1
INTRODUCTION

"Learning is not compulsory... neither is survival."
—W. Edwards Deming, Engineer and Management Consultant

Nearly everything we do today, as we manage process safety to prevent losses of primary containment that result in fires, explosions, and toxic releases, we do because of conditions that led to past incidents. Our engineering forebears began building the modern practice of process safety at the beginning of the industrial revolution. Subsequent generations have steadily advanced process safety.

For example, when E.I. DuPont built a black powder works in Delaware, USA, in 1802, he took note of the explosions that had happened in other black powder works. To protect his workers, family, and property, his process buildings were constructed of thick stone, with blow-out walls aimed away from people and buildings (Klein 2009).

Similarly, Sir Humphrey Davy noted the large number of coal dust explosions in English mines in the early nineteenth century (Gibbs 2020). After talking to miners who survived such explosions, he designed an explosion-proof lamp based on principles still used today in flame arrestors and explosion-proof electrical boxes (Figure 1.1).

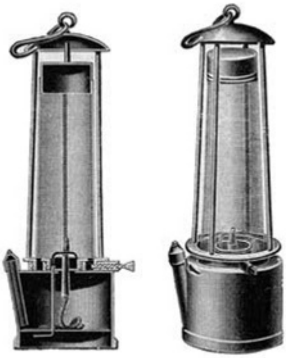

Figure 1.1 The Davy Lamp

In 1880, H.R. Worthington, A.L. Holley, and J.E. Sweet founded the American Society of Mechanical Engineers (ASME) to create uniform engineering standards that would ensure safety, reliability, and efficiency (ASME 2020).

Working on behalf of the chemical engineering profession, the American Institute of Chemical Engineers (AIChE) began to share findings and recommendations from process safety incidents via the Ammonia Plant Safety (Williams 2005) and Loss Prevention Symposia in the 1950s and 1960s (Freeman 2016). AIChE's Design Institute for Emergency Relief Systems (DIERS) began publishing guidelines for multiphase relief systems in the 1970s (AIChE 2020a).

Until the mid-1980s, institutional lessons learned came in the form of technology innovations, new or revised standards and codes, or back-up systems. This began to change with the formation of AIChE's Center for Chemical Process Safety (CCPS) in 1985. CCPS began the process of formally leveraging incident findings and successful practices into "Guidelines" and "Concepts" (Berger 2009). In 1988 CCPS codified the first Process Safety Management System (PSMS). The CCPS 12 Elements (CCPS 1989) provided the first organized common framework to comprehensively manage all the standards, technologies, and practices needed to control a company's process safety hazards. The original framework has evolved into today's 20 elements of Risk Based Process Safety (RBPS), which are organized in four pillars: Commit to Process Safety, Understand Hazards and Risk, Manage Risk, and Learn from Experience (CCPS 2007).

Regulations around the world also began to emerge in the 1980s, most notably the Sevesso Directive in the European Union, the Process Safety Management (PSM) regulation in the USA, and the Control of Major Accident Hazards (COMAH) in the UK. Most national and regional process safety regulations are based on one or a combination of these original regulations.

Unfortunately, incidents continue to happen despite 200 years of continuous development of technology, standards, publications, and management systems. They continue to happen despite the great number of recommendations from incident investigations conducted by every operating company in this industry. And nearly every incident that occurs in an industry, a company, or a plant has root causes that resemble the causes of previous incidents.

1.1 The Focus of this Book

CCPS (CCPS 2019a) and others have written guidelines addressing the general process of incident investigations. These books focus heavily on the process of investigation, the determination of root causes and causal factors, and the process of developing findings and recommendations. CCPS and others also have published books that describe past incidents to extract the lessons that could be learned from them (Gil 2008; CCPS 2019b; Kletz 2019; Hopkins 2008; Hopkins 2012). What's more, CCPS provides several publications addressing how to drive a culture of improvement in process safety (CCPS 2018; 2019c).

Just the same, incidents that look the same as previous incidents continue to occur—whether they happen at a site, or within a company, or replicate well publicized external incidents. Section 3.2 will discuss the numerous reasons companies fail to learn, including but not limited to:

- imbalance between production and safety
- corporate culture problems
- employment turnover
- financial or liability concerns
- lack of employee involvement
- lack of leadership ownership of process safety
- lack of sense of vulnerability
- knowledge remaining in silos
- normalization of deviance.

This book seeks to help companies overcome the reasons they fail to learn. It greatly expands on the process for:

- Seeking and obtaining key findings from external incidents.
- Translating findings into lessons learned. And especially
- Converting these lessons learned into institutional knowledge.

While the examples in this book focus on learning from incidents outside the company, the process described in this book can—and should—be applied to transform findings from internal incidents and near-misses into institutional knowledge.

Let's define some key terms for this book. Note that most of these terms can be found in the CCPS glossary, while a handful are specific to this book.

Causal factor: A major unplanned, unintended contributor to an incident (a negative event or undesirable condition) that, if eliminated, would have either prevented the incident or reduced its severity or frequency.

Root cause(s): A fundamental, underlying, system-related reason why an incident occurred that identifies a correctable failure(s) in management systems. There is typically more than one root cause for every process safety incident.

Findings: The root causes and causal factors of the incident, as determined by the investigator.

Near-miss: An event in which an accident (that is, property damage, environmental impact, or human loss) or an operational interruption could have plausibly resulted if circumstances had been slightly different.

Lessons learned: The process of applying knowledge gained from past incidents in current practices.

Institutional knowledge: The translation of the lessons learned by the experts into the company's standards and policies, its PSMS, its culture, and into the rigor and professionalism with which it manages process safety.

The difference between the latter two terms is critical in this book. Specifically, individuals do the primary learning, and then work with others in the organization to translate what they learned into improvements to 1) the corporate PSMS, 2) relevant standards and policies, and 3) designs and practices in company facilities. Only once these improvements are in place, are being followed, and are being managed on a reliable ongoing basis do lessons learned become institutional knowledge.

After making the case for continuous learning from incidents, we will evaluate ways that individuals and companies learn. We will then describe a recommended model for continuous corporate change driven from incidents, the Recalling Experiences and Applied Learning (REAL) Model. Next, we will provide a variety of scenarios that show companies in different industries applying this model to transform findings from incidents into institutional knowledge—and permanently retain that knowledge.

1.2 Why Should We Learn from Incidents?

In 1995 The Dow Chemical Company established a “Generational Goal” of reducing its process safety incidents by 90% between 1996 and 2005. Dow took many proactive steps including:

- implementing a rigorous process safety management system
- establishing centers of excellence
- defining key roles for leaders in driving process safety improvement
- learning from internal and external incidents.

Additional detail may be found in the reference (Champion 2017). Although Dow didn't quite meet its initial goal, the reduction in incidents was still quite significant. Inspired by the progress, Dow set a new goal: to reduce incidents by another 75% by 2015. However, by 2008 Dow realized that, for the past five years, their performance had effectively plateaued. Other members of the American Chemistry Council (ACC) had the same result, as shown by the dotted and dashed lines in Figure 1.2.

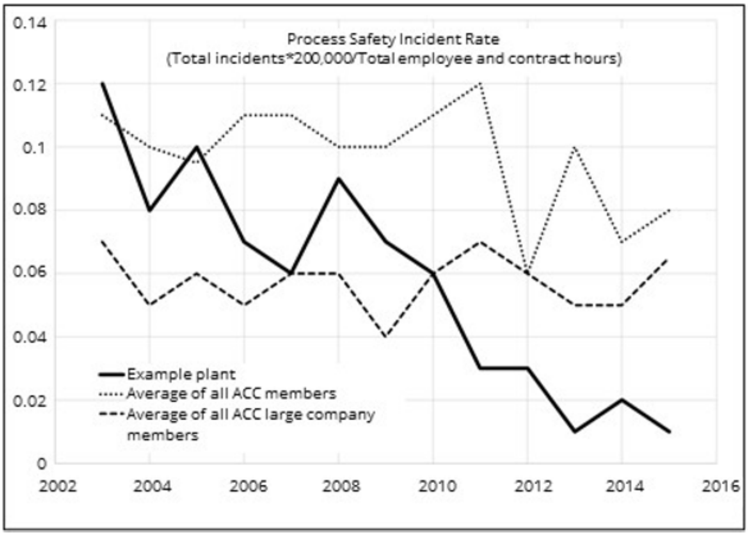

Figure 1.2 Incident Reduction Case Study (Champion 2017)

Dow analyzed the bottlenecks preventing further incident reduction and noted that many incidents had the same management system failures and causal factors: asset integrity and work practices related to corrosion under insulation (CUI). Dow sought out findings, recommendations, and best practices related to these factors from many internal and external sources. They translated what they learned into new standards, updated their PSMS, and drove training and knowledge about CUI across all their facilities. The solid line in Figure 1.2 shows the result at one plant, where the process safety incident rate dropped from 0.12 per 200,000 person-hours to 0.01 between 2003 and 2015.

With the current industry rate of process safety incidents, few days pass without a media report of a fire, explosion, or toxic release that has caused injuries or fatalities. We need to do better than we have been doing. And the

Dow Plant example shows that we can—by learning from incidents and embedding what we learn in the culture.

1.2.1 The Theory of Root Cause Correction

Most process safety hazards require multiple barriers to control them. No barrier is 100% reliable. Every barrier has a "probability of failure on demand," represented in Figure 1.3 as holes in slices of Swiss cheese.

- Hazards are controlled by multiple protective barriers.
- Barriers may have weaknesses or "holes."
- When the holes align, a hazard may pass through all the barriers, with the potential for adverse consequences.
- Barriers may be physical or engineered containment, or procedural controls dependent on people.
- Holes may be latent/incipient or opened by people.

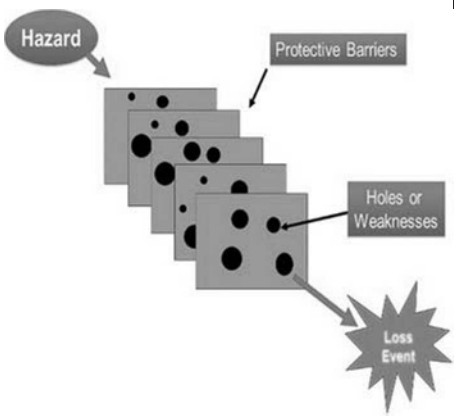

Figure 1.3 The Swiss Cheese Model (Adapted from Reason 1990)

Preventive barriers control process deviations and keep hazards within process equipment. When releases do occur, mitigating barriers prevent or reduce the consequences for workers, the facility, the public, and the environment.

If we do not manage our barriers properly, it's as if we increased the size of the holes in the Swiss cheese. The probability of failure on demand—the probability that hazards will pass through the barriers and cause harm—will increase.

We manage process barriers by adhering in a disciplined way to our PSMS and applicable standards. For example, the safe work practices element of RBPS (CCPS 2007) controls the following barriers:

- control of ignition sources
- hot work

- human factors
- isolation
- job hazard analysis/job safety analysis
- line and equipment opening
- lockout/tagout
- monitoring for flammables/toxic gases in work area
- non-routine work
- permits to work.

Very few process safety incidents occur for unforeseen reasons. In nearly every incident that has occurred, at least one, and usually more than one, important process barrier has failed. This means gaps existed in the PSMS and/or standards, or in the execution of the PSMS and/or standards.

Faithful and professional execution of the PSMS and adherence to standards should control and manage <u>all</u> barriers. When an incident has occurred, a proper incident investigation should identify the gaps in the PSMS and standards that allowed some barriers to fail. Closing these gaps will prevent the same incident from happening again. More importantly, closing these gaps makes progress toward eliminating all incidents that the existence of these gaps would allow.

1.2.2 Acting on Learning from High-Potential Near-misses

A near-miss is sometimes defined as an incident that, by chance, had no or only minimal consequences on people, the process, and the environment. As mentioned above, most process hazards require more than one barrier to control them. What if only one of these barriers fail, but the other(s) function? What if a confused operator reaches to open a valve and realizes just in time that it was the wrong valve? These, too, are near-misses. In all the following cases, a near-miss has occurred:

- any time your process has gone outside the safe operating window
- when testing or inspection reveals that a barrier has failed or has a latent defect
- when an incorrect action was stopped just in time.

> Near-misses are a gift — on a silver platter.

Just like actual incidents, near-misses happen because of gaps or weaknesses in PSMS, standards, and process design. Because near-misses point out these gaps without harming people or your process, they are a gift on a silver platter. Use this gift to find weaknesses in your company's PSMS, standards, culture, and knowledge. Develop actions broad and deep enough to correct these weaknesses. Ensure that the company implements these actions. Then ensure that weaknesses don't creep back in by using metrics and audits. Finally, keep everyone across the company aware of the consequences of tolerating gaps and weaknesses.

1.2.3 Learning from Other Company's (External) Incidents

A significant body of literature (and other media) describing the details of high-profile incidents has accumulated over the years. Many CCPS books and publications from other sources describe the conditions that led to incidents and the root causes, highlighting important lessons that companies should learn and embed.

The US Chemical Safety and Hazard Investigation Board (CSB) is one of the best-known sources of literature and videos about incidents. Many more sources exist, as Section 2.2 will cover in more detail.

By evaluating external incident reports, you will usually recognize root causes, findings, and recommendations that apply directly to your process, plant, or company. You can harvest them and begin to apply them immediately. As you institutionalize these lessons learned, you can use images from the reports to drive the message home visually.

The resources listed in Section 2.2 describe hundreds, perhaps thousands, of external incidents. Many of these incidents have been indexed in the Appendix to this book, along with their key root cause or causal factor as identified by the investigation team and the CCPS subcommittee members who championed this book. External incident reports are the gift that keeps on giving. If you haven't evaluated the learning opportunities from external incidents, or if you haven't evaluated them broadly or deeply enough, you have missed valuable opportunities to adapt and improve your PSMS and standards to prevent similar incidents from happening in your plant(s). There is no reason why your company should experience an incident with the same root cause as an external incident.

1.2.4 Societal Expectations and the Business Case

The CCPS guidelines for corporate process safety leadership detail many ways that society expresses its demand for industry to eliminate process safety incidents (CCPS 2019). Government agencies would not provide external incident reports for us to learn from if society didn't want us to learn and improve, nor would they enact and enforce process safety regulations. Similarly, community advocates press for new and stronger regulations, and victims seek civil penalties when incidents occur.

Society does not want companies to forego profitability, but instead wants profitability and protection go hand in hand. CCPS puts it this way:

> "A business case for process safety should not be necessary. The need to protect workers, the community, and the environment is as obvious as the need to protect market share, provide and protect shareholder value, and make payroll. But with the many daily demands of business, leaders can sometimes leave the obvious behind. When a company and its leaders leave process safety behind, they lose out on the significant financial and organizational benefits (CCPS 2019)."

CCPS further explains the business case for process safety, touching on five financial and organizational benefits:

- *corporate social responsibility*. Acting responsibly has a positive impact on share price.
- *loss prevention*. By avoiding incidents, the company avoids associated costs.
- *sustainable growth*. Process safety enhances the company's reliability and productivity.
- *business flexibility*. Easing societal resistance to the company's presence enables it to focus on growth.
- *leadership excellence*. Policies, practices, and competencies that drive rigor, dedication, and professionalism carry over to all other parts of the business.

In summary, society expects our industry to eliminate incidents and their impacts on workers, the public, and the environment. With strong leadership and continuous learning, the company can meet society's expectations while adding business value.

With all the external incidents available to learn from, we can meet both societal and shareholder expectations. We must study the findings of these incidents, build them into our PSMSs, standards, and policies, and make them part of our culture.

So, let's get to work.

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