More Lessons "Re-Learned" from Corrosion Under Insulation

Acknowledgements

This presentation is part of Dow Chemical Company efforts to prevent corrosion under insulation events. It was developed by the Global Mechanical Integrity Safety Standard Steering Team. Our special acknowledge to Tim Overton, former Chief Process Safety Engineer (retired on August/09).

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Abstract

Mechanical Integrity programs have been an essential element of process safety programs in the chemical and petroleum industries for decades. This is an area where considerable materials have been published regarding industry best practices for inspection and maintenance – including excellent advice on inspection for "corrosion under insulation". However, The Dow Chemical Company experienced a significant near miss event at one facility recently caused by lapses in understanding by local personnel of corrosion under insulation, as well as inadequate leveraging of learnings from plants of similar design.

This paper explains the circumstances behind this event and the key lessons Dow learned to help other companies avoid similar occurrences.

Before the incident

Dow's process safety performance historical performance has been good. No multiple fatality incidents since 1981. Both Injury/Illness statistics and normalized process safety incident performance are among the industry's best. Dow had corporate-wide mechanical integrity programs in place since the 1960s – and the mechanical integrity program standard called upon piping inspections consistant with API 570 since 2001 for piping in highly hazardous services (earlier standards existed that may not have been aligned to API 570).

The company experienced a few line failures resulting from corrosion under insulation (CUI); however, most of these failures were in piping systems not meeting Dow's previous hazard criteria within the mechanical integrity safety standard. However, some less severe incidents and a few close calls had occurred. Dow updated its corporate mechanical integrity standard in mid-2004 to clarify the mechanical integrity program's requirements and accountabilities. (The need for this will be described in more detail later in this document). Following the rollout of Dow's new mechanical integrity standard, there were indications that CUI inspection quality improved – including better piping systems inspections. A number of piping systems which were inspected after 2004 revealed corrosion under insulation which were fortunately corrected before failure.

The incident – the failure of a 8 inch carbon steel, high pressure hydrocarbon line due to Corrosion Under Insulation

On March 13, 2008, at a Dow's LHC plant, an 8 inch, schedule 20, carbon steel hydrocarbon line failed. The event began with a small pinhole leak, detected by the operators. While the operators were isolating and de-pressuring the line, it failed catastrophically. Fortunately, this catastrophic line failure produced such explosive force that the line bent in two locations – essentially sealing itself and avoiding a major release.

Fig. 1 - photo of the failed 8” pipe

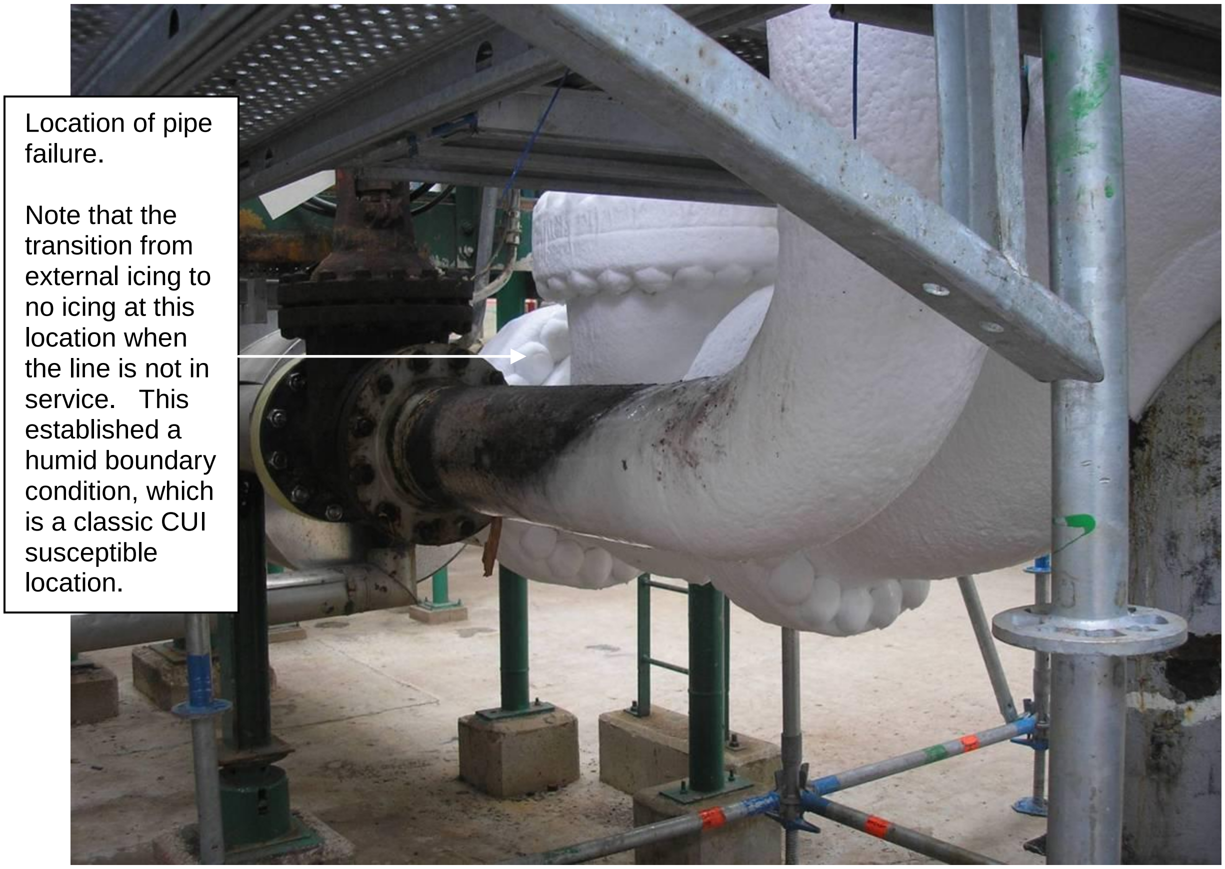
Fig. 2 – photo of the crease in pipe self-sealing the leak

Fig 3 – photo of pipe once removed

The piping was a 30 year old, schedule 20, carbon steel regeneration line to a cracked gas dryer of an ethylene plant (one of two parallel drying trains). The material in the line was non-corrosive hydrocarbon cracked gas (40% ethylene). Due to the regeneration service, the piping alternates between three different conditions, and the location of failure was where operating temperatures cause frequent or continuous condensation and re-evaporation of atmospheric moisture:

Regeneration condition (4 bar, 220° C)
On stream time: 20 days (30 bar, -17° C)
Regeneration time: 24 hrs (220° C)
Standby: 19 days (ambient temperature)

Figure 4 – photo showing installed piping when out of service



Root Cause Investigation findings / Lesson's Learned

A number of root causes were identified in the root cause investigation from this incident. Some of the root causes were related to insufficient previous inspection. As noted above, Dow rolled out an update to their global mechanical integrity safety standard in mid-2004. This is Dow's current global mechanical integrity safety standard. Ironically, this line had last been inspected just a few weeks earlier in 2004. Therefore, the inspection organization had not yet been notified or trained on the new standard. Some of the root causes or lesson's learned described below were corrected in the new standard.

Cause #1 - Inadequate Inspection in 2004 and earlier

Upon reviewing the inspection records, and discovery of the amount of corrosion under insulation at the point of failure, it was clear that neither the inspection in 2004 nor any of the earlier inspections, had been performed in accordance with API 570. Specifically, insufficient insulation was removed to allow adequate external inspection. Instead, only a small plug of insulation at the elbow was removed, under the assumption that the elbow was the most critical inspection location.

Lesson Learned #1: Pre-2004 Mechanical Integrity Standard was too vague and left the burden to obtain external standards upon the local inspection and maintenance organization. The pre-2004 standard simply stated:

- ….piping systems in **highly** hazardous service shall be identified and registered *[i.e., the steps required to place in the mechanical integrity system for future inspections]* An evaluation shall be made to determine if a potential spill under normal operating conditions could exceed threshold external authority reportable quantities (e.g., EPA[13]). If the piping system has the potential to release highly hazardous chemicals in quantities greater than the threshold limit, then the piping system shall be registered.
- … API 570 shall be used for guidance in performing inspections and repairs.

This wording left too much discretion to the plants to identify which piping should be inspected, and assumed that the plant or inspection organization would obtain copies and follow API 570. The pre-2004 standard also was vague in describing who was responsible for the steps of registration, inspection, and follow-up associated with the inspection program.

The 2004 version of the Dow mechanical integrity safety standard (rolled out a few weeks after the last time this piping was inspected), provided much greater clarity regarding piping to be inspected, insulation to be removed, and CUI susceptible regions per API-570. Examples of figures or text from the 2004 standard are below:

Figure 5 – Table describing different types of hazardous service and Dow's minimum piping inspection frequency

The piping inspection frequency is based on the hazard rating

Appendix A – Table 1 Piping Inspection Class based on Hazard / Risk Potential

Threshold Quantity or Release Potential ►► / Hazard / Risk Category ▼▼	100 – 1000 Lbs	1000 - 10,000 Lbs	10,000 - 100,000 Lbs	100,000 + Lbs
Very Toxic ≥ Boiling Point	Class 2	Class 1	Class 1	Class 1
Very Toxics < Boiling Point Extremely; Flammable Extremely Explosive; Toxics ≥; Boiling Point	N/A	Class 2	Class 1	Class 1
Toxics < Boiling Point; Explosives; Oxidizers; Highly Flammable Liquids w/ Boiling Point < 95ºF / 35ºC; Water reactive - liberates toxic gas; Violently reacts w/ Water; Very Toxic to Aquatic Organisms	[illegible]	N/A	Class 2	Class 2
Highly Flammable Liquids with Boiling Point > 95º[illegible] 35ºC; Flammable Liquids; Toxic to Aquatic Orga[illegible] and may cause long term adverse effects in the environment	N/A	N/A	N/A	Class 3

Step 1
Determine Inspection Class

Step 2
Select Inspection Frequency

A. Class 1 Piping	Maximum* Visual Inspection Interval	5 years
	Maximum Non-Destructive Testing Interval	5 years
B. Class 2 Piping	Maximum* Visual Inspection Interval	5 years
	Maximum Non-Destructive Testing Interval	10 years
C. Class 3 Piping	Maximum* Visual Inspection Interval	10 years
	Maximum Non-Destructive Testing Interval	10 years

Fig 6 – Extent of Corrosion Under Insulation Inspection Following Visual Inspection described in Dow's 2004 Mechanical Integrity Safety Standard

Piping Class	**Approximate amount of CUI Inspection by NDE or Insulation Removal at "Suspect Areas" on piping systems within "Susceptible Temperature Ranges."**	**Approximate amount of follow-up examination with NDE or Insulation Removal in areas with Damaged Insulation on piping systems within "Susceptible Temperature Ranges."**
1	50 % of suspect areas	75 % of area of damaged insulation
2	33 % of suspect areas	50 % of area of damaged insulation
3	10 % of suspect areas	25 % of area of damaged insulation

Susceptible Temperature Ranges – API 570 Piping Inspection Code, Section 5.3.3.1 e, f & h:

e. Carbon steel piping systems, including those insulated for personnel protection, operating between 25°F–250°F (–4°C–120°C). CUI is particularly aggressive where operating temperatures cause frequent or continuous condensation and re-evaporation of atmospheric moisture.

f. Carbon steel piping systems that normally operate in-service above 250°F (120°C) but are in intermittent service.

h. Austenitic stainless steel piping systems operating between 150°F–400°F (65°C–204°C). (These systems are susceptible to chloride stress corrosion cracking.)

Suspect Areas – API 570 Piping Inspection Code, Section 5.3.3.2

The areas of piping systems listed in 5.3.3.1 may have specific locations within them that are more susceptible to CUI, including the following:

a. All penetrations or breaches in the insulation jacketing systems, such as: 1) Deadlegs (vents, drains, and other similar items), 2) Pipe hangers and other supports, 3) Valves and fittings (irregular insulation surfaces), 4) Bolted-on pipe shoes and 5) Steam tracer tubing penetrations.

b. Termination of insulation at flanges and other piping components.

c. Damaged or missing insulation jacketing.

d. Insulation jacketing seams located on the top of horizontal piping or improperly lapped or sealed insulation jacketing.

e. Termination of insulation in a vertical pipe.

f. Caulking that has hardened, has separated, or is missing.

g. Bulges or staining of the insulation or jacketing system or missing bands. (Bulges may indicate corrosion product buildup.)

h. Low points in piping systems that have a known breach in the insulation system, including low points in long unsupported piping runs.

i. Carbon or low-alloy steel flanges, bolting, and other components under insulation in high-alloy piping systems.

j. Locations where insulation plugs have been removed to permit piping thickness measurements on insulated piping should receive particular attention. These plugs should be promptly replaced and sealed. Several types of removable plugs are commercially available that permit inspection and identification of inspection points for future reference.

The 2004 standard also describes all activities and responsibilities associated with the mechanical integrity program by role (e.g., Site Maintenance Leader, Equipment owner, Site Leader, Inspector, Designer) – to increase the understanding and accountability.

Including specific expectation and reproducing the requirements inspectors should follow from external standards are critical for consistant global mechanical integrity inspections.

Lesson Learned #2 – Mechanical Integrity Programs can not rely solely upon contract inspectors and need adequate involvement of plant personnel familiar with plant operations.

As is a growing trend within the industry, this facility had contract inspectors performing most mechanical integrity inspections. There was also inadequate communications with the plant operations personnel when developing the inspection plans. As a result, the inspector was unaware of the intermittent operations at different temperatures (hot, cold, ambient) which led to accelerated corrosion under insulation.

Effective communications and involvement of persons familiar with all modes of operation within the plant is critical to develop a robust inspection plan.

Cause #2 - Inadequate Leveraging of Learnings

During the root cause investigation, the team concluded that there had been indications that this specific pipe location was susceptible to CUI and the piping location should be: 1) replaced with thicker wall pipe or alternative metallurgy and 2) periodically inspected thoroughly for CUI (i.e., insulation removed). Examples include:

- This plant was a typical of a specific technology licensor's design, purchased from a previous operating company. A plant of identical design was owned and operated immediately adjacent to this plant by the other company. (The two companies shared a control room and maintained good communications.) The other company had identified significant corrosion at this specific piping location in their sister plant and had replace the piping.
- Dow also owned and operated other plants of a similar design in at least one other location. That plant had discovered CUI at this specific piping location and had replaced the piping.
- The inspection of the parallel train dryer in this specific plant had revealed excessive corrosion and had replaced the piping.

Yet none of these events prompted the plant to identify this specific piping location as a CUI susceptible region, accelerate the CUI inspection, remove more insulation for CUI inspections, or replace this specific piping location.

Lesson Learned #3 – An effective program to leverage learnings from other incidents should include discoveries of excessive corrosion or any other losses of mechanical integrity.

Following this incident, the technology experts in each of Dow's major business units were instructed to compile a "high priority CUI susceptible location" document for their technology based upon historical inspections and/or failures. These documents were distributed to plants around the globe with instructions to ensure that all such piping locations had completed a thorough CUI inspection. (Prompt inspection was recommended for any locations that had not been recently inspected.)

Other company actions following this event

Dow's leadership and employees were aware of the potential severity of this CUI incident. If not for the good fortune of the pipe bending in a perfect angle to self-seal, there would have been a very large discharge of highly flammable vapors and a high probability of a vapor cloud explosion resulting in major damages and potential human casualties. This awareness prompted Dow's leadership and company mechanical integrity program steering team to launch a number of corporate-wide initiatives. These included:

- A mandatory refresher training for all site and production plant leaders on the key elements and responsibilities under the corporate mechanical integrity program.
- The creation of a list of high priority CUI inspection locations, by technology, to be inspected as soon as possible.
- The creation and delivery of new CUI inspection training to train maintenance and operations personnel how to better identify areas susceptible to CUI.
- The launch of an additional, one-time mechanical integrity program audits of all major sites. (The mechanical integrity program of each site should be audited as part of the sites' ongoing periodic EH&S audits . This special audit was intended supplement this auditing with a highly visible site-wide, mechanical integrity focused audit to respond to this near miss event.)

Evidence that the increased emphasis is working

Since the rollout of the CUI special emphasis program a number of CUI discoveries have been reported. This is similar to what Dow saw in response to the rollout of the 2004 corporate mechanical integrity safety standard. This demonstrates there is increased awareness and emphasis in mechanical integrity is indeed avoiding future incidents.

Conclusion

Effective management of CUI risks is a critical part of proper process safety hazard management leading to good safety performance. There are so process safety management systems and best practices that it would be impossible to rank one as "the most important" to incident elimination. An effective mechanical integrity program would certainly be among the top. Justifying the expense of an effective CUI inspection program is often challenging since to identify all areas of CUI requires a very expensive process of removing insulation and re-insulating – even if the inspection reveals no corrosion damage. But the failures prevented by an effective CUI inspection program are often the most dangerous – since they can occur in areas where there was no previous indications of a problem.

References

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