



Fab ER

July 2022

Emergency Response Equipment

Semiconductor Fabs are quite large. To quickly move the team and equipment to the incident location many Fabs have dedicated vehicles



Fig. 2: ERT Cart (Photo Courtesy of Micron)

For chemical ER many unique ER equipment designs have been developed and used. The most common are:

Emergency Response Containment Vessel (ERCV)

Emergency Response Containment Vessels (ERCV), also known as Salvage Receptacles (Cylinders) or Cylinder Salvage Containers, are designed to completely contain and isolate a leaking gas cylinder have become indispensable ER devices for compressed gas emergency response teams. Some call these "cylinder coffins" which has a negative connotation.

ERCV's are ASME pressure vessels with a quick opening flange. During the initial introduction of ERCV's in the 1980's they were authorized for use under a DOT Special Permit. Recognizing that ERCV's had been in use without major incident for over 20 years in the US, DOT on Jan. 24, 2005, published final rules entitled "Hazardous Materials; Incorporation of Exemptions into Regulations", Federal Register Vol 70, No.14 pages 3302-3310 removing the requirement for ERCV special permits. In addition, the hydrotest and inspection period of two years was extended to five years. The regulations are now under 49 CFR 173.3 Packaging and exceptions. (d) Salvage Cylinders.

The primary high pressure ERCV's in use are

1. Sigri GMBH
2. Solkatronic (EMD Electronics)



3. Integrated Environmental Services
4. JD Cousin



Fig. 3: ERCV's for Large High Pressure Cylinders, 50 liter or less (Photos by E. Ngai)

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The Sigri ERCV was the first to be introduced in 1984, the others followed.

The large high pressure ERCVs are rated for pressures over 1,100 psig which makes them suitable for a 50-liter cylinder with a pressure of 2,400 psig.

For toxic, corrosive or pyrophoric gases, the IFC requires a "leaker" gas cabinet, which is an empty gas cabinet where a leaking cylinder can be safely isolated and ventilated until the supplier or waste disposal company removes it. There is an exception when an ERCV and a fully trained ERT are relocated on site.

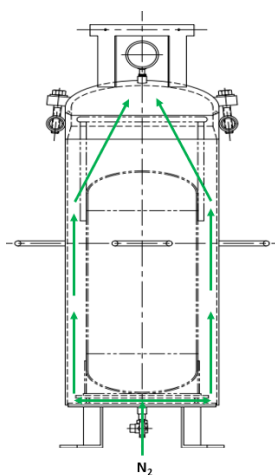
As a best practice, many Fabs require ERCV's to be on site for ERT use.

Reactive Liquid/Solid ERCV

Leaking or damaged containers of pyrophoric or water reactive materials, such as hexachlorodisilane or trimethylaluminum, must be purged to remove air and moisture. The 1226LP ERCV has a flow through purge capability. Nitrogen will enter the bottom of the ERCV where it will



hit a metal plate that the container will sit on top of. The N_2 will then be distributed around the plate to flow up the side of the container and out the top valve



Figs 4 & 5: Drawing of 1226 LP and 1226 ER CV with Cart and Hoist, (Photos by E. Ngai)

Other ER Equipment include:

All Fabs want to be able to quickly and safely isolate a leaking cylinder or container. There have been many unique systems that have been developed for packages or products to do this. The following are examples of these

Y Cylinder Capping Kit

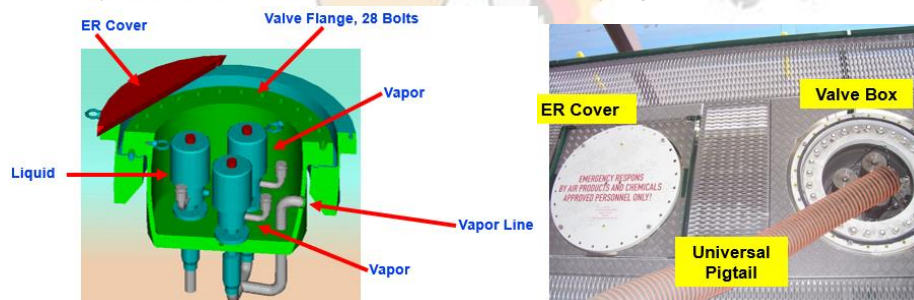
For bulk high pressure ton cylinders containing low vapor pressure less than 100 psig liquefied gases, such as ammonia, chlorine, dichlorosilane, monochlorosilane, can be capped if the appropriate gasket is used. This device requires a DOT exemption/special permit to legally be transported.



Fig. 6: Capping Kit Fully Assembled (Photos by E. Ngai)

Ammonia ISO ER Kit

Ammonia ISO Containers containing 23,000 lbs of material were custom designed to include emergency response capabilities. An ER Cover is located at the top very close to the Valve Box which is recessed into the tank. It will seal off the Valve Box where all the valves are located. The same concept can be used for other low-pressure hazardous materials ISO Containers, such as hydrogen fluoride.



Figs. 7 & 8: Description of Valve Box and location of ER Cover and Valve Box (Photos by E. Ngai)

There are also 2 capping kits for the 2 springloaded Pressure Relief Devices (PRV) located on the ISO frame at ground level for easy access.

Gaskets and tools are located in an enclosure mounted to the ISO frame.

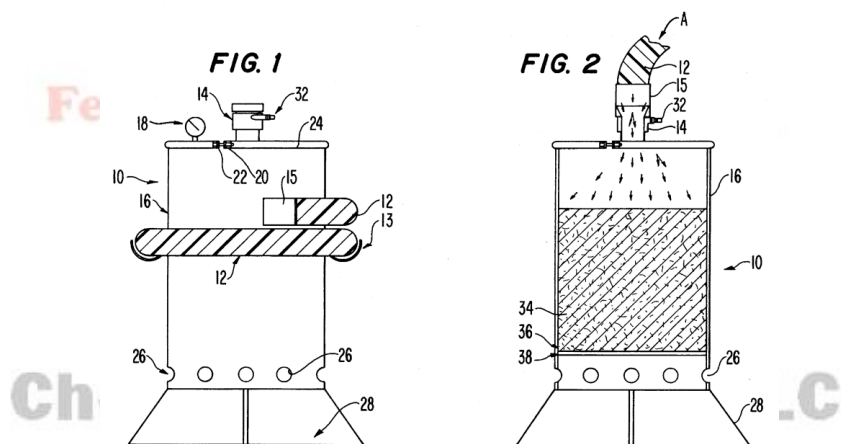


Figs. 9 & 10: Capping Device and PRV. Assembly of Capping Kit (Photos by E. Ngai)

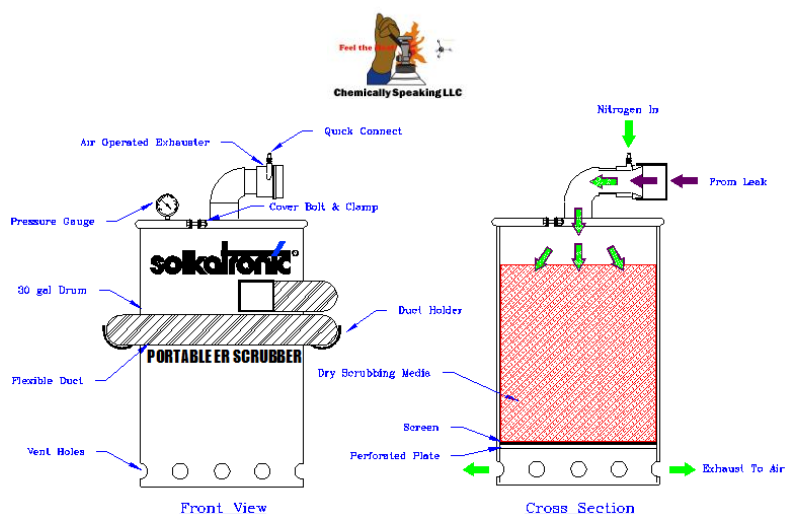
Air Products and Chemicals was issued US Patent No. 6651703, Transportation and Storage of Ultra High Purity Products, November, 25, 2003 for this invention.

Portable Scrubber

A metal container that can be quickly filled with a scrubbing media for alkaline, acid or metal hydride gas scrubbing. A venturi eductor on top of the container creates an exhaust vacuum on a 3" diameter flexible hose that can be placed over the leaking cylinder valve to capture the leak and direct it into the solid media where it is chemically reacted;



Figs 11 & 12 Patent US Patent No. 5482536

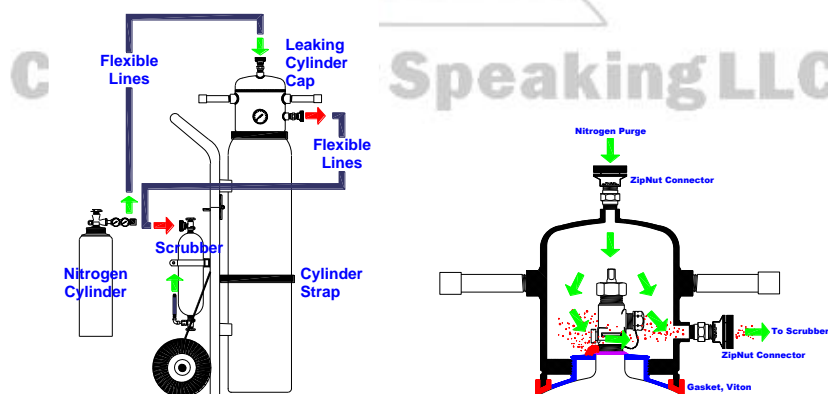


Figs 13 & 14: Portable Scrubber Exterior and Interior Descriptions (Photos by E. Ngai)

Solkatronic Chemicals was issued US Patent No. 5482536, Apparatus for Containment and Scrubbing of Toxic Gas from a Leakage Location and Method, January 9, 1996 for this invention.

Leaking Cylinder Cap

A metal cap that is screwed onto the cylinder collar with a cup gasket to seal off the valve area may be used to divert a leak in the cylinder valve to a local scrubber. It is not designed for pressure containment. It is purged with nitrogen which sweeps the leaking gas into the appropriate solid media scrubber. Like the Portable Scrubber there is Alkaline, Acid or Metal Hydride scrubbing media. The system is mounted onto a custom designed cylinder handcart for rapid deployment.



Figs:15 & 16: Overall Leaking Cap System, Purge Flow Through Cap (Photo by E. Ngai)

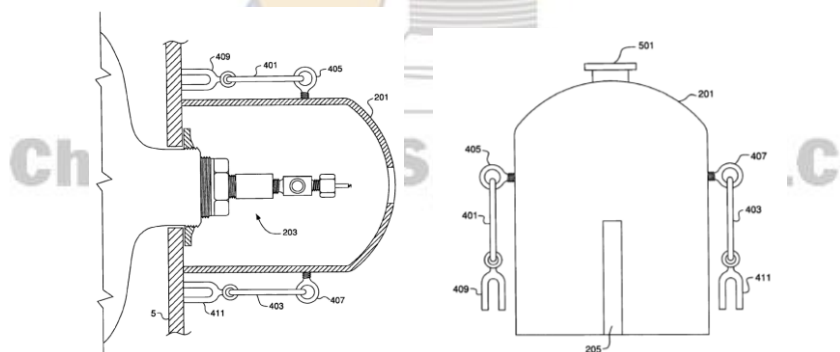


Fig.17: Leaking Cylinder Cap Cart (Photo by E. Ngai)

This system is designed to quickly isolate a leaking cylinder at the site. It cannot be used to transport the leaking cylinder. Solkatronic Chemicals was issued US Patent No. 5086804, Emergency Security Device for Head of a Leaking Gas Cylinder, February 11, 1992 for this invention

ISO Acid Gas Ventilated Cap

This is a plastic cap that is attached magnetically to the bulkhead of an acid gas or fluorine mixture tube trailer/ISO Module. It is exhaust ventilated using a venturi eductor into a small scrubber or the Portable Scrubber



Figs.18 & 19: ISO Cap Exterior and Interior US Patent No. 7448402 (Photo by E, Ngai)

The kit is stored in a plastic crate

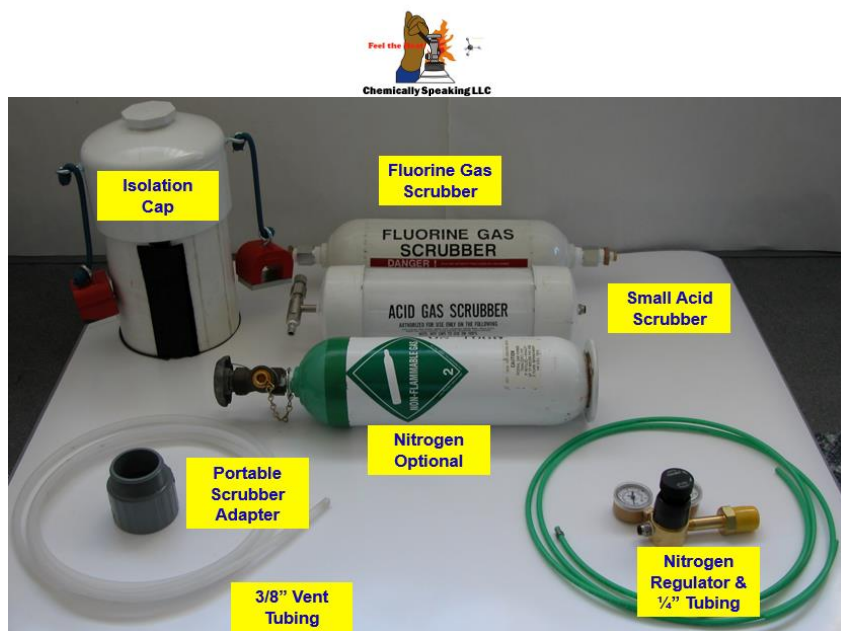


Fig. 20: Acid Gas Kit Stored in Plastic Crate (Photo by E. Ngai)

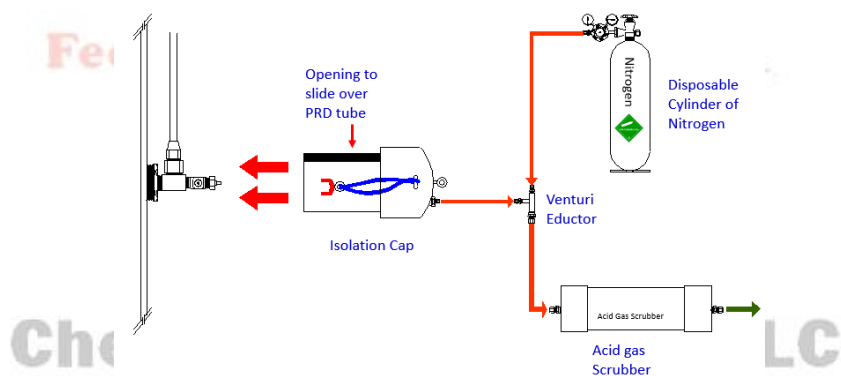


Fig. 21: Low Leak Rate System <50 cc/min (Drawing by E. Ngai)

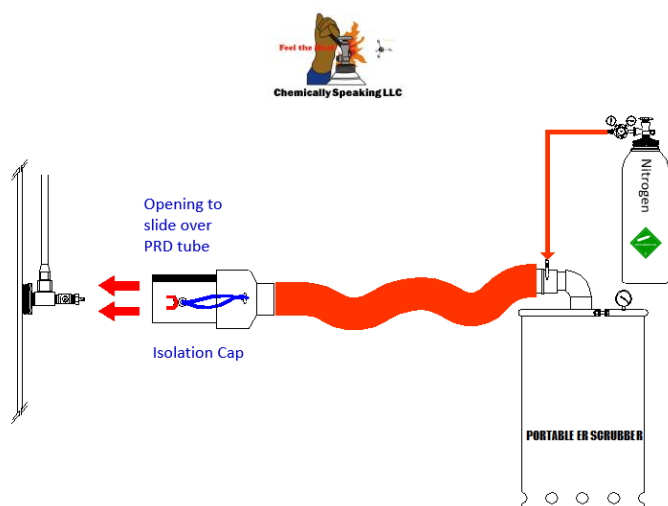


Fig. 22: High Leak Rate System >50 cc/min (Drawing by E. Ngai)

Air Products and Chemicals was issued US Patent No. 7448402, Leak Containment Apparatus for Reactive Gases, November 11, 2008 for this invention.

Gas Cabinet and Scrubber

Matheson had a gas cabinet that was connected to a liquid scrubber. Mobile Emergency Scrub Apparatus (MESA)



Fig. 21: Matheson MESA System (Photo by E. Ngai)

Gaslok Cap



Figs 22 & 23: Gaslok Cap Kit and Patent(Photo by E, Ngai)

This system was developed in 1989 and patented in 1990. It entails a custom cylinder cap which is filled with hot lead to stop leak from cylinder valve. Holes must be drilled in the cylinder collar to attach it. It cannot be used with valves containing fuse metal pressure relief devices which limit its use to highly toxic gases such as arsine. A number were sold in early 1990's

A method and apparatus for sealing a leaking valve on a compressed gas tank to accommodate safe transport of the tank and valve from the place of use in the field to a repair depot where the tank and valve may be safely serviced. The apparatus comprises a valve cap specifically designed for practice of the method. The method resides in the steps of placing the cap over the leaking valve and attaching the cap to the tank, filling the cap with a fusible substance in liquified form, the fusible substance having a fusion temperature in excess of ambient temperature but less than about 200° F. and, upon cooling, solidifying within the cap about the valve, sealing off the cap, transporting the tank, cap and encapsulated valve from the place of use to a repair depot, at the repair depot converting the fusible substance from solidified form to liquified form and draining the substance from the cap, and removing the cap from the tank and valve to accommodate safe servicing of the valve at the repair depot. This cap was unique but limited in use plus it was a challenge to use effectively. Therefore, it never found a use with gas supplier ER Teams or others.

Silane

Techniques for silane ER are to manually vent/burn the contents of the cylinder/tube. The burners at user sites however are very limited in capacity so this is not a practical option. A 50-liter cylinder, if not on fire, can be safely contained in an ERCV and transported back to the gas supplier site for disposal if air is first evacuated from the ERCV before inserting the leaking silane cylinder. This option is not available for bulk cylinders/or tubes.

Cascading is an effective method of offloading as much of the silane (or similar flammable compressed gases) from the leaking cylinder/tube as possible by equalizing the pressure using one cylinder at a time rather than all of the cylinders at the same time.

In this example a 10 kg silane cylinder was reduced to 0.62 kgs vs the 2 kg of pressure equalization.

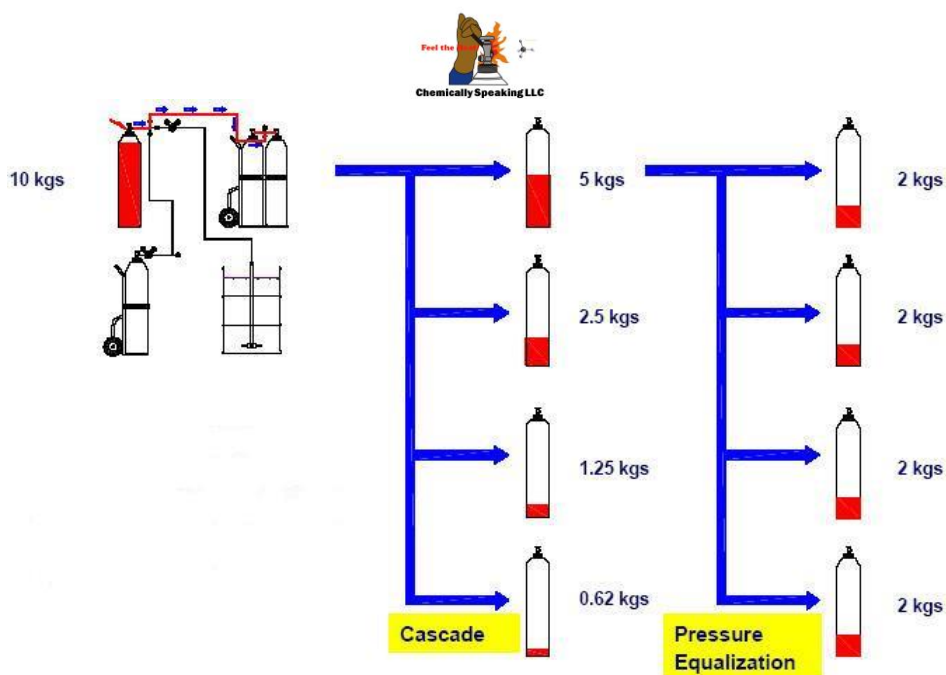


Fig. 23: Effect of Cascade versus Pressure Equalization (Drawing by E. Ngai)
 Cascading is the only effective method for silane removal from bulk cylinders, containers and tubes

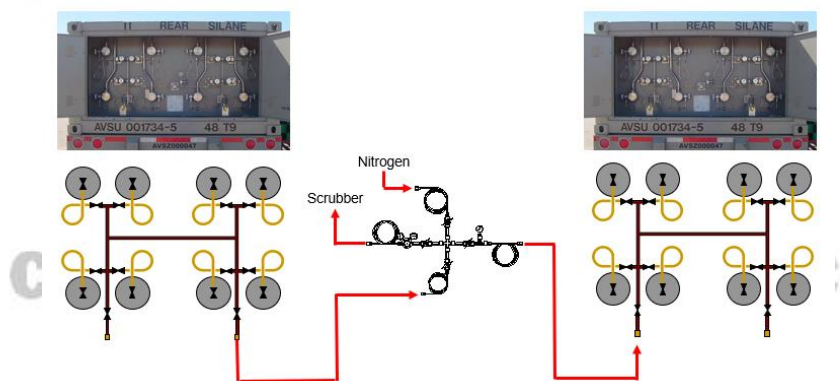


Fig. 24: Silane ISO System Setup for Cascade (Drawing by E. Ngai)

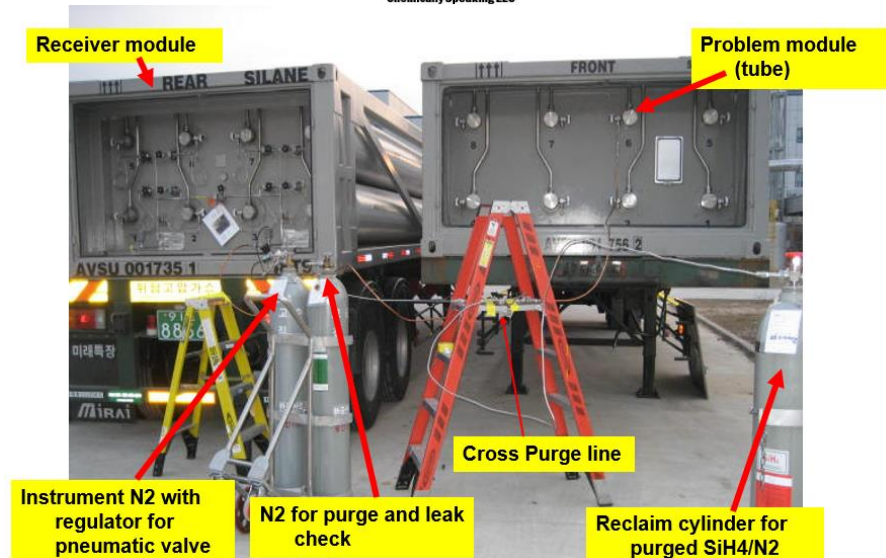


Fig 25: Actual Silane ISO Cascade (Photo by E. Ngai)

Safety Testing of ESM

Testing of ESM to determine PPE selection or ER actions have been done for those with unique hazards.

Such ESM include:

1. Chlorine trifluoride
2. Hexachlorodisilane
3. Trichlorosilane
4. Trimethylaluminum

Chlorine trifluoride

One of the most reactive ESG's is chlorine trifluoride (ClF_3) and it must be handled with extreme care. Testing demonstrated how much more reactive it is as a liquid. It must always be handled as a gas. New PPE or materials were not reactive, even with the liquid. Used PPE or materials immediately reacted and in some cases the reaction was much more energetic. Liquid water hydrolyzing an unreacted area with chlorine trifluoride on it can initiate the reaction due to hydrolysis heat. The reaction two drops of liquid ClF_3 onto Tyvek after it is ignited with a drop of water is violent and considerable.

ER recommendation is to work with chlorine trifluoride in the vapor phase which means the cylinder is never laid in the horizontal position to drip liquid. All PPE must be new and inner gloves will be leather for thermal protection with new Nitrile as an outer glove for chemical protection. Any clothing exposure to chlorine trifluoride liquid that has not ignited should be removed before being exposed to water, such as from a safety shower or eyewash.



ClF_3 cannot be placed in the ERCV as it cannot be cleaned and passivated. One user in a panic loaded up a cylinder with the valve open into a 5502 ERCV. It immediately reacted with the cylinder labels, the contaminants on the ERCV interior surface and the O Rings, When the ERT closed the ERCV, the reaction continued. The dripping liquid ClF_3 burned a hole in the bottom of the ERCV



Fig. 26: ClF_3 Liquid Reaction With 5502 ERCV Bottom. (Photo by E. Ngai)

Feel the Heat

Hexachlorodisilane

Hexachlorodisilane (HCDS) readily hydrolyzes with the moisture in the air to form shock sensitive gels. This could be in as little time as 10 minutes after a spill of the HCDS. Hexachlorodisilane can undergo a partial reaction with water leading to formation of siloxane gel or solid deposit containing Si-Si bonds. Gel formation restricts the reaction so that you end up with some Si-OH groups in the gel that can react explosively with Si-Si bonds when provided sufficient activation energy or physical impact, i.e., they are shock sensitive.

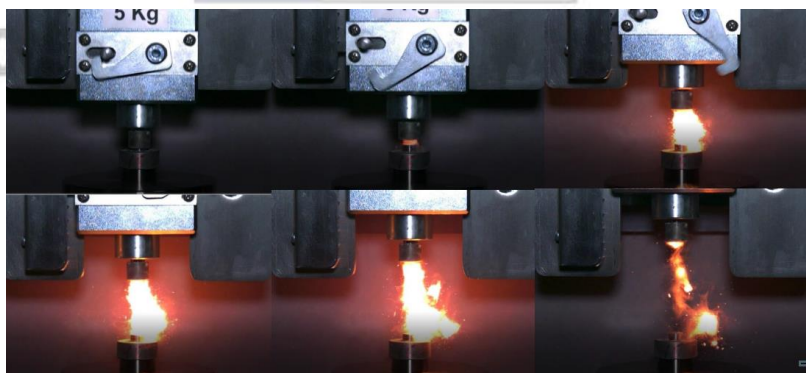


Fig.27: Fall Hammer Testing of Hydrolyzed HCDS (Photo By Prof J R Chen)



Neutralizing the gel with a dilute alkaline material will form an even more sensitive gel, one that is too dangerous to even handle.

Wetting the gel by water may suppress the shock sensitivity but upon drying, the gel will regain shock sensitivity. Concentrated sulfuric acid was found to be effective in suppressing the shock sensitivity of the gel by preventing the gel or deposit from being dried.

Trichlorosilane

Trichlorosilane (TCS) is a clear corrosive liquid that is widely used in Semiconductor Fabs. A challenge with a TCS spill that ignites is the difficulty in putting out the fire and suppressing the acidic vapors that are released.

Union Carbide, a major manufacturer of Chlorosilanes, conducted numerous tests which are summarized in L. Britton Article "Improve Your Handling of Chlorosilanes" in 1991.

Field tests of release and burning of TCS in combination with OP-FTIR air measurement are performed to measure evaporation rate, burning rate, and air pollutants.

The TCS burning mass flux was found to be $1.98 \text{ kg/m}^2\text{-min}$, independent to ambient conditions.

The TCS evaporative mass flux was found to be $0.188 \text{ kg/m}^2\text{-min}$, and may be subject to wind and temperature effects.

Major air pollutants are silicon dioxide, HCl and Cl_2 for TCS combustion, and TCS and HCl for TCS release.

The results can be used to estimate the source mass flux for dispersion modeling during emergency and risk assessment.



Fig. 28: Medium Expansion Foam Application onto TCS Fire (Photo by Prof J.R. Chen)



It has been reconfirmed that medium expansion foam is the best means to suppress a TCS fire. The application of the foam must be to float it onto the liquid rather than directly to the fire which will prevent the barrier layer from forming. The depth of the foam is also critical.

Water spray is effective in rapidly reacting a small TCS spill by overwhelming it with flooding amounts of water.

Trimethylaluminum

Trimethylaluminum is pyrophoric and violently water reactive. Use of various fire extinguishing agents were ineffective; it always reignited. Vermiculite will absorb and suppress the fire if it can be safely applied. It would however reignite when it was disturbed.

Eugene Ngai

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