
U.S. Chemical Safety and Hazard Investigation Board
CSB
Preventing Hydraulic Shock:
Millard Refrigerated Services, Inc.
Anhydrous Ammonia Release
Lucy Tyler, CSP, CIH
U.S. Chemical Safety Board
GCAP Ammonia Safety Day - May 28, 2015
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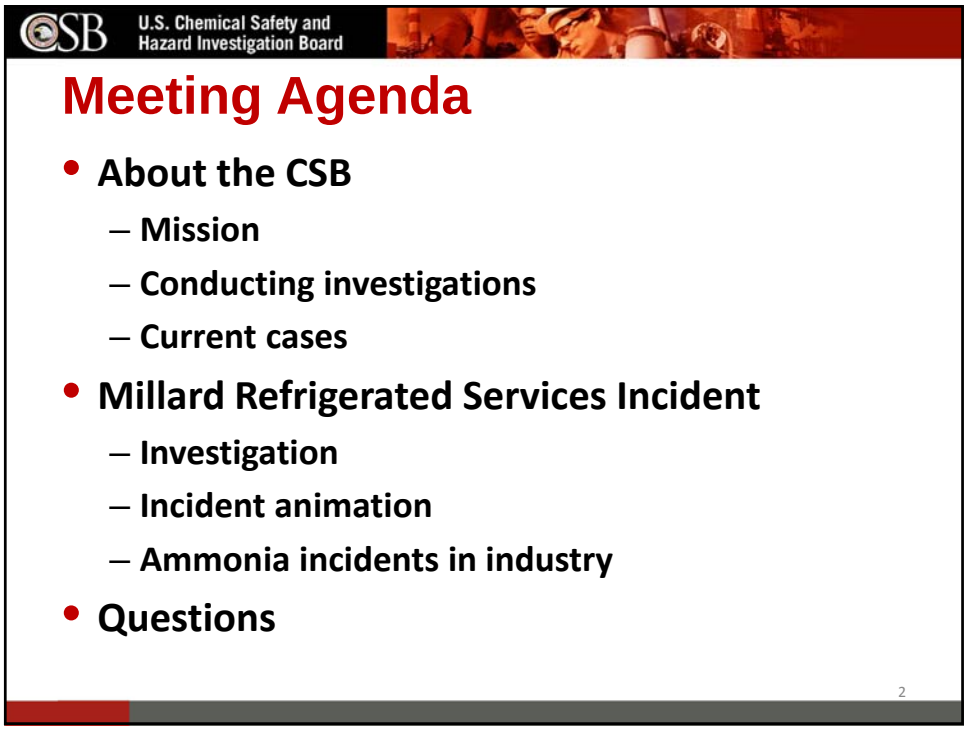
CSB
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Meeting Agenda
About the CSB
Mission
Conducting investigations
Current cases
Millard Refrigerated Services Incident
Investigation
Incident animation
Ammonia incidents in industry
Questions
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U.S. Chemical Safety and Hazard Investigation Board

About the CSB

- Independent U.S. Federal Agency
- Investigates chemical incidents at fixed facilities
- Authorized by United States Congress in 1990
  - Clean Air Act

U.S. Chemical Safety and Hazard Investigation Board

About the CSB

- Modeled after the NTSB
- Five member Board
  - Currently 3 members
  - Appointed by the President and confirmed by the Senate
- Offices in Washington, DC and Denver, CO

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About the CSB

- The CSB independently investigates incidents and makes its findings public

- We are not an enforcement agency
- We do not issue fines or penalties
- We determine root causes
- We make recommendations

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Common Recommendation Recipients

- Regulatory Agencies
  - OSHA, EPA
- State and local Agencies
- Industry consensus standard organizations
- Trade associations
- Companies involved in the incident

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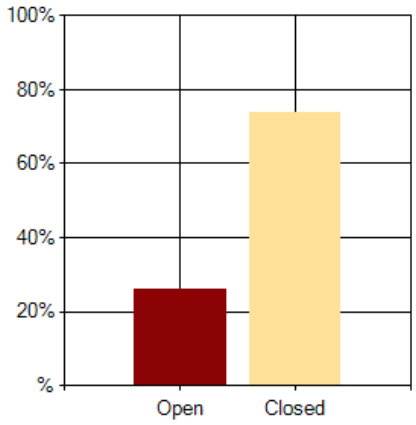
Recommendations Statistics

- 189 (26%) Open Recommendations (awaiting response)
- 548 (74%) Closed Recommendations



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Conducting Investigations: Incident Screening

- Collect information on recent chemical incidents
  - Media sources
  - National Response Center
  - Other regulatory agencies
- Follow-up with company and local emergency responders
  - Board makes decision to deploy investigation team
  - Deploy within 48 hours

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Conducting Investigations: Field Deployment

- Arrive on scene
- Collect information and company documents
- Interview witnesses, company personnel and emergency responders
- Take photos
- Obtain physical evidence for sampling and testing

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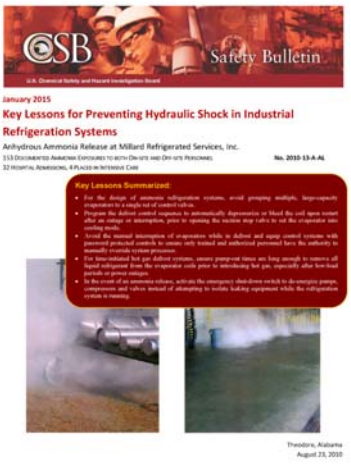
Conducting Investigations: Draft Report

- Investigation Reports
- Safety Studies
- Case Studies
- Safety Bulletins



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Conducting Investigations: Public Meeting

- The CSB investigation team releases findings to the public
- CSB Board votes on the investigation report and recommendations
- Investigation product released on CSB website


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Current CSB Investigations

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West Fertilizer

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Freedom Industries

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Caribbean Petroleum

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Williams Olefins

Photo: Reuters

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DuPont La Porte

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ExxonMobil Torrance

Photo: LA Times

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Macondo Blowout and Explosion

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Questions?


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Millard Refrigerated Services, Inc.
Anhydrous Ammonia Release
August 23, 2010
Theodore, AL
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Company Overview
Millard Refrigerated Services Inc. operated as a refrigerated warehouse and distribution company.
36 facilities in the United States and Canada in 2010
Headquartered in Omaha, NE
Millard was acquired by Lineage Logistics in 2014
The Theodore facility became Millard Maritime
– Not acquired by Lineage
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Millard Theodore Facility

- The Millard Theodore, AL facility was a marine export facility.
- Stored refrigerated product for international shipment.

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Millard Theodore Facility

- 240,000 square foot cold storage facility
- Could store 24 million pounds of frozen meat products
- 5 product storage freezers
- 3 blast freezers that were capable of rapidly freezing product

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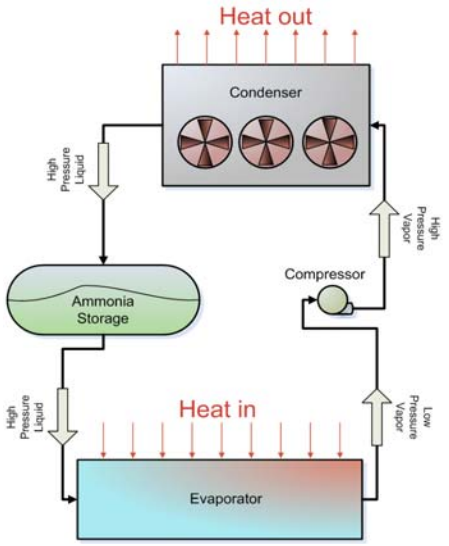
Ammonia Refrigeration

- Millard operated a 143,000-pound capacity system.
- The refrigeration system is a closed system that removes heat when ammonia liquid changes to a vapor.



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Anhydrous Ammonia (NH_3) Properties

- Colorless gas at normal temperature and pressure
- Irritating odor
- Produces a visible white cloud when released in atmosphere
- Irritating to the respiratory system
- Exposure to high concentrations can result in death
- Can deflagrate if concentration is in the explosible range

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Millard Incident Animation
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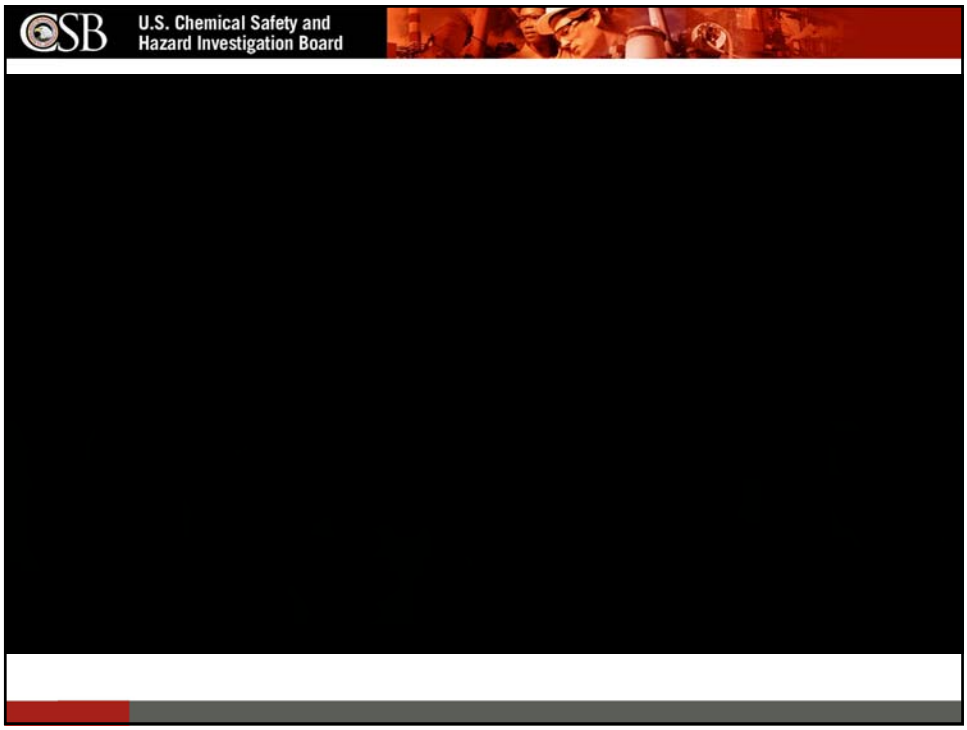
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Incident Consequences – Offsite Ammonia Exposures

- 32,100 lbs NH_3
- Deepwater Horizon oil spill clean-up operations were ¼ mile south of Millard.
- Over 800 contractors working outdoors on the day of the incident.

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Incident Consequences – Offsite Ammonia Exposures

- 152 offsite contractors and ship crew reported ammonia exposure symptoms.
  - 32 hospitalized, 4 placed in intensive care
- The Mobile Fire Department and EMS set up triage near the Deepwater Horizon clean up site
  - Many evaluated, treated and released
- CDC ATSDR conducted an onsite exposure survey following the incident.

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Incident Consequences – Offsite Ammonia Exposures

- Common symptoms reported:
  - Headache (71%)
  - Shortness of breath (64%)
  - Coughing (62%)
- Other symptoms included
  - Eye irritation
  - Nausea
  - Chest pain
  - Dizziness
- No documented long-term impacts from ammonia exposure

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Incident Consequences – Millard Injuries

- One Millard employee was overcome with ammonia while working in the crane loading ships docked at Millard.
  - He attempted to escape and fell several feet, injuring his leg
  - Reported symptoms consistent with ammonia exposure
- Another Millard employee was treated for heat-exhaustion after responding to the release.

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Additional Incident Consequences

- Mobile County Emergency Management ordered a shelter-in-place order for nearby community
- 8 million pounds of product stored at Millard contaminated by anhydrous ammonia
- The U.S. Coast Guard temporarily halted water traffic in the industrial canal until the release was contained

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Preliminary Information

- Millard experienced a power outage for 7 hours on the night before the ammonia release incident
- Around 8:45 am, a group of blast freezer evaporators were in the defrost cycle
- An operator was troubleshooting alarms in the control system after the prior power outage

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Preliminary Information

- Shortly before 9:00 AM
- Millard was loading two international ships with frozen poultry.
- An ammonia release occurred inside a blast freezer in the Millard facility.
- Set off NH_3 alarms

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Preliminary Information

- At about the same time, a visible cloud appeared on the roof of the facility
- Traveled south across the canal

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Suction Piping Damage

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Evaporator Coil Damage – Blast Freezer

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Defrost Cycle Controls

Pump Out	• Liquid ammonia feed valve closes • Pump Out cycle initiated
Soft Gas	• Main suction valve closes • Soft gas valve opens and evaporator coil pressure increases
Hot Gas	• Main hot gas valve opens • Defrosting begins
Equalization	• Soft and hot gas valves close • Pressure bleed opens and system pressure reduces
Fan Delay	• Bleed valve closes • Evaporator coil temperature decreases
Refrigeration	• Main suction valve opens • Liquid ammonia feed opens for refrigeration cycle and fans are energized

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Defrost Time of Incident

Normal Sequence	Day of Incident
Pump-out	Pump-out
Soft gas	Soft-gas
Hot gas	<interrupted>
Equalization	<interrupted>
Fan Delay	<interrupted>
Refrigeration	Refrigeration (“Max Cool”)

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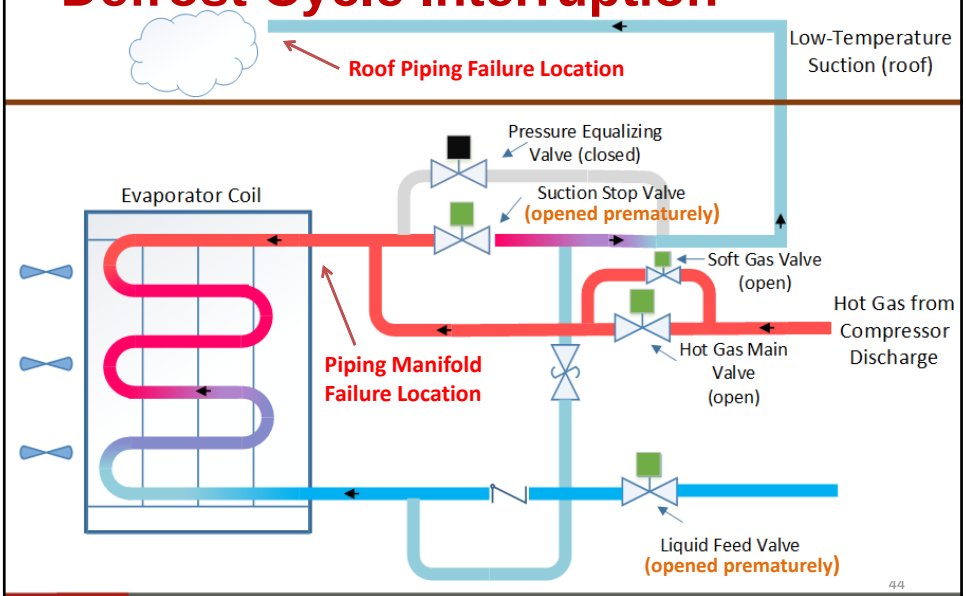
Defrost Cycle Interruption



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Hydraulic Shock

- Evaporator piping in ammonia refrigeration systems is susceptible to hydraulic shock during the hot gas defrost cycle.
  - Typically during the transition between low-temperature liquid ammonia and hot, high pressure gas
- Avoided by proper refrigeration system design and operation

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Hydraulic Shock

- Sudden localized pressure surge
- Common in steam and water systems
  - Often causes audible hammering or knocking sounds in piping
- During hot gas defrost, evaporator coils are isolated from the low temperature side of the system by control valves

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Hydraulic Shock

- If the defrost cycle is interrupted, causing a valve to rapidly open, the hot high-pressure gas can come into contact with low-temperature ammonia under vacuum.
- Refrigerant liquid and vapor will accelerate into downstream piping
- Causes a damaging hydraulic shock event

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Millard Hydraulic Shock Event

- When clearing alarms in the control system, the defrost cycle was interrupted and reset.
- Programming error triggered a valve to open and feed liquid ammonia to the coil while it contained hot gas.
- The low-temperature caused the hot gas to rapidly condense and liquid accelerated through the coil and into the suction header on the roof.

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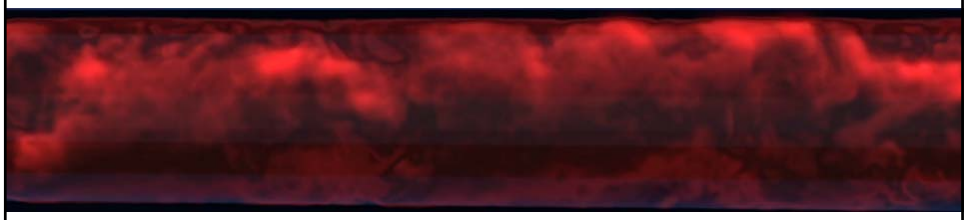
Hydraulic Shock Progression



Hot gas in evaporator coil piping

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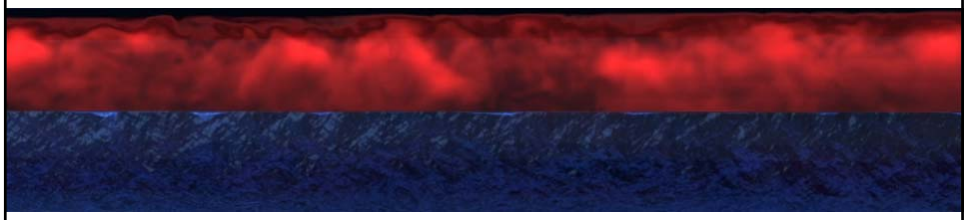
Hydraulic Shock Progression



Hot gas and low-temperature liquid

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Hydraulic Shock Progression

Hot gas rapidly condenses

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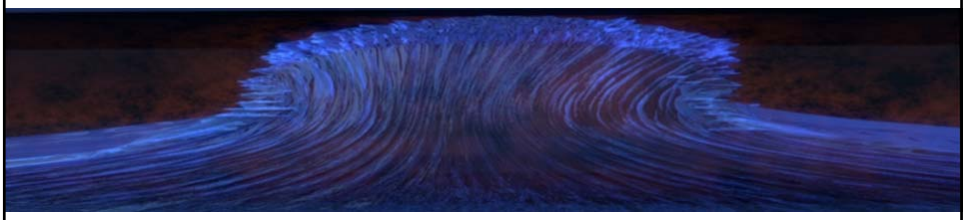
Hydraulic Shock Progression



Voids of gas build up pressure and create a vacuum

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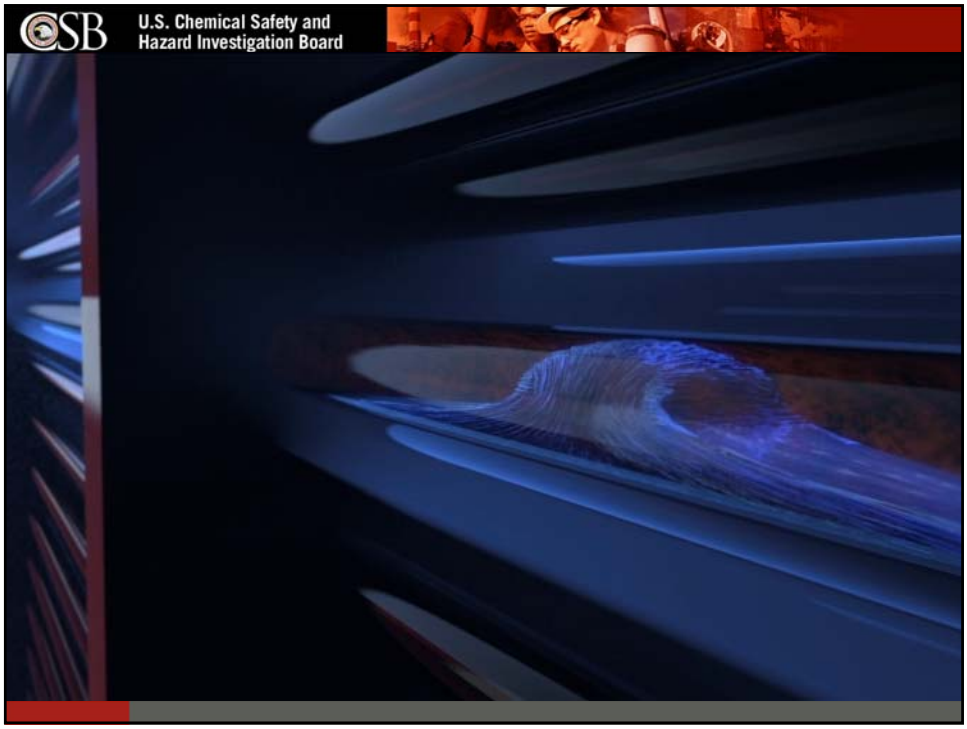
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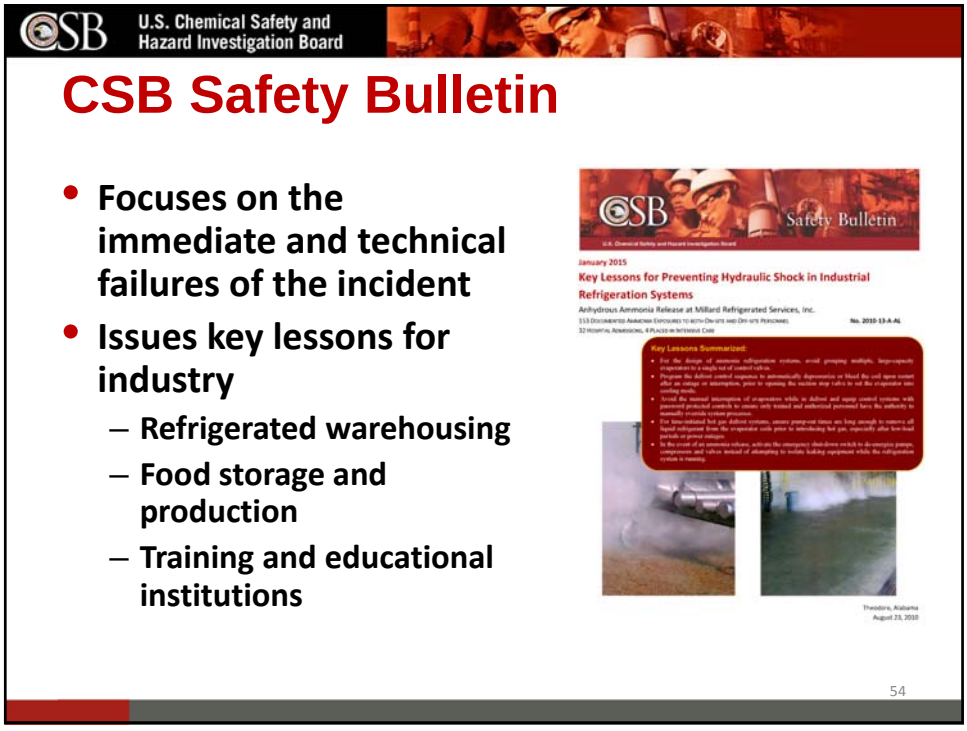
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CSB Safety Bulletin
Focuses on the immediate and technical failures of the incident
Issues key lessons for industry
Refrigerated warehousing
Food storage and production
Training and educational institutions
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Safety Bulletin
January 2015
Key Lessons for Preventing Hydraulic Shock in Industrial Refrigeration Systems
Anhydrous Ammonia Release at Millard Refrigerated Services, Inc.
Key Lessons Summarized:
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Lessons Learned

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Lessons Learned
Refrigeration System Design:

1. For the design of ammonia refrigeration systems, avoid grouping multiple evaporators to a single set of control valves. This is especially important for large capacity evaporators in excess of 20 tons. Evaporators with hot gas defrost systems should be controlled by individual valve control groups dedicated to each evaporator coil.

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Lessons Learned
Refrigeration System Design:

- Examined P&IDs and control logic for evaporators
- 4 coils from 2 sets of evaporators tied to one set of control valves
- There was an excessive volume of ammonia in the coils when the suction valve prematurely opened

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Lessons Learned
Refrigeration System Design:

- 15 ft^3 per coil → 60 ft^3 total of hot gas introduced into the -40 deg F suction line
- Large amount of energy rapidly condensed creating the shock event
- Avoid ganging multiple coils to a single valve group
- The risk of failure from hydraulic shock increases

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Lessons Learned
Refrigeration System Operation:

2. Program or configure defrost control systems with interlocks to ensure the low-temperature liquid feed and hot gas remain isolated during the initiation and termination of the hot gas defrost cycle in the event of a power outage, cycle interruption, or other abnormal situation.

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Lessons Learned
Refrigeration System Operation:
(continued)

2. Program the defrost control sequence to automatically depressurize or bleed the coils in defrost upon restart after an outage or interruption, prior to opening the suction stop valve to set the evaporator into cooling mode.

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Lessons Learned
Refrigeration System Operation:

3. Avoid the manual interruption of evaporators in defrost and ensure control systems are equipped with password protection to ensure only trained and authorized personnel have the authority to manually override system processes.

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Lessons Learned
Refrigeration System Operation:

4. For time-initiated hot gas defrost systems, ensure pump-out times are long enough to remove a sufficient amount of residual liquid refrigerant in the evaporator coils prior to introducing hot gas, especially after low-load periods or power outages.

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Lessons Learned
Responding to an Ammonia Release:

5. In the event of an ammonia release that cannot be promptly isolated, activate the emergency shut-down switch to de-energize pumps, compressors and valves instead of attempting to isolate leaking equipment while the refrigeration system is running.

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Lessons Learned
Responding to an Ammonia Release: (continued)

5. Shutting down the equipment will stop the circulation of ammonia and limit the release of additional ammonia from components running upstream of failed equipment or piping.

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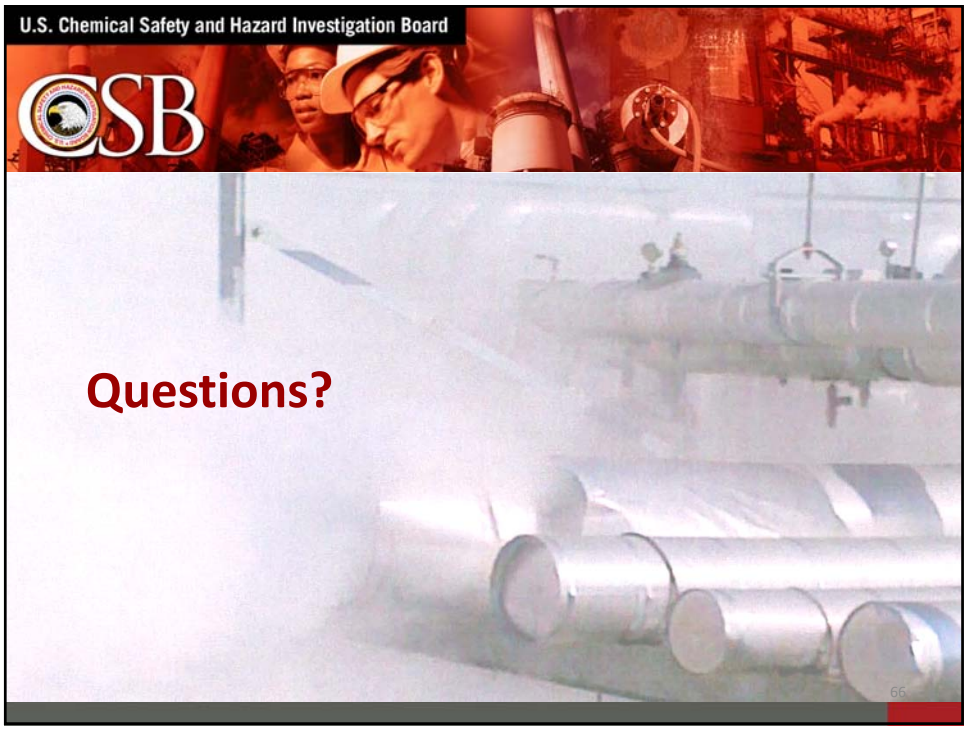
Safety videos available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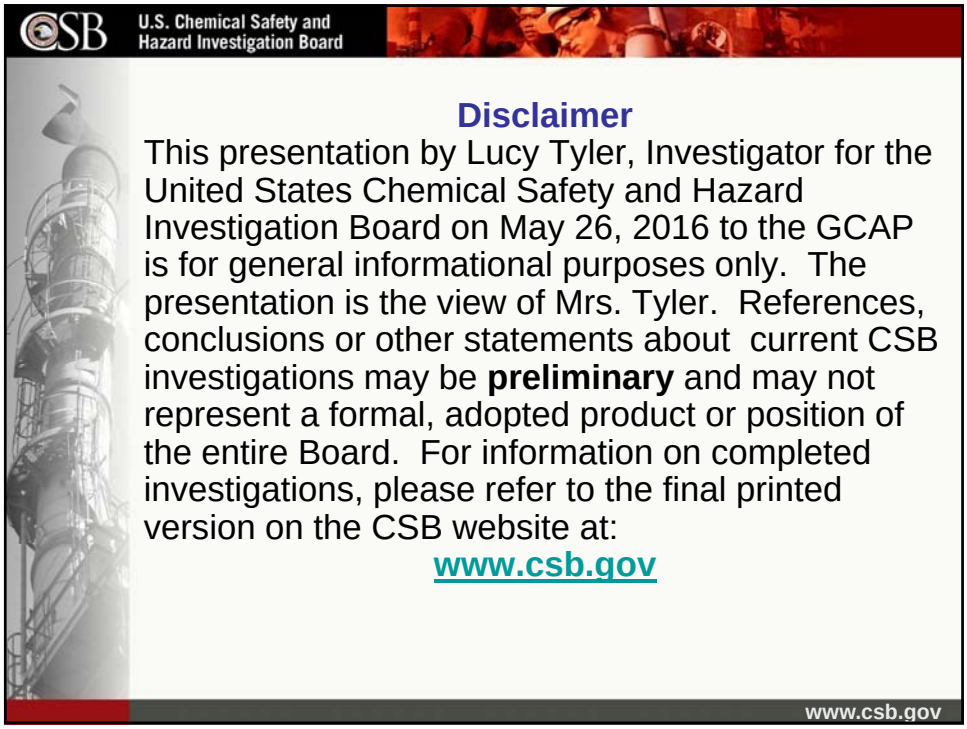
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