Question 25: How do you manage process hazard analysis (PHA) scenarios related to corrosion?

Brad Palmer (ConocoPhillips)

First, ConocoPhillips has developed generic PHA scenarios for each major technology to determine what scenarios are applicable to a particular unit. These tables contain initiating categories (such as Corrosion), potential causes and consequences, possible safeguards and suggested consequence rankings. These documents serve as aides to PHA teams with varying levels of experience and reminders of certain scenarios to be considered. They also serve to calibrate a PHA team's consequence ranking across multiple refineries within the company and industry. These tables are intended for use throughout the PHA process and cover the range of operating equipment and conditions, including alternate operating conditions such as Reformer regeneration.

Second, Corrosion/Materials/Inspection are valuable participants on the PHA team. These experts can provide an overview of the potential for corrosion or damage in the unit. They can also review the current equipment condition and any operating concerns that could cause corrosion or other damage mechanisms. ConocoPhillips next revision of our PHA Required Standard will require PHA teams to complete the Fixed Equipment MI Review posted at the end of this response.

Third, when a PHA team identifies scenarios that are corrosion related (or any other damage mechanism); they review them with the Corrosion/Materials/Inspection/Reliability specialists to verify a risk based (API 510/570) or a rule based (API 580/581) program is in place to prevent and mitigate the scenario. If a program does NOT exist, recommendations are issued for program development. If a program does exist, the team reviews the effectiveness of the preventative safeguards, whether the scenario has occurred, and if so, the effectiveness of the mitigative safeguards.

Fourth, Corrosion and other damage mechanism scenarios are not “LOPA-able” since there is no known initiating cause likelihood. Therefore, other risk management tools must be employed to prevent and/or mitigate high PHA consequence scenarios. These tools can include robust material design, robust Corrosion/Materials/Inspection/Reliability programs and Reliability Operating Limits (ROLs). ConocoPhillips has established a Reliability Operating Limit (ROL) Required Standard which includes generic ROL tables for each major technology to serve as reminders to refinery personnel of certain parameters to be monitored and potentially alarmed to prevent these damage mechanism scenarios. The ROL program is being implemented by tiered approach to prevent acute (high risk/short term) conditions with potential process safety consequences, followed by medium risk scenarios and then chronic (low risk/long term) problems. These ROLs may include, for example, Reformer regeneration caustic-solution pH monitoring for corrosion prevention or reactor outlet temperature monitoring for HTHA prevention, etc.

These operating limits are evaluated and approved by each site. Exceedences are reviewed by the appropriate experts to determine if operation is safe to continue or if alternative actions must be taken, i.e., inspection, repair or replacement.

Finally, it is important to realize that the LOPA risk management tool can only be applied to a portion of the high consequence PHA scenarios. Depending on the unit, "LOPA-able" scenarios may be a small subset of identified risk 4/5 consequences. For example, only 15% of the ConocoPhillips Reformer scenarios, risk ranked 4/5, fit the LOPA methodology. Other risk management tools are being used, and in some cases are being developed, to address these remaining scenarios: Safe Operating Limits (SOLs), Reliability Operating Limits (ROLs), Compressor Hazard Assessments Guide, Pump Hazard Assessment Guide, Relief System Required Standard, robust Inspection program, Engineer Design and robust Operator Training. Although these numbers may not apply to other technologies, the point is clear; more focus needs to be made on multiple risk management methodologies if a refinery wants to adequately protect against all process hazard scenarios.

Example of Fixed Equipment Mechanical Integrity Review

The following checklist items shall be reviewed during the PHA with input from Inspectors and/or Corrosion Engineers who have experience with the process under review. Some items may be directly addressed during the review. Other items may simply be a check to assure that proper Mechanical Integrity activities/assessments are happening outside of the PHA process. Not all checklist items will be applicable to the process under review.

1. Brittle fracture of materials not designed for low temperature conditions

2. Low-silicon carbon steel in sulfidation service

3. Vibration that could lead to fatigue failure of piping, threaded connections, unsupported overhead weight or exchanger tubes

4. Contamination that could cause stress corrosion cracking (e.g. wet H2S, caustic, amines, chlorides, polythionic acids or corrosion fatigue cracking in deaerators)

5. High temperature hydrogen attack, accelerated creep or other ageing or embrittlement phenomena, Nelson curve operating limits

6. Water wash and chlorides control

7. Rapid corrosion due to change in flow rates, injection or other mix points, changes in flow patterns or injection system failures

8. Thermal fatigue cracking due to large temperature cycling or severe temperature swings

9. Dead legs that could freeze and rupture (i.e. especially in light hydrocarbon services)

10. Localized hot spot or excessive temperature that could cause equipment rupture from short term overheating (e.g. furnace tubes, transfer lines, catalyst vessels)

11. Liquid slugging of piping or flare lines that could cause piping failure due to hydraulic shock and transient overstress conditions

12. Hot spots from improper tracing installation that could cause localized corrosion

13. Localized corrosion or cracking of heat affected zones of welds in alloy piping

14. Fouling or plugging of inlet or outlet piping of relief devices

15. Caustic cracking of non-stress relieved equipment from boiler feed water leaks or other caustic containing streams

16. Dew point corrosion due to process upsets

17. Process upsets that introduce moisture into moisture free environments or remove moisture from environments reliant on moisture for the protection of the system

18. Liquid carryover in gas streams, or velocity changes of mixed phase streams causing accelerated corrosion/erosion (e.g. downstream of control valves)

19. Changes in pumping or compressor capacity leading to increased corrosion rates

20. Changes in process conditions leading to increased corrosion under insulation (e.g. idling of normally hot equipment

21. Changes in pH or corrosion control measures leading to increased corrosion or cracking

22. Changes in feed compositions adversely affecting corrosion rates (loss of trace amounts of corrosion inhibitors)

23. Potential to introduce a new corrosive material

24. Issues with CUI (corrosion under insulation), buried piping/soil-air interface and piping over water

Praveen Gunaseelan (Vantage Point Consulting)

The question as stated is general and pertains not just to gasoline processes but to overall refinery safety. There are certain systems for which corrosion issues may arise during a PHA. When a PHA team encounters a corrosion-related scenario, the team will typically propose mitigation measures, such as appropriate material selection, corrosion coupons, etc. In such instances, it is imperative that the PHA team include or consult with a subject matter expert on corrosion. However, it must be recognized that PHA is not the primary approach to identify and address refinery corrosion problems. Corrosion within a facility is more comprehensively addressed under the Mechanical Integrity (MI) element of Process Safety Management (PSM) programs. A Mechanical Integrity program may oversee implementation of risk-based inspection, periodic inspection and monitoring, asset management software, etc.

Useful references:

API Recommended Practices (RP) 580 and 581 provide guidelines for risk-based inspection. Publication 42, “Corrosion in Refineries” by the European Federation for Corrosion, contains detailed reviews of corrosion problems in catalytic reforming and HF alkylation, and provides strategies for corrosion management.

Erik Myers (Valero)

While our sites do not necessarily have a uniform methodology on this deviation, all sites take a similar approach. Corrosion is a Cause, usually used in Leak/Rupture Deviations, that is covered in each node for each PHA. We rely on the SMEs participating on the PHA team to state whether or not corrosion is an issue and how this is addressed if it is an issue. Safeguards are listed by the Team such as chemical injection, inspection etc. Previous incidents are also reviewed in each PHA.

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