Silane Safety

North Texas SESHA
April 23, 2009
Eugene Y. Ngai
Disclaimer

To the best of our knowledge, the information contained herein is accurate. However, Chemically Speaking LLC assumes no liability whatsoever for the accuracy or completeness of the information contained herein. Final determination of the suitability of any information or products for the use contemplated, the manner of use, and whether there is any infringement of patents is the sole responsibility of the user.
Eugene Y. Ngai

Biography

Eugene has a BS in Chemical Engineering and an MS in Environmental Engineering, all from New Jersey Institute of Technology.

He has over 35 years of Specialty Gas Experience in Production, Laboratory, R&D, Engineering, Safety positions at Matheson, Exxon Research, Solkatronic Chemicals and Scientific Gas Products. Had increasing management responsibilities during his career and held an Executive Management position as Vice President of Corporate Development and Technology for Solkatronic Chemicals for 10 years prior to the Air Products acquisition in 1999. He had responsibility for EHS, Engineering, Information Technology, Research and Development, and Quality. At Air Products he was Director of Compound Semiconductor Technology in the Electronics Division and retired in 2009 as Director of ER and Disposal Technology in the Product Safety Group.

He is active in a number of industry associations, Compressed Gas Association (CGA), Asia Industrial Gas Association (AIGA), National Fire Protection Association (NFPA) and the Semiconductor Environmental Health and Safety Association (SESHA). He is a member of the UN TC58 SC2 WG7

He also developed and managed the Emergency Response Equipment and Training group from 1990-2008. He was the Course Director for a 3 day Specialty Gas Emergency Response course, which has trained over 4000 customers, government agencies and employees since 1990. He has trained over 750 Firefighters in Compressed Gas Safety and Emergency Response. He has taught at a number of Fire Academies worldwide, including New York and Singapore

He has made numerous presentations worldwide on Emergency Response, Product Safety, Gas Technology and Environment over the last 20 years. His most recent effort was on Silane Safety. He coordinated 1 day silane safety seminars, in Taiwan, Korea, Singapore, US and Europe.

He has 5 US patents for Gas Safety Devices and 1 pending for new gas purification technology
Silane Learnings Today

- Unpredictable
- Ignition behavior is still a mystery
- Procedure
- PPE
- Proper Installation
Cooling Incident and Leak

- Always be prepared for a leak and to shutoff the source if it happens
- Proper PPE is critical for all operations
Pyrophoric?

DILBERT

These are some of the advanced materials I'm designing at work. That jar holds a pyrophoric substance.

Let's see.

Flash!

Yep, that's a good batch.

A person from a smarter gender might have said "What does 'pyrophoric' mean?"
Spontaneously Flammable?
Gas Cabinet Testing, May 2006

Color is 0.033 sec/frame
Black/White is 0.002 sec/frame
Flames for 0.010-0.012 sec

4/23/2009
Technical Article

Experimental Studies on the Ignition Behavior of Pure Silane Released into Air

Hsiao-Yun Tsai¹, Sheng-Wei Wang¹, Sin-Ying Wu¹, Jenq-Renn Chen¹*, Eugene Y. Ngai², Kelvin Pai-Ping Huang³

1. Department of Safety, Health and Environmental Engineering, National Kaohsiung First University of Science & Technology, Kaohsiung, 824, Taiwan.
2. Chemically Speaking LLC, 26 Casper Berger Rd., Whitehouse Station, NJ 08889, USA
3. Air Products San Fu Co. Ltd., Chu Pei, Hsinchu, Taiwan
Behavior of Silane is Unpredictable

- Of all the Pyrophoric gases, Silane is the most unpredictable. When released into air, Silane will react in one of the following manner:
  - Delayed Ignition (Explosion)
  - No Ignition
  - Immediate Ignition

Of these the latter is only safe condition. Temperature, humidity, flow rate, orifice diameter will influence the ignition.

- Silane can easily be released without ignition.
  - Smaller the diameter of the release tube the lower the pressure at which no ignition would occur
  - The releases may not ignite until flow velocity decays or is shutoff
  - FM Global found that Silane did not ignite in 11 out of 12 release tests at 33 psig from 1/8” line. Even at 7.8 psig. For a ¼” line the lowest pressure with no ignition was 70 psig.
Ignition at Abrupt Shutoff

- Numerous theories on what would cause a release to suddenly ignite.
- Dr. Tamanini’s testing determined that one was abrupt shutoff of the flow.
- The pictures are the 4 frames in sequence from a cylinder valve wide open with Silane pressure of 1250 psig. Within 0.033 sec of shutoff, it popped.
This unpredictability has caused major incidents.
Taiwan, Silane Explosion, Nov. 23, 2005

During a cylinder change Silane was released from a full cylinder unignited. The metastable mixture ignited, fatally injuring the operator and rupturing the cabinet.

Other silane and Ammonia cylinders in the gas room also started to release their contents.
Silane (Product Guardian)

- Release behavior unpredictable despite 40 years of research
- Has caused more fatalities (11) and damage than all the other ESG (0) combined (Arsine, Phosphine, Hydrogen Selenide in the last 20 years)
- After the fatal incident on Nov 2005 in Taiwan, I led effort to educate users and suppliers
  - Silane Safety Seminars
  - Presentations
  - Testing
  - Standards
Silane Safety Seminars

- Spearheaded worldwide effort to improve the industry understanding of silane through a series of silane safety seminars.
- Coordinated seminars in
  - Taiwan
  - Korea
  - Singapore
  - Shanghai
  - Phoenix
  - Portland
  - Belgium
History of Silane Use

- The Semiconductor Industry started to use Silane in small quantities in 1968.
- During this time there were many small Silane manufacturing processes at a number of gas companies. The manufacturing method was a batch reaction of Trichlorosilane or Silicon Tetrachloride in a molten Lithium Aluminum Hydride salt bath.
- As a new compound there was a lot of concern with safety. Considerable study on the safe fill density in the early days only 1 kg.
- During transportation there were numerous fires due to valves vibrating open and no secondary valve outlet seal on the valve.
- Due to major incidents, SEMATECH funded a series of studies in the 1980’s.
Silane, Chemical & Physical Properties

- Silane is a compressed gas which is pyrophoric
- Silicon Tetrahydride, SiH₄
- CAS# 7803-62-5
- UN# 2203
- Molecular Weight 32.11
- Compressed Gas which is filled by weight due to high compressibility
- Gas Density of 0.083 lb/ft³, 1.33 gm/l @ 70°F (21°C)
- Boiling Point, 1 atm. -169.6°F (-112°C)
- Freezing Point, 1 atm. -299°F (-184°C)
- Critical Temperature 19.9°F (-7°C)
- Critical Pressure 632 psia (43 atm)
- Liquid Density @ 10°F (-12°C) 21.1 lbs/ft³ (338 gm/l)
Silane?

Major hazard of Silane

- **Pyrophoric**
- **Pressure**
Pyrophoric

- Pyrophoric gases are flammable gases which have autoignition temperatures below $130^\circ F$ ($54.4^\circ C$).
- Pyrophoric gases require oxidizers to burn.
- Pyrophoric gases must be in the flammable range to burn.
- Of all the Pyrophoric gases, Silane is the most unpredictable. When released into air, Silane will react in one of the following manner:
  - Delayed Ignition (Explosion)
  - No Ignition
  - Immediate Ignition
Of these the latter is only safe condition.
Temperature, humidity, flow rate, orifice diameter will influence the ignition.
## Autoignition Temperature Of Common Gases

<table>
<thead>
<tr>
<th>Gases</th>
<th>Autoignition</th>
<th>ºF</th>
<th>ºC</th>
<th>Autoignition</th>
<th>ºF</th>
<th>ºC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silane</td>
<td>&lt; -148</td>
<td>-100</td>
<td>-100</td>
<td>Butylene</td>
<td>725</td>
<td>385</td>
</tr>
<tr>
<td>Disilane</td>
<td>-100</td>
<td>-73</td>
<td>-73</td>
<td>Hydrogen</td>
<td>752</td>
<td>400</td>
</tr>
<tr>
<td>Phosphine</td>
<td>&lt; 32</td>
<td>&lt; 0</td>
<td>&lt; 0</td>
<td>1,3 Butadiene</td>
<td>788</td>
<td>420</td>
</tr>
<tr>
<td>Nickel Carbonyl</td>
<td>68</td>
<td>20</td>
<td>20</td>
<td>Ethylene Oxide</td>
<td>804</td>
<td>429</td>
</tr>
<tr>
<td>Diborane</td>
<td>44</td>
<td>7</td>
<td>7</td>
<td>Propane</td>
<td>842</td>
<td>450</td>
</tr>
<tr>
<td>Dichlorosilane</td>
<td>136</td>
<td>58</td>
<td>58</td>
<td>Ethylene</td>
<td>842</td>
<td>450</td>
</tr>
<tr>
<td>Diethyl Ether</td>
<td>320</td>
<td>160</td>
<td>160</td>
<td>Propylene</td>
<td>851</td>
<td>455</td>
</tr>
<tr>
<td>Trichlorosilane</td>
<td>360</td>
<td>182</td>
<td>182</td>
<td>Vinyl Chloride</td>
<td>882</td>
<td>472</td>
</tr>
<tr>
<td>Hydrogen Sulfide</td>
<td>500</td>
<td>260</td>
<td>260</td>
<td>Ethane</td>
<td>882</td>
<td>472</td>
</tr>
<tr>
<td>Butane</td>
<td>550</td>
<td>288</td>
<td>288</td>
<td>Ammonia</td>
<td>928</td>
<td>498</td>
</tr>
<tr>
<td>Acetylene</td>
<td>581</td>
<td>305</td>
<td>305</td>
<td>Methane</td>
<td>999</td>
<td>537</td>
</tr>
<tr>
<td>Diethyl Amine</td>
<td>594</td>
<td>312</td>
<td>312</td>
<td>Hydrogen Cyanide</td>
<td>1000</td>
<td>538</td>
</tr>
</tbody>
</table>
The Flammability of Silane

- The hazard of Silane released into air is a function of the concentration and what it has been mixed with
  - Nonflammable
  - Flammable
  - Pyrophoric
  - Metastable
- Changes in cylinder pressure, flow rate, confinement area, humidity, impingement on objects, etc. can cause ignition.
- The greater the confinement of the gas the greater the over pressurization
Flame Temperatures

▪ At lower flammability limit < 3 % silane
  – flame temperature ~ 800 °F
  – will not ignite paper

▪ At stoichiometric mix with air 9.51 % silane
  – Flame is white and smoke is white
  – most efficient ratio of fuel to air
  – flame temperature ~ 4400 °F
  – will melt metal
Burning Silane

- Release conditions will influence how silane is burned.
- Depending on available oxygen oxidation may be incomplete. Brown smoke and a dull orange flame is an indication of incomplete oxidation.

\[
\begin{align*}
\text{SiH}_4 + O_2 & \rightarrow \text{SiO}_2 + 2\text{H}_2 \\
\text{SiH}_4 + 2\text{O}_2 & \rightarrow \text{SiO}_2 + \text{H}_2\text{O} \\
\text{SiH}_4 + O_2 & \rightarrow \text{SiH}_2\text{O} + \text{H}_2\text{O} \\
\text{SiH}_4 + \frac{1}{2} O_2 & \rightarrow \text{SiH}_2\text{O} + \text{H}_2 \\
\text{SiH}_2\text{O} + O_2 & \rightarrow \text{SiO}_2 + \text{H}_2\text{O}
\end{align*}
\]
Hazards of By-Products

- **Brown Dust** is reactive & pyrophoric
  - Typically silicon oxyhydrde $\text{SiH}_2\text{O}$
  - Can also absorb hydrogen or trap silane

- **White Dust**
  - Silicon dioxide $\text{SiO}_2$
Toxicity of Silane

- TLV - Threshold Limit Values
  - PEL none established
  - TWA 5 ppm
  Certain countries classify Silane as Toxic because it has a TLV less than 200 ppm (Japan, Korea and Taiwan)
  Classification as a toxic gas requires the cylinder to be in an enclosure

- IDLH - none established

- LC$_{50}$ - 19,200 ppm 1 hr (this is higher than LFL)

- Odor "irritating acidic" Controversial
  - warning properties unknown. Normally odorless
  - Repulsive odor in literature may be attributable to impurities (chlorosilanes)
Reactivity of Silane

- Delayed reaction with oxidizer gases like $\text{N}_2\text{O}$, $\text{NF}_3$, requires a ignition source (Gollub 1988 & Osaka University 1991)
- Immediate reaction with strong oxidizer gases like $\text{ClF}_3$, $\text{Cl}_2$ & $\text{F}_2$
- Oxygen reaction can be delayed or immediate
- Other Oxidizers like Nitric Acid ($\text{HNO}_3$), Hydrogen Peroxide ($\text{H}_2\text{O}_2$)
- Reacts with some of the Chlorofluorocarbons
  - Halocarbon 12 (Dichlorodifluoromethane) & Halocarbon 22 (Chlorodifluoromethane)
  - fire extinguishers, cleaning agents, refrigeration units and lubricants may contain these materials
  - contact with these materials may result in a fire or explosion
Accidental backflow of Nitrous Oxide into Silane Cylinder

- In some processes Nitrous Oxide is reacted with Silane to form a Silicon Nitride layer.
- In two cases, Nitrous Oxide accidentally backflowed into a Silane cylinder forming a metastable mixture.
- They reacted when the cylinder valve was opened causing adiabatic compression heat. In the Gollub incident 3 people were killed and 1 severely injured. At Osaka University 2 were killed and 6 injured.
Silane Cylinders

- Silane is packaged in specially polished and conditioned high pressure seamless carbon steel or aluminum cylinders. Note: Aluminum will embrittle under heat.
- Aluminum cylinders of Silane in use must have a barrier between cylinders
- DOT Spec. 3A, 3AA or 3 AL
- Seamless Chrome Moly Steel or Aluminum
- Typical working pressures of 1800 - 2400 psig
- Typical sizes from 2 liter to 49 liter (US) 50 liter in Europe and 47 liter in Asia
Bulk Silane Supply Options

- ~200 kg
- 140 kg
- 1000 kg
- 3000 kg
- 4500 kg
- 6000 kg

REC Silicon Slide
Silane Package Equivalents

* x 600

* x 48

* x 38

REC Silicon Slide
8 Tube, 40’, 6000 kg, PRD
Rear of ISO Module

- CGA Connection is DISS 632
- Pressure Relief Device is a CGA-4, combination 165°F (73.9°C) fuse metal with 4000 psig metal rupture disk. These are piped to the top of the module. Ends are sealed with plastic Cap
- All Eight Tubes are connected together by a ½” stainless steel welded manifold in the back of the trailer. Pigtails to the manifold are ¼” diameter
- For positive shutoff, each tube has a manifold valve.
- Gooseneck angled upward to prevent liquid Silane from entering the system
Manifold Valves

**Tube ("Root") Valve**
- Manual Operation
- Ceodeux D335
- Or
- Ceodeux D300

**Pressure Gauge**
- Swagelok S-Model
- 0-3000 psi

**Isolation Valve**
- Manual Operation
- Parker 16 Series

**Line Valve**
- Manual Operation
- Parker 16 Series

**Master (Inlet/Outlet) Valve**
- Pneumatic Operation
- Parker 16 Series

**Inlet/Outlet Connection**
- CGA/DISS 632
**Tied Diaphragm**

**Series D388 – pneumatic actuation**

The new Silane cylinder valve

**Standard specification**

- Working pressure $p_{\text{max}}$ 200 bar/3000 psi
- Temperature range $-40 \degree C - + 70 \degree C$
- Helium leak rate at $p_{\text{max}}$
  - internal $<1 \times 10^{-8}$ mbarl/sec
  - external $<1 \times 10^{-8}$ mbarl/sec
  - safety $<1 \times 10^{-8}$ mbarl/sec
- Flow coefficient $Cv: 0.35$
- Seat orifice size 4 mm
Leaking Silane Cylinder Valve

- During the early days, numerous incidents were reported of a Silane release when the vaportight outlet cap on a cylinder valve was loosened.
- The reactions were reported to be a fire, minor “pops” to explosions. The “pops” can occur when a small amount of Silane trapped behind the valve cap or pigtail is released. In a few cases they have been severe enough to cause eardrum rupture.
- A severe explosion was reported to have occurred in the US in 1977. A piggyback trailer containing 20 cylinders of Silane and 28 drums of antifreeze exploded as the train was moving at 70 mph. A 5 kg cylinder leaked into the trailer and exploded at some point. The sides and roof of the trailer were blown out. 17 cylinders and 4 drums were thrown out of the trailer.
- This and another incident led to improved procedures for inspection, handwheel wiring, gastight outlet caps. Also block and bracing.

![Handwheel Wire Outlet Cap](image)
Restrictive Flow Orifice (RFO) from GasFlo

- To limit worst case flow during an accident, cylinder valve have RFOs installed.
DISS Leak with and without RFO (0.010”, 0.25mm)
Ceoduex Valve with RFO (0.010”, 0.25mm) and Without

- 0.5 m vs 3 m flame
- 2.5 cfm (70.8 lpm) vs 333 cfm (9430 lpm) silane flow
- A 15 kg cylinder with RFO will take over 10 hours to empty while without, it will be 6-7 minutes
Seal Leakage

- SiO$_2$ Particles formed due to inadequate system purging will adhere to the sealing surfaces preventing tight closure
- Valve seats, VCR beads, MFC
- Dark skin might be nickel oxyhydroxide NiO(OH) compound, since the melting point is relatively low and the mixed nickel oxidation state would make it look black.
Valve Seat Differences

- New valve seat design

![Valve Seat Differences Diagram](image-url)
Proper Procedure to Remove Silane Vaportight Cap

- Don Appropriate PPE (Fire Gloves, Nomex Suit, Faceshield, Earplugs, safetyglasses)
- Secure cylinder away from other cylinders
- Stand to side of Valve and remove plastic bag, holddown wire
- Check Valve closure
- Position cylinder to pull down with wrench (boxwrench preferred) when loosening Vaportight Cap
- Pull slowly and anticipate a leak, be ready to push up to reseal
- If Silane is behind Vaportight Cap, one of the following will occur
  - Ignite Immediately
  - Explode
  - Release and not ignite
Valve Flamers and Poppers
Valve Flamers and Poppers
Pressure Relief Device (PRD)

- Silane PRD is a CG-4, combination 165°F (73.9°C) fuse metal with 3360 - 4000 psig metal rupture disk.
- Cylinders longer than 64” must have PRD’s on both ends.
- On ISOModules the disk is laser welded to the plug and is piped upward.
Small PRD Leaks
Silane Systems

- Non corrosive so most materials of construction are suitable
  - **DO NOT** use polymer lines
- Leak check with inert gas at use or maximum pressure
- Eliminate oxygen from system
  - purge and evacuation cycles
  - huff and puff if vacuum unavailable
  - use cycle times that permit cleaning of dead ends and through RFO
  - store system under inert gas pressure
  - allow gentle inert flow at disconnect
Personal Protective Equipment (PPE)

- **General Cylinder Handling**
  - safety glasses
  - leather gloves
  - safety shoes

- **System Operations**
  - faceshield in addition to safety glasses
  - Nomex or equivalent full body protection with hood
  - leather gloves or equivalent flame resistant hand protection

- **Emergency Operations**
  - Self Contained Breathing Apparatus
  - Full body Nomex with hood
  - Optional - proximity or entry suit
PPE Is Absolutely Critical!
Worker burned in flash fire

Investigator: Unknown source ignites chemical

A 54-year-old man suffered serious burns in a flash fire at a Tempe industrial park Tuesday that left skin "dripping" from his left arm, a co-worker said.

Richard Aldred of Tempe apparently had been trying to unclog a pipe that was part of a cylinder of compressed silane gas. A "pop" was heard in the area, said Ray Andrews, a co-worker at Silica-Source Technology, 1155 W. 3rd St.

Larry Randall, a Tempe fire investigator, said the chemical, which is toxic and can readily ignite when exposed to air, "had escaped and caught fire and flashed over."

Andrews, who witnessed the accident, said, "There was a lot of fire, the guy got burned really bad."

"He ran out yelling and screaming ... I finally convinced someone to take him to the hospital ... the skin was dripping from his arm."

When firefighters arrived a few minutes after the accident, they found co-workers had already driven Aldred to Tempe St. Luke's Hospital. He was later transferred to Maricopa Medical Center, where he was in fair condition with second-degree burns on his left hand and arm, and a ruptured left eardrum.

A single sprinkler head extinguished the fire, Randall said. "That fire sprinkler system not been in place and in service we probably would have lost that building," he added.

About 15 employees were evacuated for several hours while hazardous material crews checked and shut valves and piping inside the building, Randall said, noting that other chemicals had been stored nearby.

He said there was little water damage but did not have a damage estimate.

The fire closed 23rd Street from Industrial Park Avenue nearly to Priest Drive for nearly four hours, Randall said.
Silane Release Behavior
Silane Leak/Release Behavior

- **Small Silane leaks**
  - without visual indication (smoke, solids, flames)
  - Popping Sound
  - Solids Formation
  - Fire continuous flame or Puffs

- **Medium & Large Releases can**
  - Immediately Ignite
  - Not Ignite
    - With Delayed Ignition
    - Ignition At Abrupt Shutoff
    - Unknown Ignition Source
    - Not at all
Small Leak no Visual Indication

- Very small Silane leaks may give no visual indication of a leak. These are detected only with the use of a hydride specific leak detector or soap solution.
- Concentrations of 8-15 ppm have been reported.
Small Leak with Popping Sounds

- Some small releases have also been discovered by reports of a popping sound.
- Sometimes when soap solution is applied to a small leak, it can accumulate enough Silane in a bubble, releasing it with a pop and fire.
Small Leak with Solids Formation

- Some small releases oxidize to form pure Silicon Dioxide which is white
- There are no flames or popping
Solids Plugging

- Sometimes these seal themselves even at full cylinder pressures of 1450 psig
- 0 ppm using a hydride leak detector
- Leak will start again if solids are removed. It will not however become worst
Most leaks will ignite, causing a fire
Valve Crossport Leakers

- Valve seats leak. Silane cylinder valves must have a secondary seal on the outlet.
Silane Cylinder Valve Outlet Connection

- Numerous incidents when a DIN 1, DISS or JIS cylinder valve outlet connection and a elastomer gasket is used
- Elastomer gaskets will cold flow under pressure
- In a fire it will melt causing an even bigger fire
- Best practice to offer customers only DISS 632 Connection with a Nickel Gasket
DISS and VCR Are Mechanically Weak

- Leaks have occurred from
  - Under or over torque
  - Rapid Cooling (Rapid Expansion of high pressure)
  - Impact (Bumping of fitting with tool)
  - Mechanical stress (Lowering of ISO)
  - Vibration (Transportation of trailer)
  - Twisting (Pigtail movement to remove cylinder)
  - Use of elastomer gasket and high pressure cold flow
Under certain conditions, silane will explode.
Silane Metastable Mass

- Larger the orifice and higher the pressure, the greater the amount of metastable mass in an open jet release
- Obstructions create dramatically higher mixing and mass
- Table below assumes 1200 psig release pressure

<table>
<thead>
<tr>
<th>Orifice dia “</th>
<th>Release</th>
<th>Estimated Mass, kgs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Open Jet</td>
<td>7.22</td>
</tr>
<tr>
<td>0.75</td>
<td>Open Jet</td>
<td>3.14</td>
</tr>
<tr>
<td>0.5</td>
<td>Open Jet</td>
<td>0.96</td>
</tr>
<tr>
<td>0.125</td>
<td>Open Jet</td>
<td>0.016</td>
</tr>
<tr>
<td>0.125</td>
<td>Obstructed</td>
<td>0.362</td>
</tr>
</tbody>
</table>
Open Air Release with Obstruction Creates Even Larger Amounts of Metastable Mixtures

- Release for 17.5 secs from 1/8” (3.175 mm) dia orifice then bulk ignition
- Approx 6” away from obstruction
- Cylinder Pressure of 1260 psig
- Overpressure significantly greater than unobstructed flow
Gas Cabinet Explosions

- High pressure jet release may not ignite
- Reduce or eliminate these conditions with design, proper installation and training
- Reduce confinement for high pressure Silane
- Incidents reported where Silane was released into a gas cabinet without immediate ignition and exploded after a delay
  - Germany, 1976 – 1 fatality
  - Japan, 1989, 1 fatality & 1 injury
  - Japan, Dec. 13, 1990 – 1 fatality & 3 injuries
  - US, Jan 1992 – 1 injury
  - Japan, Dec. 21, 1996 – 1 fatality
  - US Dept of Energy, Date Unknown – no injuries
  - US, 2003, no injuries
  - Taiwan, Nov 23, 2005 – 1 fatality
  - India, March 2007 – 1 fatality
Hazards Research Report 5038
May 11, 1982
500 cfm air flow
1 mm orifice, 500 psig
Discharge at Window
10.5 sec flow, Explosion 5 sec after shutoff
Promoted Ignition
Confinement

- Increased confinement increases mixing and overpressure
- Open air promoted ignition had little overpressure
Silane Standards & Regulations
U.S. Silane Codes and Standards

- NFPA 318 & 55 (National Fire Protection Agency)
- IFC Chapters 18, 27, 30 & 41 (International Fire Code)
- FM Global 7-7 (Factory Mutual)
- ANSI/CGA-G-13 (American National Standards Institute / Compressed Gas Association)
- SEMI S-18
Two standards for Silane are being adopted worldwide

- SEMI S18-1102 Environmental, Health and Safety Guideline for Silane Family Gases Handling
- CGA G-13 adopted as an ANSI standard.
  adopted by the US Fire Codes as the silane safety standard
It is being adopted as a global standard by European Industrial Gas Association (EIGA), Asia Industrial Gas Association (AIGA) and Japan Industrial and Medical Gas Association (JIMGA)
Scope and Purpose of CGA G-13

- Addresses the hazards in handling silane
- Covers storage, use and cylinder filling facilities
- Prescribes controls for installation of silane systems
- Recommends methods for storage & transfer of silane
- Provides guidance for siting, design of equipment, safety systems & installation of silane storage and gas delivery/filling systems
- Provides guidance on operational steps
- Does NOT cover user facilities and gas distribution after the gas cabinets or VMB’s
CGA Release Testing

- Six large scale silane release tests
  - 2 one inch vertical, no barrier, used PRD’s
  - 1 0.5 inch vertical, no barrier
  - 1 one inch horizontal, no barrier
  - 2 0.5 inch, with barrier

- Eight small scale silane release tests
  - 1/8 inch orifice
    - 2 horizontal, no barrier
    - 3 vertical, no barrier
    - 3 horizontal, with barrier
Silane Test Site
Valve System
Silane Tube Trailer Release Studies Conducted by CGA at Socorro, NM, 1996

Immediate Ignition

No Ignition

Detonation
Silane Supply Systems

- For safety silane bulk supply systems are located outdoors in an open area.
- Bulk supply reduces the frequency of cylinder changes, improving safety and quality.
- Bulk supply systems will supply the entire site with Silane. One cylinder will be in use while one is on standby.

- Typical components of a gas delivery system are:
  - Source Container (Cylinder, Y-cylinder, Isomodule)
  - High Pressure Control Manifold (HPCM)
  - Tubing
  - Valve Manifold Boxes (VMB)/ Gas Isolation Boxes (GIB)
Bulk Silane Supply Layout
Typical Silane Supply System

- SiH4 ISO module
- SiH4 Y Cylinder or ISO Module
- Universal pigtail A
- Universal pigtail B
- Purge Rack
- HPCM
- ECC
- VMB

To process tool
To fab
Thank You

Questions?
chemicallyspeakingllc@gmail.com