Chemical
SAFETY AND SECURITY TRAINING

Incident Investigation and Reporting

SAND No. 2011-1036C

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy's National Nuclear Security Administration
under contract DE-AC04-94AL85000.

Sandia National Laboratories

Key acronyms

RCA = *root cause analysis*

SVA = *security vulnerability analysis*

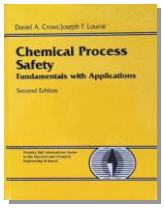
Incident investigation resources

CCPS 2003. Center for Chemical Process Safety, ***Guidelines for Investigating Chemical Process Incidents, 2nd Edition***, NY: American Institute of Chemical Engineers.

Chapter
1 Introduction
2 Designing an incident investigation management system
3 An overview of incident causation theories
4 An overview of investigation methodologies
5 Reporting and investigating near misses
6 The impact of human factors
7 Building and leading an incident investigation team
8 Gathering and analyzing evidence
9 Determining root causes – structured approaches
10 Developing effective recommendations
11 Communication issues and preparing the final report
...

Incident investigation resources

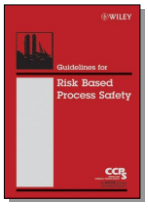
D.A. Crowl and J.F. Louvar 2001. ***Chemical Process Safety: Fundamentals with Applications, 2nd Ed.,*** **Upper Saddle River, NJ: Prentice Hall.**



Chapter 12 • Accident Investigations
12.1 Learning from accidents
12.2 Layered investigations
12.3 Investigation process
12.4 Investigation summary
12.5 Aids for diagnosis
12.6 Aids for recommendations

Incident investigation resources

CCPS 2007a. Center for Chemical Process Safety, *Guidelines for Risk Based Process Safety*, NY: American Institute of Chemical Engineers.



Chapter 19 • Incident Investigation

19.1 Element Overview
19.2 Key Principles and Essential Features
19.3 Possible Work Activities
19.4 Examples of Ways to Improve Effectiveness
19.5 Element Metrics
19.6 Management Review

Incident Investigation and Reporting

1. What is an *incident investigation*?
2. How does incident investigation fit into PSM?
3. What kinds of incidents are investigated?
4. When is the incident investigation conducted?
5. Who performs the investigations?
6. What are some ways to investigate incidents?
7. How are incident investigations documented?
8. What is done with findings & recommendations?
9. How can incidents be counted and tracked?

Photo credit: U.S. Chemical Safety & Hazard Investigation Board

Incident Investigation and Reporting

1. What is an *incident investigation*?

Results of explosion and fire at a waste flammable solvent processing facility
(U.S. CSB Case Study 2009-10-I-OH)

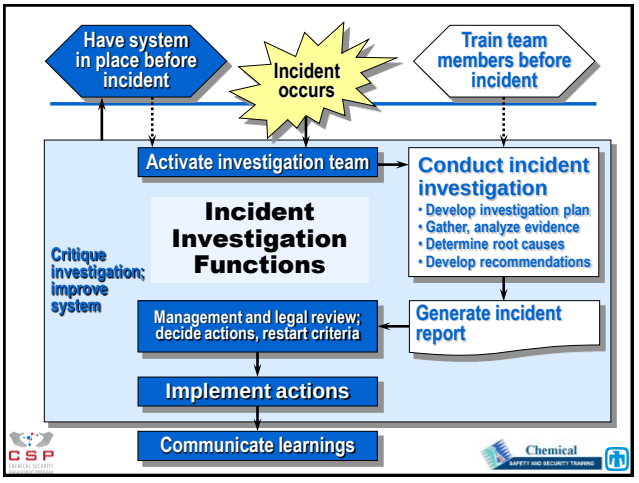
What is an *incident investigation*?

An *incident investigation*
is the management process

by which underlying causes of undesirable events are uncovered

and steps are taken to prevent similar occurrences.

- CCPS 2003



Learning from incidents

Investigations that will enhance learning

- are **fact-finding**, not fault-finding
- must get to the ***root causes***
- must be reported, **shared** and retained.

Definition - Root cause

Root Cause: **A fundamental, underlying, system-related reason why an incident occurred that identifies a correctable failure or failures in management systems.**

There is typically more than one root cause for every process safety incident.

- CCPS 2003

Incident Investigation and Reporting

1. What is an *incident investigation*?
2. How does incident investigation fit into PSM?

How does incident investigation fit into PSM?

Risk-Based Process Safety (CCPS 2007a)

Commit to Process Safety	Understand Hazards and Risks	Manage Risk	Learn from Experience
• Process safety culture	• Process knowledge management	• Operating procedures	• Incident investigation
• Compliance with standards	• Hazard identification and risk analysis	• Safe work practices	• Measurement and metrics
• Process safety competency		• Asset integrity and reliability	• Auditing
• Workforce involvement		• Contractor management	• Management review and continuous improvement
• Stakeholder outreach		• Training and performance assurance	
		• Management of change	
		• Operational readiness	
		• Conduct of operations	
		• Emergency management	

Historical **Potential**

Four perspectives for designing, building and operating a safe, secure and profitable facility

Actual **Hypo-thetical**

Historical

Codes, Standards, RAGAGEPs

• The historical perspective tells us what to do based on codes, standards and best practices that represent our accumulated experience and lessons learned from previous industry incidents.

Potential

Hazards, Consequences

• The potentials are what could happen if containment or control of a process hazard was lost or if a security incident occurred.

• The hypothetical, or predictive, perspective looks at what could go wrong, even if it has never happened before. This is a probabilistic perspective, based on hypothetical loss event scenarios.

Hypothetical

What-If, HAZOP, SVA

• The actual or real-time perspective can inform us of previously unrecognized or uncorrected problems, as they are manifested in actual incidents and near misses, as well as by ongoing inspections and tests that can detect incipient problems.

Actual

Incidents, Inspections, Tests

Incident Investigation and Reporting

1. What is an *incident investigation*?
2. How does incident investigation fit into PSM?
3. What kinds of incidents are investigated?

What kinds of incidents are investigated?

• The first step in an incident investigation is recognizing that an "incident" has occurred!

What kinds of incidents are investigated?

- The first step in an incident investigation is recognizing that an "incident" has occurred!

Yes

What kinds of incidents are investigated?

- The first step in an incident investigation is recognizing that an "incident" has occurred!

?

Definitions

Incident: An unplanned event or sequence of events that either resulted in or had the potential to result in adverse impacts.

Incident sequence: A series of events composed of an initiating cause and intermediate events leading to an undesirable outcome.

Source: CCPS 2008a

Incident types

Three categories of incidents, based on outcomes:

- Loss event
- Near miss
- Operational interruption

Incident types

Three categories of incidents, based on outcomes:

Loss event

- Actual loss or harm occurs (also termed *accident* when not related to security)

Near miss

Operational interruption

- Actual impact on production or product quality occurs

Incident types

Three categories of incidents, based on outcomes:

Loss event

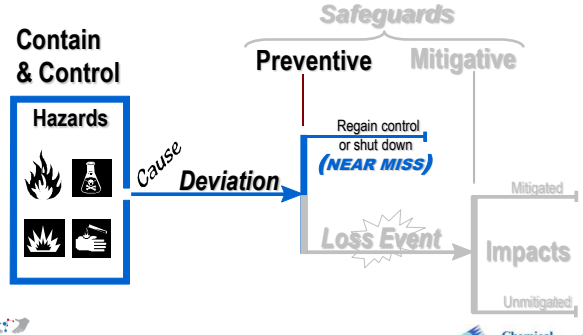
Near miss

Operational interruption

Near miss: **An occurrence in which an accident (i.e., property damage, environmental impact, or human loss) or an operational interruption could have plausibly resulted if circumstances had been slightly different.** - CCPS 2003

(Same concept for security incidents also)

One type of near miss



DISCUSSION

Give three or four examples of simple near-miss scenarios that would fit the graphic on the previous slide.

Include at least one related to facility security.

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Preventive safeguards revisited

Operational Mode: **Abnormal operation**

Objective: **Regain control or shut down; keep loss events from happening**

Examples of Preventive Safeguards:

- Operator response to alarm
- Safety Instrumented System
- Hardwired interlock
- Last-resort dump, quench, blowdown
- Emergency relief system

REVIEW

What are the equivalent of *preventive safeguards* for facility security physical protection systems?

___

___

___

___

Incident Investigation and Reporting

When is the incident investigation conducted?

- **Basic answer: As soon as possible.**
- **Reasons:**
  - **Evidence gets lost or modified**
    - **Computer control historical data overwritten**
    - **Outside scene exposed to rain, wind, sunlight**
    - **Chemical residues oxidize, etc.**
  - **Witness memories fade or change**
  - **Other incidents may be avoided**
  - **Restart may depend on completing actions to prevent recurrence**
  - **Regulators or others may require it**
    - **E.g., U.S. OSHA PSM: Start within 48 h**

When is the incident investigation conducted?

Challenges to starting as soon as possible:

- Team must be selected and assembled
- Team may need to be trained
- Team may need to be equipped
- Team members may need to travel to site
- Authorities or others may block access
- Site may be unsafe to approach / enter

DISCUSSION

What might be done to overcome some of the challenges to starting an investigation sooner?

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Incident Investigation and Reporting

Who performs the investigations?

Options:

- Single investigator
- Team approach

Who performs the investigations?

Options:

- Single investigator
- **Team approach**

Advantages of team approach: (CCPS 2003)
- Multiple technical perspectives help analyze findings
- Diverse personal viewpoints enhance objectivity
- Internal peer reviews can enhance quality
- More resources are available to do required tasks
- Regulatory authority may require it

Who performs the investigations?

The "best team" will vary depending on the nature, severity and complexity of the incident.

Some possible team members:

- Team leader / investigation method facilitator
- Area operator
- Process engineer
- Safety/security specialist
- I&E / process control or computer systems support
- Union safety representative
- Contractor representative
- Other specialists (e.g., metallurgist, chemist)

Train team members before incident

Training site management, potential team members and support personnel ahead of time will speed up the start of the investigation.

- Larger companies may have one or more specially trained persons available for major incident investigations
- All personnel need to be familiar with the basic incident recognition and reporting requirements

Conduct incident investigation
- Develop investigation plan
- Gather, analyze evidence
- Determine root causes
- Develop recommendations

Generate incident report

Incident Investigation and Reporting

1. What is an *incident investigation*?
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6. What are some ways to investigate incidents?

Older investigations

- Only identified obvious causes; e.g.,
  - "The line plugged up"
  - "The operator screwed up"
  - "The whole thing just blew up"
- Recommendations were superficial
  - "Clean out the plugged line"
  - "Re-train the operator"
  - "Build a new one"

Layered investigations

- Deeper analysis
- Additional layers of recommendations:
  1. Immediate technical recommendations
     - *e.g., replace the carbon steel with stainless steel*
  2. Recommendations to avoid the hazards
     - *e.g., use a noncorrosive process material*
  3. Recommendations to improve the management system
     - *e.g., keep a materials expert on staff*

Investigation process

1. Choose investigation team
2. Make brief overview survey
3. Set objectives, delegate responsibilities
4. Gather, organize pre-incident facts
5. Investigate, record incident facts
6. Research, analyze unknowns
7. Discuss, conclude, recommend
8. Write clear, concise, accurate report

Discovery phase

- Develop a plan
- Gather evidence
  - Take safety precautions; use PPE
  - Preserve the physical scene and process data
  - Gather physical evidence, samples
  - Take photographs, videos
  - Interview witnesses
  - Obtain control or computer system charts and data

Analysis of facts

- Develop a timeline
- Analyze physical and/or electronic evidence
  - Chemical analysis
  - Mechanical testing
  - Computer modeling
  - Data logs
  - etc.
- Conduct multiple-root-cause analysis

Some analysis methods

- Five Why's
- Causal Tree
- RCA (Root Cause Analysis)
- FTA (Fault Tree Analysis)
- MORT (Management Oversight and Risk Tree)
- MCSOII (Multiple Cause, Systems Oriented Incident Investigation)
- TapRooT®

Some analysis methods

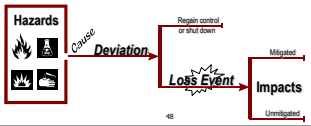
General analysis approach:

- Develop, by brainstorming or a more structured approach, possible incident sequences
- Eliminate as many incident sequences as possible based on the available evidence
- Take a closer look at those that remain until the actual incident sequence is discovered (if possible)
- Determine the underlying root causes of the actual incident sequence

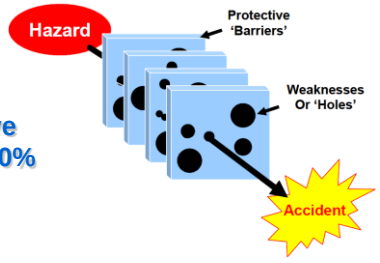
Incident sequence questions

Determine, for the incident being investigated:

- What was the *cause* or *attack* that changed the situation from "normal" to "abnormal"?
- What was the actual (or potential, if a near miss) *loss event*?
- What safeguards failed? What did not fail?



"Swiss cheese model" revisited



REMEMBER:

No protective barrier is 100% reliable.

EXERCISE

Conduct "Five Why's" on the most recent loss event that has happened to you personally.

Why **did the loss event happen? Because** _____

_____

Why? **Because** _____

Why? **Because** _____

Why? **Because** _____

Why? **Because** _____

Discuss, conclude, recommend

- Find the most likely scenario that fits the facts
- Determine the underlying management system failures
- Develop layered recommendations

Aids for diagnosis

- Location of fire ignition?
- Deflagration or detonation?
- Hydraulic or pneumatic failure?
- Pressure required to rupture containment?
- Medical evidence?

See Crowl and Louvar 2001 Section 12.5 for details

Incident Investigation and Reporting

How are incident investigations documented?

A written report documents, as a minimum:

- Date of the incident
- When the investigation began
- Who conducted the investigation
- A description of the incident
- The factors that contributed to the incident
- Any recommendations resulting from the investigation

Typical report format

1. Introduction
2. System description
3. Incident description
4. Investigation results
5. Discussion
6. Conclusions
7. Layered recommendations

Investigation summary

- The investigation report is generally too detailed to share the learnings to most interested persons
- An **Investigation Summary** can be used for broader dissemination, such as to:
  - Communicate to management
  - Use in safety or security meetings
  - Train new personnel
  - Share lessons learned with sister plants

(See also: Crowl & Louvar 2001, Figure 12-1 and Example 12-2)

Accident involving contractors' injury during the operation of opening of a vessel for standard maintenance

Description: This accident occurred in May 2003 during repair work in a propylene reactor at a European Petrochemicals site. The cover of a manhole was ejected 5 metres by a residual pressure inside the reactor.

Consequences: 5 operators from the maintenance department were rushed to hospital. Nobody was seriously injured.

History: Work had to be done in the vessel. Before the work could start, the vessel must be put into safe conditions and the manhole must be opened. That has been decided during the safety preparation meeting.

Preparation: The putting into safe conditions started on Wednesday. The drawings of this part of the plant have been taken; the valves to be closed are noted on the drawing and then closed in the field. Then, a nitrogen flush is installed in the entire installation (vessel and lines) to ensure that all flammable gases are removed from the system. Flushing means that nitrogen pressure is applied and then the wash out is released to a safe location. This operation goes on for several days.

After that, on Friday, before opening the vessel, blinds had to be placed into the lines (to ensure that no product could enter the vessel). The entire system has been depressurised. These blinds are indicated on the drawing and the maintenance people started to put in the blinds (opening the lines to put them in).

The accident: Having started this operation, all of a sudden, they smell some gas odour and called the shift supervisor. They find out that a valve on a small line has not been closed. They close the valve and decided to flush 5 additional times. After that and while monitoring the depressurisation of the vessel via the manometer on the outside of the tank (from zero to 25 bars, impossible to read lower that 0.5), they opened the manhole. A whistling sound has been heard indicating a residual pressure in the vessel. When the noise was ended, they continued to open the manhole. At a certain moment the manhole was sprang heavily out by the residual pressure in the vessel, it was ejected and fell to the ground striking two employees.

Lesson Learned:

- The application of the procedure has to be strictly followed and supervised.
- Monitoring has to be done using multiple devices or means, so as to be sure of the indicators.
- The equipment handling has to be done using the principles of inherent safety.

Investigation summary example

Source: **S2S** - A Gateway for Plant and Process Safety, www.safety-s2s.eu

Chemical SAFETY AND SECURITY TRAINING

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Chemical SAFETY AND SECURITY TRAINING

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Findings and recommendations

What is the most important product of an incident investigation?

1. The incident report
2. Knowing who to blame for the incident
3. Findings and recommendations from the study

Findings and recommendations

What is the most important product of an incident investigation?

1. The incident report
2. Knowing who to blame for the incident
3. Findings and recommendations from the study
4. The actions taken in response to the findings and recommendations from the study

Findings and recommendations

Example form to document recommendations:

ORIGINAL STUDY FINDING / RECOMMENDATION			
Source: ☐ PHA ☐ Incident Investigation ☐ Compliance Audit ☐ Self-Assessment ☐ Other			
Source Name			
Finding No.		**Risk-Based Priority** *(A, B, C or N/A)*	
Finding / Rec-ommendation			
Date of Study or Date Finding / Recommendation Made			

Aids for recommendations

Overriding principles (Crowl and Louvar 2001, p. 528):

- Make safety [and security] investments on cost and performance basis
- Improve management systems
- Improve management and staff support
- Develop layered recommendations, especially to eliminate underlying causes

Aids for recommendations

Overriding principles:

- **Make safety [and security] investments on cost and performance basis**
- **Improve management systems**
- **Improve management and staff support**
- **Develop layered recommendations, especially to eliminate underlying causes and hazards**

CCPS Process Safety Beacon

An AIChE Industry Technology Alliance

http://www.aiche.org/CCPS/Publications/Beacon/index.aspx

Messages for Manufacturing Personnel

Sponsored by CCPS Supporters

How Can You Use "The Beacon"?

February 2008

One important issue in maintaining a good process safety culture in any organization is to maintain a sense of vulnerability. In other words, we must always remember, and respect, the hazards associated with our processes and materials. If we have good and effective process safety management systems, one result is that we will have fewer incidents. This can lead to complacency - we forget why we are doing all of the activities in the process safety management system which result in good performance and few or no incidents. So, it is important to use resources like "The Beacon" to remind ourselves of what can happen if we don't do those activities – such as Hazard Identification and Risk Analysis (including assigning our most knowledgeable people to Process Hazard Analysis studies), Operating Procedures, Asset Integrity and Reliability, Management of Change, Emergency Management, Incident Investigation, Auditing, and others. In all of the incidents we discuss in the Beacon, there has been a failure in one or more of these important process safety management systems

(continued from previous slide)

Did you know?

- Nearly all incidents are the result of more than one failure. Some failures result in near misses - that is they did not cause an incident this time, but could have.
- Almost every month, "The Beacon" receives a number of emails pointing out other lessons that can be learned from the incident discussed, which have not been included in the Beacon.
- Because of the limited space available in "The Beacon", we must pick one of the many lessons from each incident, and focus the Beacon on that lesson. But there are always other lessons.
- Whenever possible, if the reports on the incidents described are publicly available, we will provide a reference in the Beacon cover email note.

What can you do?

- Good – post the Beacon in places where workers will see it and read it – for example, bulletin boards, locker rooms, lunch rooms, control rooms, the gate house.
- Better – use the Beacon as the basis for safety meetings or other safety discussions with operators and other workers.
- Better yet – Develop additional information which relates the topic in the Beacon to the operations in your own plant, including any similar incidents or near misses in your company, and discuss this information with workers.
- Best – Unit or plant management leads a discussion of the Beacon with workers and challenges them to find other lessons in the incident described, beyond those discussed in the Beacon. Challenge plant safety committees to use the Beacon in their work.

Learn from the experience of others!

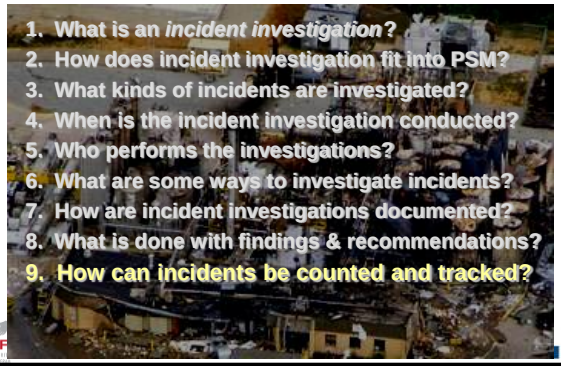
Implementation

As for PHA action items,

a system must be in place to ensure all incident investigation action items are completed on time and as intended.

- **Same system can be used for both**
- **Include regular status reports to management**
- **Communicate actions to affected employees**

Incident Investigation and Reporting



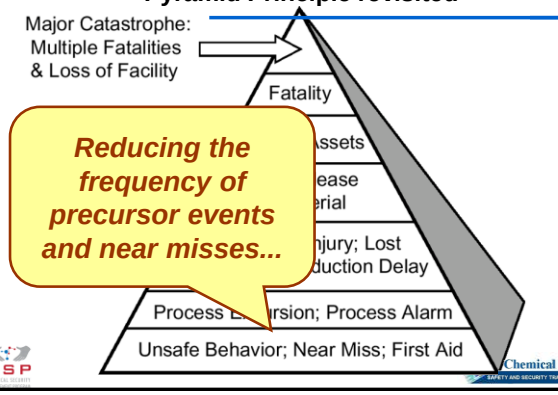
How can incidents be counted and tracked?

- **"Lagging indicators"** — ***actual loss events***
  - **Major incident counts and monetary losses**
  - **Injury/illness rates**
  - **Process safety incident rates**

How can incidents be counted and tracked?

- "Lagging indicators" — *actual loss events*
  - Major incident counts and monetary losses
  - Injury/illness rates
  - Process safety incidents rate
- **"Leading indicators"** — ***precursor events***
  - **Near misses**
  - **Abnormal situations**
    - **E.g., Overpressure relief events**
    - **Safety alarm or shutdown system actuations**
    - **Flammable gas detector trips**
  - **Unsafe acts and conditions**
  - **Other PSM element metrics**

Pyramid Principle revisited



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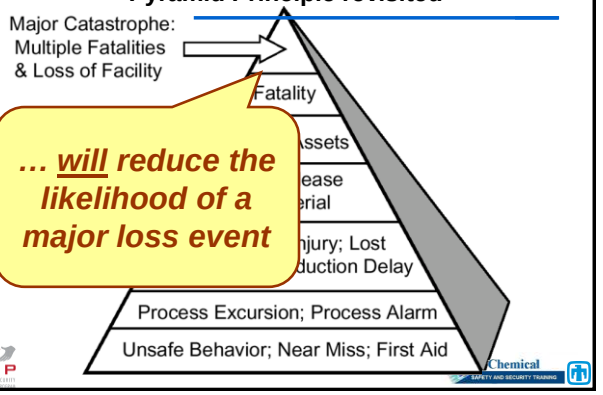

Additional resources

- AIChE *Loss Prevention Symposium*, Case Histories session (every year)
- www.csb.gov reports and videos
- CCPS 2008b, Center for Chemical Process Safety, ***Incidents that Define Process Safety***, NY: American Institute of Chemical Engineers
- CCPS, "**Process safety leading and lagging metrics – You don't improve what you don't measure**," available at www.aiche.org/uploadedFiles/CCPS/Publications/CCPS_ProcessSafety2011_2-24.pdf