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

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Acknowledgment
The South Bay Piping Industry would like to thank Reinhard Hanselka and Jeff Tarter for their contributions to the TGO Data Book Update.
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 Arshe, 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.
# Toxic Gas Ordinance Data Book

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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


CEC


CFC


CMC


CPC


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.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>LC$_{50}$</td>
<td><em>Lethal Concentration (50).</em> The median exposure level, expressed in ppm, at which 50% of the testing animals died following inhalation exposure.</td>
</tr>
<tr>
<td>TGO Lab std.</td>
<td>Laboratory Standard for limited use of toxic and highly toxic gases.</td>
</tr>
<tr>
<td>LEL</td>
<td><em>Lower Explosive Limit.</em> 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).</td>
</tr>
<tr>
<td>Moderately-Toxic (gas)</td>
<td>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.</td>
</tr>
<tr>
<td>PEL</td>
<td><em>Permissible Exposure Limit.</em> 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).</td>
</tr>
<tr>
<td>Pyrophoric</td>
<td>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.</td>
</tr>
<tr>
<td>Silane, Bulk Source</td>
<td>A container or interconnected group of containers with a water volume exceeding 8.8 cubic feet.</td>
</tr>
<tr>
<td>Silane, Outdoor</td>
<td>A system located outside that is open to the surrounding environment where objects do not encroach upon the installation.</td>
</tr>
<tr>
<td>TGO</td>
<td><em>Toxic Gas Ordinance.</em> 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.</td>
</tr>
</tbody>
</table>
**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.
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:

\[
\text{Max TQ (lbs.)} = \text{LC50 (ppm) of regulated material} \times 2 \text{ lb.}
\]

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 LC50 for a mixture containing a regulated material, the following formula may be used per appendix E103.1.3.1 of the CFC:
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:

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

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 $\frac{1}{2}$ 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, Chapter 2, 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.
Pyrophoric Gas

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 provided 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.
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.

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## GENERAL REQUIREMENTS

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<th>Class III M.T.</th>
<th>Min.TQ</th>
<th>PYRO</th>
<th>FG</th>
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<td>Permit - Install, Alter, Modify or Repair</td>
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<td>Permit - Close, Decomission or Demolition</td>
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<td>Emergency Response Plan</td>
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<td>Protective Plugs &amp; Caps in place - Safety</td>
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<tr>
<td>Flow-Limiting Orifices &amp; Devices</td>
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<tr>
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<td>Emergency Control Station</td>
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# GENERAL REQUIREMENTS

<table>
<thead>
<tr>
<th></th>
<th>Class I H.T.</th>
<th>Class II Toxic</th>
<th>Class III M.T.</th>
<th>Min.TQ</th>
<th>PYRO</th>
<th>FG</th>
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<tbody>
<tr>
<td><strong>Piping Systems</strong></td>
<td></td>
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<tr>
<td>Installed and leak tested per ASME B31.3</td>
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<td>Excess Flow Control</td>
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<td>X</td>
<td>-¹</td>
<td>-</td>
<td>X</td>
<td>-²</td>
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<tr>
<td>Seismic Protection - Importance Factor</td>
<td>I=1.5</td>
<td>I=1.25</td>
<td>I=1.0</td>
<td>-</td>
<td>I=1.5</td>
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<tr>
<td>Welded piping or ventilated enclosures</td>
<td>X</td>
<td>X</td>
<td>-¹</td>
<td>-</td>
<td>X</td>
<td>-³</td>
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<tr>
<td>Double Walled Secondarily Containment Piping</td>
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</tbody>
</table>

**Testing & Maintenance (annually, or in accordance with approved manufacturer’s requirements)**

<table>
<thead>
<tr>
<th></th>
<th>Class I H.T.</th>
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<th>PYRO</th>
<th>FG</th>
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<tbody>
<tr>
<td>Gas detection and leak monitoring systems.</td>
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<td>X</td>
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<td>-</td>
<td>X</td>
<td>-²</td>
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<tr>
<td>Limit controls: level, temperature, pressure or flow</td>
<td>-²</td>
<td>-²</td>
<td>-²</td>
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<table>
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<th>Min.TQ</th>
<th>PYRO</th>
<th>FG</th>
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<tbody>
<tr>
<td>Manual and Automatic ESO controls</td>
<td>X</td>
<td>X</td>
<td>-¹</td>
<td>-</td>
<td>X</td>
<td>-²</td>
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<tr>
<td>Alarms and alarm functions</td>
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<td>X</td>
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**Exhaust Ventilation System**

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<th>Class III M.T.</th>
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<th>PYRO</th>
<th>FG</th>
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<tr>
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<td>-</td>
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<tr>
<td>Gas Cabinet, VMB’s &amp; Exhausted Enclosures</td>
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<td>X</td>
<td>-¹</td>
<td>-³</td>
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<tr>
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**Emergency Alarm Monitoring & Controls**

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<th>Class III M.T.</th>
<th>Min.TQ</th>
<th>PYRO</th>
<th>FG</th>
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<tr>
<td>Gas Detection</td>
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<tr>
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<tr>
<td>Smoke Detection</td>
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<td>-</td>
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<td>Seismic Sensor</td>
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<td>X</td>
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<tr>
<td>Exhaust Flow</td>
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## GENERAL REQUIREMENTS

<table>
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<th>PYRO</th>
<th>FG</th>
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</thead>
<tbody>
<tr>
<td>Manual or remotely actuated automatic ESO</td>
<td>X</td>
<td></td>
<td></td>
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<tr>
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<td>Exhaust Flow</td>
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<td>Activation of automatic Fire Alarm System</td>
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<table>
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<th>FG</th>
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</thead>
<tbody>
<tr>
<td>Smoke Detection</td>
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<tr>
<td>Seismic Sensor</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
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<td>-</td>
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<tr>
<td>Exhaust Flow</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>-</td>
</tr>
<tr>
<td>Manual or remotely actuated automatic ESO</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Temperature Control</td>
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</table>

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.
<table>
<thead>
<tr>
<th>Gas &amp; Formula</th>
<th>CAS No./ UN No.</th>
<th>IBC/CFC Class</th>
<th>Common Regulated Gases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia - NH₃</td>
<td>7664-41-7 UN1005</td>
<td>NR Corrosive</td>
<td>Highly Toxic Flammable</td>
</tr>
<tr>
<td>Arsine - AsH₃</td>
<td>7784-42-1 UN2188</td>
<td>Corrosive</td>
<td>Toxic Pyrophoric</td>
</tr>
<tr>
<td>Boron Tribromide - BBr₃</td>
<td>10294-33-4 UN2692</td>
<td>Corrosive</td>
<td>Toxic</td>
</tr>
<tr>
<td>Boron Trichloride - BCl₃</td>
<td>10294-34-5 UN1741</td>
<td>Corrosive</td>
<td>Toxic</td>
</tr>
<tr>
<td>Boron Trifluoride - BF₃</td>
<td>7637-07-2 UN1008</td>
<td>Corrosive</td>
<td>Other Health Hazard</td>
</tr>
<tr>
<td>Bromine - Br₂</td>
<td>7726-95-6 UN1744</td>
<td>NR Corrosive</td>
<td>Toxic Corrosive</td>
</tr>
</tbody>
</table>

**Minimum Detectable Concentrations (ppm):**

- LEL: 50 ppm
- ILC: 0.5 ppm
- IDLH: 300 ppm
- TGO: 50 ppm
- PEL: 5 ppm
- LC₅₀: 25 ppm
- IDLH: 38 ppm
- TGO: 380 ppm
- PEL: 50 ppm
- NC: 2541 ppm
- IDLH: 25 ppm
- TGO: 864 ppm
- PEL: 406 ppm³

**Other Health Hazard:**

- NR: Not Relevant
- Other: Other Health Hazard

**Classifications:**

- I: Inert
- II: Toxic
- WR: Weakly Reactive
- CS: Corrosive
- WD: Weakly Detergent
- LD: Low Detergent
- NT: Not Toxic
- WR-1: Weakly Reactive
- WR-2: Weakly Reactive
- CS-1: Corrosive
- CS-2: Corrosive
- CS-3: Corrosive
- CS-4: Corrosive
- CS-5: Corrosive

**Corrosive Classes:**

- 1: Highly Corrosive
- 2: Corrosive
- 3: Mildly Corrosive
- 4: Slight Corrosive
- 5: No Corrosive

**Flammable Classes:**

- 1: Flammable
- 2: Non-Flammable

**Other Health Hazard Classes:**

- I: Low Health Hazard
- II: High Health Hazard
<table>
<thead>
<tr>
<th>Gas &amp; Formula</th>
<th>CAS No./ UN No.</th>
<th>IBC/CFC Class¹</th>
<th>TGO Class²</th>
<th>CAS No./ UN No.</th>
<th>IBC/CFC Class¹</th>
<th>TGO Class²</th>
<th>CAS No./ UN No.</th>
<th>IBC/CFC Class¹</th>
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<th>CAS No./ UN No.</th>
<th>IBC/CFC Class¹</th>
<th>TGO Class²</th>
<th>CAS No./ UN No.</th>
<th>IBC/CFC Class¹</th>
<th>TGO Class²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disulfide - CS₂</td>
<td>75-15-0</td>
<td>FL-1B</td>
<td>Carcinogen</td>
<td>630-08-0</td>
<td>UN1016</td>
<td>Flammable</td>
<td>Carcinogen</td>
<td>630-08-0</td>
<td>UN1016</td>
<td>Flammable</td>
<td>Carcinogen</td>
<td>630-08-0</td>
<td>Flammable</td>
<td>Carcinogen</td>
<td>630-08-0</td>
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<tr>
<td>Carbonyl Fluoride - COF₂</td>
<td>10049-04-4</td>
<td>UN9191</td>
<td>Toxic</td>
<td>7790-91-2</td>
<td>UN1749</td>
<td>Toxic</td>
<td>WR-3</td>
<td>7790-91-2</td>
<td>UN1749</td>
<td>Toxic</td>
<td>WR-3</td>
<td>7790-91-2</td>
<td>Toxic</td>
<td>WR-3</td>
<td>7790-91-2</td>
</tr>
<tr>
<td>Chlorine Trifluoride - ClF₃</td>
<td>19278-45-7</td>
<td>UN1911</td>
<td>Toxic</td>
<td>Highly Toxic</td>
<td>Flammable</td>
<td>WR-2</td>
<td>Highly Toxic</td>
<td>Flammable</td>
<td>WR-2</td>
<td>Highly Toxic</td>
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<td>WR-2</td>
<td>Highly Toxic</td>
<td>Flammable</td>
<td>WR-2</td>
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<table>
<thead>
<tr>
<th>Gas &amp; Formula</th>
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<th>TGO Class²</th>
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<th>CAS No./ UN No.</th>
<th>IBC/CFC Class¹</th>
<th>TGO Class²</th>
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</thead>
<tbody>
<tr>
<td>Carbon Disulfide - CS₂</td>
<td>75-15-0</td>
<td>FL-1B</td>
<td>Carcinogen</td>
<td>630-08-0</td>
<td>UN1016</td>
<td>Flammable</td>
<td>Carcinogen</td>
<td>630-08-0</td>
<td>UN1016</td>
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<td>WR-2</td>
<td>Highly Toxic</td>
<td>Flammable</td>
<td>WR-2</td>
</tr>
</tbody>
</table>

1. CAS No./ UN No.: ChemicalAbstract Society/UN Number
2. IBC/CFC Class: International Brad Code/Chemical Abstracts Classification
3. TGO Class: Toxicity Group Ordering
4. LC₅₀: Lethal Concentration 50
5. PEL: Permissible Exposure Limit
6. IDLH: Immediately Dangerous to Life and Health
<table>
<thead>
<tr>
<th>Common Regulated Gases</th>
<th>Gas &amp; Formula</th>
<th>CAS No./ UN No.</th>
<th>IBC/CFC Class(^1)</th>
<th>Toxic Corrosive Flammable</th>
<th>Flammable (liquified)</th>
<th>Flammable (liquified)</th>
<th>Flammable (liquified)</th>
<th>Highly Toxic Oxidizer</th>
<th>UR-3 Toxic Pyrophoric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dichlorosilane - SiH(_2)Cl(_2) (Halocarbon 32)</td>
<td>4109-96-0 UN2189</td>
<td>Toxic Corrosive Flammable</td>
<td>50 ppm (as HCl)</td>
<td>314 ppm (as HCl)</td>
<td>15200 ppm</td>
<td>12.7%</td>
<td>-</td>
<td>1 ppm</td>
<td>0.1 ppm</td>
</tr>
<tr>
<td>Difluoromethane - CH(_2)F(_2) (Halocarbon 32)</td>
<td>75-10-5 UN3252</td>
<td>Toxic Corrosive Flammable</td>
<td>-</td>
<td>-</td>
<td>3900 ppm(^9)</td>
<td>-</td>
<td>3.0%</td>
<td>-</td>
<td>0.2 ppm(^9)</td>
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<tr>
<td>Ethane - C(_2)H(_6)</td>
<td>74-84-0 UN1035</td>
<td>Flammable (liquified)</td>
<td>1000 ppm(^9)</td>
<td>1000 ppm(^9)</td>
<td>20000 ppm(^10)</td>
<td>-</td>
<td>2.7%</td>
<td>800 ppm</td>
<td>25 ppm</td>
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<tr>
<td>Ethylene Oxide - C(_2)H(_4)O</td>
<td>74-85-1 UN1922</td>
<td>Flammable (liquified)</td>
<td>-</td>
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<td>4000 ppm(^10)</td>
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<td>2920 ppm</td>
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<td>Ethylene Trichloride - C(_2)H(_4)Cl(_3)</td>
<td>75-21-8 UN1040</td>
<td>Flammable UR-3 Moderately Toxic</td>
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<td>185 ppm</td>
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<td>Fluorine - F(_2)</td>
<td>7782-41-4 UN1045</td>
<td>Highly Toxic</td>
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</tr>
<tr>
<td>Germane - GeH(_4)</td>
<td>7782-65-2 UN2192</td>
<td>UR-3 Toxic Pyrophoric</td>
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</tr>
</tbody>
</table>

**Notes:**
- **IDLH:** Immediate danger to life or health.
- **LC\(_{50}\):** Lethal concentration for 50% of the population.
- **LEL:** Lower explosive limit.
- **PEL:** Permissible exposure limit.
- **TGO:** Threshold gap online.

**Classes:**
- **I:** Flammable
- **II:** Toxic Corrosive
- **III:** Moderately Toxic
- **UR-3:** Highly Toxic Oxidizer
- **WR-2:** Pyrophoric
- **WR-3:** Flammable

**Units:**
- ppm: Parts per million
- \(^9\): ppm\(^9\)
- \(^10\): ppm\(^10\)
<table>
<thead>
<tr>
<th>Gas &amp; Formula</th>
<th>IBC/CFC Class</th>
<th>CAS No./ UN No.</th>
<th>LC&lt;sub&gt;50&lt;/sub&gt;</th>
<th>IDLH</th>
<th>PEL&lt;sub&gt;5&lt;/sub&gt;</th>
<th>TGO Class&lt;sup&gt;2&lt;/sup&gt;</th>
<th>LEL</th>
<th>CAS No./ UN No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,3-Butadiene - C&lt;sub&gt;4&lt;/sub&gt;F&lt;sub&gt;6&lt;/sub&gt;</td>
<td>Flammable</td>
<td>685-63-2 UN3160</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>II</td>
<td>5.6%</td>
<td>-</td>
</tr>
<tr>
<td>Hydrogen - H&lt;sub&gt;2&lt;/sub&gt;</td>
<td>Toxic</td>
<td>1333-74-0 UN1049</td>
<td>133 ppm&lt;sup&gt;10&lt;/sup&gt;</td>
<td>-</td>
<td>-</td>
<td>II</td>
<td>13&lt;sup&gt;10&lt;/sup&gt; ppm</td>
<td>-</td>
</tr>
<tr>
<td>Hydrogen Bromide - HBr</td>
<td>Flammable</td>
<td>10035-10-6 UN1048</td>
<td>30 ppm</td>
<td>5 ppm</td>
<td>3 ppm</td>
<td>II</td>
<td>4.0%</td>
<td>-</td>
</tr>
<tr>
<td>Hydrogen Chloride - HCl</td>
<td>Corrosive&lt;sup&gt;6&lt;/sup&gt;</td>
<td>7647-01-0 UN1050</td>
<td>50 ppm</td>
<td>5 ppm</td>
<td>5 ppm</td>
<td>II</td>
<td>5.6%</td>
<td>-</td>
</tr>
<tr>
<td>Hydrogen Cyanide - HCN</td>
<td>Corrosive&lt;sup&gt;6&lt;/sup&gt;</td>
<td>74-90-8 UN1051</td>
<td>50 ppm</td>
<td>10 ppm</td>
<td>10 ppm</td>
<td>II</td>
<td>5.6%</td>
<td>-</td>
</tr>
<tr>
<td>Hydrogen Flouride - HF</td>
<td>Highly Toxic</td>
<td>7664-39-3 UN1052</td>
<td>140 ppm</td>
<td>30 ppm</td>
<td>30 ppm</td>
<td>II</td>
<td>5.6%</td>
<td>-</td>
</tr>
<tr>
<td>Hydrogen Selenide - H&lt;sub&gt;2&lt;/sub&gt;Se</td>
<td>Flammable</td>
<td>7783-07-5 UN2202</td>
<td>1307 ppm</td>
<td>1 ppm</td>
<td>0.05 ppm</td>
<td>II</td>
<td>4%&lt;sup&gt;10&lt;/sup&gt;</td>
<td>-</td>
</tr>
<tr>
<td>Hydrogen Sulfide - H&lt;sub&gt;2&lt;/sub&gt;S</td>
<td>Toxic</td>
<td>7783-06-4 UN1053</td>
<td>712 ppm</td>
<td>100 ppm</td>
<td>20 ppm</td>
<td>II</td>
<td>4.0%</td>
<td>-</td>
</tr>
</tbody>
</table>

<sup>1</sup> CAS Number/UN Number
<sup>2</sup> Threshold Limit Value (TLV)
<sup>3</sup> Maximum Allowable Concentration (MAC)
<sup>4</sup> Lethal Concentration (LC<sub>50</sub>)
<sup>5</sup> Permissible Exposure Limit (PEL)
<sup>6</sup> IDLH (Immediately Dangerous to Life and Health)
<table>
<thead>
<tr>
<th>Gas &amp; Formula</th>
<th>CAS No./ UN No.</th>
<th>IBC/CFC Class(^1)</th>
<th>TGO Class(^2)</th>
<th>LC(_{50})</th>
<th>IDLH(^3)</th>
<th>PEL(^5)</th>
<th>LEL</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane - CH(_4)</td>
<td>74-82-8 UN1971</td>
<td>Flammable</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Methyl Bromide - CH(_3)Br</td>
<td>74-83-9 UN1062</td>
<td>Toxic</td>
<td>I</td>
<td>20 ppm(^1)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Methyl Fluoride - CH(_3)F</td>
<td>593-53-3 UN2454</td>
<td>Flammable</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Methylisocyanate - CH(_3)NCO</td>
<td>624-83-9 UN2480</td>
<td>Highly Toxic</td>
<td>WR-2</td>
<td>-</td>
<td>10 ppm(^1)</td>
<td>0.02 ppm</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Methyl Mercaptan - CH(_3)SH</td>
<td>74-93-1 UN1064</td>
<td>Highly Toxic</td>
<td>Flammable WR-2</td>
<td>-</td>
<td>0.5 ppm(^8)</td>
<td>3 ppm</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Nickel Carbonyl - Ni(CO)(_4)</td>
<td>13463-39-3 UN1259</td>
<td>Highly Toxic</td>
<td>UR-3, WR-1</td>
<td>-</td>
<td>0.001 ppm</td>
<td>2 ppm</td>
<td>115 ppm</td>
<td></td>
</tr>
<tr>
<td>Nitric Oxide - NO</td>
<td>7647-01-0 UN1050</td>
<td>Corrosive</td>
<td>-</td>
<td>-</td>
<td>5 ppm(^1)</td>
<td>50 ppm</td>
<td>3120 ppm</td>
<td></td>
</tr>
<tr>
<td>Hydrogen - H(_2)</td>
<td>1333-74-0 UN1049</td>
<td>Flammable</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Hydrogen Bromide - HBr</td>
<td>10035-10-6 UN1048</td>
<td>Corrosive</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Hydrogen Chloride - HCl</td>
<td>7664-39-3 UN1052</td>
<td>Toxic</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Hydrogen Cyanide - HCN</td>
<td>7783-06-4 UN1053</td>
<td>Highly Toxic</td>
<td>Flammable</td>
<td>I</td>
<td>0.05 ppm</td>
<td>1 ppm</td>
<td>51 ppm</td>
<td></td>
</tr>
<tr>
<td>Hydrogen Flouride - HF</td>
<td>7664-39-3 UN1052</td>
<td>Toxic</td>
<td>II</td>
<td>3 ppm</td>
<td>30 ppm</td>
<td>1307 ppm</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Hydrogen Selenide - H(_2)Se</td>
<td>7783-07-5 UN2202</td>
<td>Highly Toxic</td>
<td>Flammable</td>
<td>I</td>
<td>0.05 ppm</td>
<td>1 ppm</td>
<td>51 ppm</td>
<td></td>
</tr>
<tr>
<td>Hydrogen Sulfide - H(_2)S</td>
<td>7783-06-4 UN1053</td>
<td>Toxic</td>
<td>II</td>
<td>20 ppm</td>
<td>100 ppm</td>
<td>712 ppm</td>
<td>4.0%</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) IBC/CFC Class: Flammable, Toxic, or Corrosive

\(^2\) TGO Class: Flammable, Toxic, or Corrosive

\(^3\) IDLH: Immediate danger to life and health

\(^4\) LC\(_{50}\): Lethal concentration for 50% of the population

\(^5\) PEL: Permissible exposure limit

\(^6\) LEL: Lower explosive limit

\(^8\) ppm: Parts per million
<table>
<thead>
<tr>
<th>Gas &amp; Formula</th>
<th>CAS No./ UN No.</th>
<th>IBC/CFC Class¹</th>
<th>IDLH³</th>
<th>PEL⁵</th>
<th>LEL⁴</th>
<th>IDLH¹</th>
<th>CAS No./ UN No.</th>
<th>IBC/CFC Class¹</th>
<th>IDLH³</th>
<th>PEL⁵</th>
<th>LEL⁴</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen Trifluoride - NF₃</td>
<td>7783-54-2 UN2451</td>
<td>5-6</td>
<td>10 ppm</td>
<td>0.1 ppm</td>
<td>1 ppm</td>
<td>-</td>
<td>7803-51-2 UN1076</td>
<td>1-2</td>
<td>0.1 ppm</td>
<td>0.3 ppm</td>
<td>-</td>
</tr>
<tr>
<td>Phosgene - COCl₂</td>
<td>75-44-5 UN1294</td>
<td>5-6</td>
<td>1 ppm</td>
<td>0.1 ppm</td>
<td>-</td>
<td>-</td>
<td>10025-87-3 UN1810</td>
<td>1-2</td>
<td>0.1 ppm</td>
<td>0.3 ppm</td>
<td>-</td>
</tr>
<tr>
<td>Phosphine - PH₃</td>
<td>7803-51-2 UN1294</td>
<td>5-6</td>
<td>2 ppm</td>
<td>0.2 ppm</td>
<td>-</td>
<td>-</td>
<td>7647-19-0 UN1810</td>
<td>1-2</td>
<td>0.1 ppm</td>
<td>0.3 ppm</td>
<td>-</td>
</tr>
<tr>
<td>Phosphorus Oxychloride - POCl₃</td>
<td>10025-87-3 UN1810</td>
<td>1-2</td>
<td>2 ppm</td>
<td>0.2 ppm</td>
<td>-</td>
<td>-</td>
<td>7719-12-2 UN1809</td>
<td>1-2</td>
<td>0.1 ppm</td>
<td>0.3 ppm</td>
<td>-</td>
</tr>
<tr>
<td>Phosphorus Pentachloride - PCl₅</td>
<td>7783-55-3 UN3304</td>
<td>1-2</td>
<td>3 ppm</td>
<td>0.5 ppm</td>
<td>-</td>
<td>-</td>
<td>7783-79-1 UN2194</td>
<td>1-2</td>
<td>0.1 ppm</td>
<td>0.3 ppm</td>
<td>-</td>
</tr>
<tr>
<td>Phosphorus Trichloride - PCl₃</td>
<td>7783-79-1 UN2194</td>
<td>1-2</td>
<td>4 ppm</td>
<td>0.6 ppm</td>
<td>-</td>
<td>-</td>
<td>7783-79-1 UN2194</td>
<td>1-2</td>
<td>0.1 ppm</td>
<td>0.3 ppm</td>
<td>-</td>
</tr>
<tr>
<td>Phosphorus Trifluoride - PF₃</td>
<td>7783-79-1 UN2194</td>
<td>1-2</td>
<td>5 ppm</td>
<td>0.7 ppm</td>
<td>-</td>
<td>-</td>
<td>7783-79-1 UN2194</td>
<td>1-2</td>
<td>0.1 ppm</td>
<td>0.3 ppm</td>
<td>-</td>
</tr>
<tr>
<td>Selenium Hexafluoride - SeF₆</td>
<td>7783-79-1 UN2194</td>
<td>1-2</td>
<td>6 ppm</td>
<td>0.8 ppm</td>
<td>-</td>
<td>-</td>
<td>7783-79-1 UN2194</td>
<td>1-2</td>
<td>0.1 ppm</td>
<td>0.3 ppm</td>
<td>-</td>
</tr>
<tr>
<td>Gas &amp; Formula</td>
<td>CAS No./UN No.</td>
<td>IBC/CFC Class</td>
<td>TGO Class</td>
<td>PEL</td>
<td>IDLH</td>
<td>LC&lt;sub&gt;50&lt;/sub&gt;</td>
<td>LEL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------</td>
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<td>---------------</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Silane - SiH&lt;sub&gt;4&lt;/sub&gt;</td>
<td>7803-62-5 UN2203</td>
<td>Pyrophoric UR-3 Irritant</td>
<td>-</td>
<td>5 ppm&lt;sup&gt;8&lt;/sup&gt;</td>
<td>-</td>
<td>-</td>
<td>1.37%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silicon Tetrachloride – SiCl&lt;sub&gt;4&lt;/sub&gt;(HCl)</td>
<td>10026-04-7 UN1818</td>
<td>Toxic Corrosive</td>
<td>II</td>
<td>5 ppm&lt;sup&gt;1&lt;/sup&gt;</td>
<td>50 ppm</td>
<td>750 ppm</td>
<td>-</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Silicon Tetrafluoride – SiF&lt;sub&gt;4&lt;/sub&gt;(HF)</td>
<td>7783-61-1 UN1859</td>
<td>Toxic WR-2</td>
<td>II</td>
<td>0.1 ppm</td>
<td>30 ppm</td>
<td>450 ppm</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Stibine – SbH&lt;sub&gt;3&lt;/sub&gt;</td>
<td>7803-52-3 UN2676</td>
<td>Highly Toxic Flammable</td>
<td>I</td>
<td>0.1 ppm</td>
<td>5 ppm</td>
<td>20 ppm</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfur Dioxide – SO&lt;sub&gt;2&lt;/sub&gt;</td>
<td>7446-09-5 UN1079</td>
<td>Corrosive Moderately Toxic&lt;sup&gt;6&lt;/sup&gt;</td>
<td>III</td>
<td>5 ppm</td>
<td>100 ppm</td>
<td>2520 ppm</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfuryl Fluoride – SO&lt;sub&gt;2&lt;/sub&gt;F&lt;sub&gt;2&lt;/sub&gt;</td>
<td>2699-79-8 UN2191</td>
<td>Corrosive Moderately Toxic&lt;sup&gt;6&lt;/sup&gt;</td>
<td>III</td>
<td>5 ppm</td>
<td>200 ppm</td>
<td>3020 ppm</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tellurium Hexafluoride – TeF&lt;sub&gt;6&lt;/sub&gt;</td>
<td>7783-80-4 UN2195</td>
<td>Highly Toxic</td>
<td>I</td>
<td>0.02 ppm (as Te)</td>
<td>1 ppm</td>
<td>25 ppm</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tetraethyl Orthosilicate - Si(OC&lt;sub&gt;2&lt;/sub&gt;H&lt;sub&gt;5&lt;/sub&gt;)&lt;sub&gt;4&lt;/sub&gt; (TEOS)</td>
<td>78-10-4 UN1292</td>
<td>Combustible Liquid-II Irritant Other Health Hazard</td>
<td>-</td>
<td>100 ppm 10 ppm&lt;sup&gt;8&lt;/sup&gt;</td>
<td>700 ppm</td>
<td>7000 ppm&lt;sup&gt;10&lt;/sup&gt;</td>
<td>1.3%</td>
<td></td>
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<tr>
<td>CAS No. / UN No.</td>
<td>IBC/CFC Class</td>
<td>Gas &amp; Formula</td>
<td>I</td>
<td>II</td>
<td>III</td>
<td></td>
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</tr>
<tr>
<td>7550-45-0</td>
<td>Highly Toxic Corrosive WR-2</td>
<td>TiCl₄</td>
<td>1.3 ppm</td>
<td>50 ppm (As HCl)</td>
<td>7 ppm</td>
<td></td>
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<tr>
<td>10025-78-2</td>
<td>Toxic Flammable Liquid-1A</td>
<td>SiHCl₃ (TCS)</td>
<td>0.06 ppm</td>
<td>5 ppm (As HCl)</td>
<td>7 ppm</td>
<td></td>
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</tr>
<tr>
<td>75-24-1</td>
<td>Pyrophoric</td>
<td>Al(CH₃)₃ (TMA)</td>
<td>1 ppm</td>
<td>15 ppm (As HCl)</td>
<td>7 ppm</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>593-90-8</td>
<td>Pyrophoric</td>
<td>B(CH₃)₃ (TMB)</td>
<td></td>
<td>1 ppm (As HCl)</td>
<td>7 ppm</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>1445-79-0</td>
<td>Pyrophoric</td>
<td>Ga(CH₃) (TMG)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>993-07-7</td>
<td>Flammable (liquified)</td>
<td>C₃H₁₀Si</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gas &amp; Formula</th>
<th>IBC/CFC Class</th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trimethyl Gallium - Ga(CH₃) (TMG)</td>
<td>Pyrophoric</td>
<td>150 ppm¹⁰</td>
<td>70 ppm¹⁰</td>
<td>700 ppm¹⁰</td>
</tr>
<tr>
<td>Trimethyl Silane - C₃H₁₀Si</td>
<td>Flammable (liquified)</td>
<td>5 ppm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **TGO** Class: I = Very Toxic, II = Toxic, III = Flamable (liquified)
- **PEL** (Permissible Exposure Limit): I = 0.06 ppm, II = 5 ppm (As HCl), III = 5 ppm
- **LC₅₀** (Lethal Concentration for 50%): 400 ppm
- **IDLH** (Immediately Dangerous to Life and Health): 1.3 ppm
- **LC** (Lethal Concentration): 5 ppm (As HCl)
- **LEL** (Lower Explosive Limit): 1.2%
## COMMON REGULATED GASES

<table>
<thead>
<tr>
<th>Gas &amp; Formula</th>
<th>CAS No./UN No.</th>
<th>IBC/CFC Class¹</th>
<th>TGO Class²</th>
<th>PEL⁵</th>
<th>IDLH³</th>
<th>LC⁵₀⁴</th>
<th>LEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tungsten Hexafluoride – WF₆</td>
<td>7783-82-6 UN2196</td>
<td>Toxic Corrosive WR-2</td>
<td>II</td>
<td>0.1 ppm (as HF)</td>
<td>30 ppm (as HF)</td>
<td>218 ppm (as HF)</td>
<td>-</td>
</tr>
</tbody>
</table>

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.
<table>
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<tr>
<th>COMMON REGULATED GASES</th>
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<tr>
<td>6. Moderately toxic (LC50 = 2000 – 5000 ppm) as defined in local adoptions of the fire code incorporating the TGO.</td>
</tr>
<tr>
<td>7. When used as a refrigerant, CBC Class does not apply. See TGO consensus guidelines for additional information regarding ammonia refrigeration systems.</td>
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<tr>
<td>8. Cal OSHA PEL, Title 8, Section 5155, 9/1/95.</td>
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<tr>
<td>9. Threshold Limit Values (TLV) from the American Conference of Governmental Industrial Hygienists (1/30/2008)</td>
</tr>
<tr>
<td>10. Estimated value as determined by HPM Systems, Inc. PhD, MPH Chemist and Industrial Hygienists for regulatory purposes only.</td>
</tr>
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</table>
ACCO Engineered Systems
1133 Aladdin Ave.
San Leandro, CA 94577

Gregg Holbrook
Vice-President of Project Group
Phone: (510) 346-4300
Email: gholbrook@accoeg.com

Specialties: Your needs are our focus here at ACCO. Our goal is to provide cost effective solutions to your demanding projects. Whether it requires basic plumbing or complex chemical handling, our team will deliver a quality installation on-time and on budget.

Plan & Spec, Design/Build or Assist, our specialists can provide products and services to meet your needs. From Bio-technology and organic synthesis, to semi-conductor and photonics fabrication, we install process systems to meet your manufacturing needs. For more information, see us on the web at www.accoes.com.

Established 1934.

Service Area: Western United States
Air Systems Inc.  
940 Remillard Ct  
San Jose, CA 95122  
www.airsystemsinc.com  

Phone: (408) 280-1666  
Fax: (408) 280-1020  
Contact: Art Williams


**Service Area:** Northern California Coverage
De Bella Mechanical, Inc.
605 Nuttman Street Santa Clara, CA 95054

Phone: (408) 980-8741 • Fax: (408) 980-8744
Paul De Bella • paul@debellamech.com

Specialties: De Bella Mechanical, Inc. was founded in 1987 and has now enjoyed over thirty years of continued success as a mechanical contracting company.

From our inception as an Ultra High Purity (UHP) Process Piping contractor serving the high tech microelectronics/semiconductor industry, DMI has evolved into a full service mechanical serving the High Tech, Biotech, and Biopharmaceutical industries, as well as standard commercial HVAC plumbing.

As a full service mechanical contractor, De Bella Mechanical, Inc. is working with all forms of piping and sheet metal applications, as well as providing preventative maintenance and 24-hour service to our clients.

Our facilities house welding and fabrication bays for both sheet metal and piping with the most experienced and professional staff you could hope for. In 2011 De Bella Mechanical, Inc., formed a mechanical insulation division to our firm. (BAM) Bay Area Mechanical-Insulation, which provides mechanical insulation and fire stopping to the Bay Area firms in the Mechanical Industry.

We believe our personalized, high quality service and commitment to customer satisfaction separates De Bella Mechanical, Inc. from our competition by delivering positive results with innovative solutions.

Service Area: West Coast and Hawaii
Environmental Systems Inc.  
3353 De La Cruz Blvd.  
Santa Clara, CA 95054  

Phone: (408) 980-1711  
FAX: (408) 980-0714  
Contact: Phil Enfantino  
Mike Camino  
E-mail: esi@esite.net  
Website: www.esite.net  

Specialties: Design Build Systems for piping, plumbing and HVAC; environmental chambers, chiller replacement; double-containment piping, high-purity gas and liquid piping, vacuum piping; biotech, certified clean rooms, metal fabrication, service and maintenance for all systems.  

Established in 1975.  

Service Area: California
Ray L. Hellwig Mechanical, Inc.
Ray L. Hellwig Service Co., Inc.
1309 Laurelwood Road
Santa Clara, CA 95054

Contact: Elden Shreve
Sheet Metal and HVAC Dry Side
Phone: (408) 727-5080
FAX: (408) 727-5409

Scott Shreve
Service and Equipment Start-Up
Phone: (408) 727-5080
FAX: (408) 727-5409

Specialties: Clean room process equipment hook-up and fume scrubbing exhaust systems; demolition of contaminated piping and exhaust systems with hazardous-waste, operations-trained employees; quality heating and air conditioning systems, and OSHPD projects.

Service Area: Greater San Francisco Bay Area
W.L. Hickey Sons, Inc.
P.O. Box 61209 190 Commercial St.
Sunnyvale, CA 94088

Contact: Roy Jackson
Phone: (408) 736-4938
FAX: (408) 736-4055
E-mail: rjackson@wlhs.com
Website: www.wlhs.com

Specialties: W.L. Hickey Sons, Inc is a company which has been installing quality plumbing systems for over 110 years. The company has played an integral part in the expansion of the Greater San Francisco Bay Area and surrounding areas. Our company prides itself on being one of the few contractors to do both commercial and residential plumbing installations. This diversity has enabled us to do projects from manufacturing facilities, distribution centers, multi-story office buildings, hotels, motels, restaurants, medical facilities, historical buildings, apartment complexes, along with over ten thousand residential homes. Established in 1975.

Service Area: Greater San Francisco Bay Area and surrounding regions.
ICOM Mechanical, Inc.
477 Burke St.
San Jose, CA 95112

Phone: (408) 792-2200
FAX: (408) 292-4968
Contact: Dan Littleton
E-mail: danl@icominc.com

Specialties: ICOM Mechanical, Inc. was founded in 1981 with the intent to provide clients with the most professional, highest quality service possible. Our firm represents excellence in design, installation, maintenance and repair of HVAC, process piping systems and plumbing.

ICOM is comprised of the following departments:

• **Design and Engineering:** HVAC, Process Piping, Controls, Plumbing

• **Construction:** HVAC, Process Piping, Plumbing, Controls

• **Service:** Commissioning (Start-up), Maintenance & Repair on Mechanical Systems, Back Flow Prevention, Environmental and Process Controls, 24 Hour Emergency Repair

**Service Area:** West Coast
Kinetic Systems, Inc.
48400 Fremont Boulevard,
Fremont, CA 94538

Phone: (510) 683-6000
FAX: (510) 683-6001
E-mail: greg.bauer@kinetics.net
www.kinetics.net

Specialties: Global Leader in Process and Mechanical Systems Solutions
Call Kinetics for assistance in providing cost effective, on-schedule, reliable installation solutions for basic or technically challenging projects leveraging over 40 years of process systems and full service mechanical services. Our technical teams of skilled engineers, designers, CAD specialists, and installation technicians provide facility systems support that maximize efficiency and meet client project requirements. We offer turnkey Design/Build, Design/Assist, or Plan & Spec services for any sized projects and can contribute our best value with early project engagement. Local fabrication services are available to optimize project execution including central utility plant equipment installation piping systems (high / low purity), plumbing, chemicals/slurries, HVAC, bulk & specialty gases, ultra pure & city water, exhaust, air, chilled water, waste treatment, life safety, and process tool hookups and other facility critical systems needs. We support Semiconductor, Biotechnology, Solar, Data Centers, Healthcare, Universities/Government/Research Institutions and other Commercial /Industrial industries. Kinetics is your one-stop resource for process and mechanical solutions.

Service Area: Kinetics has 9 locations across the US and 16 internationally with over 100,000 sq.ft. of fabrication shop area.
O.C. McDonald Co., Inc.
1150 W. San Carlos St.
San Jose, CA 95026

Phone: (408) 295-2182
FAX: (408) 295-0626
Contact: Ron Almond
E-mail: info@ocmcdonald.com
www.ocmcdonald.com
www.facebook.com/ocmcdonald

Specialties: High Purity Process Piping; Medical Gas Stations; Stainless Steel Piping; Mechanical & HVAC Systems; Clean Room Fabrication; Ultra Pure Water Systems; Plumbing; Preventive Maintenance For HVAC Systems.

Servicing: Biotech Facilities; Pharmaceutical; Semiconductor; Disc Manufacturers; Chemical Companies; Telecommunication; Aerospace; Utilities; Government Bldgs.; Manufacturing; Hospitals, Apartments; Hotels; Office Complexes; Food Processing: High Rise Buildings; General Contractors; Industrial Plants; Airports.

Service Area: Santa Clara County, Alameda County, San Mateo County, Santa Cruz, Carmel and the Central Valley.
Paragon Mechanical Inc.
16160 Caputo Drive
Morgan Hill, CA 95037
Office (408) 727-7303

Phone: (408) 727-7303
FAX: (408) 566-6190
Contact: Steve Benakovich
           Richard Pignone
E-mail: info@paragonmechanical.com
        www.paragonmechanical.com

Specialties: Paragon Mechanical brings experience and distinction to every project and our specialities are:

• Design & Engineering
• CAD/BIM
• Heating, Ventilation & Air Conditioning
• Architectural Sheet Metal
• Process Piping & Plumbing
• High Purity Piping
• Service Department

Service Area: San Francisco Bay Area & surrounding communities
Purity Systems, Inc.  
2109 O’Toole Ave., Suite I  
San Jose, CA 95131

Phone: (408) 435-9119  
FAX: (408) 435-1155  
Contact: David Sisto  
E-mail: DavidS@puritysystems.com


All Inspectors and Technicians are qualified to ASNT-SNT-TC-1A MSLT Level II or VT Level II. On staff P.E. Welding/Metallurgical Engineer & PhD Material Scientist.

**Purity Systems is your partner in Quality**  
A veteran owned business.
Southland Industries
33225 Western Avenue
Union City, CA 94587

Phone: (510) 477-3300
(Northern California)
(800) 613-6240
(Toll-Free)
Contact: Ian MacLaren
southlandind.com

Specialties: With firm roots in the region, Southland Industries provides innovative, practical results for your engineering, construction, service, and energy needs. Optimizing each stage of the building lifecycle with our in-house expertise, we connect to your business strategy by delivering holistic solutions.

Service Area: Nationwide
Specialties: High concept. High tech.
Therma Corporation is a full-service design/build mechanical contractor with nearly 50 years of industry experience. Our solution-based approach is tailored to each client, resulting in the most efficient and economical designs for your projects. Whether it’s a “one-off” custom part or a full-service, design-build mechanical system, we’re experts at finding the perfect configuration for your needs. Our teams can help you with creative solutions in HVAC, process piping, plumbing, architectural sheet metal, maintenance, controls, custom fabrication and more. At Therma Corporation we’re fond of saying, “If you can imagine it, we can build it!”

Service Area: Silicon Valley and San Francisco Bay Area
Thermal Mechanical
425 Aldo Avenue
Santa Clara, CA. 95050

Phone: (408) 988-8744
FAX: (408) 988-0233
Contact: David Rood
E-mail: thermal@thermalmech.com
www.thermalmech.com

Specialties: Commercial and industrial process piping; plumbing; Sheet Metal; HVAC; Clean Rooms, equipment upgrades; DDC Controls. Design, Sales, Construction and Service of all related systems, serving the San Francisco Bay Area Since 1969
Only HPM Systems Provides Toxic Gas Monitoring Design, Controls, and Testing All On One Team

Based on nearly two decades of proven quality and experience, HPM Systems provides cost-effective, safe and reliable gas monitoring and control systems specifically designed to meet code compliance and industry standards. We create a customized approach for your gas monitoring control systems.

> Design
> Integration
> Installation and Start-Up
> Maintenance and Support

Please visit HPMsystems.com today for more information about how we can assist you with your toxic gas monitoring systems.
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