Preventing Corrosion Under Insulation (CUI) – A Chlorine Institute Perspective

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Examples of CUI

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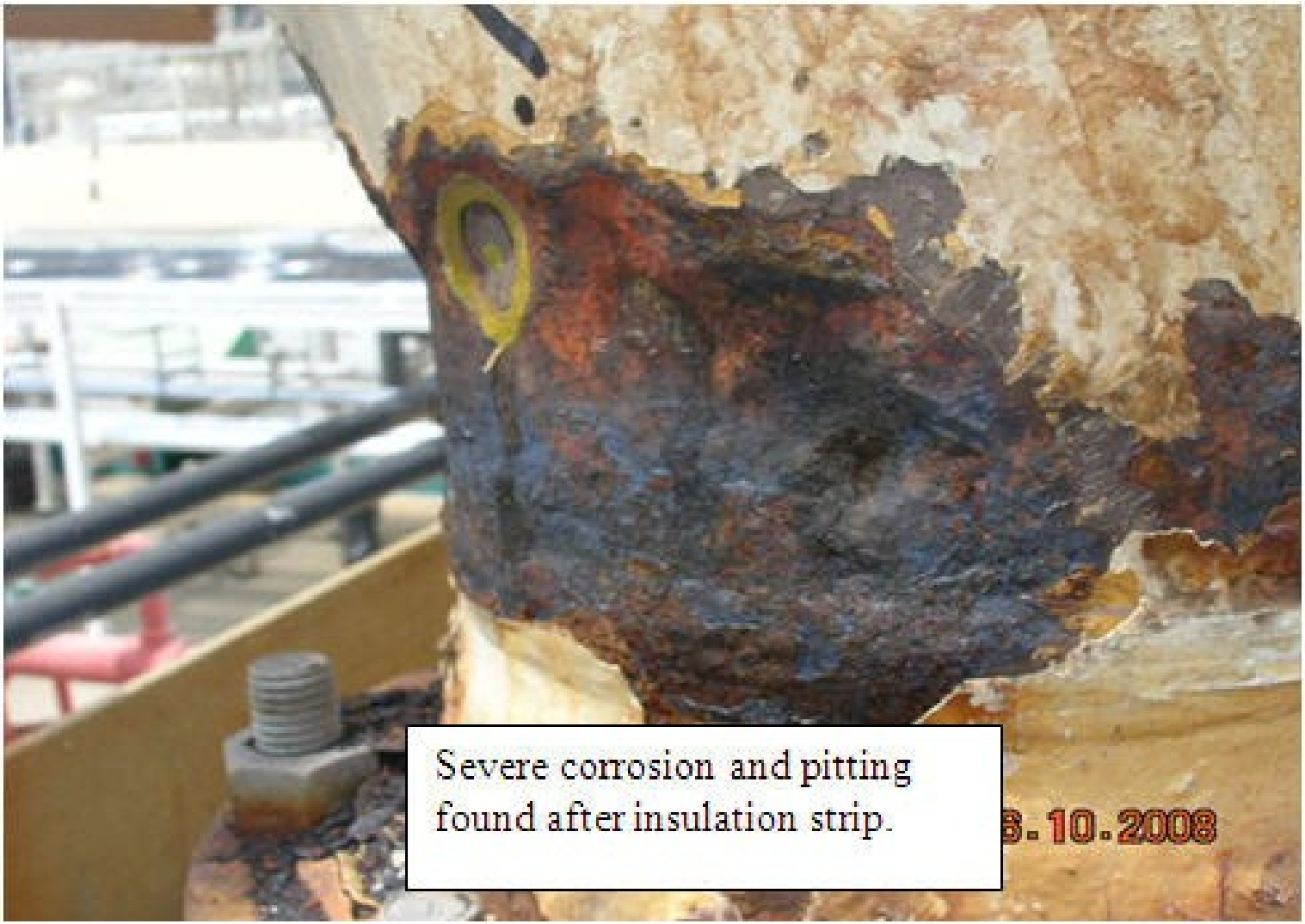
oxides to 5" thick

Cladding with hole


CUI suspect area.Not sealed at ¾" piping.
06.08.2008



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The area of severe external corrosion before the insulation was removed.
C.U.I. (corrosion under insulation)

Section of pipe after the insulation was removed. Replace from the 4" flange back 2' pass the double 45° due to severe CUI. Remaining wall 0.097".

Corrosion in the Chlorine Environment

- Chlorine is readily reactive
- Careful control can help prevent corrosion

Bottom of Severely Corroded Chlorine Cylinder

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Conditions That Support CUI

- Carbon Steel
- Operating conditions 25°F (-3.9°C) and 330°F (165.6°C)
- Common thought – That any temperature above 212°F (100°C) would not be a problem. Not So!
- **Use of incompatible construction materials**
- **Wet insulation is the root cause!**

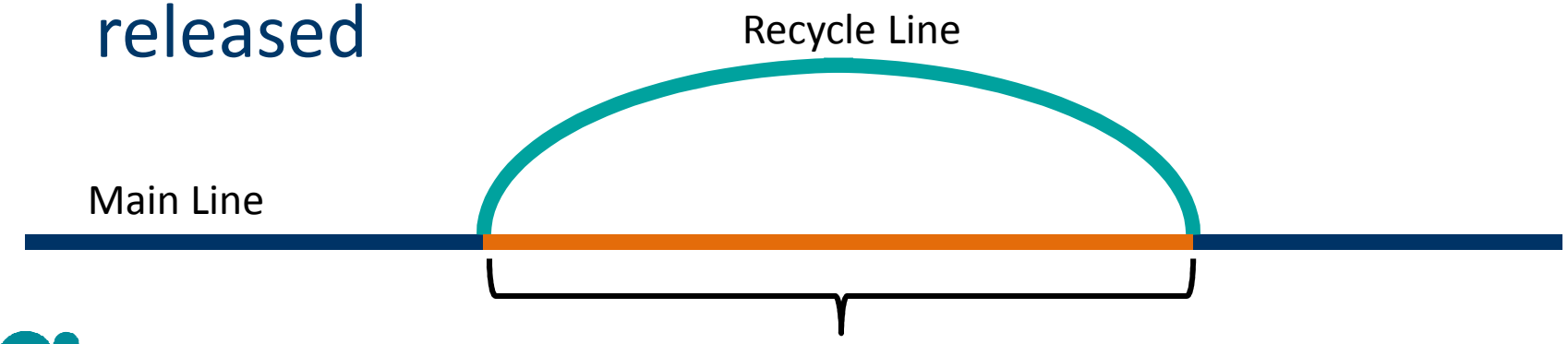
Inspection Techniques

- Strip insulation / Ultrasonic Meter
- Install inspection plug / Ultrasonic Meter
- Other techniques:
  - Guided Wave Ultrasonic
  - Neutron Backscatter
  - Digital Radiograph
  - Pulse Eddy Current

Moisture Intrusion

2004 Incident:

- Spare chlorine recycle line put into service during maintenance activity
- Leak quickly developed
- 1800 pounds (816.5 kg) of chlorine were released



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Moisture Intrusion

2004 Incident, continued:

- Chlorine + Water <-> Hypochlorus Acid + Hydrochloric Acid

- The acid rapidly corroded the metal, causing the release

Why is Moisture Content Important?

Wet Chlorine can be very corrosive to steel equipment:

- Equipment deterioration
- Leaks
- Plugging of lines, valves, or equipment
- Sluggish or inconsistent valve operation
- High pressure drops
- Inconsistent system operation
- Product quality problems

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The Chemistry of Iron and Steel Corrosion in Chlorine Service

- Normally dry chlorine reacts and forms a thin but dense and tough layer of Ferric Chloride ($FeCl_3$) that acts as a corrosion inhibiting layer
- Free water can destroy that corrosion barrier and result in aggressive corrosion
- Water reacts with $FeCl_3$ to form a number of less-resistant hydrates

The Chemistry of Iron and Steel Corrosion in Chlorine Service (2)

- Water dissolves $FeCl_3$ and its hydrates and forms Hydrochloric Acid
- Water reacts with chlorine to generate Hydrochloric and Hypochlorous acid
- The acids generated can quickly corrode the steel

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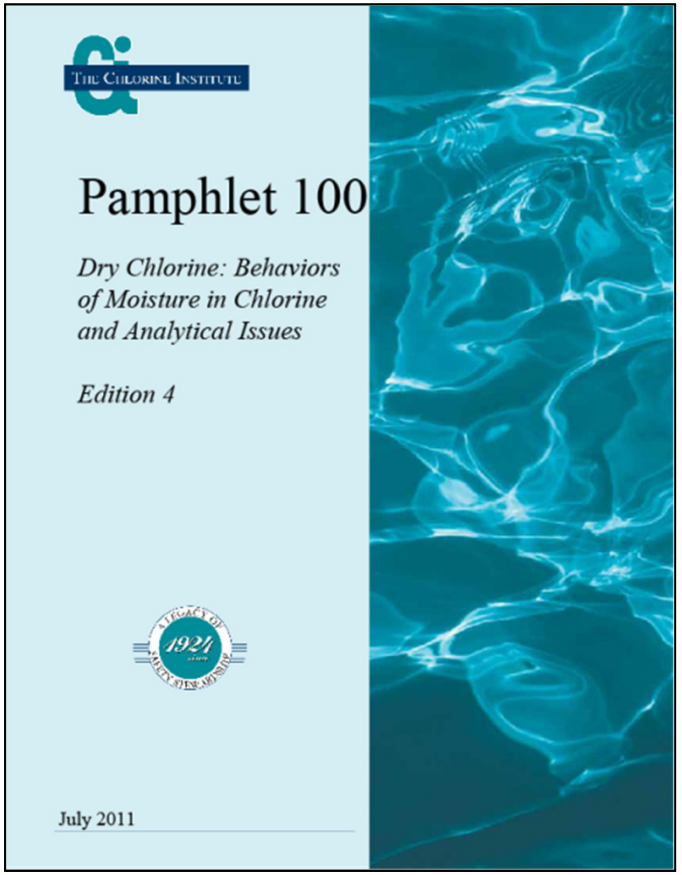
Wet Chlorine/Dry Chlorine - A Complex System

A single point definition is inadequate:

- A certain water content in liquid chlorine can be “dry” in one set of conditions yet “wet” under another set of conditions
  - e. g., 300 ppm water
    - Dry at 50°F (10°C)
    - Wet at -4°F (-20°C)
- Water content of chlorine vapor will be about 4x the water content of the liquid chlorine from which it vaporizes

Wet Chlorine/Dry Chlorine - A Complex System (2)

- Best way to manage is to keep moisture as low as possible
- A good resource for more detailed understanding is CI Pamphlet 100
- Pamphlet 100 is available to download for free from CI's bookstore, bookstore.chlorineinstitute.org



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Keeping Moisture Out of Your System

Manage the pad/purge gas process:

- Compressed air – at most -40°F (-40°C)
  - Properly designed – water removal and drying
  - Regularly monitored – on-line moisture analyzer
  - Don't blindly trust the on-line monitor – regularly validate dew point manually throughout the system
  - Well maintained – scheduled maintenance includes emphasis on water removal system, driers and monitors
  - Dedicated to the chlorine system
- Supplied Nitrogen
  - Don't blindly trust your supplier – Periodically validate dew point manually throughout the system

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Keeping Moisture Out of Your System (2)

Keep replacement parts moisture free:

- Angle valve nipples ("stabbers") – Most commonly found with high moisture exposure
  - Cap the threaded end and blind the flange end
  - For very short duration rubber stoppers will suffice
  - Keep stabber out of the weather
- Hoses, fittings, valves

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Keeping Moisture Out of Your System (3)

Minimize any portions of your system that stay open when performing maintenance:

- Blind flanges -- plug off equipment even when you think the repair may be short

The $FeCl_3$ that is naturally on the equipment rapidly reacts with the humidity in the air:

- $FeCl_3$ becomes much less resistant barrier
- $FeCl_3$ hydrates and holds water then releases it when chlorine is introduced the system

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Keeping Moisture Out of Your System (4)

- Dry the portion of your process that has been open after maintenance
- Many think that drying is necessary only after water washing
- At a minimum, purge the system thoroughly with dry pad gas

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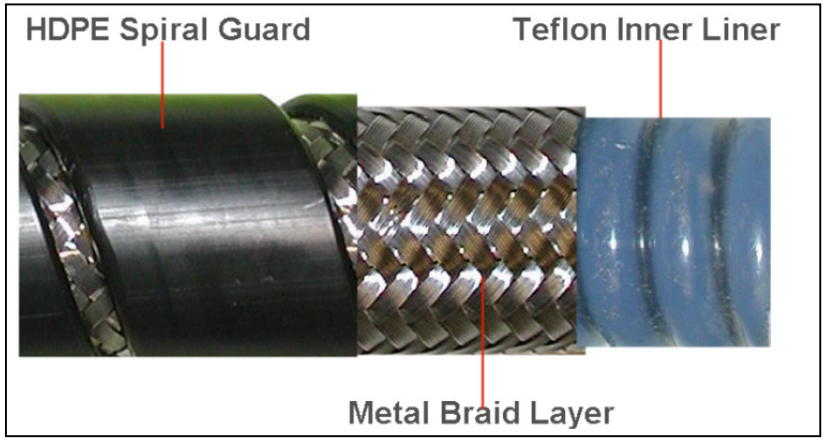
Keeping Moisture Out of Your System (5)

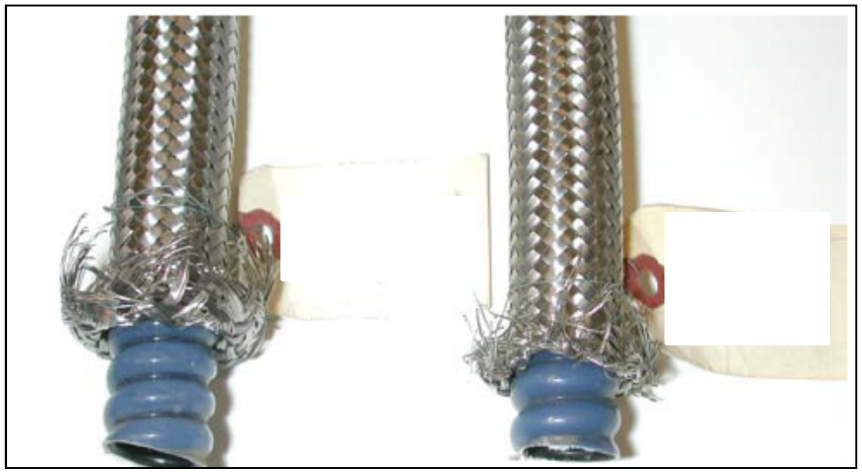
- Drying can be enhanced by
  - Higher pad gas flows
  - Lower dew point pad gas
  - Heating pad gas or preheating the system (e.g. with steam)
  - Swinging the pad gas pressure in the system
- Test the gas dew point in and out of the process at low flow
  - Low flow allows “equilibrium” to be established
  - Dew points should be “the same” in and out

Incompatible Materials

2002 Incident:

- 48,000 pounds (21,772 kg) of chlorine released over 3 hours
- 66 people sought medical treatment
- Hose with incompatible braid was put into service, leading to corroded hose, causing the release
- Emergency shutdown system did not function as designed





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Incompatible Materials

KTVI-TV Aerial Footage of Incident

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Incompatible Materials

2002 Incident, continued:

- Positive material identification is key
- The supplied hose was not what the company ordered
- Difficult to distinguish between different hoses

Titanium Tubing Valve on Cl_2 Accumulator, 2003

Failure after ~2 hrs of service Valve Stamped "HC"

Valve Body actually Titanium

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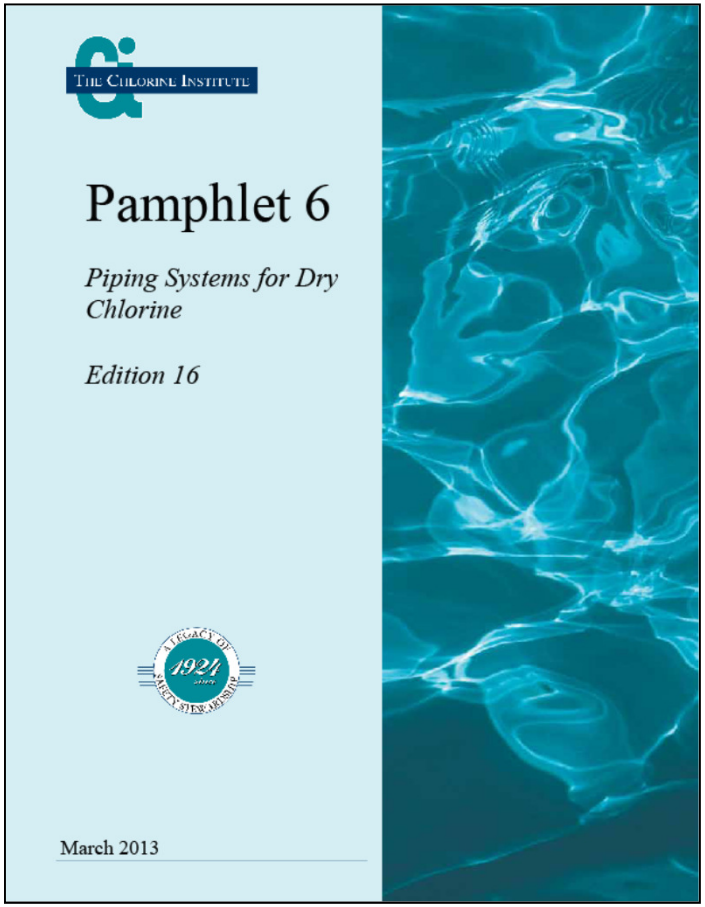
Materials Compatible with **Dry** Chlorine Service

- Carbon Steel Piping
- Hastelloy C-276 Hose
- Virgin PTFE-Core Hose
- Copper Tubing
- Monel Tubing
- Select Plastics
- Specific recommendations can be found in Pamphlet 6, which is free to download from our bookstore.



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Positive Material Identification (PMI)

PMI Testing /Analysis:

- Refers to the identification and analysis of metal alloys based upon elemental composition
- PMI is a non-destructive testing technique
- PMI is typically used to:
  - Verify alloy, grade or composition specified
  - Look for unwanted impurities
- PMI analyzers are portable

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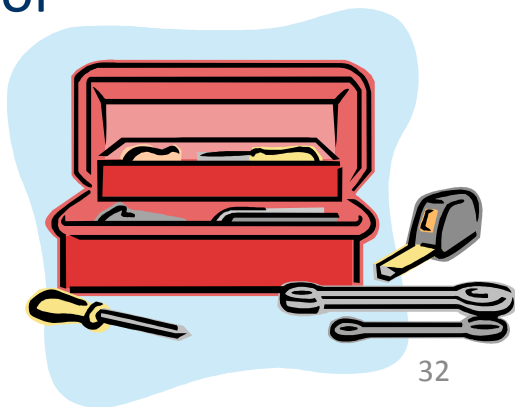
Positive Material Identification Limitations

PMI is a Tool in the Toolbox … but you need to understand the limitations

- Use of PMI is a preventative measure to detect improper materials of construction, specific to alloys
- PMI Analyzers cannot detect all elements
- PMI Analyzers cannot differentiate polymers
- PMI cannot determine defects in the casting or formation process



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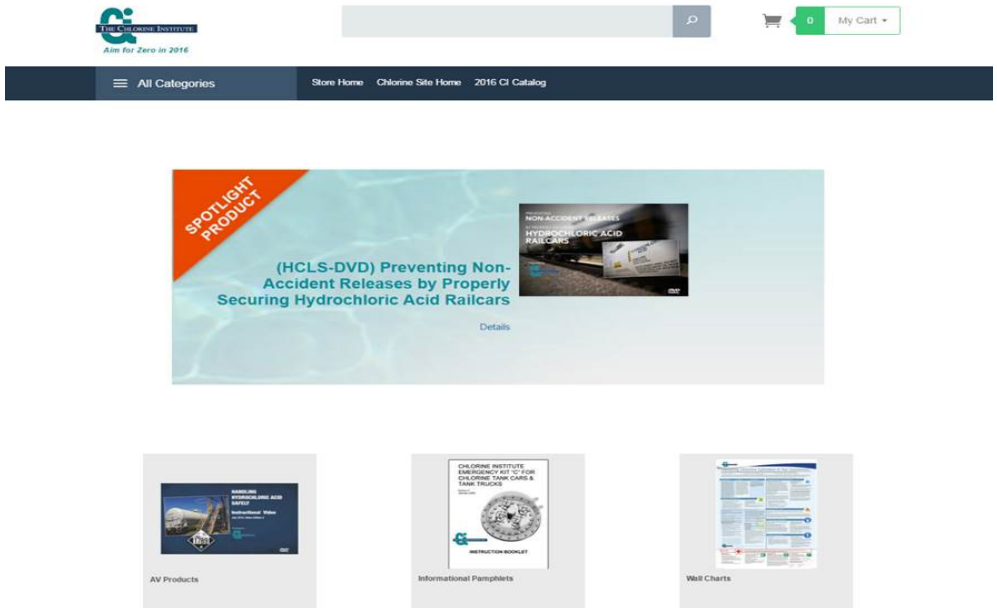
Useful CI Pamphlets

- Pamphlet 5: Bulk Storage of Dry Chlorine
- Pamphlet 6: Piping Systems for Dry Chlorine
- Pamphlet 60: Chlorine Pipelines
- Pamphlet 72: Properties of Chlorine in SI Units
- Pamphlet 100: Dry Chlorine: Definitions and Analytical Issues
- Pamphlet 164: Reactivity and Compatibility of Chlorine and Sodium Hydroxide with Various Materials
- Pamphlet 167: Learning from Experience

How to Download Free Safety Pamphlets

1. Go to https://bookstore.chlorineinstitute.org/

2. Search for the pamphlet you want OR browse the catalog.



3. Click on the desired pamphlet.

Thank You & Questions

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