

# Chlorine Safety: The Rest of the Story

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Hershey, PA**

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# Topics to Be Covered

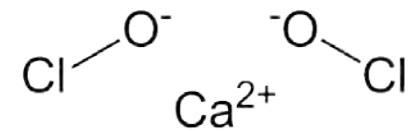
- Background
- Solid Chlorine
  - Calcium Hypochlorite
- Liquid Chlorine
  - Commercial (Bulk) Sodium Hypochlorite
  - On-Site Hypochlorite Generation
- Gas Chlorine
  - Gas Basics
  - Your Father's Chlorine Safety
  - Containment Systems
  - Automatic Shut Off Valves
  - Emergency Scrubber Systems
- Summary



# Potable Water Disinfection

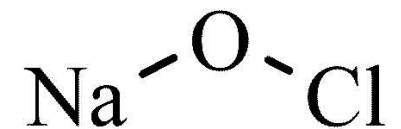
- Chlorine Based

- Calcium Hypochlorite
- Commercial hypochlorite
- Gas chlorination
- On-site hypochlorite generation
- Chlorination-De-chlorination
- Chloramines
- Chlorine dioxide



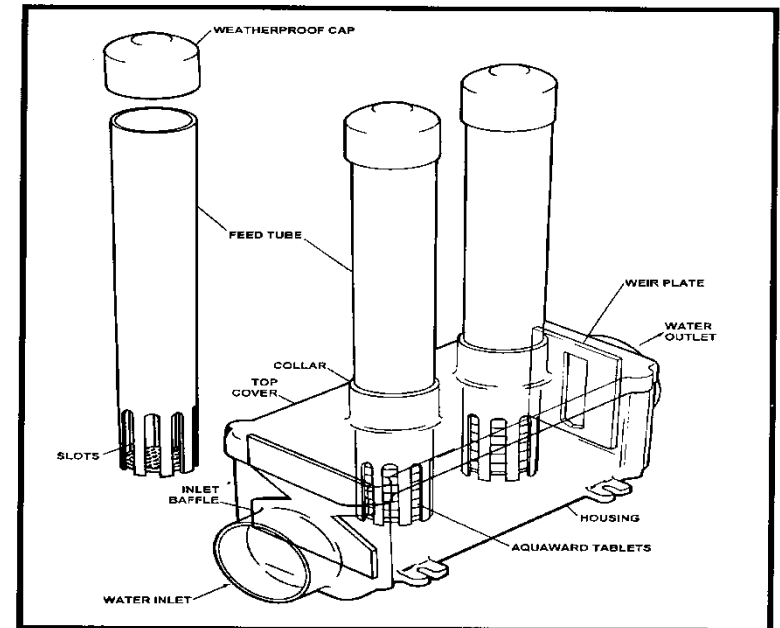
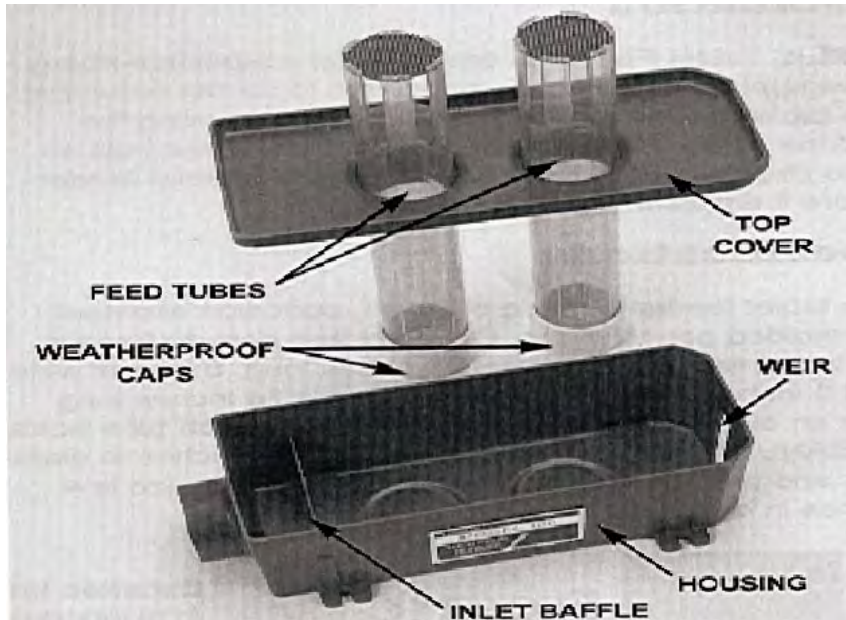
- Alternate

- UV disinfection
- Ozone



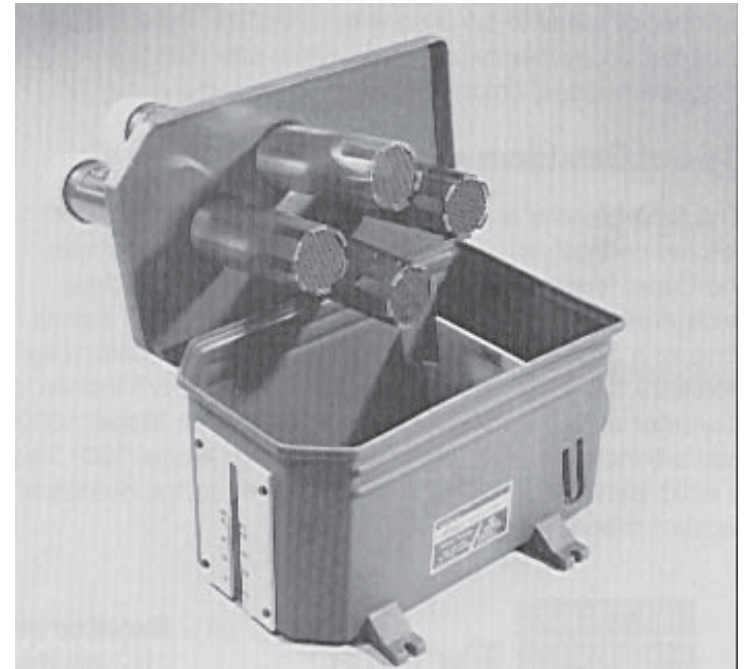
# Calcium Hypochlorite Tablet Feeders

They are not complicated



# Calcium Hypochlorite Tablet Feeders

- Safe and simple
- Low initial cost
- Low annual maintenance
- Typically used for smaller Systems





# Calcium Hypochlorite Safety Lesson



**Spontaneous fire in SUV cause by calcium hypochlorite mixing with a solvent which caused the death of two children**

# Commercial Sodium Hypochlorite



Typical Sodium Hypochlorite Dosing Station

## Commercial Sodium Hypochlorite Highlights

- Delivered to site in usable liquid form
- Delivered as 12-15% chlorine
- Major system components include 1) storage tanks, 2) metering pumps 3) analytical instrumentation





# Commercial Sodium Hypochlorite

Advantages	Disadvantages
Very effective at typical pH	Reacts with ammonia
Proven & reliable	Effectiveness decreases at high pH
Widely used for water	Concentration decays quickly
Leaves a residual	THM Formation
Simple chemical feed system	High cost per pound
Low capital cost	
<b>Safety</b>	
<ul style="list-style-type: none"><li>Liquid safer &amp; more familiar than Gas</li></ul>	<ul style="list-style-type: none"><li>Can cause severe burns</li></ul>
<ul style="list-style-type: none"><li>No make down required</li></ul>	<ul style="list-style-type: none"><li>Potential for gas formation</li></ul>
<ul style="list-style-type: none"><li>Not highly regulated</li></ul>	<ul style="list-style-type: none"><li>Secondary Containment required</li></ul>
	<ul style="list-style-type: none"><li>Safety issues often overlooked</li></ul>

# On-Site Sodium Hypochlorite Generation



Typical 24 lb On-Site Hypochlorite Generation System

## On-site Sodium Hypochlorite Highlights

- Delivered to site as salt
- Sodium hypochlorite produced on-demand with minimum storage
- 0.8 % sodium hypochlorite solution produced
- Utilizes DC current, salt, water

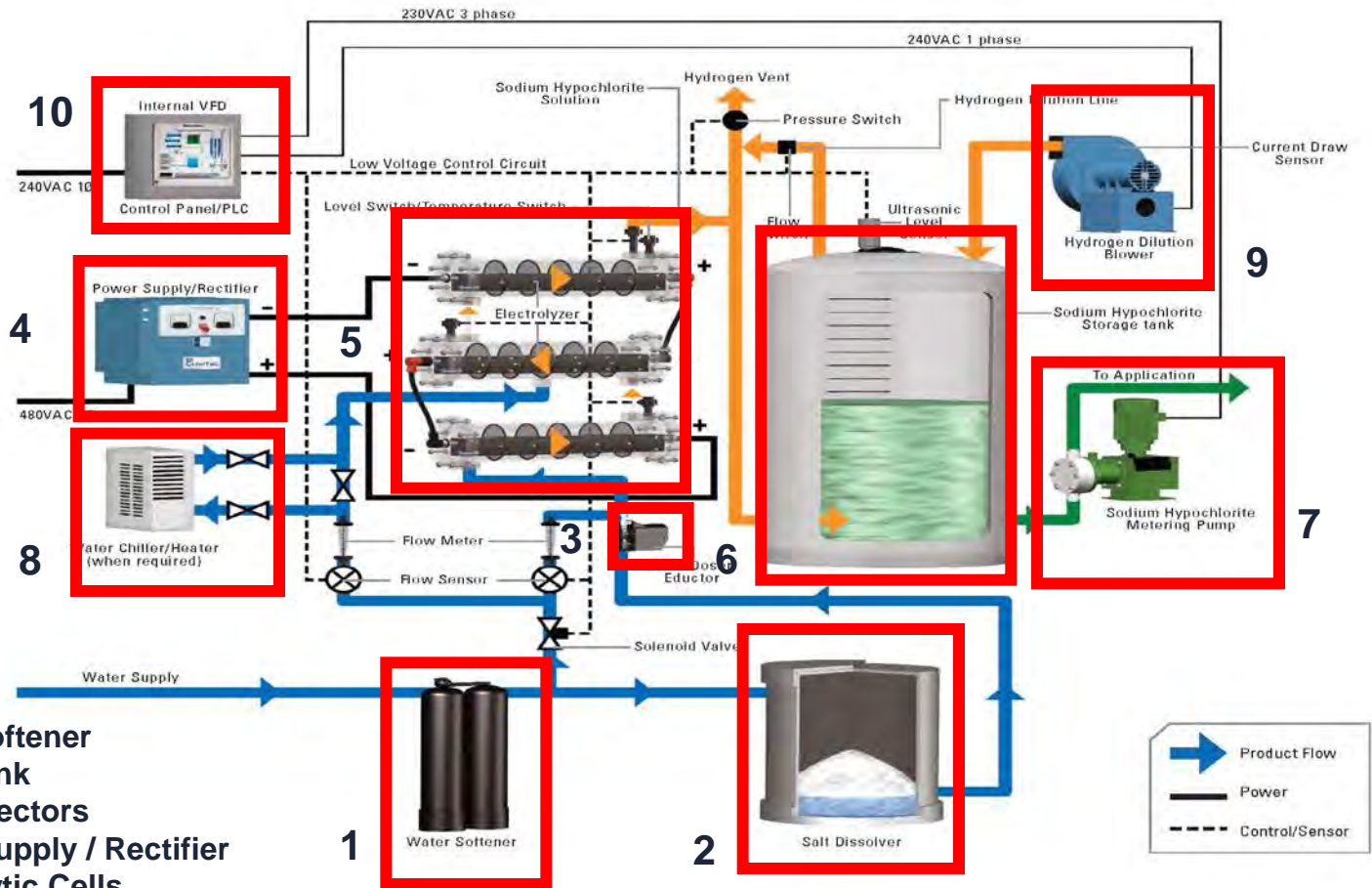
# On Site Sodium Hypochlorite Generation



- For each lb. equivalent of Cl<sub>2</sub>:
  - Salt (NaCl) 3.0 lbs
  - Softened Water 15 gal
  - Electrical energy 2 kWh
- For each pound of Cl<sub>2</sub> equivalent produced:
  - (15 gallons of 0.8% concentration Sodium Hypochlorite)
  - 1/35 lb. of H<sub>2</sub> gas produced (5.6 ft<sup>3</sup>)
- H<sub>2</sub> gas Immediately diluted upon production with air blower 100:1 to reduce H<sub>2</sub> to 25% of LFL



# On-site Sodium Hypochlorite Generation



1. Water Softener
2. Brine Tank
3. Brine Injectors
4. Power Supply / Rectifier
5. Electrolytic Cells
6. NaOCl Tank
7. NaOCl Dosing System
8. Water Chiller / Heater
9. Hydrogen Dilution system
10. Control Panel

On-Site Hypochlorite Generation System Schematic

# On-site Sodium Hypochlorite Generation



# On-Site Generated Sodium Hypochlorite

Advantages	Disadvantages
<ul style="list-style-type: none"><li>• Very effective at typical pH</li><li>• Proven &amp; reliable</li><li>• Often used for water</li><li>• Leaves a residual</li><li>• Minimal Concentration decay</li><li>• Low cost per pound</li></ul>	<ul style="list-style-type: none"><li>• Reacts with ammonia</li><li>• Effectiveness decreases-high pH</li><li>• THM Formation</li><li>• More complex process than Bulk</li><li>• Higher capital cost than bulk</li></ul>
<b>Safety</b>	<b>Safety</b>
<ul style="list-style-type: none"><li>• 0.8% liquid safer than Bulk</li><li>• Deliver &amp; Store salt. Small quantity of chlorine on-site</li><li>• Not highly regulated</li><li>• Secondary containment not required</li></ul>	<ul style="list-style-type: none"><li>• Can cause severe burns</li><li>• Potential for gas formation</li><li>• Secondary Containment required</li><li>• Safety issues often overlooked</li></ul>

# Chlorine Gas Feed Systems



Typical Chlorine Gas Feed System

## Chlorine Gas System Highlights

- Delivered to site as gas in cylinders or containers or rail cars
- Stored on-site in original containers
- Chlorine removed from containers as liquid or gas
- Mixed with water prior to injection

Automatic control valve controlled by residual

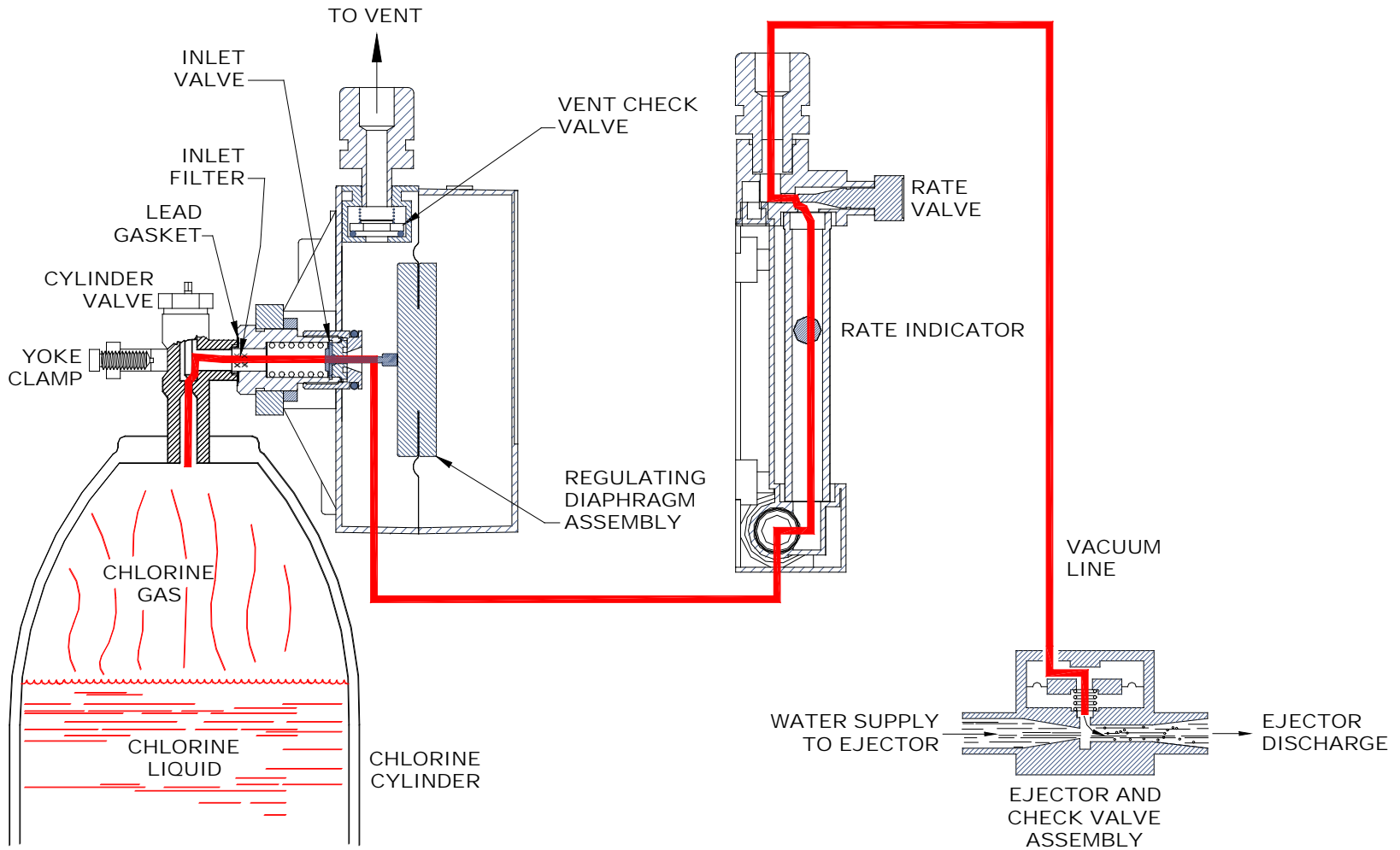
# Gas Properties Comparisons

	Chlorine (Cl <sub>2</sub> )	Sulfur Dioxide (SO <sub>2</sub> )	Ammonia (NH <sub>3</sub> )
Detectable Odor:	1.0 PPM	3 - 5 PPM	5 PPM
Throat Irritation:	5.0 PPM	8 - 12 PPM	400 PPM
Coughing:	20 PPM	20 PPM	1700 PPM
Dangerous in 30 - 60 Min.:	40 - 60 PPM	400 - 500 PPM	2500 - 4500 PPM
Specific Gravity (Air=1.0):	2.49:1	2.26:1	0.596:1
Color:	Yellow-Green	Colorless	Colorless
Solubility in Water (Lbs/Gal) :	0.1216	1.9	4.417
Expansion Factor (Liquid/Gas):	1:457	1:73	1:146

- Of the three gases, Chlorine (Cl<sub>2</sub>) is the most commonly used in the water and wastewater industry, followed by Sulfur Dioxide (SO<sub>2</sub>), and Ammonia (NH<sub>3</sub>).

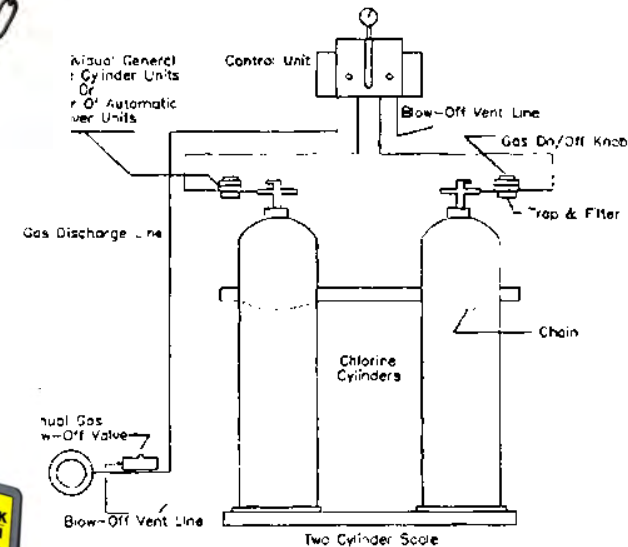
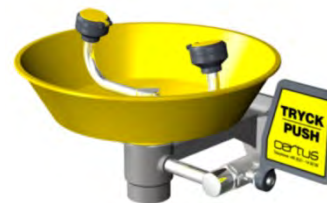


# How Gas Vacuum Feeders Work



# Your Father's Chlorine Gas Safety

- Pressurized systems
- Dangers Signs
- Ammonia bottle to find leaks
- Chain cylinders together
- Keep cool and away from combustibles
- Eye wash



# Modern Chlorine Gas Safety

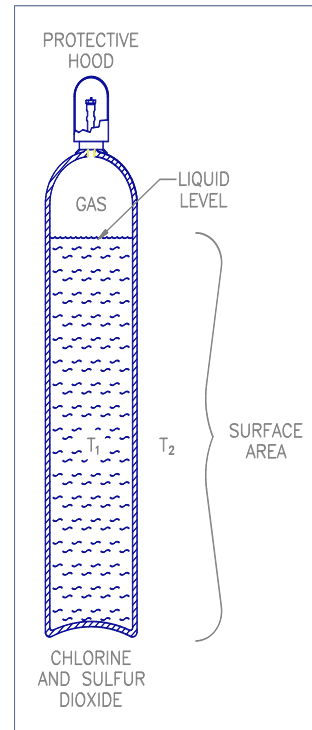
- Significant Technical Advances
- Residual analyzer with feedback loop
- Non-pressurized vacuum systems
- Chlorine gas leak detector
- Alarm Systems / SCADA
- Automatic shut off valve
- Vega scrubber system for small leaks
- Scrubber system for gas containment
- Positive pressure breathing apparatus
- Specialized chlorine safety kits
- Fully automated system to contain leaks
- Federal, state and local regulations
- Written Emergency Procedures



# Chlorine Gas Storage Cylinders



Fusible Plug



## Chlorine Gas Cylinders

Capacity 1 to 150 lb

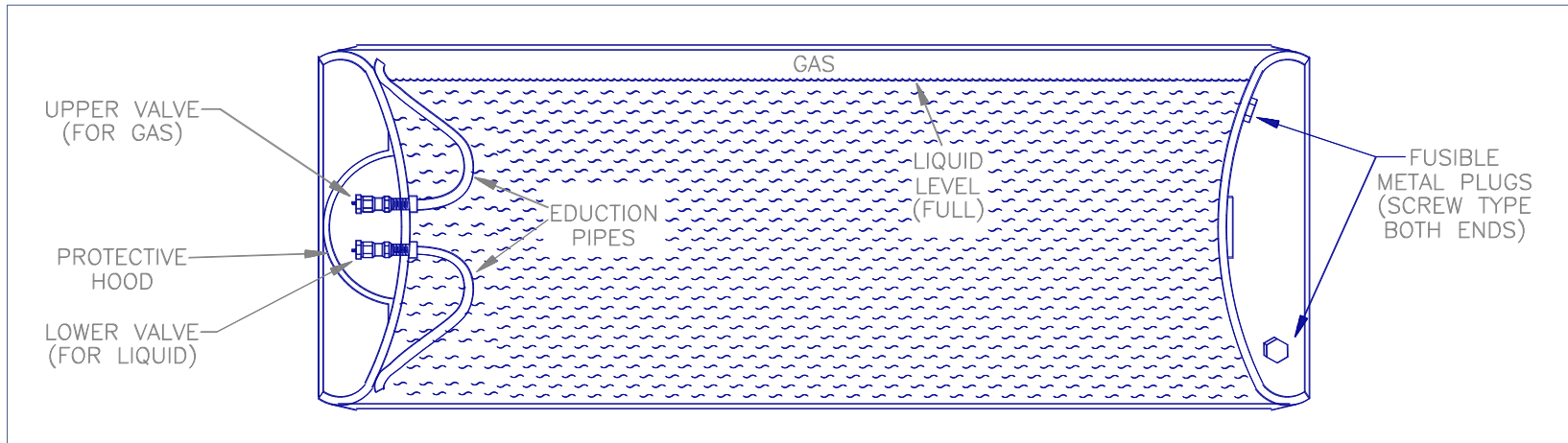
150 lb. predominate

One opening - valve connection

Standard cylinder valve with pressure relief device & fusible metal plug

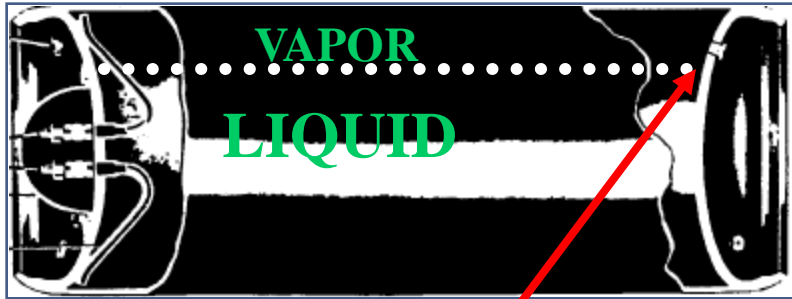
Fusible plug melts at 158-165°F

# Ton Containers

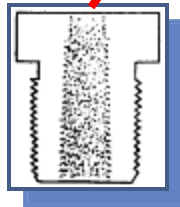


- Capacity - 2000 lb.
- Two identical valves
- Can use as gas feed (upper valve)
- Can use as liquid feed with vaporizer (lower valve)
- Six (6) fusible plugs - three (3) in each end, melt at 158-165°F

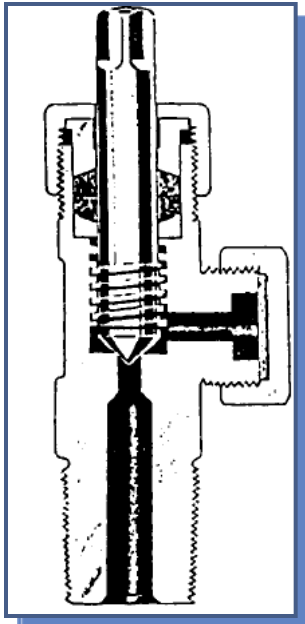
# ONE-TON CONTAINER LEAK SOURCES



Sides and Heads of Container  
Fusible Plugs and Feed Valves



Fusible Plug Core  
Fusible Plug Threads



Valve Packing  
Valve Seat  
Valve Threads – In & Out & Nut  
Broken Valve – usually at container thread



# Chlorine Gas

Advantages	Disadvantages
<ul style="list-style-type: none"> <li>• Very effective at typical pH</li> </ul>	<ul style="list-style-type: none"> <li>• Reacts with ammonia</li> </ul>
<ul style="list-style-type: none"> <li>• Proven &amp; reliable</li> </ul>	<ul style="list-style-type: none"> <li>• Effectiveness decreases-high pH</li> </ul>
<ul style="list-style-type: none"> <li>• Widely used for water</li> </ul>	<ul style="list-style-type: none"> <li>• THM Formation</li> </ul>
<ul style="list-style-type: none"> <li>• Leaves a residual</li> </ul>	<ul style="list-style-type: none"> <li>• Leaves residual - potential declor</li> </ul>
<ul style="list-style-type: none"> <li>• Low Capital Cost</li> </ul>	
<ul style="list-style-type: none"> <li>• Low cost per pound</li> </ul>	
Safety	Safety
<ul style="list-style-type: none"> <li>• Smaller room area required</li> </ul>	<ul style="list-style-type: none"> <li>• Gas phase dangers</li> </ul>
<ul style="list-style-type: none"> <li>• Widely used in industry</li> </ul>	<ul style="list-style-type: none"> <li>• Higher risk -catastrophic accident</li> </ul>
<ul style="list-style-type: none"> <li>• Significant advances in safety systems decrease risk</li> </ul>	<ul style="list-style-type: none"> <li>• Highly regulated – OSHA, NFPA, USEPA, USDHS</li> </ul>
	<ul style="list-style-type: none"> <li>• More training &amp; reporting required</li> </ul>

# Chlorine Containment Systems



Typical Chlorine Containment Systems for Ton Container

## Chlorine Containment Highlights

Steel shell containment system

Available for 150 lb. cylinders or one ton containers



# Chlorine Containment Systems -150# Cylinder



Typical 150 Lb Cylinder Containment System

# Chlorine Containment Systems



150 Lb Cylinder



One Ton Container

# Chlorine Containment Systems

Advantages	Disadvantages
Often used for wastewater	Relatively Expensive
Proven & reliable	One containment system required for each connection (cylinder or container)
Can reuse any chlorine captured	Extra time to change out cylinders or containers
Does not shut feed system down upon leak	
<b>Safety</b>	<b>Safety</b>
<ul style="list-style-type: none"><li>• Effective for leaks at tank</li></ul>	<ul style="list-style-type: none"><li>• No protection from leaks in line</li></ul>
<ul style="list-style-type: none"><li>• No release of chlorine at all for leaks at tank</li></ul>	
<ul style="list-style-type: none"><li>• Can enter room after leak</li></ul>	

# Automatic Valve Shut Off Systems

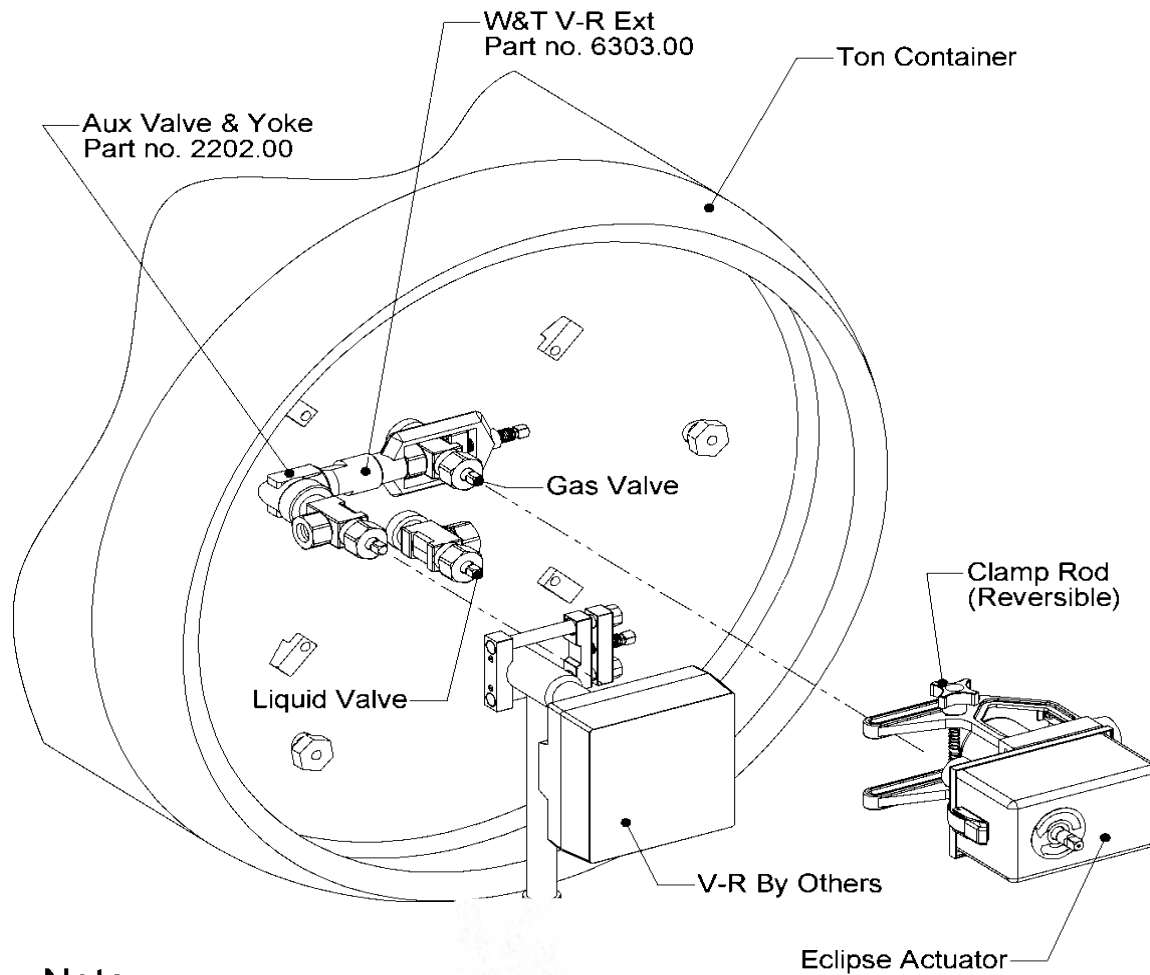


Automatic Actuator - 150 Lb Cylinder

## Automatic Valve Shut off System Highlights

- Actuators mount directly to standard valve assemblies on ton containers and cylinders
- Fully automated system to automatically close the valves
- Can be activated by
  - Leak Detector
  - Panic or Emergency Button
  - SCADA and Fire Alarm System

# Mounting the Emergency Actuator



**Note:**

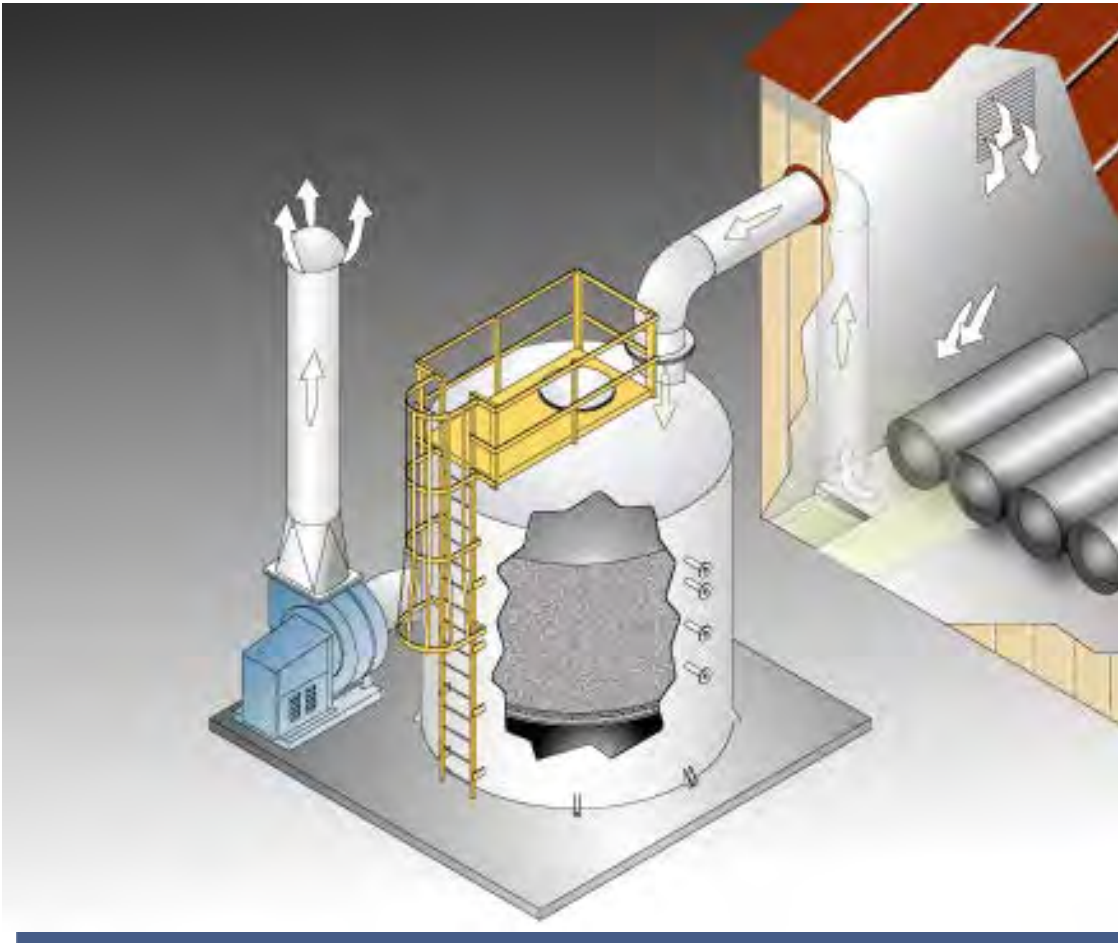
# Multi Tank System Automatic Shutoff System



# Automatic Valve Shutoff Systems

Advantages	Disadvantages
<ul style="list-style-type: none"><li>• Fully automatic system</li></ul>	<ul style="list-style-type: none"><li>• One system required for each tank in service</li></ul>
<ul style="list-style-type: none"><li>• Simple to operate and maintain</li></ul>	<ul style="list-style-type: none"><li>• Increases time to change out tank</li></ul>
<ul style="list-style-type: none"><li>• Available for cylinders and containers</li></ul>	
Safety	Safety
<ul style="list-style-type: none"><li>• Protect against line leaks</li></ul>	<ul style="list-style-type: none"><li>• Does not protect against plug or tank failure</li></ul>
<ul style="list-style-type: none"><li>• Completely automated</li></ul>	<ul style="list-style-type: none"><li>• Some gas leaks in room prior to automatic closure</li></ul>
<ul style="list-style-type: none"><li>• Battery operated – will operate in power outage</li></ul>	

# Emergency Chlorine Scrubbers



## Emergency Chlorine Scrubber Highlights

Wet or Dry Scrubbers Available

Major Components: 1) Instrumentation for activation 2) Exhaust Blower, 3) Treatment System 4) Vents to Atmosphere

Fully automatic – Start and stop based

Chlorine Room Design Very Important

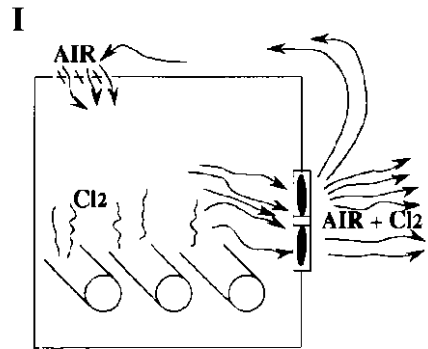
Typical Emergency Chlorine Scrubbers System



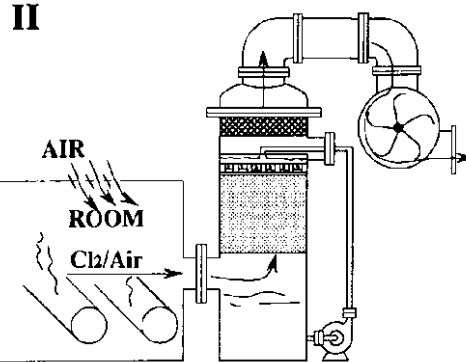
# Emergency Chlorine Scrubber History

## ADVANCEMENTS IN CHLORINE ABATEMENT TECHNOLOGY

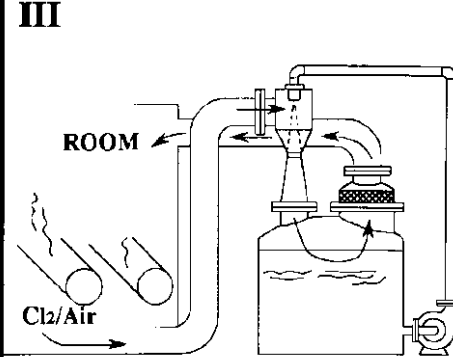
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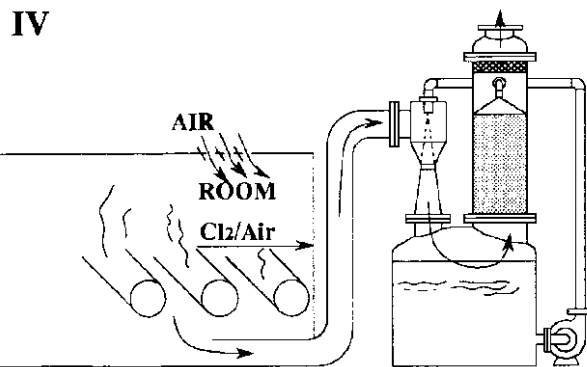
**SOLUTION BY DILUTION**  
ONE ROOM VOLUME  
CHANGE IN 1 OR 2 MINUTES  
NEGATIVE ROOM PRESSURE



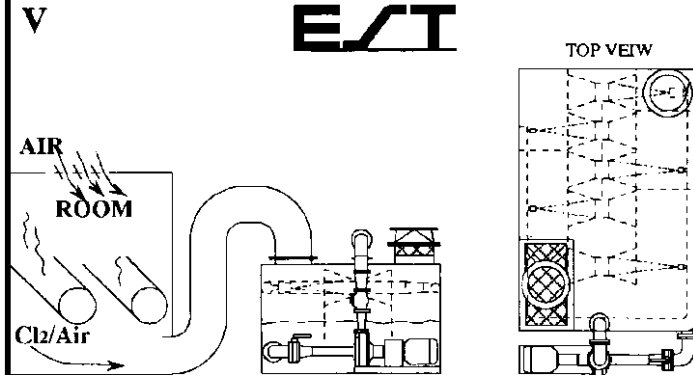
**DILUTION RATES WITH SLOW START TOWERS**  
POSITIVE TO NEGATIVE  
ROOM PRESSURE



**RECYCLE GAS SYSTEM WITH EJECTOR VENTURI SCRUBBER**  
POSITIVE ROOM PRESSURE



**ONCE THROUGH GAS SYSTEM WITH EJECTOR AND TOWER**  
EMISSIONS LESS THAN 1/2 IDLH  
NEGATIVE ROOM PRESSURE

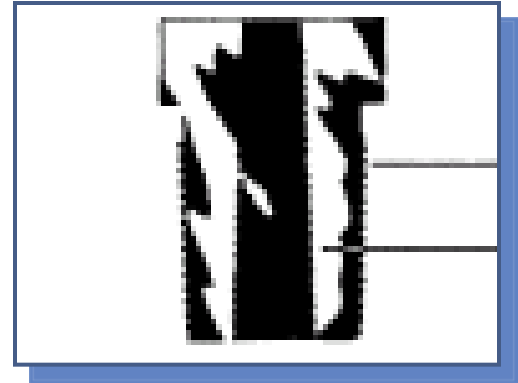


**LOW PROFILE ONCE THROUGH GAS**  
MULTI VENTURI PACKLESS SCRUBBER WITH 8' OVERALL HEIGHT ELIMINATES PACKED TOWER SCRUBBER  
EMISSIONS @ 1/2 IDLH & NEGATIVE ROOM PRESSURE

# Emergency Chlorine Scrubber Design

## FUSIBLE PLUG WORST-CASE

- Melts at approximately 160 °F
- Cl<sub>2</sub> at 80 °F = 117 psia vapor pressure
- Cl<sub>2</sub> at 160 °F = 325 psia vapor pressure
- 0.34" diameter orifice = 437 lbs/min at 160 °F
- Ton Container liquid plug empties ~ 5 minutes
- 437 lbs/min = 2380 scfm

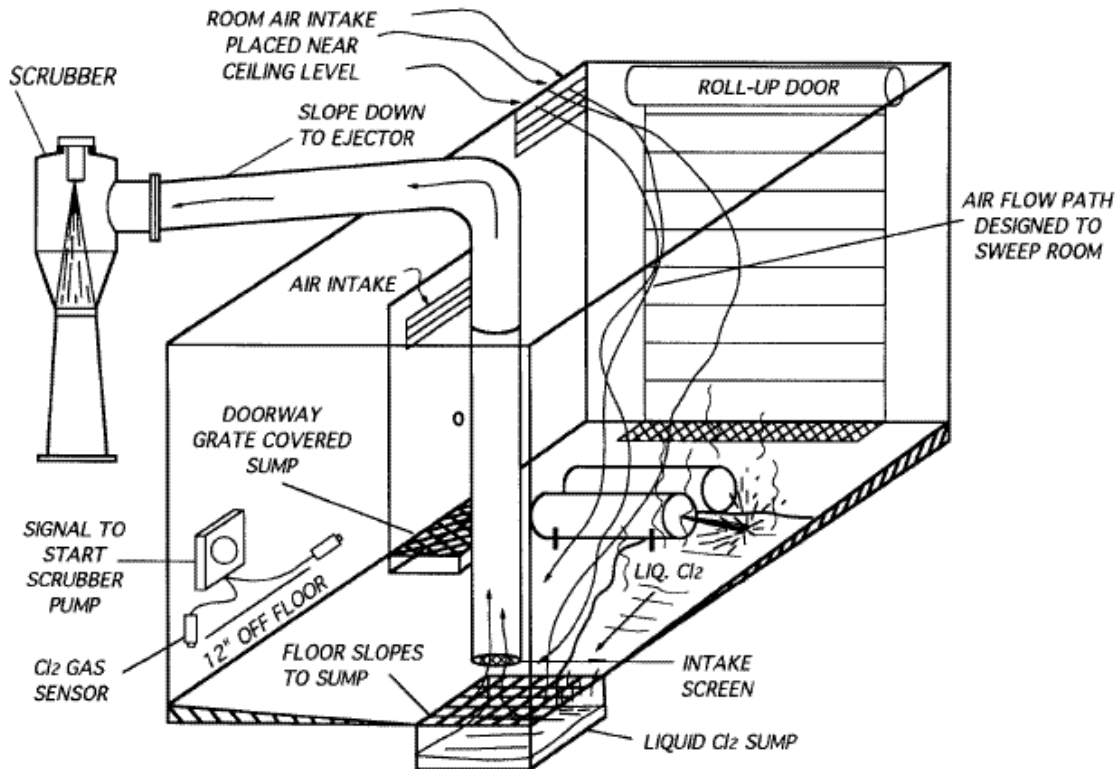


## Keep room at negative pressure

- Trend is to specify 3,000 scfm systems for one-ton containers.
- 150 lb Cylinders: Gas Leak Rate is 20 lbs/min = 110 scfm
- Scrubber Rate: Typically 250 cfm



# Gas Chlorine Room Design



## Typical Gas Chlorine Room

### Room Containment Design Considerations

Chlorine gas is heavier than air

Must Contain gas and Liquid Chlorine

Pick up duct should be 12-18 inches above floor

Slope floors – confined corner sump

Step down doorways, gratings covered

Flood room to check for liquid escape routes

Gas Detector 12 inches off floor

Dual Rooms – Dual Intakes

# Emergency Chlorine Scrubbers

## Types of Emergency Chlorine Scrubber Systems

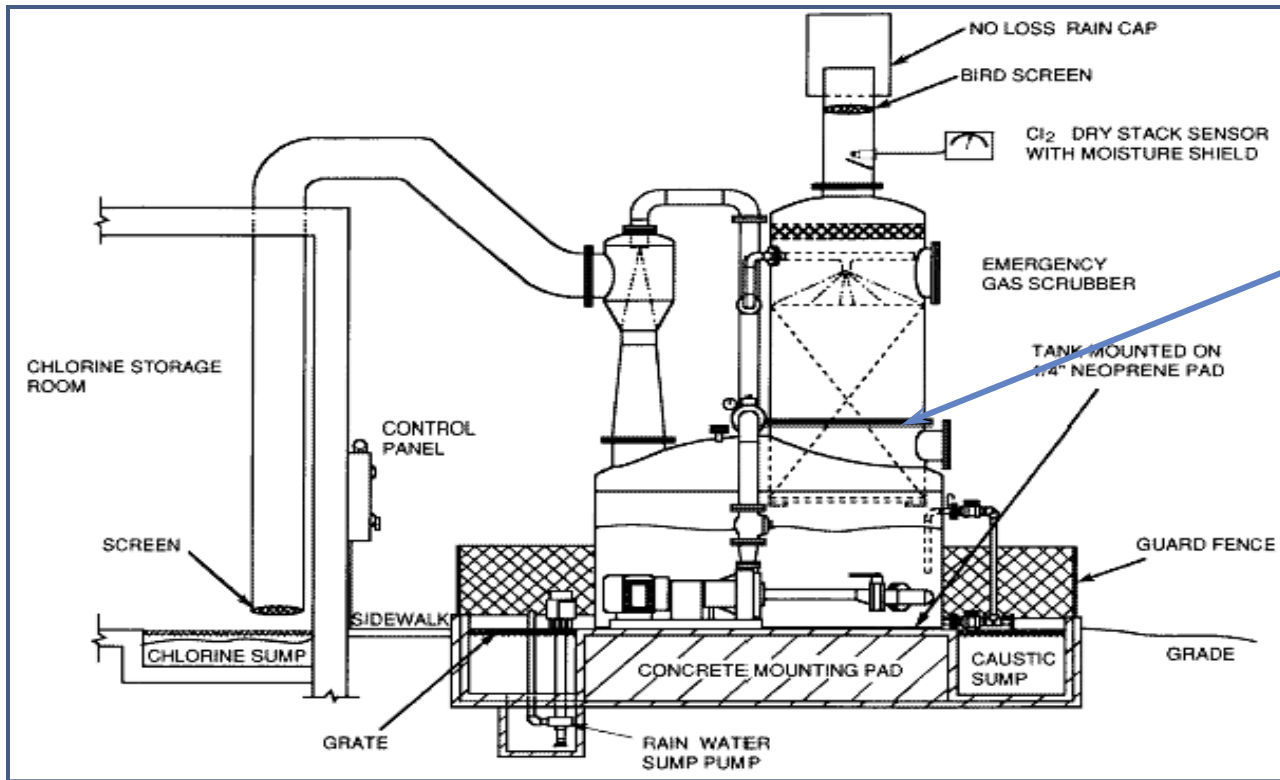
### 1. Wet Packed Emergency Chlorine Scrubber Systems

- Utilizes caustic to neutralize chlorine
- **$\text{Cl}_2 + 2 \text{NaOH} \Rightarrow \text{NaOCl} + \text{NaCl} + \text{H}_2\text{O} + 628 \text{ BTU/lb Cl}_2(\text{g})$**
- Upwards airflow, downwards chemical flow
- Produces hazardous waste material

### 2. Wet Pack-less Emergency Chlorine Scrubber Systems

- Same chemical reaction as packed tower
- **$\text{Cl}_2 + 2 \text{NaOH} \Rightarrow \text{NaOCl} + \text{NaCl} + \text{H}_2\text{O} + 628 \text{ BTU/lb Cl}_2(\text{g})$**
- Utilizes ejector venturi
- Produces hazardous waste material

# Emergency Chlorine Scrubbers



High Performance Packing Media

Typical Wet Ejector Venturi / Packed Tower

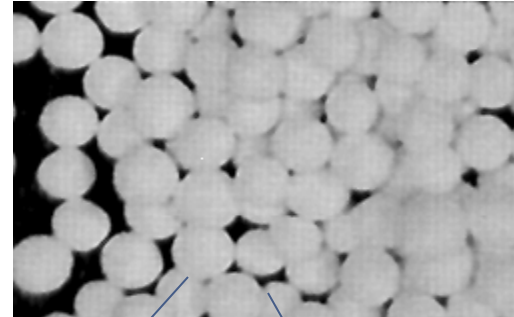
# Dry Emergency Chlorine Scrubbers

## 3. Dry Emergency Chlorine Scrubber Systems

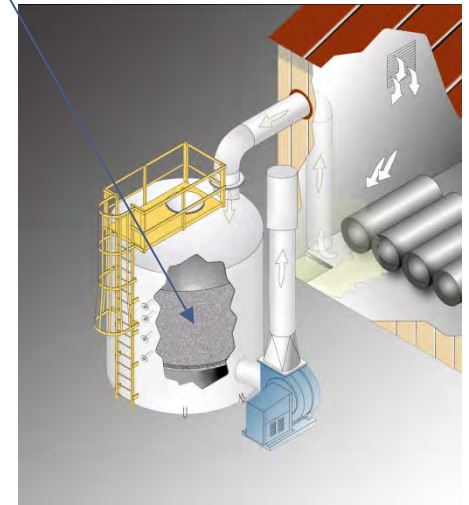
- Latest innovation in emergency scrubbers
- Utilize dry 4 mm impregnated activated alumina beads
- **$\text{Cl}_2 + \text{STS media} \Rightarrow \text{NaCl (Salt)}$**
- No liquid chemicals required –media lasts forever
- Produces non-hazardous waste material – landfill
- Automatic operation - minimum maintenance

# Dry Media Scrubber Features & Benefits as Compared to Traditional Caustic Scrubbers

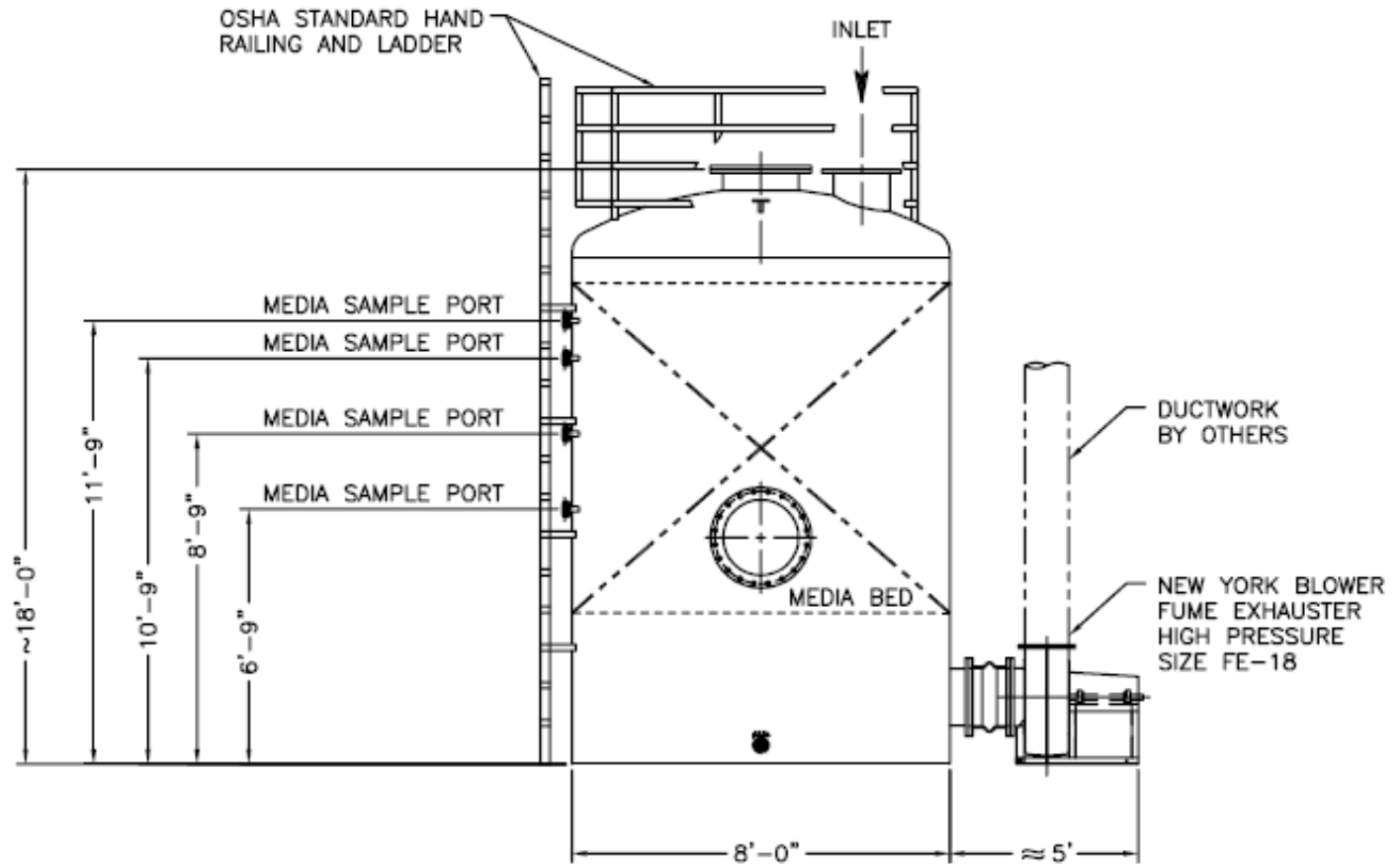
- No chemical maintenance
- New as well as exhausted media is non-hazardous
- One moving part - blower
- No chemical pumps
- Chemical leak containment is not required
- No heaters required in cold climates
- Safe
- User-friendly
- Dependable operation
- Tested and certified
- Low cost of ownership



Type "STS" 4 mm impregnated activated alumina beads

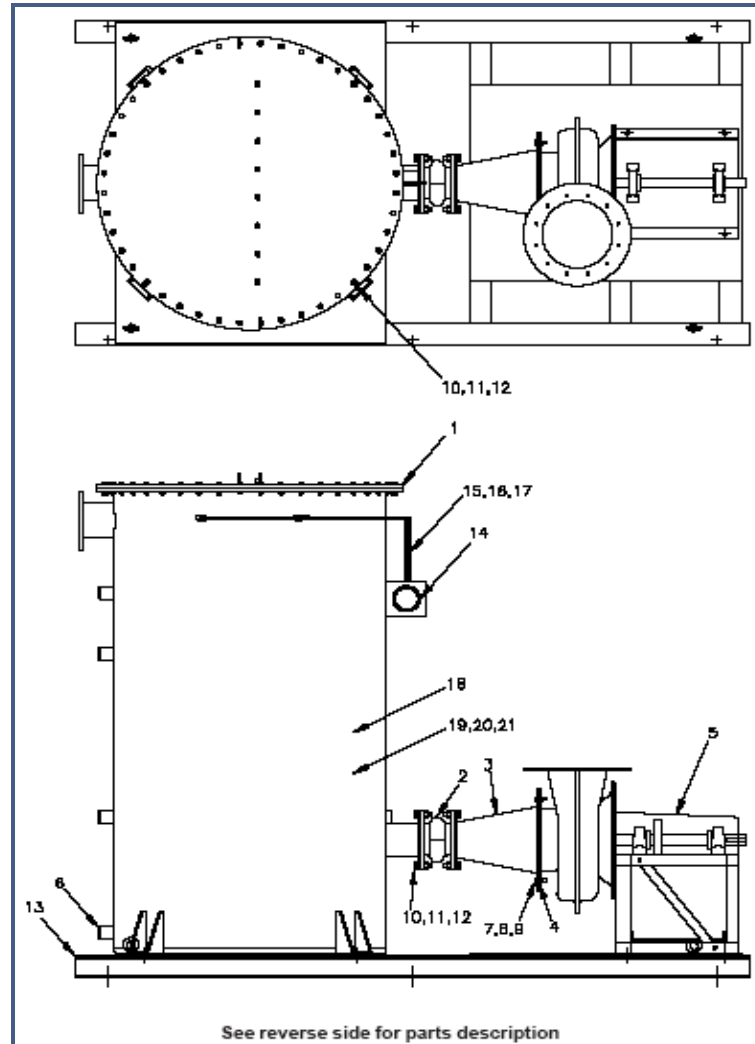


# Dry Media Scrubber (one ton container)





# Skid Mounted Dry Scrubber for 150 Lb Cylinder



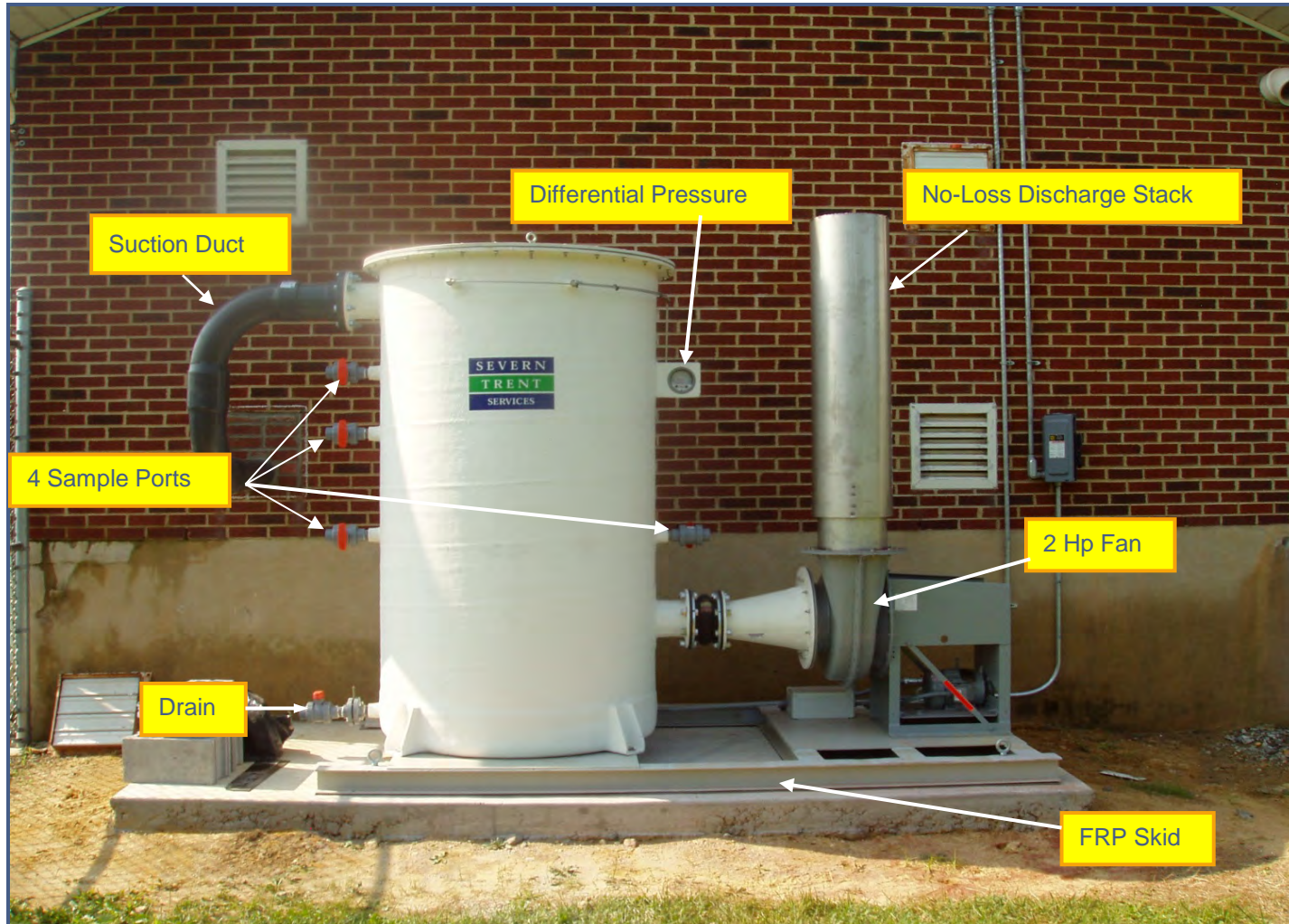
# 150 # Cylinder Scrubber Installed In Storage Room



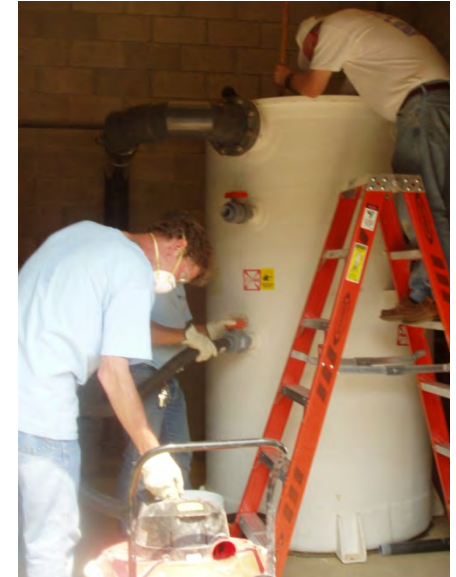
# Dry Scrubber Installed Outside Storage Room



# Dry Scrubber Skidded Assembly



# Scrubber Dry Media Refill



# VENT EXHAUST GAS ARRESTOR



- Treat vacuum regulator vent line
- Reduces room corrosion and outside releases
- Five gallon HDPE disposable bucket
- Dimensions are 10" Square x 15" Tall
- Passive – No fans required
- Pressure loss is less than same length of tubing
- Weighs 35 pounds with 'STS' 4 mm media beads
- Scrubs over 3 pounds of chlorine
- Media is non-toxic in fresh or spent forms
- Stackable for gas-side series mounting
- Visible Exhaustion Indicating Strips

# Emergency Chlorine Dry Scrubbers

Advantages	Disadvantages
<ul style="list-style-type: none"><li>Fully automatic systems</li></ul>	<ul style="list-style-type: none"><li>Like insurance – often are never used because not needed</li></ul>
<ul style="list-style-type: none"><li>Dry media scrubbers require minimum maintenance</li></ul>	<ul style="list-style-type: none"><li>Room design considerations</li></ul>
<ul style="list-style-type: none"><li>Medium capital cost</li></ul>	
<ul style="list-style-type: none"><li>Cost benefit to using gas significant</li></ul>	
<b>Safety</b>	<b>Safety</b>
<ul style="list-style-type: none"><li>Recommended by Ten States</li></ul>	<ul style="list-style-type: none"><li>Cannot enter room without safety equipment until cleared</li></ul>
<ul style="list-style-type: none"><li>Reduce liability significantly</li></ul>	
<ul style="list-style-type: none"><li>Proven safe and reliable</li></ul>	

# Safety Option Matrix – Cost vs Benefit

Safety Option	Description	Capital Cost	O&M Costs	Cost of Chlorine	Room Coverage	Ease of Operation	Operator Safety
1	<u>Gas - Auto Valve</u>	Low	Low	Low	Valve Only	Easy	Medium
2	<u>Gas – Container System</u>	High	Low	Low	Cylinder	Medium	Medium
3	<u>Gas- Wet Scrubber</u>	High	High	Low	Full Room	Medium	High
4	<u>Gas - Dry Scrubber</u>	High	Low	Low	Full Room	Easy	High
5	<u>Commercial Sodium Hypochlorite</u>	Low	Low	High	None	Easy	High
6	<u>On-site Hypochlorite Generation</u>	High	Medium	Medium	None	Easy	High



# Summary

- Chlorine gas, commercial hypochlorite and on-site hypochlorite are all very effective methods of disinfecting wastewater
- Commercial hypochlorite avoids many of the safety issues associated with chlorine gas but the cost is significantly more per pound of chlorine
- On-Site hypochlorite generation also avoids many of the safety issues associated with chlorine gas but with a lower cost per pound of chlorine than commercial hypochlorite
- There are various methods to improve chlorine gas safety including containment systems, automatic shutoff valves and emergency scrubbers
- Dry media emergency scrubbers have significantly less operation and maintenance costs compared to wet scrubbers
- A life cycle cost analysis should be completed to properly assess the costs and benefits of each safety solution

# Questions?

# THANK YOU!

Contact:

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