Identifying and Evaluating Lessons Learned to Improve Performance

Jack Toellner, PE, CSP, MPH
Owner
Toellner Consulting LLC

Joseph Drago, PE
Director, Culture & Change Management
Marathon Consulting Group

Tutorial Objectives…

- ✓ **Deliver a tutorial that helps the audience grasp the fundamental value of identifying and evaluating lessons learned to improve business performance.**
- ✓ **Help the audience understand the importance of having a lessons learned mindset.**
- ✓ **Demonstrate that one must address not just the tactics of properly executing a lesson learned but also be willing to address systemic and cultural issues that can sabotage the efforts to improve performance.**
- ✓ **Outline the fundamental steps of identifying and evaluating a lessons learned.**
- ✓ **Share several examples of lessons learned associated with past significant events, AND possibly identify missed opportunities for improvement.**

Question for the Audience…

….How do engineers make a difference?

How do engineers make a difference?

…Jack and Joe's Experiences

- ✓ Solve problems
- ✓ Improve performance and efficiency
- ✓ Reduce risk
- ✓ Increase level of confidence
- ✓ Demonstrate leadership
- ✓ Build culture
- ✓ Implement management systems and associated controls
- ✓ Assure development of the next generation of engineers

A "Lessons Learned Mindset" can facilitate success!

….What is a “Lessons Learned Mindset”?

- ✓ **Recognition that the learning process never stops,**
- ✓ **Willingness to not accept the status quo (or the convenient answer),**
- ✓ **A belief that applying engineering and leadership fundamentals can make a difference, and**
- ✓ **Courage to accept that investigating and sharing a lesson learned may not always set well with others.**

Jack and Joe's Experiences

Examples of failure to recognize and follow thru on lessons learned…

…Quite often an event takes place and the worst thing that could have happened does not happen simply because of luck.

…And given that, the organization does not take time to capture the "lesson learned" thus failing to reduce the chance of the event reoccurring in the future.

Jack and Joe's Experiences

Lessons repeated can…

- × Increase financial exposures exponentially.
- × Significantly damage individual and corporate reputations.
- × Significantly increase the chance that government regulators will dictate future operational practices.

Jack and Joe's Experiences

Examples of failure to recognize and follow thru on lessons learned…

…Lost opportunity to improve upon:

- ✓ **Existing operating practices and standards,**
- ✓ **Management systems and controls,**
- ✓ **Organizational culture, and**
- ✓ **Business results.**

Jack's Personal Belief…

…Lessons learned should be an integral part of the engineering journey of design and operational practices.

A Personal/Real Example…

Time Frame…	1980
Location…	South Texas
Work Description…	Construction/start-up of a gas processing facility
Challenge…	How to safely purge air in new pipe/vessels

Photos courtesy of iStock Credit: dszc

A Personal/Real Example…

1980 Challenge… **How to safely purge air from new pipe/vessels**

1980 Recommended Approach…

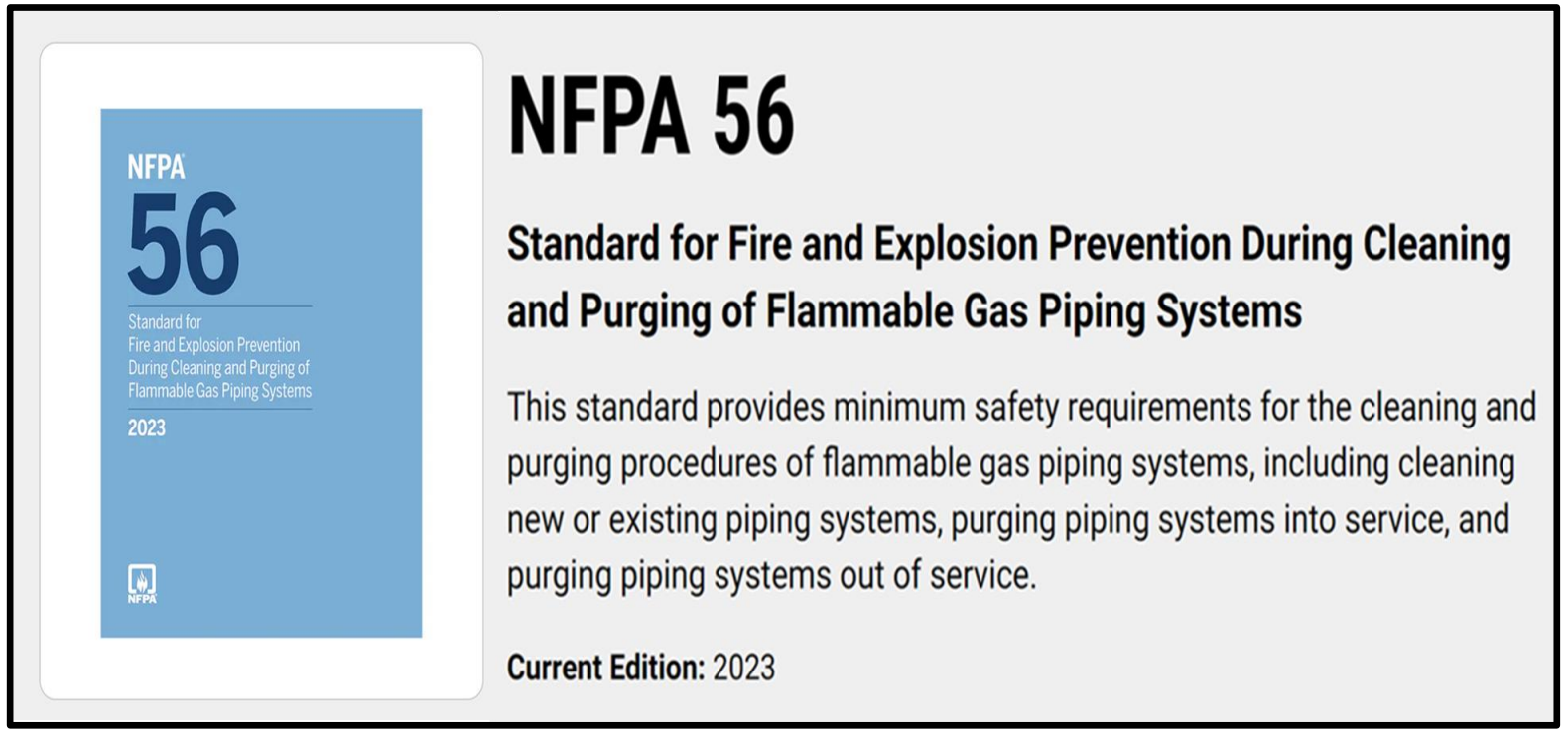
- ✓ **Pressure during purging should not exceed 10% of the design operating pressure of the piping and vessels.**
- ✓ **Consideration should be given to how and where purge gases are released to the atmosphere.**

A Personal/Real Example…

Challenge… How to safely purge air from new pipe/vessels

2024 Recommended Approach…

Note:
First edition published in 2013



NFPA 56 Drivers….

2009 - ConAgra Natural Gas Explosion and Ammonia Release

ConAgra Slim Jim Facility in North Carolina.

Gas explosion resulting from using natural gas to purge new pipe installation. Gas was vented inside the building where it eventually reached an ignition source.

Fatally injured 4 workers and injured 67 others.

Photos courtesy of CSB

NFPA 56 Drivers….

2010 – Kleen Energy Natural Gas Explosion

Kleen Energy Connecticut power generating facility.

Workers were conducting a “gas blow” using natural gas to remove debris from newly installed piping. The gas was vented to the atmosphere where it eventually reached a source of ignition.

Fatally injured 6 workers and injured 67 others.

Photos courtesy of CSB

NFPA 56

Standard for Fire and Explosion Prevention During Cleaning and Purging of Flammable Gas Piping Systems

General Requirements…

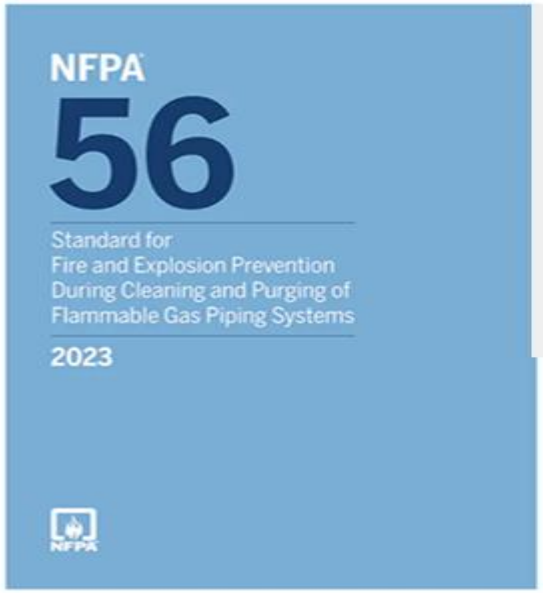
- ✓ **Inspection prior to purging**
- ✓ **Documented/written procedures reviewed by a "competent person"**
- ✓ **Temperature and pressure considerations**
- ✓ **Numerous cleaning and purging activities to address**
- ✓ **Communication plans + Management of change/stand-down**

NFPA 56

Standard for Fire and Explosion Prevention During Cleaning and Purging of Flammable Gas Piping Systems

Chapter 6 - Cleaning

- ✓ Flammable gas shall not be used
- ✓ Air, inert gas, steam, and water may be used as cleaning media
- ✓ Must address power/fuel supply for equipment supporting the process
- ✓ Temporary piping considerations
- ✓ Use of mechanical pigs



NFPA 56

Standard for Fire and Explosion Prevention During Cleaning and Purging of Flammable Gas Piping Systems

Chapter 7 – Purging into Service

- ✓ **First displace air w/inert gas, and then displace inert gas w/flammable gas**
- ✓ **Discharge of purged gases**
  - **Vent line sizing**
  - **Monitoring requirements**
  - **Written procedures**
  - **Pressure relief issues**
- ✓ **Detection equipment**

NFPA 56

Standard for Fire and Explosion Prevention During Cleaning and Purging of Flammable Gas Piping Systems

Chapter 8 – Purging Out of Service

- ✓ **Residual gas shall be displaced with inert gas**
- ✓ **Pressurized systems must be depressurized prior to purging**
- ✓ **Written procedures**
- ✓ **Gas should be discharged to a specified and unconfined outdoor location**
- ✓ **Monitoring requirements and detection equipment**

NFPA 56

Standard for Fire and Explosion Prevention During Cleaning and Purging of Flammable Gas Piping Systems

Annex A – Explanatory Material

Annex B – Purged End Points for Common Flammable Gases

Annex C – Sample Purge Procedure

Annex D – Human Factors Considerations

Annex E – Informational References

Question for the Audience…

….What was missing between 1980 and 2013?

Maybe an industry wide “Lesson Learned Mindset”?

Considerations for Evaluating a Lesson Learned

1. Need a qualified and unbiased team

Things that will bring value to the team…

- ✓ **Operational experience**
- ✓ **Technical experience**
- ✓ **Management systems experience**
- ✓ **Investigative experience**
- ✓ **Individuals driven by the need to understand**
- ✓ **Fearlessness**
- ✓ **Values that are consistent with professional engineering ethics**

Considerations for Evaluating a Lesson Learned

1. Need a qualified and unbiased team

Things that may negatively impact the outcome…

- ✕ **Going in mindset of knowing the answer before the evaluation begins**
- ✕ **Willingness to focus on "blame"**
- ✕ **Willingness to stop the minute a reasonable answer comes to light**
- ✕ **Concerns about the "politics" of the answer**
- ✕ **Concerns about legal/financial liability**

Considerations for Evaluating a Lesson Learned

2. Need a documented evaluation process

…How to gather/document facts

…How to interview individuals and teams

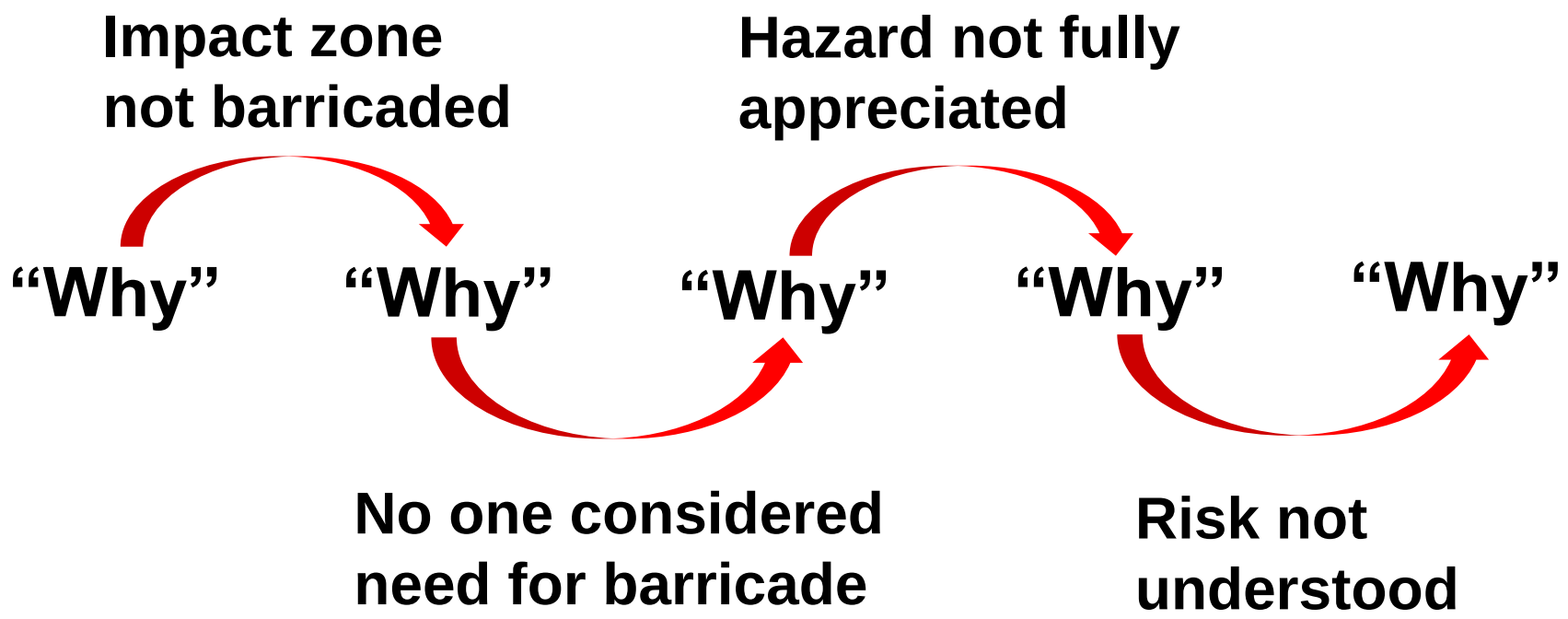
…Considers all the aspects

- ✓ Individual behaviors
- ✓ Team behaviors
- ✓ Management systems behaviors
- ✓ Use of controls
- ✓ Cultural drivers

Considerations for Evaluating a Lesson Learned

2. Need a documented evaluation process

… Demonstrates depth of investigation

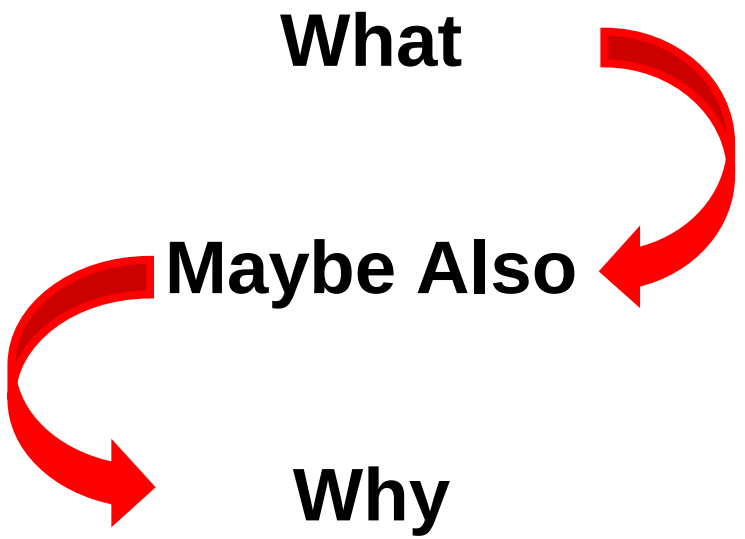


Considerations for Evaluating a Lesson Learned

2. Need a documented evaluation process

… Demonstrates critical thinking

- ✓ Thinking beyond the obvious answer
- ✓ Considering other factors that may also contribute
- ✓ Looking for problems behind the problem



Considerations for Evaluating a Lesson Learned

3. Need a willingness to follow through by leadership

- ✓ How do we implement change?
- ✓ Where are the resources going to come from?
- ✓ Is there a feedback loop to the leadership team?
- ✓ How do we assure confidence that the lesson is actually learned?

Considerations for Evaluating a Lesson Learned

4. **Must be willing to address the elephant(s) in the room!**

"I suppose I'll be the one to mention the elephant in the room."

Photos courtesy of iStock
Credit: andrewgenn

Fundamental Steps of Identifying & Evaluating A Lesson Learned

Where should I look?

- Look to the heavens?
- Internal condition reports
- Corporation condition reports & investigations
- Professional society publications
- Applicable codes & standards

Pillars of Creation
James Webb Space Telescope
Credit: NASA 2022

Fundamental Steps of Identifying & Evaluating A Lesson Learned

Where should I look?

- Equipment & product recalls
- News articles of same industry events
- News articles of different industry events
- Other sources?
- **Chemical Safety Board Investigation Reports**

How Should We Proceed

1. Critically read the document
2. Be cognizant of your facility & organization's performance history
3. Be open to asking questions of
   - same or similar events/conditions,
   - missing or broken barriers

How Should We Proceed

4. **Map deficiencies/weaknesses in the report to the CCPS Risk-Based Process Safety Management framework**
5. **Confirm robust barriers**
6. **Perform effectiveness reviews as needed**

Executive Summary

- April 2, 2019, a flammable isobutylene vapor cloud exploded at KMCO facility in Crosby, Texas.
- One fatality – KMCO employee
- 2 KMCO employees seriously injured (burns)
- 5 KMCO employees injured
- 23 contract workers injured
- Residents within 1-mile radius shelter-in-place for 4 hrs
- Preparing a batch of sulfurized isobutylene

Executive Summary (Continued)

- **Fist-sized piece of metal broke away from the body of a 3-inch cast iron y-strainer in the batch reactor's liquid isobutylene supply piping**
- **10,000 pounds isobutylene released**
- **Substantial facility damage from explosion & fires**
- **KMCO filed Chapter 7 bankruptcy (liquidation) May 2020**
- **Facility sold to Altivia Oxide Chemicals who planned to dismantle the sulfurized isobutylene equipment and operate new oxide reaction equipment.**

CSB Identified 3 Safety Issues

1. Emergency Response

- **KMCO's emergency response procedures and training did not properly limit the role of its operators during emergency response.**

- **KMCO's plant culture relied on unit operators taking quick actions to stop a release before the site's emergency response team assembled.**

- **Hazardous Waste Operations and Emergency Response (HAZWOPER) implementation was less than adequate.**

CSB Identified 3 Safety Issues (continued)

2. Remote Isolation

- **When the y-strainer ruptured, KMCO's workers lacked the safety equipment needed to isolate the isobutylene release from a safe location.**

- **Industry knowledge about the need to provide workers with the capability to remotely isolate a major leak from a safe location dates to at least 1969 – 50 years before this explosion.**

- **KMCO had an existing recommendation from a 2010 insurance underwriting report that called for remote isolation equipment.**

CSB Identified 3 Safety Issues (continued)

3. Hazard Evaluation

- **KMCO's hazard evaluations consistently overlooked or misunderstood that its y-strainer was made of cast iron –**
  - **Existing industry standards & good practice guidance documents either prohibit or warn against using in hazardous applications.**
- **None of the KMCO hazard evaluations identified the potential for liquid thermal expansion or other possible scenarios to develop high-pressure conditions within the piping system that included the y-strainer.**
- **Unlike other portions of the KMCO isobutylene piping, this piping section was not equipped with pressure relief device or otherwise protected form potential high-pressure conditions.**

Schematic

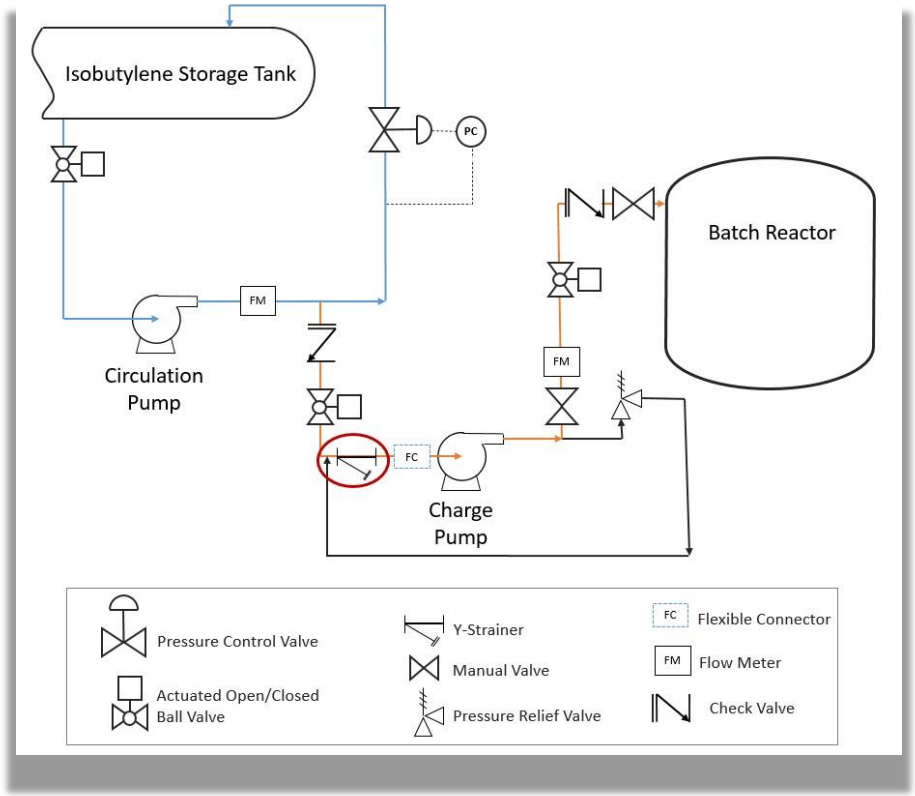


Figure 3. Isobutylene System. This simplified schematic shows the isobutylene system KMCO used to supply (charge) its batch reactor. The red circle shows the location of the y-strainer. (Credit: CSB)

Failed Y-strainer

Figure 18. Y-Strainer Piece. This photo shows the single piece that broke away from the failed y-strainer. (Credit: CSB)

Hole size: Roughly 3-in by 5 ½-in.

CSB

MISSION

Drive chemical safety excellence through independent investigations to protect communities, workers, and the environment.

VISION

A nation free from chemical disasters.

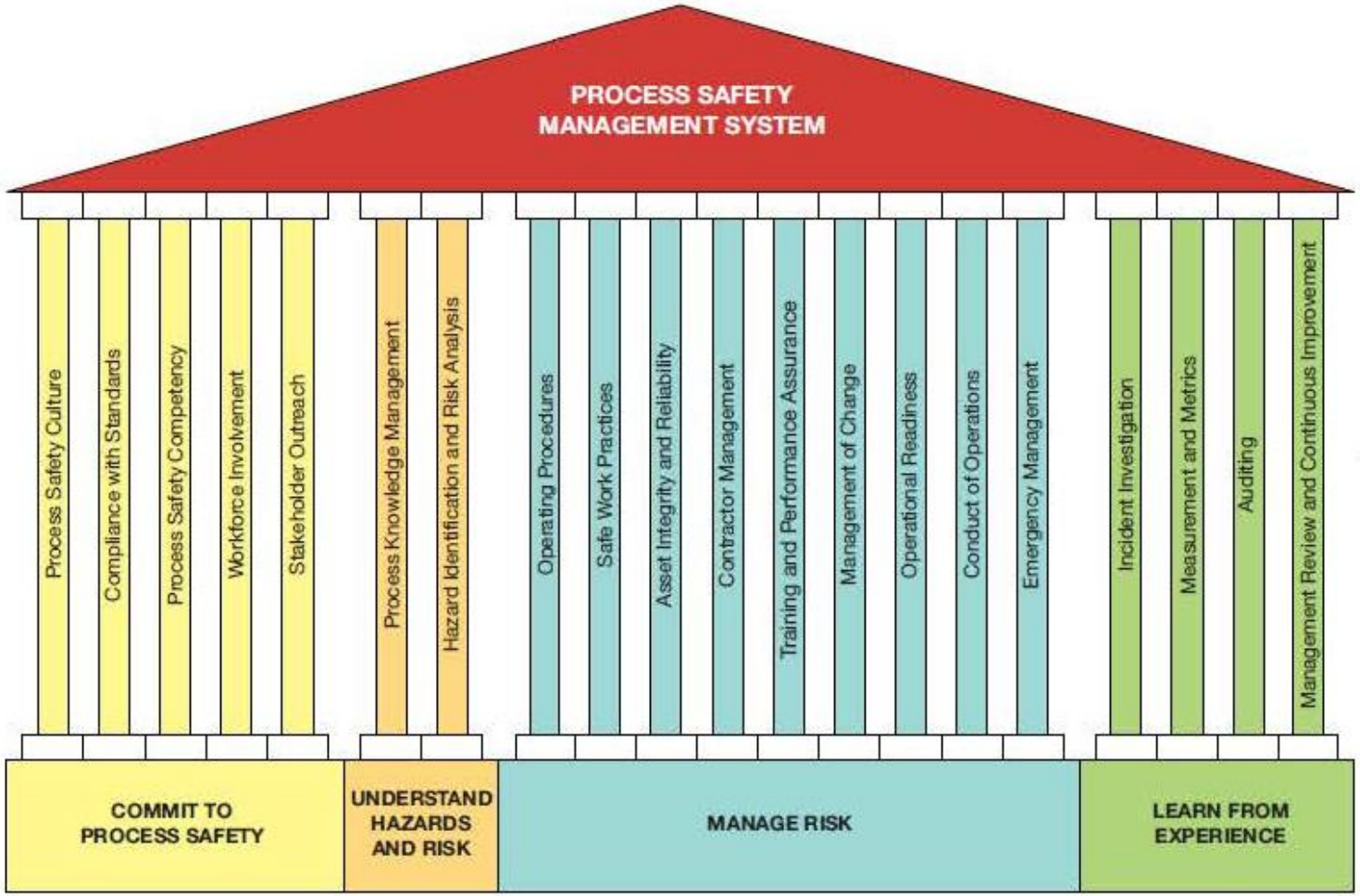
Source: CSB FY 2022-2026 Strategic Plan

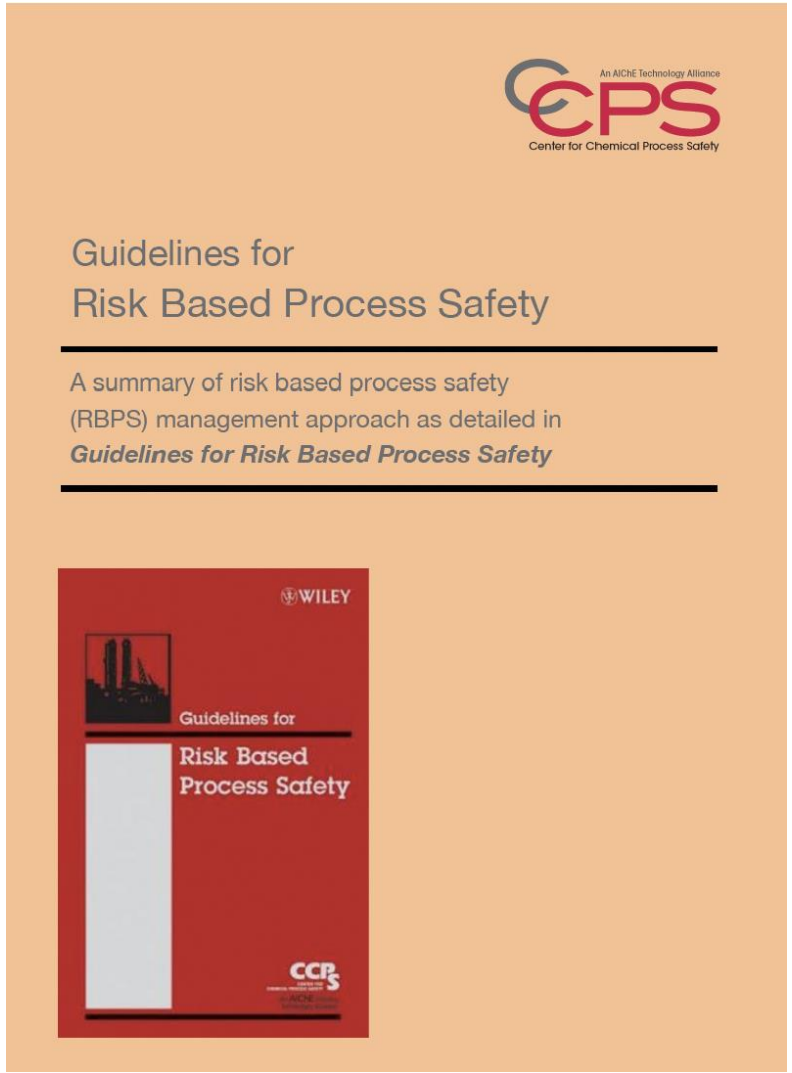
The CSB investigation report communicates the facts, conditions, and circumstances and the cause or probable cause of the event.

The report provides an excellent starting point for learning from the events of others.

The CSB investigation report does not always provide the deeper underlying causal factors.

Risk Based Process Safety Management System





1st Pillar: Commit to Process Safety

Element 1: Process Safety Culture

❑ **Authentic commitment to process safety excellence.**

- **KMCO had identified the area where the Reaction Control Room 2 Building (R2) was located as a Class 1, Division 2 location.**
- **One of the hazardous classified locations under the National Fire Protection Association (NFPA) 70, *National Electrical Code.***
- **Possibility of fire or explosion hazards may exist under abnormal conditions because of the presence of flammable material, such as isobutylene.**
- **R2 Building likely did not meet the NFPA's requirements because it contained unclassified electrical equipment, such as motor starters, and the building was not pressurized to prevent flammable vapor from entering the building.**

1st Pillar: Commit to Process Safety

- **KMCO Did Not Implement a Sound Safety Culture**

- **KMCO had not implemented its insurance underwriting recommendation from 2013 to "harden" certain electrical equipment inside the R2 Building or relocate this electrical equipment to the new blast-resistant Reaction Control Room.**

❑ **Is management ensuring effective execution of the corrective action program such that timely responses to process safety issues are occurring?**

27-year-old fatally injured in KMCO Explosion

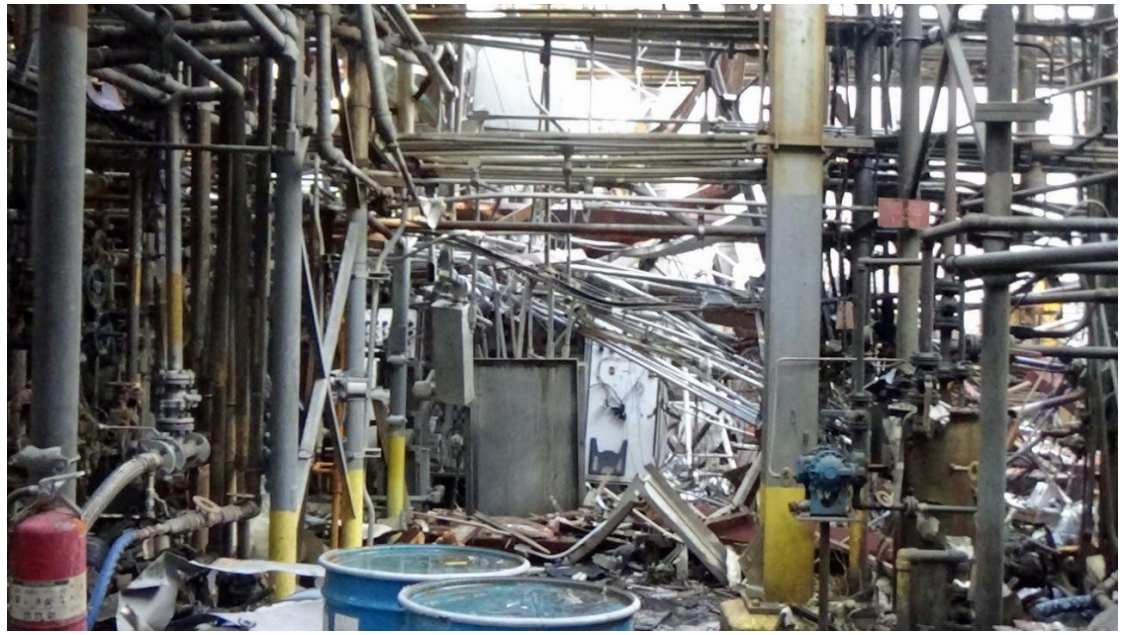


Figure 13. R2 Building (North Side). This post-incident photo shows the path KMCO workers commonly took to enter the R2 Building. With process units on the left and right, this walkway led to the entrance on the north side of the R2 Building, where emergency responders found Board Operator 2. (Credit: CSB)

James Mangum

November 7, 1991 – April 2, 2019

Source: Obituary

1st Pillar: Commit to Process Safety

Element 2: Compliance with Standards

- ❑ **Applicable regulations, standards, codes, and other requirements issued by national, state/provincial, and local governments, consensus standards organizations, and the corporation.**

  - ❖ **Cast iron is widely recognized as a brittle material.**

CSB identified 14 references, e.g.,

✓**NFPA 58, Liquefied Petroleum Gas Code**

NFPA 58 has prohibited the use of cast iron fittings in LPG piping systems since 1931.

✓**API Recommended Practice 574: Inspection Practices for Piping System Components**

✓**API Standard 2510: Design and Construction of LPG Installations**

Lack of Pressure-Relief Device on Charging Pump Inlet Piping

- **API Standard 521, *Pressure-relieving and Depressuring Systems***
  - **Ambient heat gain within an isolated piping system is among the most common causes of overpressure from liquid thermal expansion.**
  - **The API recommends installing a pressure-relief device if liquid thermal expansion is a credible hazard.**

  - **Pressure-relief device installed on isobutylene circulation loop piping**
  - **No reason why *(causal factors)* this protection was missed on the charging pump piping.**

1st Pillar: Commit to Process Safety

Element 2: Compliance with Standards

- ✓ **When was our organization's process for ensuring that applicable regulations codes, standards, etc. reviewed to ensure that the information is current and controlled in the design, operation, and maintenance of the existing and planned facilities?**

- ✓ **Have there been Condition Reports of out of date or incorrect regulations, codes, standards misapplied or missing in the design, operation, maintenance of the facility?**

1st Pillar: Commit to Process Safety

Element 3: Process Safety Competency

- ❑ **Organization has the skills and resources to mange process hazards.**

2018 Process Hazards Analysis (PHA) - November

- **KMCO does a "re-do" of the PHA**
  - **PHA team of 8 members:**
    - **7 KMCO employees averaging 16 years professional experience**
    - **Contract facilitator with 42 years of professional experience**
  - **PHA did not document potential high-pressure scenarios from liquid expansion hazards**
  - **P&ID showed charging pump inlet piping was stainless steel - CORRECT**
  - **PHA documentation y-strainer was stainless steel - INCORRECT**

1st Pillar: Commit to Process Safety

Element 3: Process Safety Competency

- ❑ Organization has the skills and resources to mange process hazards.

2018 Process Hazards Analysis (PHA) - November

- KMCO does a "re-do" of the PHA
  - PHA documented that previous incidents and near misses for the isobutylene system since 2016 were discussed.
  - 2015 event not acknowledged.
    - December 10, 2015, the cast iron y-strainer in the isobutylene system was discovered leaking.
    - KMCO maintenance replaced y-strainer on same day with in-kind replacement.

1st Pillar: Commit to Process Safety

Element 3: Process Safety Competency

- ❑ **Organization has the skills and resources to mange process hazards.**

- ✓ **How have we validated that our organization has adequate resources and the right mix of operational experience and PSM knowledge to conduct a robust PHA?**

- ✓ **Are we confident that the configuration management program of our facility is robust?**

- ✓ **Is the facility configuration periodically verified?**

2nd Pillar: Understand Hazards & Risks

Element 7: Hazard Identification & Risk Analysis

- ❑ **Identification of process safety hazards & potential consequences.**

2014 Process Hazards Analysis (PHA) - September

- **PHA for new isobutylene system**
- **Identified the potential high-pressure conditions within circulation piping and need for pressure relief**
- **DID NOT IDENTIFY thermal expansion hazard identified for charging pump piping**
- **P&ID DID NOT IDENTIFY check valve, y-strainer, or manual isolation valves on inlet to charging pump**

2nd Pillar: Understand Hazards & Risks

Element 7: Hazard Identification & Risk Analysis

- **KMCO acknowledged isobutylene system under OSHA PSM & EPA RMP.**

- **January 2017, KMCO ‘s PSM system audited to:**
  - **Conformance to regulations & good industry practice guidance**
  - **OSHA PSM standard & EPA RMP rule**
  - **CCPS book: *Risk Based Process Safety***

- **Results:**
  - **370 questions used in evaluation**
  - **Recommendations made for 92% of these questions**

2017 Audit Team Identified Factors

- **Hazard Evaluation Programs**
  - **Existing Process Hazard Analysis (PHA) program was “not in line with industry standards” with recommendations:**
    - **Ensure that an initial PHA had been performed for all covered processes**
    - **Existing PHAs be updated**
    - **Address previous incidents in future PHAs**
  - **KMCO had been addressing the audit findings**

2nd Pillar: Understand Hazards & Risks

Element 7: Hazard Identification & Risk Analysis

- ❑ **Identification of process safety hazards & potential consequences.**
  - ✓ **Are our internal and external audit corrective action items adequately risk-managed?**
  - ✓ **Do we conduct a root cause analysis when significant findings are identified?**
  - ✓ **Do we perform an Extent of Condition & Extent of Cause analyses?**

Areas of Concern

1st Pillar: Commit to Process Safety

Element 1 – Process Safety Culture
Element 2 – Compliance with Standards
Element 3 – Process Safety Competency

2nd Pillar: Understand Hazards & Risks

Element 6 – Process Safety Information Management
Element 7 – Hazard identification & Risk Analysis

Areas of Concern

3rd Pillar: Manage Risk

Element 10 – Asset Reliability & Integrity
Element 12 – Training
Element 13 – Management of Change
Element 14 – Operational Readiness
Element 15 – Conduct of Operations
Element 16 – Emergency Management

4th Pillar: Learn from Experience

Element 17 – Incident Investigation
Element 19 – Auditing
Element 20 – Management Review & Continuous Improvement

Questions

Thank You!