not the volume of gas or liquid.

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

5.3.4 *chlorosilane* — any substance designated in Table 1 as being corrosive.

5.3.5 *compressed gas* — a gas that exerts a gauge pressure of 200 kPa (29.0 psig/43.8 psia) or greater at 20°C (68°F).

5.3.6 *controlled condition* — when related to flammable silicon compounds, a condition in which the chemical 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.

5.3.7 *exhaust ventilation* — any of primary, secondary, or additional exhaust ventilation (i.e., PEV, SEV, or AEV), as defined herein. [SEMI S6]

5.3.7.1 *primary exhaust ventilation (PEV)* — airflow that, in normal operation, extracts substances of concern from the equipment. [SEMI S6]

⁷ KHK, Sumitomo-Toranomon Bldg., 4-3-9 Toranomom, Minatoku, Tokyo 105-8447

⁸ Centers for Disease Control and Prevention, <http://www.cdc.gov/Niosh/>

5.3.7.2 *secondary exhaust ventilation (SEV)* — airflow that, in normal operation of the equipment, does not extract substances of concern, but operates continuously to extract substances of concern should they be released from their primary containment due to failure or to maintenance or service operations. [SEMI S6]

NOTE 6: For example, the exhaust ventilation through gas panels is considered SEV, because in normal operation, the hazardous gases are within their piping and only under failure, maintenance, or service are hazardous gases removed by the exhaust ventilation.

5.3.7.3 *additional exhaust ventilation (AEV)* — airflow that is not present during normal operation but is provided to extract substances of concern during maintenance or in the case of an abnormal release from primary containment. [SEMI S6]

5.3.8 *flammable mixture* — any mixture that forms an ignitable mixture in air at 20°C (68°F) and 101.3 kPa (14.7 psia). This includes, by definition, any pyrophoric mixture. (As used in this definition, “an ignitable mixture in air” is a mixture that can be ignited.)

NOTE 7: ISO 10156 provides information on how to decide if a mixture is flammable or not.

5.3.9 *flammable silicon compounds* — within this Document, the chemicals listed in Table 1.

5.3.10 *flammable silicon compound effluent* — flammable silicon compounds or mixtures of flammable silicon compounds with process gases, purge gases, or process byproducts, but not with air, for which there is no intended use in the manufacturing processes.

5.3.11 *flow components* — components (such as valves regulators, pressure gauges, elbows, and tees) used in a piping system that normally come in contact with the chemical flowing in the piping system.

5.3.12 *flow limiting device* — a device that will reduce maximum flow rate under full flow conditions. [SEMI S5]

NOTE 8: One such device is a restricted flow orifice (RFO).

5.3.13 *gas cylinder* — a cylindrical container of less than 454 L volume used to store, transport, or dispense compressed gases and liquefied compressed gases.

5.3.14 *highly toxic* — having a median lethal concentration (LC_{50}) in air of 200 parts per million by volume or less of gas or vapor, or 2 milligrams per liter or less of mist, fume, or dust, when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.

5.3.15 *immediately dangerous to life and health (IDLH)* — the 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]

NOTE 9: OSHA has the following definition “An atmospheric concentration of any toxic, corrosive or asphyxiant substance that poses an immediate threat to life or would cause irreversible or delayed adverse health effects or would interfere with an individual's ability to escape from a dangerous atmosphere.” [29 CFR 1910.120]

5.3.16 *inert gas* — a gas that is not generally reactive (e.g., N_2 and Ar).

5.3.17 *liquefied compressed gas* — a gas which under the charged pressure is partially liquid at a temperature of 21.1°C (70°F). [SEMI C3]

5.3.18 *liquid container* — a container of less than 454 L volume used to store, transport, or dispense liquids.

5.3.19 *maximum allowable working pressure (MAWP)* — the maximum internal pressure permitted in a vessel or a piping system for continued operation at the most severe condition of coincident internal and external pressure and temperature (minimum or maximum) expected. Its value is limited by the pressure-temperature rating of the equipment and the maximum allowable stress used in the design.

NOTE 10: MAWP is generally the same as the Design Pressure as defined in ASME B31.3.

5.3.20 *maximum operating pressure (MOP)* — the maximum pressure at which a vessel or piping system is normally operated (that is Process Pressure), generally less than, and never greater than, MAWP.

5.3.21 *occupational exposure limit (OEL)* — the maximum airborne concentration of a substance to which a worker may be exposed for the specified time. OELs include TWAs, STELs, and Ceiling limits, which differ in the time period for which they specify concentrations. 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. The criteria used in determining OELs can differ among the countries that have established values. [SEMI S6]

5.3.22 *offline storage facilities* — storage facilities for flammable silicon compounds containers (e.g., gas cylinders or liquid containers) that are not physically connected to any distribution system.

5.3.23 *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 F51]

5.3.24 *pyrophoric chemical* — a chemical which upon contact with air may ignite spontaneously at or below a temperature of 54°C (130°F).

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

5.3.26 *safe state* — a condition in which the equipment does not present any unacceptable risk 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.

5.3.27 *time weighted average* — an occupational exposure limit (OEL) for an exposure period of one work shift, typically eight hours. The time period is specified as part of the TWA. [SEMI S6]

5.3.28 *threshold limit value (TLV®)* — for chemical substances in the work environment adopted by ACGIH® (TLV® is a registered trademark of the American Conference of Governmental Industrial Hygienists). [SEMI F6]

5.3.29 *toxic* — having a median lethal concentration (LC₅₀) in air of more than 200 parts per million but not more than 2,000 parts per million by volume of gas or vapor, or more than 20 milligrams per liter but not more than 200 milligrams per liter of mist, fume, or dust, when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.

5.3.30 *unacceptable risk* — a risk of Medium, High, or Very High as defined by SEMI S10 or SEMI S14.

5.3.31 *unsafe gas condition* — a condition with a risk of Medium, High, or Very High as defined by SEMI S10 or SEMI S14.

6 General Principles

Paragraph	Not Corrosive			Corrosive		
	CG	LG	L	CG	LG	L
6.1 As flammable silicon compounds have several hazardous properties, personnel should wear appropriate protective equipment when working with them.	Y	Y	Y	Y	Y	Y
NOTE 11: Related Information 1 provides physical and chemical properties of flammable silicon compounds that are within the scope of this safety guideline.	Y	Y	Y	Y	Y	Y
6.2 <i>Risk Management Strategies</i> — Fundamental concepts of safety and accident prevention are:	Y	Y	Y	Y	Y	Y
6.2.1 An understanding of facilities, piping and equipment (from storage to abatement) is essential for safe handling of flammable silicon compounds in manufacturing facilities.	Y	Y	Y	Y	Y	Y
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, self-diagnostic and predictive functions.	Y	Y	Y	Y	Y	Y

Paragraph	Not Corrosive			Corrosive		
	CG	LG	L	CG	LG	L
6.2.3 Facilities and equipment in which flammable silicon compounds flow or are processed should be provided with safety systems (by the facility owner or equipment supplier) that can detect current safety status and generate alerts that indicate conditions of elevated risk, through computer self-diagnosis and dedicated safety control system devices.	Y	Y	Y	Y	Y	Y
6.2.3.1 If the safety systems cannot confirm normal operation of assigned flammable silicon compound handling system or unit, the flammable silicon compound supply should automatically be shut off.	Y	Y	Y	Y	Y	Y
6.2.3.2 The safety systems should be capable of determining if a safe status has been achieved before proceeding to the next step in a flammable silicon compound handling process.	Y	Y	Y	Y	Y	Y
6.2.4 Safe design depends on equipment designers' and facilities designers' understanding of flammable silicon compounds properties and hazards. Design methods for controlling the risks of these hazards require full integration of measures from all portions of the delivery and use systems.	Y	Y	Y	Y	Y	Y
6.2.4.1 Safety control systems should be provided in distribution facilities, cylinder cabinets, process equipment, gas treatment systems, and the like.	Y	Y	Y	Y	Y	Y
NOTE 12: Information on the hazards of flammable silicon compounds is available from various sources, including: regulations, MSDSs, Factory Mutual Loss Prevention Data Sheets, NFPA Standards, consensus building codes, and various research papers. Related Information 1 also provides some information on the hazardous properties of flammable silicon compounds.	Y	Y	Y	Y	Y	Y
6.2.4.2 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 flammable silicon compound systems.	Y	Y	Y	Y	Y	Y
NOTE 13: Different analytical methods will identify different system hazards; no single method will find them all. It takes a combination of techniques for thorough hazard identification and risk assessment.	Y	Y	Y	Y	Y	Y
6.2.4.3 The results of the analysis should be reported using the SEMI S10 risk matrix.	Y	Y	Y	Y	Y	Y
6.2.5 <i>Minimization of Quantity</i> — The quantity of any flammable silicon compounds online and in use should be limited to the smallest amount necessary for effective production. This can be achieved, for example, by the introduction of restrictive flow orifices within equipment or in facility supply lines.	Y	Y	Y	Y	Y	Y
6.2.6 Periodic accident prevention assessments should be performed to assist in minimizing incident frequency.	Y	Y	Y	Y	Y	Y

Paragraph	Not Corrosive			Corrosive		
	CG	LG	L	CG	LG	L
6.3 Hazardous Energy Isolation (Lockout/Tagout)						
6.3.1 Hazardous energy isolation (previously called 'lock out/tag out') capability should be provided for all flammable silicon compound sources at all levels necessary to perform service or maintenance on flammable silicon compound systems safely.	Y	Y	Y	Y	Y	Y
6.3.2 Hazardous energy isolation of all other energy sources (e.g., electrical, mechanical) should be performed, as necessary, to provide safety for personnel working on systems associated with flammable silicon compounds.	Y	Y	Y	Y	Y	Y
NOTE 14: It may not be necessary to isolate nonhazardous voltage and non-hazardous power energy sources if piping systems associated with flammable silicon compounds have been isolated and purged sufficiently prior to opening the containment.						
6.4 All personnel concerned in flammable silicon compound handling should be trained for the jobs they are to perform and the hazards to which they will be exposed. All such training should be formally documented and, if regulations apply, the documentation should be in accordance with the regulations.	Y	Y	Y	Y	Y	Y
6.4.1 Inspection of system status and equipment condition should be performed and documented on a periodic basis.	Y	Y	Y	Y	Y	Y
6.4.2 The operator or technician should be capable of checking the current status and any abnormal condition before beginning work on any system or subsystem.	Y	Y	Y	Y	Y	Y
6.5 Evacuation and Purging						
6.5.1 When connecting flammable silicon compounds' piping to equipment, the piping should be purged with inert gas, such as nitrogen, into a safe location to prevent the reaction of air with flammable silicon compounds.	Y	Y	Y	Y	Y	Y
6.5.2 A means of purging should be provided for closed piping systems. If an occasional use purge port is provided for this purpose, it should have a cap or plug to seal the port when it is not connected to the purge gas.	Y	Y	Y	Y	Y	Y
6.5.3 The user should introduce flammable silicon compounds only after purging oxidizing gases and other incompatible gases, materials or substances from the system.	Y	Y	Y	Y	Y	Y
6.5.4 Flammable silicon compound 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.	Y	Y	Y	Y	Y	Y
6.5.5 An adequate means should be provided to avoid a cross contamination of purge gases and the process gases by accidental backflow.	Y	Y	Y	Y	Y	Y

Paragraph	Not Corrosive			Corrosive		
	CG	LG	L	CG	LG	L
6.5.5.1 Separation of purge gas and any flammable silicon compounds should not depend solely on check valves. A control valve, such as a pneumatic valve placed before or after the check valve, is preferred for isolating flammable silicon compounds from purge gases during procedures that might allow reverse flow.	Y	Y	Y	Y	Y	Y
6.5.5.2 The purge gas for flammable silicon compounds should be supplied from dedicated higher-than-flammable-silicon-compounds-pressure source.	Y	Y		Y	Y	
6.5.5.3 Purge gas pressures should be always greater than process gas pressures to prevent backflow of process gases.	Y	Y		Y	Y	
6.5.5.4 The purge gas sources for flammable silicon compounds should not be connected to distribution systems for gases or chemicals that can form an ignitable mixture with flammable silicon compounds.	Y	Y	Y	Y	Y	Y
NOTE 15: 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 for compressed gas or liquefied compressed gas supply system of flammable silicon compounds.	Y	Y		Y	Y	
6.5.5.5 Purge lines from dedicated bulk supplies (where allowed at all by the jurisdiction) should have multi-level back-flow prevention and pressure differential protection to prevent back-flow of flammable silicon compounds into bulk systems.	Y	Y	Y	Y	Y	Y
NOTE 16: Back-flow into these bulk purge systems has been known to generate ignitable mixtures when the purge gas is exposed to atmosphere far from the source of contamination.	Y	Y	Y	Y	Y	Y

7 Evaluation

7.1 Conformance to SEMI S18 of distribution system, process equipment, exhaust ventilation, flammable silicon compound effluent, and abatement systems should be technically evaluated in accordance with the criteria of §§ 8 through 15 that are applicable to the system or equipment under evaluation.

8 Education and Training

NOTE 17: It is important for managers as well as employees to deepen their understanding of the characteristics of flammable silicon compounds that they handle, so as to ensure safe work practices. If employees do not handle flammable silicon compounds, this section is not applicable.

8.1 Everyone who handles flammable silicon compounds should be specially educated about the hazardous properties and safe handling methods of them and their byproducts.

NOTE 18: Some jurisdictions (such as Japan, U.S. and Europe) require that users of 'specialty high-pressure gases' provide special safety education to their employees.

NOTE 19: Many of byproducts of processes using flammable silicon compounds are highly reactive to other chemicals including water that can exist in downstream sections or systems of the process chamber and may further create unstable conditions. Therefore special care may be necessary whenever downstream sections or systems of the process chamber are maintained.

8.1.1 In regard to safety education and training, each organization should maintain an appropriate program for implementing all the necessary education and training, assign a person responsible for education and training, and implement a periodic training plan.

8.1.2 Instructors should be persons who have sufficient knowledge and experience about the hazards, use and safe control of flammable silicon compounds.

NOTE 20: It may be necessary to obtain the assistance of outside experts, depending on an organization's capabilities.

8.1.3 Training should include safe use, handling, hazardous properties and by-products, and emergency procedures of flammable silicon compounds as well as case studies of past accidents.

8.1.4 Training should be performed periodically and the training results documented. Follow up training should be held when new technology is introduced, equipment failures occur, operator errors are identified, or changes in the system operation occur.

8.2 Equipment and facilities suppliers, maintenance service providers, and users should:

- establish education curricula for job specific environmental, safety, and health (ES&H)
- train their personnel, and
- keep records or issue certificates.

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

8.3.1 Maintenance personnel should understand the overall design of facilities and equipment for flammable silicon compounds.

8.3.2 Hazardous energy isolation training should be provided to all employees who are expected to perform service or maintenance on flammable silicon compound systems.

8.4 Persons performing periodic inspections should be appropriately trained to ensure that the inspections are performed and documented properly.

9 Emergency Response

Paragraph	Not Corrosive			Corrosive		
	CG	LG	L	CG	LG	L
9.1 Exhaust and abatement system should not be shut off until risk from the residual unabated gas is reduced to acceptable level. NOTE 21: Some jurisdictions require backup power for these abatement systems.	Y	Y	Y	Y	Y	Y
9.2 <i>Evacuation of Personnel</i>						
9.2.1 Procedures for evacuation response to leaks should be developed based on a hazard analysis and should be appropriate to the level of hazard.	Y	Y	Y	Y	Y	Y
9.2.2 All personnel in the facility should be trained regarding proper evacuation procedures.	Y	Y	Y	Y	Y	Y
9.2.3 After an evacuation, no one should re-enter the area until the risks associated with hazardous properties of flammable silicon compounds in use are at an acceptable level.	Y	Y	Y	Y	Y	Y
9.3 <i>Leak Identification and Isolation</i>						
9.3.1 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.	Y	Y	Y	Y	Y	Y
9.3.2 If the leak location can be accurately determined, the specific source supplying flammable silicon compounds to the leak location should be shut down.	Y	Y	Y	Y	Y	Y

Paragraph	Not Corrosive			Corrosive		
	CG	LG	L	CG	LG	L
9.3.3 If the leak location cannot be accurately determined, all of the hazardous material supplies to the area where the leak was detected should be shut down.	Y	Y	Y	Y	Y	Y
9.3.4 Do not enclose a flammable silicon compound installation where adequate exhaust ventilation flow cannot be maintained during a leak. This could lead to an explosion.	Y	Y	Y	Y	Y	Y
9.4 <i>Recovery from a Leak Incident</i>						
9.4.1 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.	Y	Y	Y	Y	Y	Y
9.4.2 Sufficiently purge all affected systems with an inert gas.	Y	Y	Y	Y	Y	Y
9.4.3 Perform appropriate leak tests to confirm that the affected system is safe before allowing flammable silicon compounds back into the system.	Y	Y	Y	Y	Y	Y
9.4.4 Determine whether the sensor still works. Calibrate or exchange the sensor if necessary.	Y	Y	Y	Y	Y	Y
9.4.5 Confirm that the system (from the flammable silicon compound source systems to the gas abatement systems) is not damaged. Perform corrective actions if necessary.	Y	Y	Y	Y	Y	Y
9.5 <i>Fire and Explosion</i>						
9.5.1 The only safe way to extinguish a gas fire is to shut off the fuel source.	Y	Y		Y	Y	
NOTE 22: Do not attempt to extinguish any gas fire except by shutting off the fuel source. Many countries require fire extinguishers at gas storage areas, but these should be used for extinguishing fire of things other than the gas.	Y	Y		Y	Y	
9.5.2 Water spray or deluge systems should be used only to cool the container or adjacent containers to prevent containers from heating or overpressurizing.	Y	Y	Y	Y	Y	Y
NOTE 23: The corrosive flammable silicon compounds all react violently with water. Refer to the Silicones Environmental, Health and Safety Council, "Manual on Chlorosilane Emergency Response Guidelines" ASTM Manual, MNL33.				Y	Y	Y
9.5.3 Accidental extinguishing of a gas fire without shutting off the gas presents an unacceptable risk of explosion.	Y	Y		Y	Y	
9.5.4 When fire is suspected, contact the emergency responders.	Y	Y	Y	Y	Y	Y
NOTE 24: Local fire departments may not be trained in flammable silicon compounds. It is recommended that emergency planning sessions are held so that local fire departments, plant emergency response teams, and public hazard response teams share information about the hazards of flammable silicon compounds.	Y	Y	Y	Y	Y	Y

Paragraph	Not Corrosive			Corrosive		
	CG	LG	L	CG	LG	L
9.5.5 Only trained personnel should enter an area affected by a flammable silicon compound fire.	Y	Y	Y	Y	Y	Y
9.5.5.1 Trained responders to a fire event should be wearing appropriate protective equipment before entering the area.	Y	Y	Y	Y	Y	Y
9.5.5.2 After a fire event, check the installed fire detectors. Change the detectors if necessary.	Y	Y	Y	Y	Y	Y

10 Offline Storage Facilities

Paragraph	Not Corrosive			Corrosive		
	CG	LG	L	CG	LG	L
10.1 <i>General Considerations</i>						
10.1.1 Offline storage facility construction materials should be noncombustible and compatible with the hazards presented by flammable silicon compounds that are present.	Y	Y	Y	Y	Y	Y
NOTE 25: For certain chemicals, it may be necessary to consider multiple hazards, such as in the case of dichlorosilane, which is both flammable and corrosive.	Y	Y	Y	Y	Y	Y
10.1.2 Flammable silicon compounds should be separated from other chemicals per SEMI S4.	Y	Y	Y	Y	Y	Y
10.1.3 The recommended storage temperature is lower than 40°C.	Y	Y	Y	Y	Y	Y
10.1.4 A water deluge or sprinkler system should be installed over storage area for flammable silicon compounds to cool the containers during a fire event and reduce the effect of impingement of flame from one container on another.	Y	Y	Y	Y	Y	
EXCEPTION: Containers of volume of 1 liter or less are exempt from this criterion.	Y	Y	Y	Y	Y	
NOTE 26: Sprinkler system over water-reactive liquid is dangerous. A medium expansion foam system is recommended for corrosive flammable silicon compound liquids.						Y
10.1.5 Containers of flammable silicon compounds in storage should have their valve plugs securely tightened and their valve protective caps in-place.	Y	Y	Y	Y	Y	Y
10.1.6 Containers should be stored in an area adequately designed to protect the building from reasonably foreseeable incidents in the storage area.	Y	Y	Y	Y	Y	Y
10.1.7 If containers of flammable silicon compounds are stored in a structure independent of occupied buildings, mechanical or natural ventilation at a minimum of 0.005 meter/second (1 cfm/square foot) should be provided for the structure in which the containers are stored.	Y	Y	Y	Y	Y	Y

Paragraph	Not Corrosive			Corrosive		
	CG	LG	L	CG	LG	L
NOTE 27: Refer to standards such as NFPA 318 or High Pressure Gas Safety Law for more details.	Y	Y	Y	Y	Y	Y
10.1.8 The construction or location of the storage should not inhibit safe container transfer.	Y	Y	Y	Y	Y	Y
10.2 <i>Gas Cylinder Storage</i>						
10.2.1 A gas cylinder should be secured to the structure (directly or indirectly) with at least two noncombustible securing devices positioned to prevent cylinders from falling sideways, as they might if only a single device were installed.	Y	Y		Y	Y	
NOTE 28: Some jurisdictions impose additional requirements.	Y	Y		Y	Y	
10.3 <i>Liquid Container Storage</i>						
10.3.1 The storage area for the containers of liquid flammable silicon compounds should be adequately separated from other hazards.			Y			Y
10.3.2 The storage area for the containers of liquid flammable silicon compounds should be designed to isolate and contain a release of 150% of the volume of the largest container stored.			Y			Y

11 Supply from Outdoor Storage/Dispensing Facilities

Paragraph	Not Corrosive			Corrosive		
	CG	LG	L	CG	LG	L
11.1 <i>Bulk Supply</i>	Y	Y	Y	Y	Y	Y
11.1.1 <i>Location and Construction</i> — Bulk flammable silicon compound systems should incorporate the following location and construction features:	Y	Y	Y	Y	Y	Y
11.1.1.1 The container and its peripherals should be constructed outside of buildings with set back from buildings and property lines no less than the greater of the values required by NFPA 318 and the legal requirements in that location.	Y	Y	Y	Y	Y	Y
NOTE 29: There may be some jurisdictions that require more separation than NFPA 318.	Y	Y	Y	Y	Y	Y
NOTE 30: Additional protective barriers may be required to shield nearby structures or activities from potential flying objects.	Y	Y	Y	Y	Y	Y
NOTE 31: CGA G-13 contains an example layout.	Y					
11.1.1.2 The storage area should have at least two exits.	Y	Y	Y	Y	Y	Y
11.1.1.3 A full risk assessment should be performed to determine if there are other risks with the location such as vehicular traffic and sabotage.	Y	Y	Y	Y	Y	Y

Paragraph	Not Corrosive			Corrosive		
	CG	LG	L	CG	LG	L
11.1.1.4 The storage configuration should be of open construction and have natural ventilation that does not allow for pocketing of flammable silicon compounds that could result in explosion.	Y	Y	Y	Y	Y	Y
NOTE 32: Enclosure is required in some country.						
11.1.1.5 Bulk systems should be separated from each other and from the regulator station by 2-hour-rated firewalls.	Y	Y	Y	Y	Y	Y
11.1.2 Controls and Safeguards	Y	Y	Y	Y	Y	Y
11.1.2.1 Bulk systems should be equipped with the following controls and safeguards:	Y	Y	Y	Y	Y	Y
a. Excess flow protection,	Y	Y		Y	Y	
b. Secondary containment for spills,			Y			Y
c. A manual shutdown valve at both the point of supply and the point of use and dispensing,	Y	Y	Y	Y	Y	Y
d. Overpressure monitors with pressure relief and automatic gas shut off,	Y	Y		Y	Y	
e. A system to prevent overfilling for automated delivery systems, and			Y			Y
f. Gas/chemical detection.				Y	Y	Y
NOTE 33: Detection of byproducts between target gas/chemical and air is sometimes more important. For example, dichlorosilane (SiH_2Cl_2) reacts in moist air to form two molecules of HCl for each molecule of SiH_2Cl_2 . Therefore, HCl is generated at twice the rate as the molar release rate of SiH_2Cl_2 . As stated in ¶ A1-5.2 of SEMI S6, both the hazards of SiH_2Cl_2 and of HCl must be considered, although the release rates should not be added, as a molecule of SiH_2Cl_2 ceases to exist upon creation of HCl from it.				Y	Y	Y
11.1.2.2 Access control should be provided to ensure entry is restricted to trained and authorized personnel.	Y	Y	Y	Y	Y	Y
11.1.2.3 Workers from the gas supplier and trained site personnel should be the only persons authorized to work in bulk flammable silicon compound areas.	Y	Y	Y	Y	Y	Y
11.1.2.4 A flow limiting device should be placed in the outlet valve of the delivery manifold serving bulk source. The flow limiting device (e.g., restricted flow orifice [RFO]) size used on the outlet valve should be as small as possible to meet combined process needs. See SEMI S5 for instructions as to how to choose the appropriate size flow limiting device.	Y	Y		Y	Y	
NOTE 34: Combined process needs include the influences of the length of the delivery line.	Y	Y		Y	Y	