2017 UPDATE

TGO

TOXIC GAS ORDINANCE DATA BOOK

A Guide to the Latest Regulations
Updated and Annotated to
Include Flammable and Pyrophoric Gases
Plus Certified Contractors

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South Bay Piping Industry
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FORWARD

In 1988 the Santa Clara County Fire Chief's Association drafted a "Model Ordinance for Toxic Gas Regulation" in conjunction with the Santa Clara County City Manager's Association, the Santa Clara County Manufacturing Group and the Silicon Valley Toxics Coalition. This model ordinance was subsequently adopted into municipal code and county ordinance by the various jurisdictions within Santa Clara County as well as various other regulatory agencies as the "Toxic Gas Ordinance" or TGO. The TGO has been subsequently used as the base model for the 1994 Uniform Fire Code (UFC) amendments for Toxic and Highly-Toxic gases through the current Fire Code adoption.

Currently, the Fire Code regulation of Toxic and Highly-Toxic gases generally corresponds to the TGO, with the following notable exceptions:

- **SECONDARY CONTAINMENT:** The TGO requires secondary containment piping for Class I (highly-toxic) gases, and for Class II (toxic) gases where the primary piping is not inert to the gas being conveyed, such as hydrogen chloride in 316 Stainless Steel rather than an inert material such as C-series Hastelloy.

- **SEISMIC SHUT-OFF:** The TGO requires an approved seismically activated shut-off valve for Class I (highly-toxic) and Class II (toxic) gases.

- **CLASS III GASES:** The TGO includes regulation of Class III (moderately-toxic) gases in addition to the Fire Code regulation of Toxic and Highly-Toxic gases. This Class III (moderately-toxic) category also generally corresponds to Department of Transportation (DOT) Division 2.3 "toxic" or "poisonous" gases not classified as toxic or highly-toxic by the Fire Code.

- **TOXIC LIQUIDS:** Alternative materials for toxic gases such as Trimethyl Boron, Trimethyl Arsine, and other highly-toxic or toxic liquids used in a gas or vapor phase shall be regulated by the TGO based on toxicological value of the gas or vapor.

- **MAXIMUM THRESHOLD QUANTITY:** The TGO regulates bulk systems containing quantities of gas exceeding a maximum threshold quantity (MTQ) as the next more stringent category of regulation, i.e. quantities of Class II (toxic) gases exceeding the MTQ shall comply with the regulations for Class

I (highly-toxic) gases, and quantities of Class III (moderately-toxic) gases exceeding the MTQ shall comply with the regulations for Class II (toxic) gases.

This guide has also been expanded and annotated to include gases classified as Pyrophoric or Flammable by the Fire Code. Although such gas may not be regulated by the TGO or Fire Code as “toxic” gases the piping standards and many of the controls are similar - including requirements for gas detection, automatic shut-off and excess flow control, and therefore have been included herein.

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DEFINITIONS

The Toxic Gas Ordinance (TGO) and the 2013 California Fire Code, chapters 50, 58, 60, and 64, use similar terminology and definitions. The most commonly used terms and definitions are listed here.

AHJ — *Authority Having Jurisdiction.* Chief Building Official or Fire Code Official having authority to enact and enforce the provisions of the code as adopted by the governing jurisdictional agency.

CBC — *California Building Code.* The Building Code adopted by the State of California for all local authorities having jurisdiction and State Facilities.

CEC — *California Electrical Code.* The Electrical Code adopted by the State of California for all local authorities having jurisdiction and State Facilities.

CFC — *California Fire Code.* The Fire Code adopted by the State of California for all local authorities having jurisdiction and State Facilities.

CMC — *California Mechanical Code.* The Mechanical Code adopted by the State of California for all local authorities having jurisdiction and State Facilities.

CPC — *California Plumbing Code.* The Plumbing Code adopted by the State of California for all local authorities having jurisdiction and State Facilities.

Control Area — Spaces within buildings, not classified as a high-hazard H-Occupancy, where regulated materials can be stored, handled, used or dispensed. A control area is defined in the CBC as an area bounded by fire barriers and fire-rated floor/ceiling assemblies.

Controls — Means used to regulate materials to prevent unauthorized discharges.

Cylinder — A pressure vessel designed for pressures higher than 40 psia and having a circular cross section with an internal water volume not exceeding 10 cu.ft. or a water capacity

	of 1000 lb. It does not include portable tanks, multiunit tanks, ISO modules or similar bulk vessels.
D.O.T.	*Department of Transportation.* United States Department of Transportation.
Exhausted enclosure	An appliance or piece of equipment that consists of a top, a back, and not more than two sides providing a means of local exhaust for capturing gases, fumes, vapors and mists. Such enclosures include laboratory fume hoods and similar appliances and equipment used to retain and exhaust locally the gases, fumes, vapors and mists that could be released.
Flammable Gas	A material which is a gas at 68 °F or less at 14.7 psia of pressure and is ignitable when in a mixture of 13% or less by volume with air; or has a flammable range of at least 12%, regardless of the lower flammable limit.
Gas Cabinet	A fully enclosed, ventilated noncombustible enclosure used to provide an isolated environment for compressed gas cylinders in storage or use. Doors and access ports for exchanging cylinders and accessing pressure-regulating controls are allowed to be included.
Guidelines	TGO Draft Consensus Guidelines. The Santa Clara Fire Chiefs' Association set forth a clarification that has been adopted into the TGO.
IDLH	*Immediately Dangerous to Life & Health.* Material concentration, expressed in ppm, that represents the maximum level from which one could escape without suffering any impairment or irreversible health effects in a 30-minute time period.
Highly-Toxic (gas)	A material that has a median lethal concentration (LC50) in air of 200 parts per million or less by volume of gas or vapor, or 2 milligrams per liter or less of mist, fume or dust, when administered by continuous inhalation for an hour, or less if death occurs within one hour, to albino rats weighing between 200 and 300 grams each.

LC_{50}	*Lethal Concentration (50).* The median exposure level, expressed in ppm, at which 50% of the testing animals died following inhalation exposure.
TGO Lab std.	Laboratory Standard for limited use of toxic and highly toxic gases.
LEL	*Lower Explosive Limit.* The minimum concentration of vapor or gas in air at which propagation of flame will occur in the presence of an ignition source. Also referred to as LFL (Lower Flammable Limit).
Moderately-Toxic (gas)	A material that has a median lethal concentration (LC50) in air more than 2,000 parts per million but not more than 5,000 parts per million by volume of gas or vapor, or more than 30 milligrams per liter but not more than 50 milligrams per liter of mist, fume or dust, when administered by continuous inhalation for an hour, or less if death occurs within one hour, to albino rats weighing between 200 and 300 grams each.
PEL	*Permissible Exposure Limit.* The maximum concentration established by OSHA to which one can be exposed over an 8-hour period. May also be expressed as TWA (Time Weighted Average) or TLV (Threshold Limit Value).
Pyrophoric	A chemical with an autoignition temperature in air at or below a temperature of 130 oF (54°C). Includes silane and silane mixtures where the concentration of silane exceeds 1.37% by volume.
Silane, Bulk Source	A container or interconnected group of containers with a water volume exceeding 8.8 cubic feet.
Silane, Outdoor	A system located outside that is open to the surrounding environment where objects do not encroach upon the installation.
TGO	*Toxic Gas Ordinance.* The regulating code, adopted by most governmental agencies in the California Bay Area, for the use, distribution, handling and dispensing of Toxic Gases. In other locations and jurisdictions refer to chapters 50 and 64 of the CFC.

Toxic (gas) A material that has a median lethal concentration (LC50) in air more than 200 parts per million but not more than 2,000 parts per million by volume of gas or vapor, or more than 2 milligrams per liter but not more than 30 milligrams per liter of mist, fume or dust, when administered by continuous inhalation for an hour, or less if death occurs within one hour, to albino rats weighing between 200 and 300 grams each.

VMB *Valve Manifold Box.* A fully enclosed, ventilated enclosure used to house valves, fittings, pressure regulating, monitoring and flow control devices for gas distribution systems.

Toxic Gas Ordinance

SYNOPSIS

A. **Introduction**

The Toxic Gas Ordinance has established a class rating for all hazardous gases. The most hazardous highly-toxic gases are rated as **Class I**, hazardous toxic gases are rated as **Class II**, and moderately-toxic gases are rated as **Class III** hazardous gases.

B. **Class I Highly-Toxic Gases.**

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

C. **Class II Toxic Gases.**

A material that has a median lethal concentration (LC_{50}) in air more than 200 parts per million but not more than 2,000 parts per million by volume of gas or vapor, or more than 2 milligrams per liter but not more than 30 milligrams per liter of mist, fume or dust, when administered by continuous inhalation for an hour, or less if death occurs within one hour, to albino rats weighing between 200 and 300 grams each.

D. **Class III Moderately-Toxic Gases.**

A material that has a median lethal concentration (LC_{50}) in air more than 2,000 parts per million but not more than 5,000 parts per million by volume of gas or vapor, or more than 30 milligrams per liter but not more than 50 milligrams per liter of mist, fume or dust, when administered by continuous inhalation for an hour, or less if death occurs within one hour, to albino rats weighing between 200 and 300 grams each. Notwithstanding the hazard class definitions Class III (moderately-toxic) gases with an LC50 greater than 2,000 ppm but less than 3,000 ppm may also be required to comply with the requirements for Class II (toxic) gases. This is an attempt by some AHJ's to retain controls for gases originally regulated by the TGO as Class II but which slipped to Class III with the change in TGO hazard class definitions to align with LC50 values used by the fire code. For example: hydrogen bromide (LC50 = 2860 ppm).

E. **Maximum Threshold Quantities.**

Maximum Threshold Quantity (Max TQ) is the maximum quantity of a moderately-toxic or toxic gas which may be stored in a single vessel before the next more stringent category of regulation is applied. The following equation shall be used to calculate the Max TQ:

Max TQ (lbs.) = LC50 (ppm) of regulated material x 2 lb.

F. **Minimum Threshold Quantities.**

Minimum Threshold Quantities (Min TQ) can be any minor quantity of gas present in such minimum quantities that the installation shall only be required to meet the minimum threshold controls. The Min. TQ's established under the original TGO are as follows:

- DOT Poison-A (highly-toxic)
  ¼ lb. per cylinder and less than 1 lb. total
- Other Regulated Materials
  1 lb. per cylinder and less than 2 lb. total.

However, with the integration of the TGO into local AHJ's adoption of the Fire Code many AHJ's have amended the minimum threshold quantities, as follows:

- Highly-Toxic
  0 cubic feet (i.e. any amount)
- Toxic Gas
  10 cubic feet (at STP)
- Moderately-Toxic Gas
  20 cubic feet (at STP)

G. **Class I Piping Requirements**

In general, Class I Highly-Toxic gases need to be dispensed in an inert piping system with welded connections. Class I gases also require a designed to withstand the sudden rupture or gradual release of the primary system. The secondary containment system must discharge into an treatment system.

H. **Class II Piping Requirements**

In general, Class II Toxic gases need to be dispensed in an inert piping system with welded connections. Secondary

containment is not required unless the material is a corrosive and the primary dispensing piping system is not inert.

I. **Class III Piping Requirements**

In general, Class III Moderately-Toxic gases need to be dispensed in an inert piping system with welded connections. Secondary containment is not required.

J. **Class I, II, III Special Requirements**

In general, the use of any hazardous gas requires certain special requirements which depend on the classification of the hazardous gas. The general requirements for the various classifications are listed in this publication

K. **Exterior Storage**

In general, the design of exterior highly-toxic, toxic and moderately-toxic gas storage must include the following criteria:

- Distance from all exposures is 75 feet.
- Storage, covered by canopy, with fire protection system.
- Tank pressure relief vents must discharge to the treatment system.
- Local exhaust at dispensing area that captures fumes and directs materials to treatment system.
- Stationary tank equipped with excess flow valves on both inlet and outlet connections.
- Leaker Cabinet

L. **Materials Regulated**

- Alternative materials for toxic gases, e.g. Trimethyl Phosphine, Trimethyl Arsine, and other highly-toxic or toxic liquids used in a gas or vapor phase shall be regulated by the TGO based on toxicological data or estimated by qualified third party.
- Mixtures of Regulated Materials
  In the absence of an established LC_{50} for a mixture containing a regulated material, the following formula may be used per appendix E103.1.3.1 of the CFC:

$$LC_{50}\ (\text{mixture}) = \frac{1}{\left(\sum_{t=1}^{N} \frac{f_t}{LC_{50t}}\right)}$$

- For mixtures where the hazardous gas component is diluted with a non-toxic gas, the LC_{50} of the mixture is estimated by using the following simplified formula:

$$LC_{50}(\text{mixture}) = \frac{\text{LC50 of toxic gas component}}{\text{Vol.\% of toxic gas component)}}$$

- Halogenated, non-carbon based gases may hydrolyze to their base mineral acid upon contact with moisture. Therefore, the TGO requirements for these gases shall apply to their decomposition products, i.e. monitoring, treatment, compatibility, etc.

  Example: Tungsten hexafluoride decomposes to hydrogen fluoride (HF), therefore, monitoring shall be required at the PEL for HF, treatment shall be required to ½ IDLH for HF, and piping material must be compatible with HF or secondary containment shall be required.

M. **Piping and Controls**

1) A permit shall be required for the installation, modification or repair of any hazardous gas piping system.

2) All primary piping for toxic gas systems shall pass a Helium Leak Test of 10^{-9} cc/sec, where practical. Persons installing toxic gas piping systems shall be qualified. Persons conducting the tests must possess a certificate of training. The authority having jurisdiction may also require “third party” testing.

3) For the purpose of calculating the , storage tanks, cylinders and piping systems, which can be isolated in a manner approved by the Fire Chief, may be designated as separate storage vessels.

N. **Inert Materials**

1) Compatibility of materials shall be determined by the National Association of Corrosion Engineers.

O. **Incompatible Materials**

1) Materials which, when in contact with each other, have the potential to react in a manner that generates heat, fumes, gases or byproducts which are hazardous to life or property.

P. **Seismic Protection**

1) Automatic shut-down shall be required for the toxic gas sources in the event of seismic activity as specified by each authority having jurisdiction.

Q. **Gas Detection**

1) Monitoring systems are to be tested at the point of use.

2) The interval time for "continuous gas detection shall be determined by the Fire Chief in each jurisdiction. The Maximum interval time is 5 minutes.

3) Automatic shut-down shall occur upon gas detection at or below PEL in occupied areas, and at or below ½ IDLH in unoccupied areas.

4) Continuous gas detection may not be required to detect the presence of gas at or below the PEL when the upper range of the odor threshold limit is less than the PEL, as determined by the critiqued and approved data published by the American Industrial Hygiene Association, 'Odor Thresholds for Chemicals with Established Occupational Health Standards" (1989, or as amended thereafter). Notwithstanding, monitoring may be required, however to provide for the proper function of the treatment system and other emergency controls. Moreover, this exemption may apply only in those jurisdictions which provide an exception based on the physiological warning properties of certain gases.

R. **Emergency Controls Alarm Testing and Maintenance**

1) Responsible persons shall cause all safety control systems at a facility to be maintained in good working condition and fully tested:

A. Not less frequently than annually;

B. According to approved manufacturer's requirements;

C. In accordance with approved recognized industry standards; or

D. In accordance with an approved schedule.

2) Maintenance and testing shall be performed by persons qualified to perform the maintenance and tests.

3) Maintenance records and certifications shall be available to any representative of the Fire Department for inspection and review upon request.

S. **Treatment Systems**

1) Treatment systems shall be capable of diluting, absorbing, neutralizing, burning or otherwise processing the maximum release of gas to one-half IDLH concentration at the point of discharge to atmosphere. (Note; although the model Fire Code provides an exception to this requirement, most AHJ's adopting the TGO delete the exception and require treatment for any highly-toxic, toxic or moderately-toxic gases in use.)

2) Maximum release rates shall be calculated based upon a worst case, single event from a single cylinder, taking into account all engineering controls.

3) Restrictive flow orifices must be permanently marked and installed in the cylinder valve to be considered in calculating the maximum release rate from a cylinder.

4) Where cylinders are manifolded together, the maximum release rate shall be the sum of the release rates for all the manifolded cylinders.

T. **Secondary Containment**

1) Secondary containment systems shall be approved and tested on a case by case basis as determined by the authority having jurisdiction.

2) Secondary containment may not be required for systems operating under subatmospheric conditions (i.e. vacuum piping systems) in accordance with NFPA 318.

U. **Portable Tanks and Cylinders**

1) Excess flow control valves, as defined in CFC, Chapter2, shall be permanently marked by the valve manufacturer to indicate the maximum designed flow rate, based on air under standard conditions.

2) Encapsulating equipment designed to contain high pressure cylinders and their contents, as approved by the Fire Chief, shall be acceptable in meeting the intent of providing a gas cabinet or exhausted enclosure for leaking gas cylinders.

V. **Inert Gas Purge Systems**

1) A dedicated inert gas purge system may be used to purge more than one gas provided that the gases are compatible.

2) Purge gas systems must be located in approved gas cabinet unless the system operates by vacuum demand.

SYNOPSIS

A. **Silane Regulation**

CGA G-13 (2006) regulates silane and silane in combination or mixed with other gases where the concentration of silane exceeds 1.37% by volume. Although silane is pyrophoric, it may not always instantaneously ignite. Lack of instantaneous ignition can lead to delayed reaction resulting in fireballs or vapor cloud explosions, which can range in character from deflagration to detonation.

B. **Outdoor Installations**

Silane installations installed outdoors shall be located in an unconfined space meeting the following criteria:

1. Objects confining the silane sources shall not be located within twice the height of the encroaching object, or where mitigation measures are applied, i.e. forced ventilation, the distance is allowed to be reduced to not less than the height of the encroaching object.

2. Where weather protection is provided, the overhead roof shall be not less than 12 ft. high and shall be protected with an automatic fire-protection system. Roofs shall not be permitted to shelter bulk silane sources.

3. Silane sources shall be located a minimum distance from incompatible materials and exposures in accordance with CGA G-13, Table 3. For cylinders containing not more than 600 scf of gas, the separation distance is required to be a minimum of 20 feet to incompatible materials, property lines and adjacent buildings of non-rated construction. These distances may be reduced to 5 ft. when protected by a fire barrier having a minimum fire resistance rating of 2 hour.

4. At least one remotely located, manually activated shutdown control shall be provided within 15 ft. from the source, and at each exit from the secured area.

5. Silane sources located within gas cabinets outdoor shall comply with the requirements for indoor installations.

C. **Indoor Installations**

Silane installations indoors in excess of the Maximum Allowable Quantity (MAQ) per control area shall be within a Group H2 hazardous occupancy meeting the following criteria:

1. The occupancy shall be protected by a fire barrier having a minimum fire resistance rating of 2 hour.

2. A means of explosion control shall be provide when the quantity of silane in individual containers exceeds 0.5 scf.

3. Gas cabinets or equivalent ventilated enclosures shall be provided for silane sources or systems in use where the pressure of the gas supply exceeds 30 psig or where silane is mixed with a toxic or highly-toxic component.

4. Indoor rooms or areas where silane is stored or used shall be protected by an automatic sprinkler system.

D. **Silane Piping Systems**

1. Process piping shall be of metal construction with all welded connections. Mechanical fittings are allowed within exhausted enclosures. Low melt point materials that soften under exposure to fire such as aluminum, copper or brass shall not be acceptable.

2. Piping systems shall be pressure leak tested in accordance with ASME B31.3. Piping systems that have been modified or repaired shall be tested as required for new systems.

3. Piping systems shall be marked, labeled and identified in accordance with ASME A13.1. Marking shall include content's name and direction of flow at each valve, wall, floor or ceiling penetration; at each change of direction; and a minimum of every 20 feet throughout the piping run.

4. Silane piping systems are not required to be secondarily contained. When secondary containment piping is provided, the containment shall be of metal construction rated to contain the maximum pressure of the primary piping or tubing system. The use of air as a means to

purge the annular space between the primary and secondary containment piping shall not be allowed.

5. Packed valves shall not be used. Bellows sealed valves and diaphragm sealed valves are allowed to be used in lieu of packless design. Automatic actuated valves shall be of fail-safe or fail-closed design.

6. Regulator bonnets shall be equipped with bonnet relief vents provided with an attached vent line or positioned to allow silane to escape to a protected location in the event of a diaphragm leak or rupture.

7. Individual cylinders containing silane shall be separated from other adjacent silane cylinders by a ¼ inch steel plate extending a minimum of 18 inches below, and 6 inches above and beyond the centerline of the cylinder valve to prevent flame impingement from a silane release to an adjacent cylinder or valve area.

E. **Emergency Shut-off (ESO) System**

1. A manual or automatic ESO valve able to be activated at each point of use and at the source shall be provided. ESO valves and shutoff controls shall be identified by means of a sign.

2. An excess flow control valve or other means shall be provided to shut off the flow of silane due to a rupture in the piping system.

3. Optical flame detection systems shall automatically shut off the silane source upon flame detection.

4. When gas monitoring is provided for exhausted locations the gas monitoring system shall automatically shut off the gas source to the location being monitored when a concentration greater than 0.34% (or 25% of the LFL) is detected.

5. When shutdown action occurs, an alarm shall be transmitted to a constantly attended location on the premises.

F. **Gas and flame detection**

1. Outdoor delivery systems shall be provided with an optical flame detection system to detect fire at potential silane leak locations.

2. Indoor delivery systems located outside of gas cabinets shall be provided with an optical flame detection system to detect a fire at potential leak points on the delivery system.

3. An optical flame detection system shall be provided inside of gas cabinets and valve manifold boxes to detect a fire within. Automatic shutoff of the silane delivery system is required whenever flame detection occurs.

4. Optical flame detectors shall be immune to sunlight, arc welding, artificial lighting or stray sources of ultraviolet or infrared light. Detectors used outdoors shall be approved for outdoor service.

5. Indoor silane delivery systems shall be monitored for leaks using a gas monitoring system for gas cabinets and VMB's. When gas monitoring is provided the gas monitoring system shall initiate a warning and automatically shut off the gas at the source when a concentration greater than 0.34% (or 25% of the LFL) is detected.

G. **Fire Protection Systems**

Fire protection systems for silane installations are intended to cool the silane container and associated equipment involved in a fire. It is not intended to extinguish a silane fire. Halon™ fire extinguishers or systems must not be used on silane fires since their use may cause a violent reaction.

1. Outdoor bulk silane delivery systems shall be provided with a deluge water spray fire protection system providing a minimum density of 0.30 gpm/sf for a minimum 2-hour duration. Activation of the water deluge system shall automatically shut off the gas flow at the source.

2. Sprinkler system piping within 50 feet of a silane area or bulk source shall be of metal construction with threaded or welded fittings. Clamped fitting with elastomeric seals shall NOT be used.

3. Gas cabinets shall be provided with an automatic fire sprinkler systems equipped with a quick response sprinkler head.

4. Canopy's for outdoor silane installations and indoor rooms or areas where silane is stored or used shall be protected by an automatic fire sprinkler systems. The design shall not be less than Extra Hazard Group 2 with a minimum design area of 2500 sf.

H. **Ventilation**

1. Natural ventilation is allowed for outdoor storage and use installations providing the space is unconfined. Mechanical ventilation used to reduce the distance required for objects encroaching upon the installation shall provide a minimum velocity of 150 fpm across cylinder valves and unwelded mechanical connections.

2. Indoor rooms or areas where silane is stored or used shall be exhausted at not less than 1 cfm/sf or 6 air changes per hour, whichever is greater.

3. Exhaust systems for unenclosed indoor silane installations, ventilated exhausted enclosures, gas cabinets and VMB's shall be designed to prevent the accumulation of silane resulting from a leak and limit the silane leak concentration to not more than 0.34% by volume (25% of the LFL) in accordance with CGA G-13.2.3.1 Table 5. Mechanical ventilation systems from gas cabinets, VMB's and exhausted enclosures or room ventilation shall be monitored to detect a failure in the ventilation system. A failure in the ventilation system shall initiate a local alarm and transmit a signal to a constantly attended location.

I. **Silane Venting, Treatment and Purge Gas Systems**

1) Silane shall not be introduced into exhaust systems in concentrations that could produce a fire or explosion within the exhaust systems.

2) Treatment systems shall be designed for the use intended and shall have the capacity to treat the flow of silane and any components of its mixture under both operational and upset conditions.

3) Dilution with an inert gas followed by open-air dispersion is one of the simplest methods of treating silane when not mixed with a toxic gas component.

4) Vent lines used for silane to be discharged from process gas lines shall be dedicated to lines used exclusively for silane service and shall be continuously purged with an inert gas to prevent atmospheric oxygen from entering in the vent line.

5) Purge gas used for silane delivery systems shall be supplied from a dedicated inert gas supply. House gas supplies shall not be used for purging silane delivery systems.

SYNOPSIS

A. **General**

The storage and use of flammable process gases and flammable cryogenic fluids shall comply with Fire Code Chapters 50, 53, 55 and 58. Flammable cryogenic fluids shall also comply with NFPA 55.

B. **Flammable Gas Piping Systems**

1) When conveyed in pressurized piping above 15 psig, an approved means of leak detection and emergency shutoff, or excess flow control shall be provided for flammable gas piping systems.

2) A manual or automatic fail-safe ESO valve shall be provided at the source and at the point of use where the equipment using the gas is connected to the supply system. Manual ESO valves and controls for automatic remotely activated ESO valves shall be clearly visible, accessible and indicated by means of signage.

3) Hazardous process piping shall not be located within exit corridors, within a portion of a fire-rated means of egress, or in concealed spaces in or above areas not classified as a Group H occupancy, except when provided with the following:

   i) Automatic sprinklers shall be installed within the space, unless the space is less than 6 inches in the least dimension,

   ii) Ventilation at not less than 6 air exchanges per hour shall be provided, and the space shall not be used to convey air from other areas,

   iii) Hazardous process piping and tubing shall be separated from the exit corridor and from areas not classified as a Group H occupancy by 1-hour fire resistive construction.

4) Piping, tubing, valves and fittings shall be designed and installed in accordance with ASME B31. Flammable gas piping systems are not required to be welded. However, some AHJ's may require gas detection in areas where flammable gases are dispensed and flammable gases or vapors are

capable of being present in quantities in excess of 20% of the LEL such as in the event of a leak from a mechanical connection.

C. **Gas-Detection System**

1) Where flammable gases are dispensed and flammable gases or vapors are capable of being present in quantities in excess of 25% of the LEL, a continuous gas-monitoring system shall be provided. The monitoring system shall be connected to the emergency control station.

D. **Gas Cabinets & VMB's**

1) Gas cabinets and VMB's shall not be required for flammable gas cylinders or piping systems. However, some AHJ's may require gas detection in areas where flammable gases are stored or used outside of exhausted enclosures, where a leak may enable flammable gases to collect in quantities in excess of 20% of the LEL.

2) Gas cabinets, VMB's and exhausted enclosures may be used to separate incompatible materials, mitigate separation distances to exposures, or to limit the extent of classified (explosion proof) electrical systems where flammable gases are located and dispensed.

3) When gas cabinets are provided as a means to separate compressed gas cylinders from exposure hazards, such gas cabinets shall comply with CFC 5003.8.6.

Conclusion

Please note that this synopsis is only intended to serve as a set of guidelines. It is not to be used for design purposes without due consultation of the TGO, CFC, CGA G-13, and in accordance with the requirements of the authority having jurisdiction.

GENERAL REQUIREMENTS

	Class I H.T.	Class II Toxic	Class III M.T.	Min.TQ	PYRO	FG
General Requirements						
General Obligation Storage & Use	X	X	X	X	X	X
Permit - Operations, Storage & Use	X	X	X	X	X	X
Permit - Install, Alter, Modidify or Repair	X	X	X	-	X	X
Permit - Close, Decomission or Demolition	X	X	X	-	X	X
Compliance Plan	X	X	X	X	X	X
Emergency Response Plan	X	X	X	X	X	X
Protective Plugs & Caps in place - Safety	X	X	X	X	X	X
Flow-Limiting Orifices & Devices	X	-	-	-	X	-
Inert Gas Purge System	X	X	X	-	X	-
Automatic Fire Sprinkler	X	X	X	-	X	X
Emergency Control Station	X				X	

GENERAL REQUIREMENTS

	Class I H.T.	Class II Toxic	Class III M.T.	Min.TQ	PYRO	FG
Piping Systems						
Installed and leak tested per ASME B31.3	X	X	X	-	X	X
Labeled per ASME A13.1	X	X	X	X	X	X
ESO located at the source and point of use.	X	X	-[1]	-	X	X
Excess Flow Control	X	X	-[1]	-	X	-[2]
Seismic Protection - Importance Factor	I=1.5	I=1.25	I=1.0	-	I=1.5	I=1.0
Welded piping or ventilated enclosures	X	X	-[1]	-	X	-[3]
Double Walled Secondarily Containment Piping	X	-	-	-	-	-
Testing & Maintenance (annually, or in accordacne with approved manufacturer's requirements)						
Gas detection and leak monitoring systems.	X	X	-[1]	-	X	-[2]
Limit controls: level, temperature, pressure or flow	-[2]	-[2]	-[2]	-[2]	-[2]	-[2]

GENERAL REQUIREMENTS

	Class I H.T.	Class II Toxic	Class III M.T.	Min.TQ	PYRO	FG
Manual and Automatic ESO controls	X	X	-[1]	-	X	-[2]
Alarms and alarm functions	X	X	-[1]	-	X	-[2]
Exhaust Ventilation System						
Gas Room	X	X	-	-	X	-
Gas Cabinet, VMB's & Exhausted Enclosures	X	X	-[1]	-[3]	X	-[3]
Treatment to 1/2 IDLH at point of discharge	X	X	-	-	-[3]	-
Emergency Alarm Monitoring & Controls						
Gas Detection	X	X	-[1]	-	X	
Optical Flame Detection	-	-	-	-	X	-
Smoke Detection	X	-	-	-	-[3]	-
Seismic Sensor	X	X	-	-	-	-
Exhaust Flow	X	X	-	-	X	-

GENERAL REQUIREMENTS

	Class I H.T.	Class II Toxic	Class III M.T.	Min.TQ	PYRO	FG
Manual or remotely actuated automatic ESO	X	X	-[1]	-	X	X
Emergency Shutoff For:						
Gas Detection	X	X	-[1]	-	X	
Optical Flame Detection	-	-	-	-	X	-
Smoke Detection	X	-	-	-	-[3]	-
Seismic Sensor	X	X	-	-	-	-
Exhaust Flow	X	X	-	-	X	-
Manual or remotely actuated automatic ESO	X	X	-[1]	-	X	X
Activation of automatic Fire Alarm System	X					
Emergency Power For:						
Gas Detection	X	X	-[1]	-	X	
Optical Flame Detection	-	-	-	-	X	-

GENERAL REQUIREMENTS

	Class I H.T.	Class II Toxic	Class III M.T.	Min.TQ	PYRO	FG
Smoke Detection	X	-	-	-	-[3]	-
Seismic Sensor	X	X	-	-	-	-
Exhaust Flow	X	X	-	-	X	-
Manual or remotely actuated automatic ESO	X	X	-[1]	-	X	X
Temperature Control	X	X	-	-	-	-

X = Required per code

Footnotes:

1. May be required per Fire Code for materials having a NFPA hazard ranking of 3 or 4.
2. Required when provided, or as an alternate to other control requirements.
3. May be provided to mitigate other code requirements.

COMMON REGULATED GASES

Gas & Formula	CAS No./ UN No.	IBC/CFC Class[1]	TGO Class[2]	PEL[5]	IDLH[3]	LC_{50}[4]	LEL
Ammonia - NH_3	7664-41-7 UN1005	Corrosive[7] Flammable Other Health Hazard	NR	50 ppm 25 ppm[8]	300 ppm	7338 ppm[10]	15.0%
Arsine - AsH_3	7784-42-1 UN2188	Highly Toxic Pyrophoric	I	0.05 ppm	3 ppm	178 ppm	5.1%
Boron Tribromide - BBr_3	10294-33-4 UN2692	Toxic WR-2	II	1 ppm[1]	38 ppm[10]	380 ppm	-
Boron Trichloride - BCl_3	10294-34-5 UN1741	Corrosive[6] WR-1	II	5 ppm	50 ppm[10]	2541 ppm	-
Boron Trifluoride - BF_3	7637-07-2 UN1008	Toxic WR-1	II	1 ppm[1]	25 ppm	864 ppm	-
Bromine - Br_2	7726-95-6 UN1744	Highly Toxic Corrosive Oxidizer	I	0.1 ppm	3 ppm	406 ppm[4]	-

COMMON REGULATED GASES

Gas & Formula	CAS No./ UN No.	IBC/CFC Class[1]	TGO Class[2]	PEL[5]	IDLH[3]	LC_{50}[4]	LEL
Carbon Disulfide - CS_2	75-15-0 UN1131	FL-1B Carcinogen	-	1.0 ppm	500 ppm	11,162 ppm	1.3%
Carbon Monoxide - CO	630-08-0 UN1016	Flammable Moderately Toxic[6]	III	50 ppm 25 ppm[8]	1200 ppm[3]	3760 ppm	12.5%
Carbonyl Fluoride - COF_2	353-50-4 UN2417	Toxic WR-1	II	2.0 ppm	36 ppm[10]	360 ppm	-
Carbonyl Sulfide - COS	463-58-1 UN2204	Toxic Corrosive Flammable	II	5 ppm[9]	1070 ppm	1700 ppm	12.0%
Chlorine - Cl_2	7782-50-5 UN1017	Toxic Corrosive Oxidizer	II	1 ppm 0.5 ppm[8]	10 ppm	293 ppm	-
Chlorine Dioxide - ClO_2	10049-04-4 UN9191	Toxic UR-3, WR-1 Oxidizer	II	0.1 ppm	5 ppm	-	-
Chlorine Triflouride - ClF_3	7790-91-2 UN1749	Toxic Oxidizer WR-3	II	0.1 ppm[1]	20 ppm	299 ppm	-
Diborane - B_2H_6	19278-45-7 UN1911	Highly Toxic Flammable WR-2	I	0.1 ppm	15 ppm	80 ppm	0.8%

COMMON REGULATED GASES

Gas & Formula	CAS No./ UN No.	IBC/CFC Class[1]	TGO Class[2]	PEL[5]	IDLH[3]	LC_{50}[4]	LEL
Dichlorosilane - SiH_2Cl_2	4109-96-0 UN2189	Toxic Corrosive Flammable	II	5 ppm[1] (as HCl)	50 ppm (as HCl)	314 ppm (as HCl)	-
Difluoromethane - CH_2F_2 (Halocarbon 32)	75-10-5 UN3252	Flammable (liquified)	-	1000 ppm[9]	39000 ppm[10]	152000 ppm	12.7%
Ethane - C_2H_6	74-84-0 UN1035	Flammable (liquified)	-	1000 ppm[9]	200000 ppm[10]	-	3.0%
Ethylene - C_2H_4	74-85-1 UN1922	Flammable (liquified)	-	200 ppm[9]	40000 ppm[10]	-	2.7%
Ethylene Oxide - C_2H_4O	75-21-8 UN1040	Flammable UR-3 Moderately Toxic[6]	III	1 ppm	800 ppm	2920 ppm	3.0%
Fluorine - F_2	7782-41-4 UN1045	Highly Toxic Oxidizer	I	0.1 ppm	25 ppm	185 ppm	-
Germane - GeH_4	7782-65-2 UN2192	UR-3 Toxic Pyrophoric	II	0.2 ppm[9]	6 ppm[10]	622 ppm	0.5%

COMMON REGULATED GASES

Gas & Formula	CAS No./ UN No.	IBC/CFC Class[1]	TGO Class[2]	PEL[5]	IDLH[3]	LC_{50}[4]	LEL
Hexafluoro-1,3-Butadiene - C_4F_6	685-63-2 UN3160	Flammable Toxic	II	13[10]	133 ppm[10]	1334 ppm	5.6%
Hydrogen - H_2	1333-74-0 UN1049	Flammable	-	-	-	-	4.0%
Hydrogen Bromide - HBr	10035-10-6 UN1048	Corrosive[6]	II	3 ppm	30 ppm	2860 ppm	-
Hydrogen Chloride - HCl	7647-01-0 UN1050	Corrosive[6]	II	5 ppm1	50 ppm	3120 ppm	-
Hydrogen Cyanide - HCN	74-90-8 UN1051	Highly Toxic Flammable	I	10 ppm	50 ppm	140 ppm	5.6%
Hydrogen Flouride - HF	7664-39-3 UN1052	Toxic	II	3 ppm	30 ppm	1307 ppm	-
Hydrogen Selenide - H_2Se	7783-07-5 UN2202	Highly Toxic Flammable	I	0.05 ppm	1 ppm	51 ppm	4% [10]
Hydrogen Sulfide - H_2S	7783-06-4 UN1053	Toxic Flammable	II	20 ppm	100 ppm	712 ppm	4.0%

COMMON REGULATED GASES

Gas & Formula	CAS No./ UN No.	IBC/CFC Class[1]	TGO Class[2]	PEL[5]	IDLH[3]	LC_{50}[4]	LEL
Methane - CH_4	74-82-8 UN1971	Flammable	-	-	-	-	5.3%
Methyl Bromide - CH_3Br	74-83-9 UN1062	Toxic Flammable	II	20 ppm[1]	250 ppm	850 ppm	10.0%
Methyl Fluoride - CH_3F	593-53-3 UN2454	Flammable	-	-	-	-	7.3%
Methylisocyanate - CH_3NCO	624-83-9 UN2480	Highly Toxic Flammable WR-2	I	0.02 ppm	3 ppm	22 ppm	5.3%
Methyl Mercaptan - CH_3SH	74-93-1 UN1064	Toxic Flammable	II	10 ppm[1] 0.5 ppm[8]	150 ppm	1350 ppm	3.9%
Nickel Carbonyl - $Ni(CO)_4$	13463-39-3 UN1259	Highly Toxic UR-3, WR-1 Flammable	I	0.001 ppm	2 ppm	20 ppm	2.0%
Nitric Oxide - NO	10102-43-9 UN1660	Highly Toxic Oxidizer	I	25 ppm	100 ppm	115 ppm	-
Nitrogen Dioxide - NO_2	10102-44-0 UN1067	Highly Toxic Oxidizer WR-1	I	5 ppm[1]	20 ppm	115 ppm	-

COMMON REGULATED GASES

Gas & Formula	CAS No./ UN No.	IBC/CFC Class[1]	TGO Class[2]	PEL[5]	IDLH[3]	LC_{50}[4]	LEL
Nitrogen Trifluoride - NF_3	7783-54-2 UN2451	Oxidizer Irritant Other Health Hazard	-	10 ppm	1000 ppm	6700 ppm	-
Phosegene - $COCl_2$	75-44-5 UN1076	Highly Toxic WR-1	I	0.1 ppm	2 ppm	5 ppm	-
Phosphine - PH_3	7803-51-2 UN2199	Highly Toxic Pryophoric	I	0.3 ppm	50 ppm	20 ppm	1.8%
Phosphorus Oxychloride - $POCl_3$	10025-87-3 UN1810	Highly Toxic WR-2	I	0.1 ppm[8,9]	.96 ppm[8]	96 ppm	-
Phosphorus Pentafluoride – PF_5	7647-19-0 UN2198	Toxic Oxidizer WR-1	II	3 ppm	2.6ppm[8]	261 ppm	-
Phosphorus Trichloride – PCl_3	7719-12-2 UN1809	Toxic UR-2, WR-2 Oxidizer	II	0.5 ppm 0.2 ppm[8]	25 ppm	208 ppm[10]	-
Phosphorus Trifluoride - PF_3	7783-55-3 UN3304	Toxic WR-1 Irritant	II	0.68 ppm[10]	43 ppm[10]	436 ppm[10]	-
Selenium Hexafluoride – SeF_6	7783-79-1 UN2194	Highly Toxic	I	0.05 ppm[10]	2 ppm	50 ppm	-

COMMON REGULATED GASES

Gas & Formula	CAS No./ UN No.	IBC/CFC Class[1]	TGO Class[2]	PEL[5]	IDLH[3]	LC_{50}[4]	LEL
Silane - SiH_4	7803-62-5 UN2203	Pyrophoric UR-3 Irritant	-	5 ppm[8]	-	-	1.37%
Silicon Tetrachloride – $SiCl_4$(HCl)	10026-04-7 UN1818	Toxic Corrosive	II	5 ppm[1]	50 ppm	750 ppm	-
Silicon Tetrafluoride – SiF_4(HF)	7783-61-1 UN1859	Toxic WR-2	II	0.1 ppm	30 ppm	450 ppm	-
Stibine – SbH_3	7803-52-3 UN2676	Highly Toxic Flammable	I	0.1 ppm	5 ppm	20 ppm	
Sulfur Dioxide – SO_2	7446-09-5 UN1079	Corrosive Moderately Toxic[6]	III	5 ppm	100 ppm	2520 ppm	-
Sulfuryl Fluoride – SO_2F_2	2699-79-8 UN2191	Corrosive Moderately Toxic[6]	III	5 ppm	200 ppm	3020 ppm	-
Tellurium Hexafluoride – TeF_6	7783-80-4 UN2195	Highly Toxic	I	0.02 ppm (as Te)	1 ppm	25 ppm	-
Tetraethyl Orthosilicate - $Si(OC_2H_5)_4$ (TEOS)	78-10-4 UN1292	Combustible Liquid-II Irritant Other Health Hazard	-	100 ppm 10 ppm[8]	700 ppm	7000 ppm[10]	1.3%

COMMON REGULATED GASES

Gas & Formula	CAS No./ UN No.	IBC/CFC Class[1]	TGO Class[2]	PEL[5]	IDLH[3]	LC_{50}[4]	LEL
Titanium Tetrachloride – TiCl4	7550-45-0 UN1838	Highly Toxic Corrosive WR-2	I	0.06 ppm	1.3 ppm	400 ppm	-
Trichlorosiliane – SiHCl3 (TCS)	10025-78-2 UN1295	Toxic Flammable Liquid-1A Corrosive WR-2, UR-2	II	5 ppm (As HCl)	50 ppm (As HCl)	1040 ppm (as HCl)	1.2%
Trimethyl Aluminum - Al(CH3)3 (TMA)	75-24-1	Pyrophoric Toxic (liquified) WR-2, UR-2	II	15 ppm	150 ppm[10]	1500 ppm[10]	NA
Trimethyl Boron - B(CH3)3 (TMB)	593-90-8	Pyrophoric Toxic (liquified) WR-2, UR-2	II	7 ppm	70 ppm[10]	700 ppm[10]	NA
Trimethyl Gallium - Ga(CH3) (TMG)	1445-79-0	Pyrophoric Toxic (liquified) WR-2, UR-2	II[10]	NA	NA	NA	NA
Trimethyl Silane - C3H10SI	993-07-7	Flammable (liquified)	III	5 ppm	500 ppm[10]	5000 ppm	2.0%

COMMON REGULATED GASES

Gas & Formula	CAS No./ UN No.	IBC/CFC Class[1]	TGO Class[2]	PEL[5]	IDLH[3]	LC_{50}[4]	LEL
Tungsten Hexafluoride – WF_6	7783-82-6 UN2196	Toxic Corrosive WR-2	II	0.1 ppm (as HF)	30 ppm (as HF)	218 ppm (as HF)	-

Footnotes: NA (Not Available)

1. Fire Code Hazard Class as defined in CFC: 1.) Health Hazards per Chapter 2; Highly Toxic = < 200 LC50, Toxic = 200 – 2,000 LC50. 2) Physical Hazards per UFC Standard 79-3.

2. TGO Class Defined As: Class I =< 200 LC50, Class II = 200 – 2000 LC50, Class III = 2001 – 5000 LC50

3. IDLH values published in 2012 by the National Institute for Occupational Safety and Health (NIOSH).

4. LC50 Data: Lowest reported value, 1 hour adjusted, taken from DOT, CGA, RTECS.

5. PEL values published by OSHA (29 CFR, part 1910. 1000, Table Z-1) dated 2/28/2006. OSHA values used if available, otherwise TLV from ACGIH or Cal OSHA values used.

COMMON REGULATED GASES

6. Moderately toxic (LC50 = 2000 – 5000ppm) as defined in local adoptions of the fire code incorporating the TGO.
7. When used as a refrigerant, CBC Class does not apply. See TGO consensus guidelines for additional information regarding ammonia refrigeration systems.
8. Cal OSHA PEL, Title 8, Section 5155, 9/1/95.
9. Threshold Limit Values (TLV) from the American Conference of Governmental Industrial Hygienists (1/30/2008)
10. Estimated value as determined by HPM Systems, Inc. PhD, MPH Chemist and Industrial Hygienists for regulatory purposes only.

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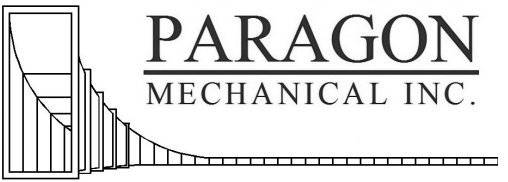

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