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ANSI/CGA G-13 — 2006 Storage & Handling of Silane and Silane Mixtures

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Introduction

- ❖ The 2006 International Fire Code (IFC) contains requirements in the Section 4106 that address the storage and use of silane in concentrations $> 2\%$ by volume in air.
 - Silane (SiH_4) is a pyrophoric and Class 1 unstable (reactive) compressed gas.
- ❖ The Compressed Gas Association submitted and obtained approval to a code change [F206-06/07] that has modified the 2009 IFC by adopting ANSI/CGA G-13 as the new minimum criteria for the storage and use of SiH_4 .



Seminar Summary

- ❖ Physical and chemical properties of SiH_4 .
- ❖ Overview of the layout and contents of ANSI/CGA G-13 – 2006, *Storage and Handling of Silane and Silane Mixtures*.
- ❖ Outdoor storage and use of SiH_4 .
- ❖ Indoor storage and use of SiH_4 .
- ❖ System configuration requirements for outdoor and indoor storage and use of SiH_4 .
- ❖ Process safety and fire protection requirements.



Properties of SiH₄

- ❖ SiH₄ is a colorless, pyrophoric gas that is able to burn at concentrations of 1.37%-96% v/v air.
 - At concentrations between 1.37% and $\approx 4.5\%$, SiH₄ can react if an ignition source is introduced.
 - CGA G-13 now has requirement to determine when hazardous (classified) locations are required for SiH₄.
- ❖ SiH₄ concentrations $> 4.5\%$ v/v air are metastable and may undergo bulk autoignition.
- ❖ Silane has a TLV-TWA of 5 ppm/v. It is not a Toxic gas as defined in IFC Section 3802.



Layout and Contents of CGA G-13

- ❖ Excluding the scope and definitions, CGA G-13 is divided into 13 sections:
 - Physical and chemical properties
 - Packaging information
 - Outdoor and indoor storage and use
 - System configuration — cylinder sources and bulk sources
 - Piping and components
 - Gas and flame detection
 - Fire protection systems
 - Ventilation systems
 - Venting and treatment
 - Purge gas systems
 - Electrical equipment



Outdoor Storage & Use of SiH₄

- ❖ The requirements for outdoor storage and use are based on the volume of cylinders with an individual volume of 450L (16Ft.³) or smaller.
- ❖ Exposures that require separation include:
 - Group A occupancies
 - Property lines that can be built upon
 - Public streets and sidewalks
 - Buildings based on the type of construction and if the building is constructed with fire-resistive rated exterior wall assemblies
 - Compatible gas storage
 - Incompatible gas storage
 - Aboveground storage tanks containing Class I, II or III flammable and combustible liquids



Outdoor Storage & Use of SiH₄

- ❖ For containers with a water capacity of more than 450L, including ISO modules and tube trailers, CGA G-13 requires that the following exposures be evaluated:
 - Place of public assembly
 - Property lines
 - Buildings on site
- ❖ The separation distances are intended to establish minimum separation distances to protect exposures from the energy of a 0.5 PSIG blast overpressure.

Separation Distances for Outdoor Silane trailers, ISO modules and containers > 450L

CGA G-13 TABLE 4 – Distance to exposures for outdoor silane trailers, ISO modules, and containers >450L in storage or use

Type of exposure	Minimum distance to exposure ^{1) 2) 3) 4) 5) 6)}		
	>450L ⁵⁾ cylinder to include tube trailer or ISO module ¹⁾		
	<600 PSIG	>600 to 1000 PSIG	>1000 to 1600 PSIG
Places of public assembly	175 Feet	275 Feet	450 Feet
Property lines	110 Feet	180 Feet	300 Feet
Buildings on site ⁷⁾	110 Feet	180 Feet	300 Feet

1) Maximum silane pressure in the container

2) The distances are based on the potential for overpressure due to latent ignition of released silane from individual containers of the size noted. Overpressures are determined in part by potential releases from the pressure relief device used for containers of the noted size. The container volumes shown are based on the maximum water content of individual containers whether manifolded or not.

3) Distances to buildings are allowed to be reduced depending on the ability to resist overpressure. See Appendix D.

4) Distances for pressures or volumes outside of those shown in the table shall be determined by engineering analysis subject to the approval of the authority having jurisdiction.

5) Volumes expressed in liters refer to the water content of containers specified.

6) Tube trailers or ISO modules equipped with PRDs with a venting orifice ≤ 1.0 inches (25 mm) in diameter.

7) Where greater encroachment is required for buildings on site refer to Appendix D for guidance.



How the Separation Distances Were Derived

- ❖ The separation distances for cylinders and larger containers are based on full-scale tests performed by A.D. Little for the CGA.
 - From these tests CGA developed mathematical models to establish minimum separation distances resulting from the radiation of a SiH_4 jet fire supplied from cylinders and blast overpressure resulting from a release at a bulk source.
- ❖ As part of the validation of the model, the following assumptions were confirmed by full scale tests:
 - The relief device complied with CGA S-1.1 & S-1.3 and was 1.0 inch or less in diameter.
 - A release of silane would produce a vapor cloud explosion (VCE).
 - A yield factor of 1.0 was used for calculating the VCE overpressure, which is far more conservative when compared to yield factors of 0.10-0.35 commonly used for calculating overpressure values for many flammable gases.



Indoor Storage and Use of SiH₄

- ❖ CGA G-13 defers MAQ and Detached Building quantity limits to the 2006 IFC and 2006 International Building Code (IBC) requirements.
 - Bulk systems are not permitted indoors.
- ❖ Explosion control is required when cylinder volumes exceed 14L (0.5 SCF).
- ❖ Mechanical ventilation requirements are based on the cylinders located inside or outside of cabinets:
 - Cylinders located outside of cabinets require a minimum airflow velocity of 150 feet/minute across unwelded mechanical connections.
 - Cabinets require a sufficient volume to maintain the atmosphere at < 25% LFL (0.34% v SiH₄/v air).



Volumetric flow rates

- ❖ The SiH₄ volumetric flow rate is now based on the maximum flow rate of silane that can be discharged from the piping system into the enclosure.
 - For < 100% concentrations, the flow rate is calculated based on the mole volume.
- ❖ An equivalent air ventilation across unwelded connections and connections at the source cylinder shall not be less than the SiH₄ volumetric flow rate X 300.
- ❖ CGA G-13 establishes SiH₄ and ventilation flow rates based on the diameter of the restrictive flow orifice (RFO) and the location of the RFO.

Minimum ventilation volumetric flow rates for gas cabinets and VMBs

CGA G-13 TABLE 5 – Minimum ventilation volumetric flow rate for gas cabinets and VMBs, unattended operations

Source pressure	Typical gas cabinet RFO 0.006 in. diameter (0.15 mm diameter)		Typical gas cabinet RFO 0.010 in. diameter (0.25 mm diameter)		Typical VMB RFO 0.014 in. diameter (0.36 mm diameter)		Typical VMB RFO 0.020 in. diameter (0.51 mm diameter)	
	Silane flow (scfm)	Ventilation flow (scfm)	Silane flow (scfm)	Ventilation flow (scfm)	Silane flow (scfm)	Ventilation flow (scfm)	Silane flow (scfm)	Ventilation flow (scfm)
50	0.025	8	0.069	21	0.136	41	0.288	86
100	0.045	12	0.124	37	0.243	73	0.497	149
200	0.085	26	0.237	71	0.465	140	0.949	285
400	0.173	52	0.480	144				
600	0.275	83	0.755	227				
800	0.395	119	1.08	324				
1000	0.555	167	1.51	453				
1200	0.724	217	1.97	591				
1500	0.913	274	2.50	750				
1650	0.987	296	2.70	810				

NOTES

- 1) Silane source temperature is 75°F (24°C)
- 2) RFO downstream pressure is 0 PSIG
- 3) RFO discharge coefficient is 0.80.



Piping and Components

- ❖ Piping systems must be constructed, erected, inspected and tested in accordance with ASME B31.3, *Process Piping*.
- ❖ All piping shall be welded except where connections are needed. Face-seal fittings are permitted when they are equipped with metal gaskets. CGA threaded connections are permitted at cylinders.
- ❖ Secondary containment piping is not required but is not prohibited provided the interstitial space is not purged with air.



Piping and Components

- ❖ Valves shall be of the bellow seal or diaphragm seal type.
- ❖ Pressure regulators shall be equipped with a relief valve vent line and means of detecting a ruptured regulator diaphragm is required.



Flame & Gas Detection

- ❖ Indoor and outdoor storage locations require a means of optical flame detection.
 - For indoor locations, a means of heat detection is allowed to be used in lieu of optical flame detection.
 - Automatic sprinkler = heat detector.
- ❖ Flame detection is required inside of gas cabinets and VMBs.
- ❖ Activation of the optical flame detection system requires the automatic shutdown of the SiH_4 system.
- ❖ The requirements for gas detection are consistent with the requirements in IFC Chapter 18.



Fire Protection

- ❖ For outdoor installations, CGA G-13 requires an overhead deluge system over the surface area of external containers and process gas panels.
 - A minimum discharge density of 0.30 GPM/Ft.² is required. Fittings using elastomeric seals (i.e. Victaulic[®]) are not permitted within 50 feet of the bulk source.
 - Activation of the deluge system shall shut of the flow of SiH₄ at the source.
- ❖ Indoor installations require QR sprinklers within gas cabinets. Cylinders not located within cabinets require protection based on a Extra Hazard Group 1 discharge density over a minimum 2,500 Ft.² design area.



Venting and Treatment

- ❖ CGA G-13 Section 14 requires a means of venting of purged SiH₄ and its treatment from process gas panels, VMBs, piping and equipment within the scope of the standard.
- ❖ Direct venting to exhaust ducts is permitted provided the volume of gas is <25% LFL.
- ❖ Dedicated process vents are permitted provided they are purged to eliminate atmospheric O₂ from migrating into the system.



Purge Gas Systems

- ❖ Nonbulk and bulk silane systems require a dedicated purge gas systems. The system requires the following elements:
 - A dedicated source of purge gas
 - A check valve and pressure relief valve to prevent contamination of the purge gas
 - A pressure regulator
 - A low pressure alarm
- ❖ If vacuum purge gas systems are used, the system must utilize nitrogen or inert gas to provide the motive force necessary to generate the negative pressure.

Supervisory Functions

**CGA G-13 TABLE 9 – Indoor requirements for supervisory control
Silane systems containing silane in concentrations exceeding 1.37% by volume**

Indoor Installations	Exhaust monitoring	Gas monitoring (See 11.1)	Flame detection (See 11.2)	Emergency shutoff (See 10.2.3)
Gas cabinet	Alarm on loss of exhaust. Source shutdown on loss of exhaust IS NOT required.	Gas detector required inside of gas cabinet Source shutdown on activation of gas detector.	An optical flame detection system or heat detector is required in the gas cabinet. Source shutdown on fire detection.	Emergency shutdown controls shall be provided outside each exit.
SiH ₄ piping system with unwelded connections in other than coaxial piping systems		Gas detection required in the room	An optical flame detection system or heat detector is required in the gas cabinet. Source shutdown on fire detection.	
Valve Manifold Box		Gas detector required inside of the VMB. Manifold branch shutdown on activation of the gas detector.	An optical flame detection system or heat detector is required in the VMB. Manifold branch shutdown on fire detection.	



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