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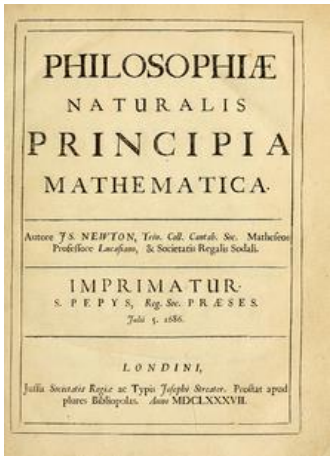
SPECIALTY CHEMICALS

Protection from Hazards – Human behaviour

GO FOR
ZERO
FOCUS - START TO FINISH

Fundamental laws on human behaviour


PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

Auctore Js. NEWTON, Trin. Coll. Cantab. Soc. Matheseos Professore Lucasiano, & Societatis Regalis Sodali.

IMPRIMATUR.
S. PEPYS, Reg. Soc. PRÆSES.
Julii 5. 1686.

LONDINI,
Justu Societatis Regiæ ac Typis Josephi Streater. Prostat apud plures Bibliopolas. Anno MDCLXXXVII.

Similar to Newton's laws of motion, there are 2 fundamental laws for the nature of mankind

First law of nature: "It is the true nature of mankind to learn from mistakes, not from example"

Second law of nature: You must learn from the mistakes of others. You can't possibly live long enough to make them all yourself".

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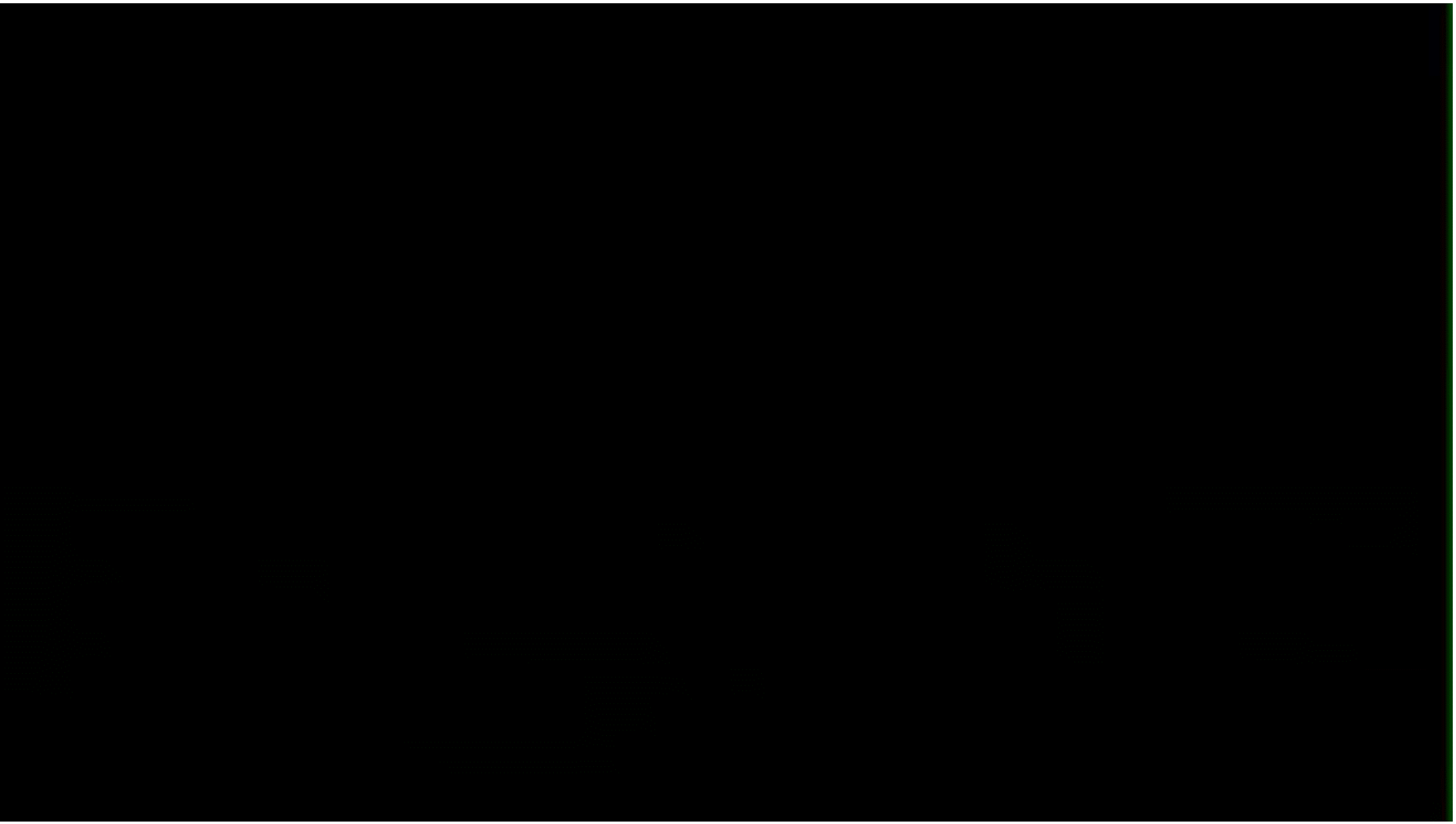
DuPont Belle incident



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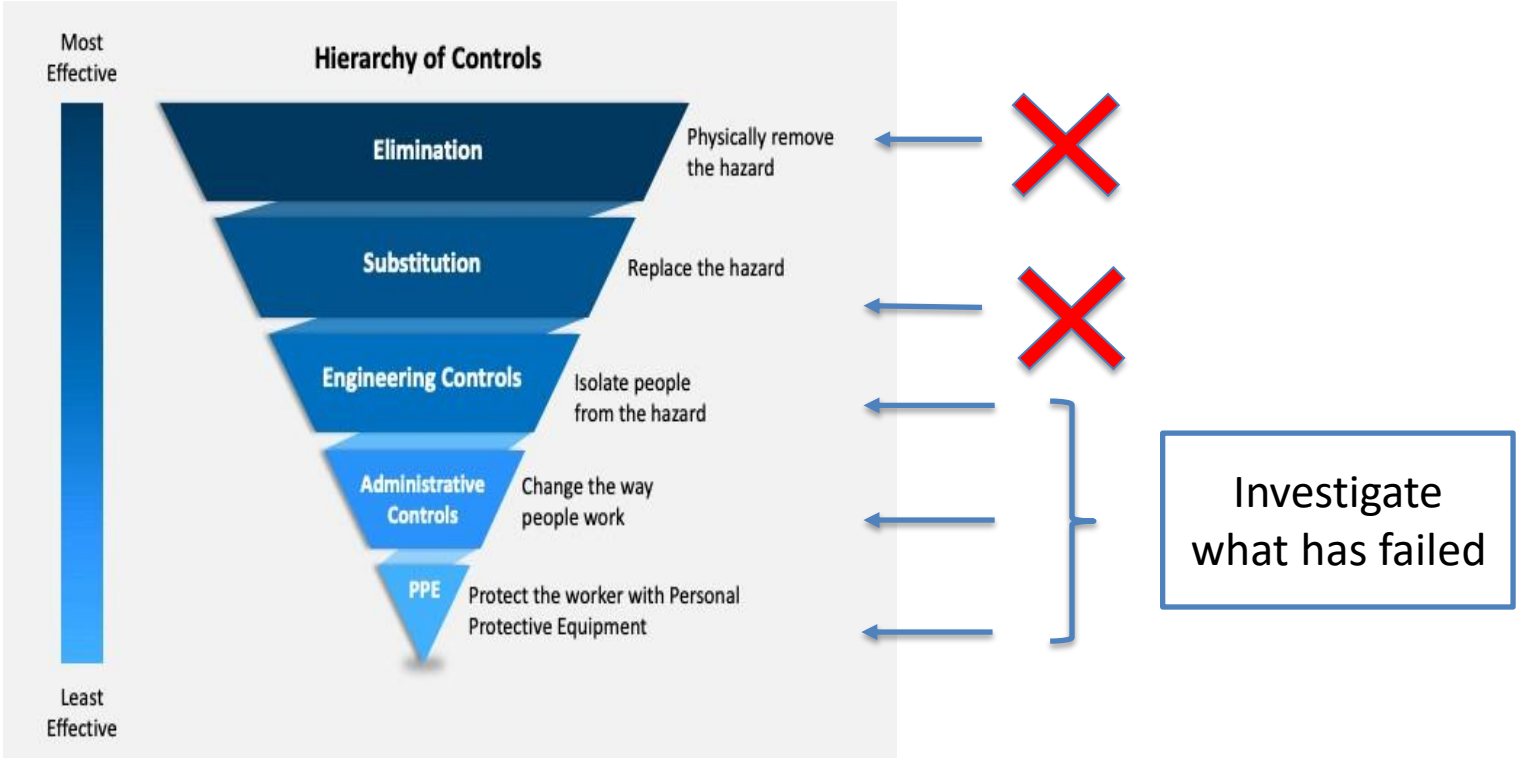
Controlling the hazard

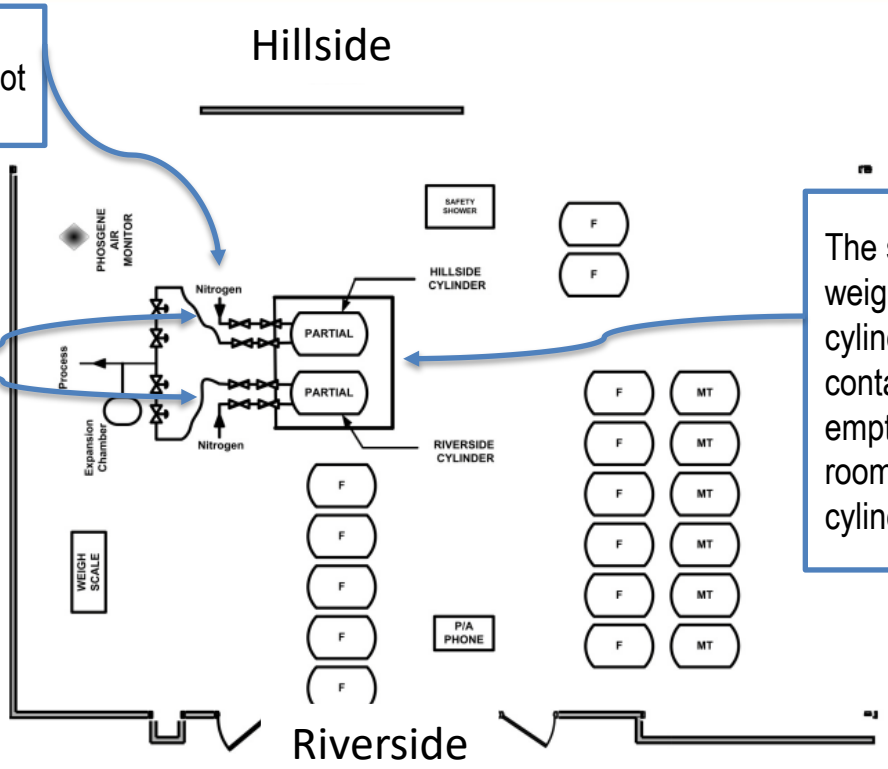


The controls

70 Psig N^2 purge. Drawing from CSB report is incomplete, does not show purge possibility.

0.25-inch diameter by 48-inch long PTFE-inner tube, 304 stainless steel overbraid hoses

PTFE is known to be permeable to phosgene, creating stress corrosion cracking under the label



The scales record the weight of the in-service cylinder and when the container is nearly empty signal the control room to initiated a cylinder change.

Figure 12. Phosgene shed and full (F) and empty (MT) cylinder locations on day of incident (not to scale)

PPE: Full suit breating air (line break)

- Changing and connecting of cylinders 2-3 times per day (After Purging transfer lines with N2).

PPE; Normal (no breathing air)

- Switching cylinders
- Loading unloading

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The failure- chronology of events

Friday, Jan 22nd

- Flow problem on hillside cylinder. Trouble shooting through repeated switching to riverside re-establishing flow.

Saturday, Jan 23rd am

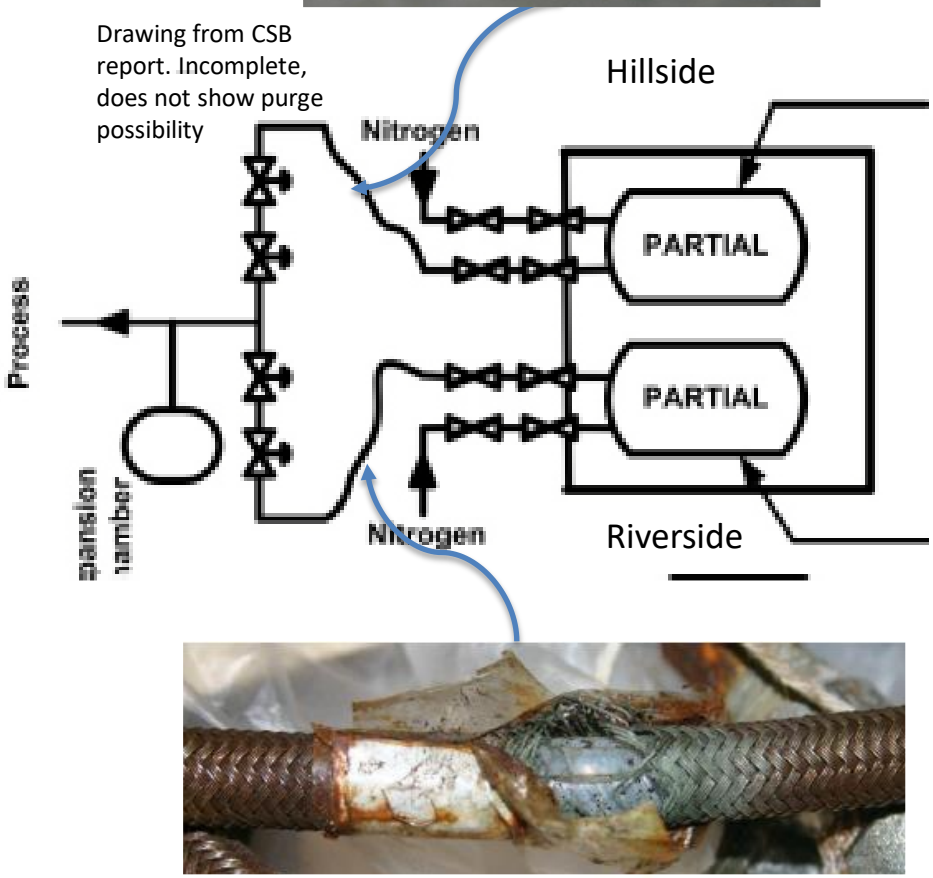
- Half full hillside cylinder taken out of service, hose was decontaminated in waterbath, corrosion was observed after decontamination.
- Riverside hose was visually inspected morning Jan 23rd Due to the solid tag the corrosion under the tag was not visible to area personnel.
- Hillside hose replaced and cylinder taken back in service to empty. Riverside cylinder was taken out of service. Riverside hose was not evacuated.

Saturday, Jan 23rd 1:45 pm

- Operator was in the shed to switch from the nearly empty hillside cylinder to the riverside cylinder. Riverside cylinder hose ruptured, 2 Lbs liquid Phosgene remaining in the blocked out hose was released and sprayed the operator.

Sunday, Jan 24th

- 2:30 pm Operator arrived at the hospital, Xray revealed no congestion in the lungs.
- 5:30 pm the operators condition deteriorated rapidly.
- Received treatment from various physicians
- Operator died 9:27pm



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Facts known from investigation

Hoses

- Material of construction of the hoses was a topic of discussion since 1987 with the DuPont Laporte plant and Engineering Dept. to identify the most suitable hose. The standard specified a corrugated inner core of Monel and Monel as braided reinforcement. Monel hoses were considered but not used due to the unavailbility of ¼" dia size, and possible leaking issues with mechanical stresses bending or twisting.
- Choice was made by the plant to use PTFE inner core and Stainless steel overbraid hoses similar to the LaPorte plant and Phosgene supplier VandeMark. The phosgene permeation from PTFE was known and to be controlled through a monthly change out.
- The monthly change out was not done due to a wrong setting in SAP, which did not automatically trigger the change request. The hoses in place Jan 23rd were not changed out for 7 months.
- Majority of tags were attached to the hoses with metal clips or plastic ties as normal, only one manufacturer's tags were attached with adhesive tape

Example of a corrugated inner core hose

Procedures and Work Practice

- SOP requires evacuating transfer lines with N^2 before taking a cylinder out of service. It is not known why the liquid phosgene was not evacuated from the riverside transfer line..

Design

- PHA did not study the possibility and consequences of the blocking in of phosgene liquid in the transfer hose and pipe, so there was no pressure relief system on the blocked-in section.

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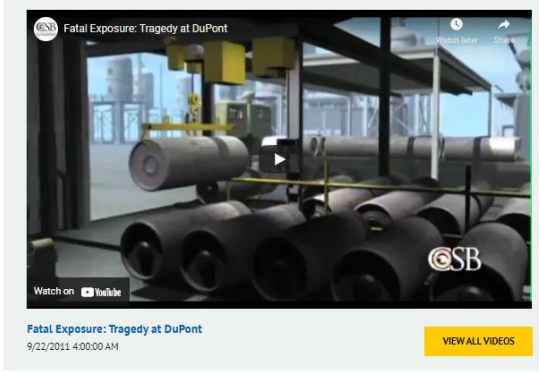
Findings with information from the CSB report and related documents

Contributing causes

- The SAP maintenance program did not initiate hose change out since 2006 due to a wrong setting. It is likely this has been detected by technicians but no-one realised the possible consequences and no-one corrected the SAP system.
- The significane of the failure of the hillside hose was not recognised. It is possible and likely that technicians did not see the connection between the observed corrosion and the label, as they had never seen this before. This also explains why the riverside hose was only visually inspected without removing the label.
- The natural proclivity to maintain operations whilst limiting efforts spent, resulted in the shortcut of not evacuating transfer lines. Who did the switching back to the hillside cylinder on the morning of Jan 23rd, blocking liquid phosgene in the line and why was this line was not evacuated is not answered.
- Risk of thermal expansion by blocking in liquid phosgene was not recognized.



Root cause

- The PHA did not assess the possibility of blocking in Phosgene liquid causing thermal expansion, and thus no pressure relief system was included in the design.

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How could this have been prevented?

The fatality would not have happened if:

- .....The hoses had been changed out monthly. The hillside hose would not have flow restriction failure and thus the valving actions and errors would not have happened
- …..The label had not been taped around the braided section of the hose.
- …..The near miss with the hillside hose triggered the right response of stopping all operation until the cause of the hose failure was known.
- ….. The non-standard valving actions to maintain phosgene flow had been risk assessed.
- …. The riverside transfer line had been purged with N^2 and liquid phosgene was not locked in.
- ….. The operator was wearing full chemical suit with breathing air.
- …. The operator was not present when the hose burst.

But most important of all, this would not have happened if the PHA had recognised the hazard and a relief system was in place to protect against thermal expansion of liquid phosgene in a blocked transfer line.

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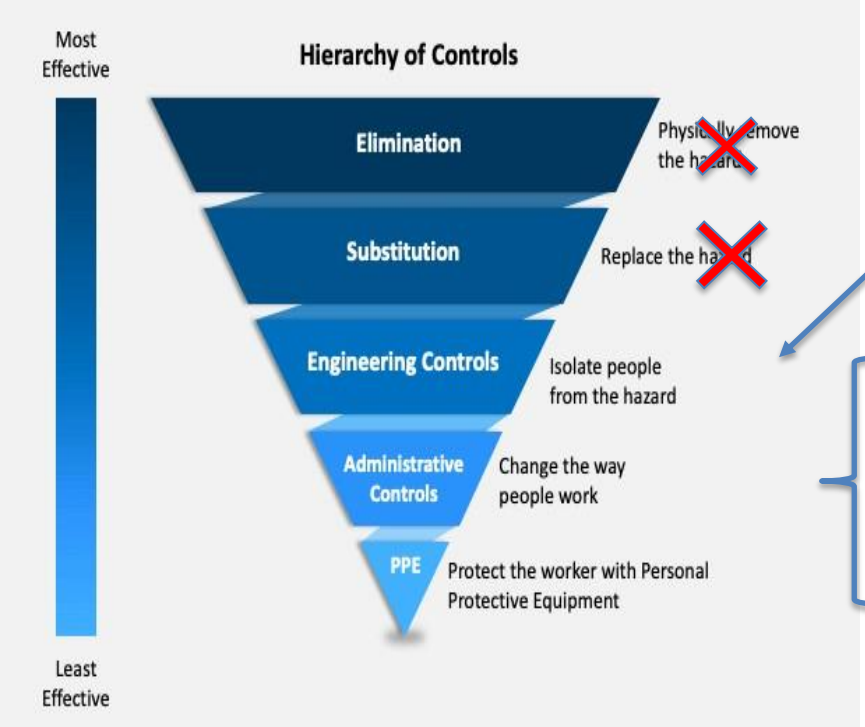
Conclusion



Inadequate engineering control right from the start, due to oversight at the PHA and subsequent PHA reviews.

Multiple failures and mistakes in administrative controls

- Failure of regular hose change out, undetected and not corrected since 2006.
- On failure of hillside hose, no action is taken even though the corrosion was never seen before.
- Non standard procedure was initiated to maintain phosgene flow to the process. Risks were not assessed or understood.

First law of nature: "It is the true nature of mankind to learn from mistakes, not from example"

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So…. what did I learn?.....

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My Lessons Learned

We don't live in a perfect world.

- Failures at the engineering control level may go undetected for years. Until we discover these failures, administrative controls are essential and can make the difference between life and death.
- Engineering controls and administrative controls work together to keep us safe.
- Most incidents are a result of the failure of the engineering controls and administrative controls coinciding simultaneously by chance.
- We should make all efforts to discover our mistakes through audits, near misses and incidents from ourselves as well as from others.

What I do differently after these incidents

- Assure PHA team are x-functional to get input on non standard operational activities.
- Audit chemical hoses and focus on a visual system with coloured ties to indicate fit for use and inspection status of a hose.
- Where possible create visuals in the plant, do not rely on IT systems that only subject matter experts consult. Audit the visuals
- Focus on practice Vs. procedures, in particular the life savings rules.
- Focus on the use of TRA's for non-standard tasks.
- Assure all incidents and near misses are reported, communicated and investigated.
- Create understanding that the default position is to stop operation after an incident unless appropriate action can be taken to maintain safe operation

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What have you learned?

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Appendix

Findings CSB

U.S. CHEMICAL SAFETY AND HAZARD INVESTIGATION BOARD
Findings out of the final investigation report

Root causes

- DuPont relied on a maintenance software program to initiate the automatic change-out of phosgene hoses at the prescribed interval.
- DuPont did not provide a back-up method to ensure timely change-out of the hoses.
- A maintenance software program change was not documented or reviewed in accordance with the MOC process.
- The Belle Plant did not use the construction materials recommended by a corporate expert, the P3H standard, CGA, or the HTM manual for phosgene hoses, even though the 2006 second-party HTM audit recorded it as an observation

Key findings[1]

- An out-of-service phosgene transfer hose failed, exposing a worker to a lethal dose of phosgene.
- DuPont did not follow its own standards for the change-out of phosgene transfer hoses.
- DuPont engineers voiced concern regarding the materials of construction for phosgene hoses that were not addressed.
- Liquid phosgene was not evacuated from the riverside hose, as the SOPs indicate, between transfers to the process from the 1-ton cylinders.
- A similar hose failure almost occurred a few hours before the exposure of the worker; however, this near-miss did not prompt an investigation when operators observed the near failure of the hose on the morning of the fatal release
- The 2009 PHA did not address thermal expansion and corrosion potential for phosgene transfer hoses.
- Operators were unaware of the hazards of liquid phosgene thermal expansion (training and procedures)

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[1] Out of the 12 key findings

CSB Recommendations for the Belle plant

SAP Maintenance system

- Improve the existing maintenance management by supplementing the computerized system with sufficient redundancy for all PSM-critical equipment.
- Conducting Management-of-Change (MOC) reviews for all changes to PM orders for all PSM-critical equipment in the computerized maintenance management system

Near miss reporting

- Revise the near-miss reporting and investigation policy and implement a program that includes the following at a minimum:
  - Ensures employee participation in reporting, investigating, analyzing, and recommending corrective actions for all near-misses.
  - Develops and encourages use of an anonymous electronic and/or hard copy near-miss reporting process for all DuPont Belle site employees.
  - Ensures that this program is operational at all times (e.g. nights, weekends, and holiday shifts)

Safeguards for Phosgene handling

- Require all indoor phosgene production and storage areas, to have secondary enclosures, mechanical ventilation systems, emergency scrubbers, and alarms.
- Prohibiting the use of hoses with permeable cores and materials susceptible to chlorides corrosion for phosgene transfer.

Training

- Conducting annual phosgene hazard awareness training for all employees who handle phosgene, including the hazards associated with thermal expansion of entrapped liquid phosgene in piping and equipment.
- For each DuPont facility that uses, but does not manufacture, phosgene onsite
  - Conduct a risk assessment of manufacturing phosgene onsite against the current configuration.
  - Communicate the findings of each assessment to compile recommendations applicable to all DuPont phosgene delivery systems.
  - Implement these recommendations

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