

# The Care and Feeding of Silane

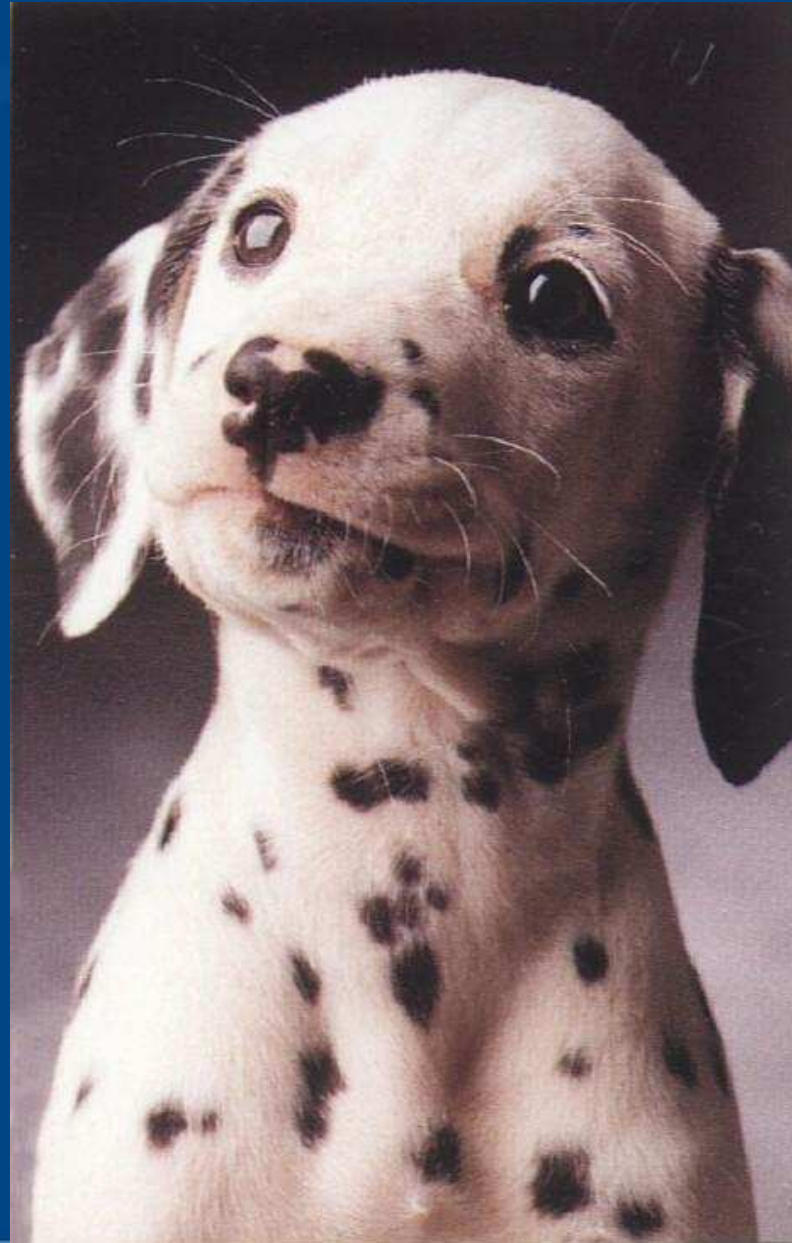
Art Garcia  
FM Global  
March 23, 2006

This is Silane



This is also  
'Silane'

Fire chief said he  
was always  
making trouble



# Silane – SiH<sub>4</sub>



### CHEMICAL HAZARD IDENTIFICATION SYSTEM

<b>HEALTH HAZARD</b> 4-Deadly 3-Extreme danger 2-Hazardous 1-Slightly hazardous 0-Normal material	<b>FLAME HAZARD</b> Flash Point 4-Below 73 F 3-Below 100 F 2-Below 200 F 1-Above 200 F 0-Will not burn	
<b>1</b>	<b>4</b>	<b>2</b>
<b>SPECIFIC HAZARD</b> Oxidizer OXY Acid ACID Alkali ALK Corrosive COR Use NO WATER $\frac{1}{2}$ Refrigerated $\frac{1}{2}$	<b>REACTIVITY</b> 4-May detonate 3-Shock and heat may detonate 2-Violent chemical change 1-Unstable if heated 0-Stable	

CHEMICAL NAME \_\_\_\_\_



# Silane Delivery System



## Location:

Silane should preferably be outside, well separated from buildings. Open cylinder system, without a cabinet is OK. Area needs to be a well ventilated. All bulk systems should be outside.

Outdoor - separate cylinders with steel partitions, preferably away from a wall. Provide deluge sprinkler protection.

Indoor - system should always be in a gas cabinet. Construction to limit damage in an explosion.

# Silane Delivery System



Gas Cabinet:

Cabinet should be minimum 12 gauge steel.

Cabinet doors and access windows should be self closing and latching.

Internal sprinkler head.

Class I, Division 2 electrically rated equipment.

Stainless steel welded piping.

# Silane Delivery System



Silane cylinders:

Stainless steel cylinders are preferred.

Aluminum cylinders can be used. Typically these cylinders will be 6061 aluminum alloy.

Do NOT use aluminum cylinders in cabinets which contain two silane cylinders.

If you have two aluminum silane cylinders in a cabinet, install a steel partition between them.

# Silane Delivery System



## Flow restriction:

Restrictive flow orifice (RFO) – Installed within the gas cylinder valve body. RFO size should be specified on the cylinder order. RFO size is usually marked or stamped into cylinder.

Excess flow valve or switch (EFV or EFS) – Separate device within the cabinet. Valve will automatically shut off the delivery of gas if the flow exceeds a preset limit.

# Silane Delivery System



Automatic shutoff:

Automatic cylinder valve (ACV) – ACV is preferred. Valve is integral to the cylinder. Can shut off a leak at the threaded pigtail connection. Must be ordered with the silane cylinder and supported by gas controller.

or

Emergency shutoff valve (ESOV) – Separate valve downstream of the pigtail connection. Can NOT shut off a leak at the pigtail connection. Cylinder has manual valve.

# Silane Delivery System



Silane concentrations:

1.4% and less – Nonflammable

1.4% to ~4.1%\* - Flammable

~4.5%\* and greater – Metastable mixtures which after a delay can undergo bulk auto-ignition causing significant overpressures

\* Dependent on pressure, exit velocity, geometry, and leak size

# Silane Delivery System



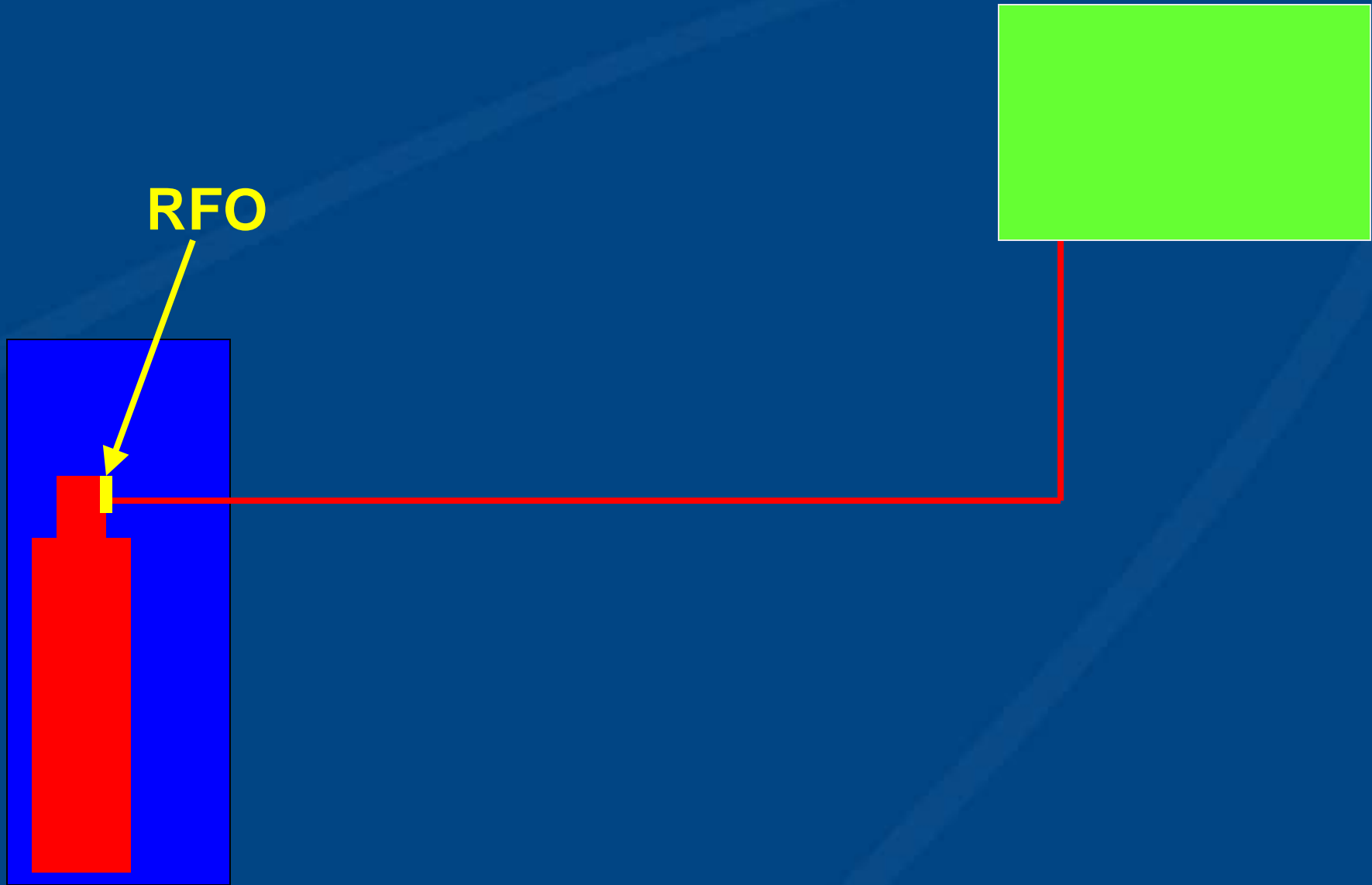
Silane holdup:

Limit the holdup of silane to 1% of the net volume of the gas cabinet or enclosure.

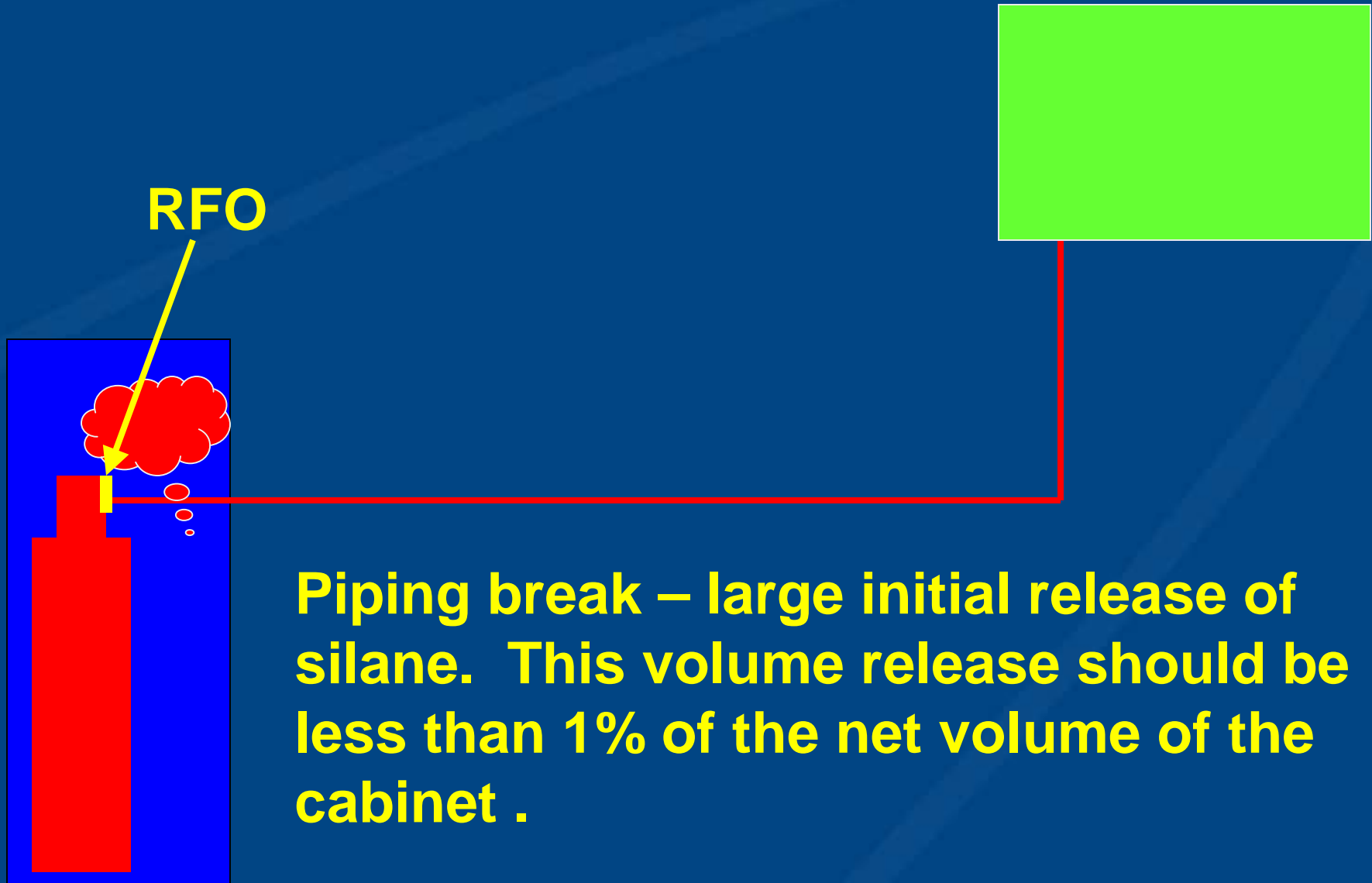
Silane volume is the amount of gas contained in the piping between RFOs or between an RFO and the end of the line.

Net volume is the space in the cabinet not occupied by the cylinder or equipment.

# Silane Delivery System

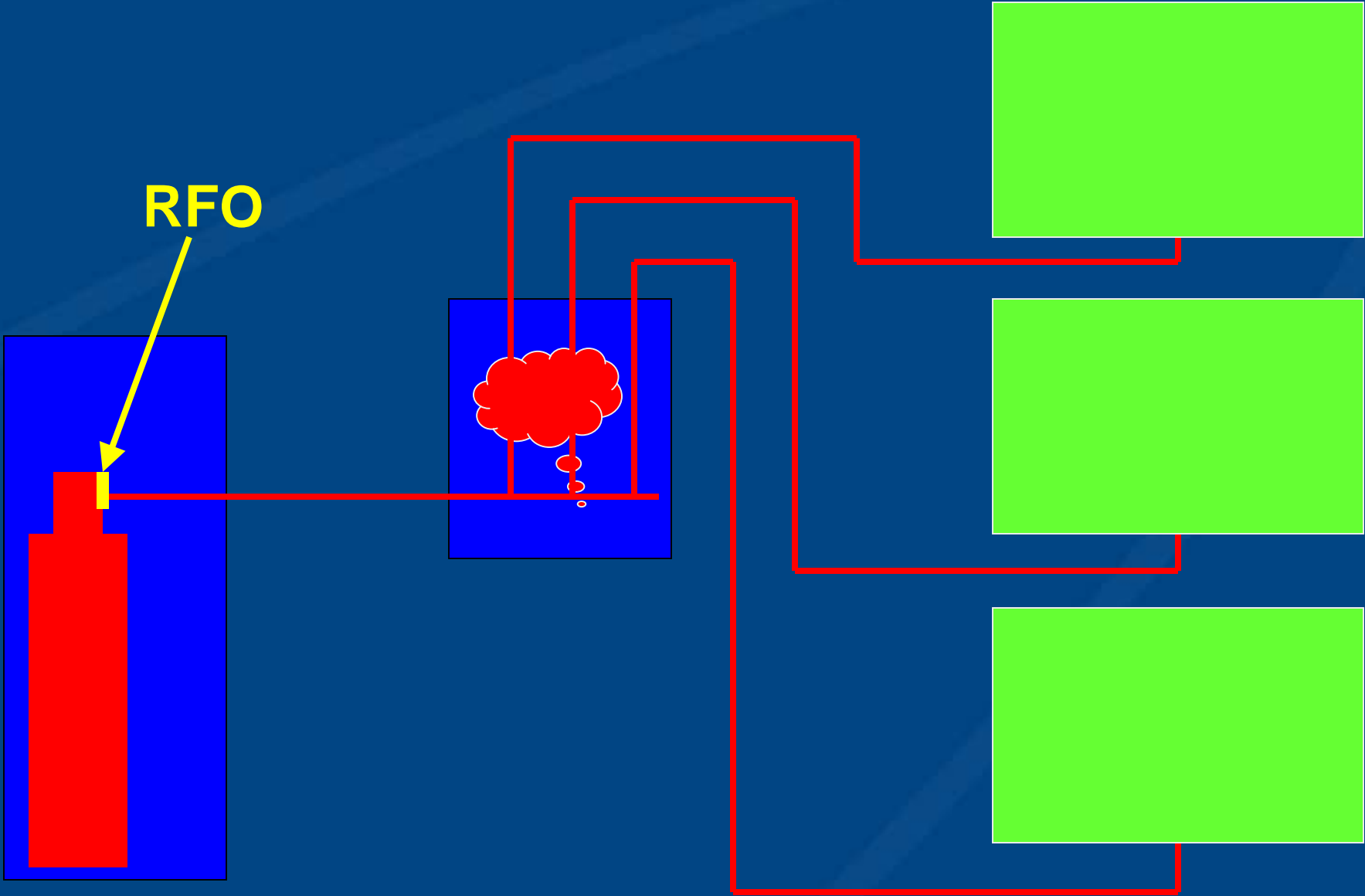


# Silane Delivery System

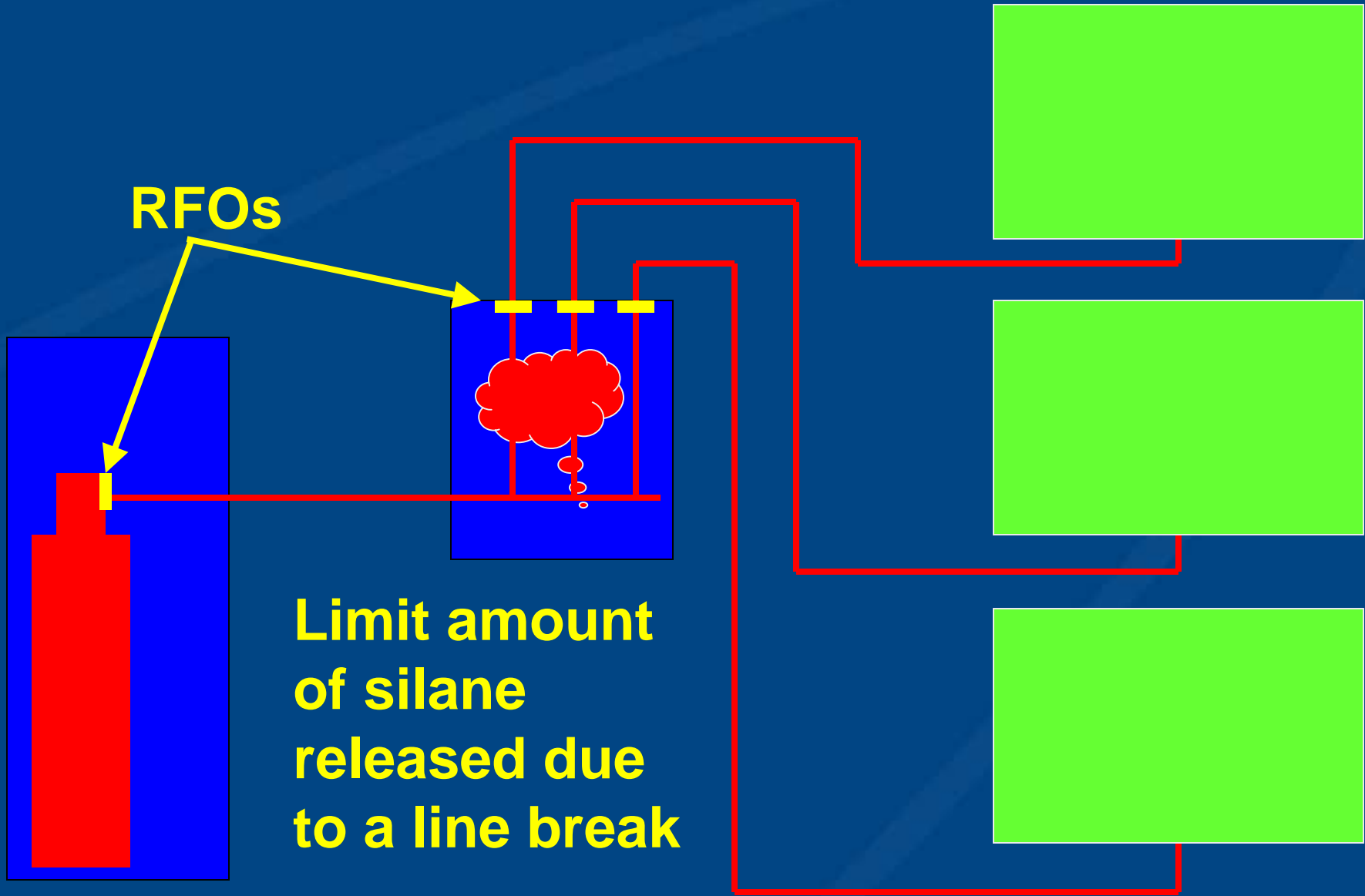


**Piping break – large initial release of silane. This volume release should be less than 1% of the net volume of the cabinet .**

# Silane Delivery System



# Silane Delivery System



RFOs

Limit amount  
of silane  
released due  
to a line break

# Silane Delivery System



## Ventilation:

Size the ventilation to limit the maximum concentration of silane to 0.4% by volume.

Base the concentration of silane on the continuous release using the flow rate given by the size of the RFO and the maximum silane pressure.

# Silane Delivery System



## Ventilation:

## Silane flow through RFO vs. various pressures

Table 2. Silane Flow Rates Through Restricted Flow Orifices Based on the Predictions from the FM Global Research Model

Silane Flow Rate [scfm]									
<i>(Source Temperature: 77°F; Downstream Pressure: 0 psig; Discharge Coefficient: 0.8)</i>									
RFO Diameter in. (mm)	Source Pressure [psig]								
	1500	1200	1000	800	600	400	200	100	50
0.020 (0.51)	10.0	7.88	6.04	4.34	3.02	1.92	0.949	0.497	0.288
0.014 (0.36)	4.91	3.86	2.96	2.13	1.48	0.941	0.465	0.243	0.136
0.010 (0.25)	2.50	1.97	1.51	1.08	0.755	0.480	0.237	0.124	0.069

### Notes:

1. The flows through the 0.014 in. (0.36 mm) and 0.010 in. (0.25 mm) RFOs are equal to 49 and 25% of the flow through the 0.020 in. (0.5 mm) diameter RFO.
2. To convert [scfm] to [slpm] multiply by 28.32.
3. To convert from psig to bar, divide by 14.5.

# Silane Delivery System



Ventilation:

800 psi silane cylinder  
0.010 inch RFO diameter

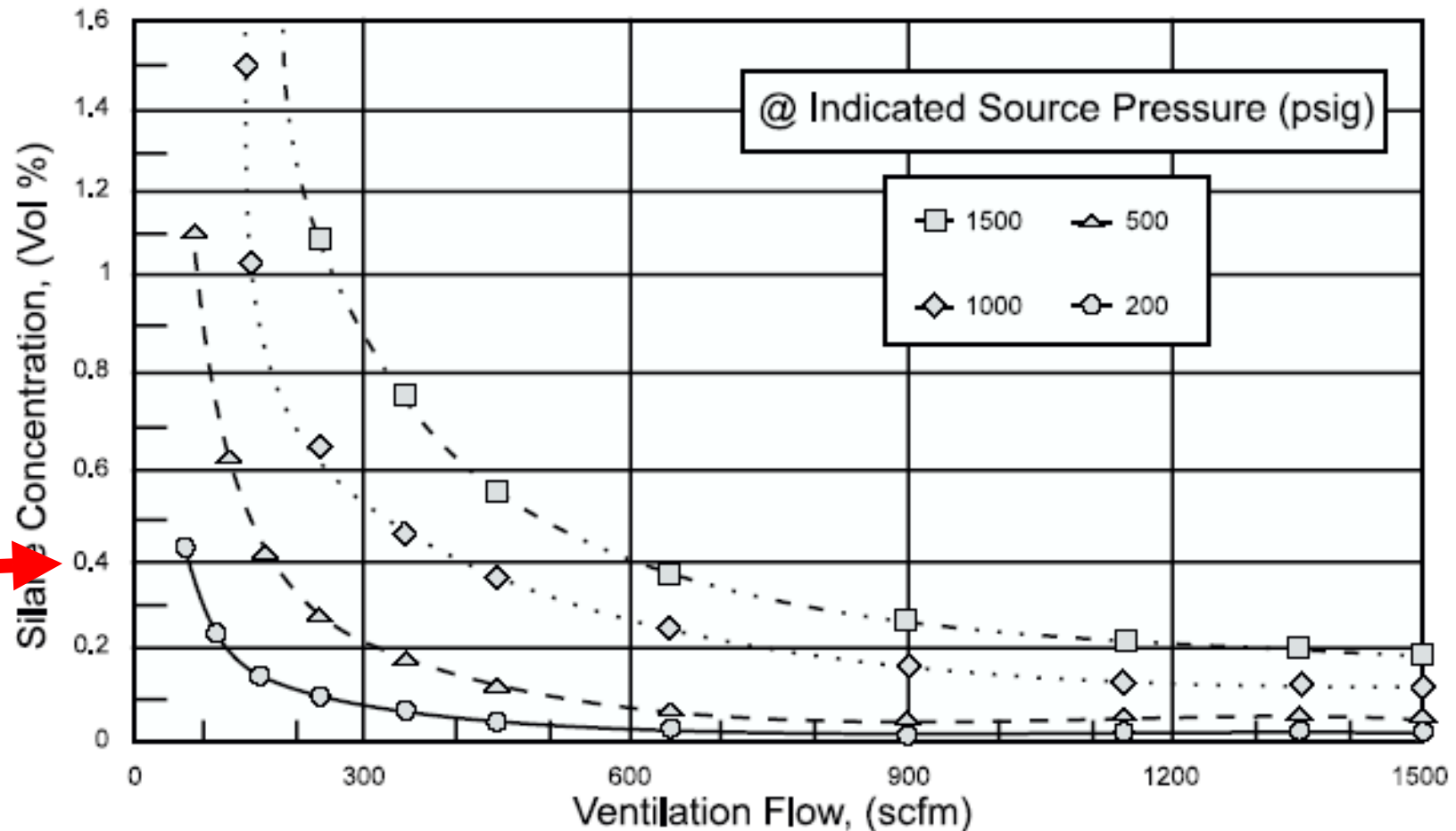
→ 1.08 cfm flow of silane

$$\frac{1.08 \text{ cfm silane}}{X \text{ cfm air}} = 0.4 \%$$

$$X = 270 \text{ cfm air}$$

# Silane Delivery System

Average Silane Concentration in a Ventilated Enclosure  
RFO Size: 0.010 inch • Discharge Coefficient: 0.8



Note:

- RFO = 0.014 in. (0,36 mm), multiply silane concentration by 2,0
- RFO = 0.020 in. (0,51 mm), multiply silane concentration by 4,0
- RFO = 0.006 in. (0,15 mm), multiply silane concentration by 0,36

# Silane Delivery System



Gas monitoring system:

Silane reacting with oxygen in the air



As the oxygen is consumed



Monitor for silane (hydride), silicon dioxide, hydrogen???

# Silane Delivery System



Emergency shutoff:

Activation of the gas monitoring system

Loss of cabinet ventilation

Power failure

Activation of the excess flow switch

Seismic activity

Manual shutoff – at the cabinet, at the tool,  
remote shutoff (outside the gas room, control  
room, etc.)

# Silane Delivery System



Major Hazards:

Fires

Explosions

How do we stop them?

# Silane Delivery System



## Hazards:

### Outdoor locations

- Area without adequate ventilation
- Lack of deluge sprinkler protection
- Multiple cylinders exposing each other
- Mixed cylinder storage

### Indoor locations

- Lack of explosion venting
- Poor condition of gas cabinets
- Unrated electrical equipment

# Silane Delivery System



Hazards:

Over sized RFOs

Excess flow valves or switches with high limits

Automatic shutoffs never tested

Silane systems with large holdups

# Silane Delivery System



## Hazards:

### Lack of adequate ventilation

- Closed air dampers on exhaust ducts

- Clogged air filters on cabinets

- Obstructed air inlets

### Poor ventilation

- Open cabinet windows

- Open cabinet doors

- Holes in the top of the gas cabinet

- Unbalanced air flows between cabinets

# Silane Delivery System



Hazards:

Monitoring systems out of calibration

Gas sensing port lines disconnected

Monitoring system not appropriate for silane

Monitoring system not tested

# Silane Delivery System



You do not want a visit from 'Silane'



Your town

# So hopefully you now know the story about the Care and Feeding of 'Silane'

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