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INTRODUCTION

1.1 AN INTRODUCTION TO PROCESS SAFETY AND METRICS

Process safety management[1] is a disciplined framework for managing the integrity of operating systems and processes handling hazardous substances by applying good engineering, operating, and maintenance practices. It deals with the prevention and control of risks that have the potential to release hazardous materials or energy. Such incidents can result in a toxic release, fire, or explosion and could ultimately result in serious injuries, property damage, environmental degradation, and lost production.

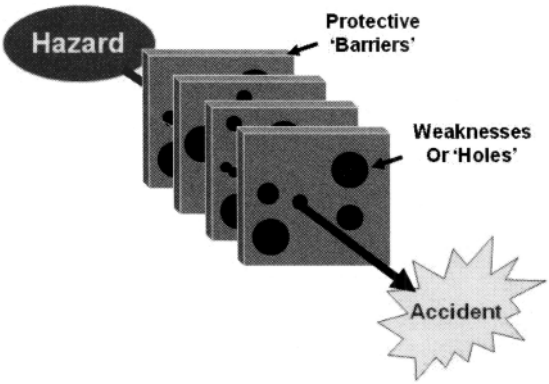
Process safety incidents are rarely caused by a single catastrophic failure, but rather by multiple events or failures that coincide and collectively result in an incident. This relationship between simultaneous or sequential failures of multiple systems is illustrated by the "Swiss cheese model,"[2] as shown in Figure 1.1, where hazards are contained by multiple protective barriers that may have weaknesses or "holes."

The barriers (represented as individual slices of "cheese") are elements of a process safety management system or some other layer of protection designed to prevent an incident from occurring. The holes in the slice of cheese represent deficiencies (or failures) in those barriers, gaps that may allow an event to escalate into an incident. When holes align, hazardous energy or chemical may be released, resulting in the potential for harm. Barriers may be physically engineered containment or behavioral controls dependent on people. Holes may be latent, incipient, or actively opened by people.

[1] "Process safety" is the term used in the process industries for what, in a more general technological context, is called "system safety."

[2] The Swiss cheese model of accident causation was originally proposed by British psychologist James T. Reason and has since gained widespread acceptance in many risk-analysis and management fields including process safety.

Figure 1.1 Swiss Cheese Process Safety Model (CCPS, 2007b)



This analogy can also describe two types of metrics—leading and lagging. Events that occur by passing through gaps in a process safety management system or protective system (e.g., loss of primary containment events, near misses, or process safety incidents) can be described as "lagging indicators." However, detecting and measuring a failure of a management system or protective system (i.e., a hole in the "cheese") before an incident occurs (e.g., failure to complete a scheduled mechanical integrity system, failure to use an appropriate management of change (MOC) process) are described as "leading metrics."

Serious incidents may be predicated by a number of less-severe related incidents resulting in minor or even no loss. Such predicating events may be low-consequence incidents such as loss of containment into a diked area, near misses, or failures in which no injuries, damage, or loss occurred. This relationship between no- or low-impact events and actual process safety incidents is demonstrated in the process safety pyramid (see Figure 1.2).[3]

In *Guidelines for Risk Based Process Safety*, CCPS defines process safety management as a "management system that is focused on prevention of, preparedness for, mitigation of, response to, and restoration from catastrophic releases of chemicals or energy from a process associated with a facility" (CCPS, 2007a). The process safety management system comprises the design, procedures, and hardware needed to operate and maintain the process safely throughout the operational life cycle (CCPS, 1999). Such a process safety management system will include metrics to identify and measure not only actual process safety incidents that meet an established reporting threshold, as well as metrics to identify

[3] Use of the process safety pyramid in selecting metrics is discussed in Chapters 3 and 6.

lower-severity incidents, near misses (no-loss incidents), and unsafe behaviors. Process safety metrics should track performance of individual system components to ensure that the process safety systems are performing as intended and to identify nonconformities within systems before they can cascade and result in a serious, reportable incident.

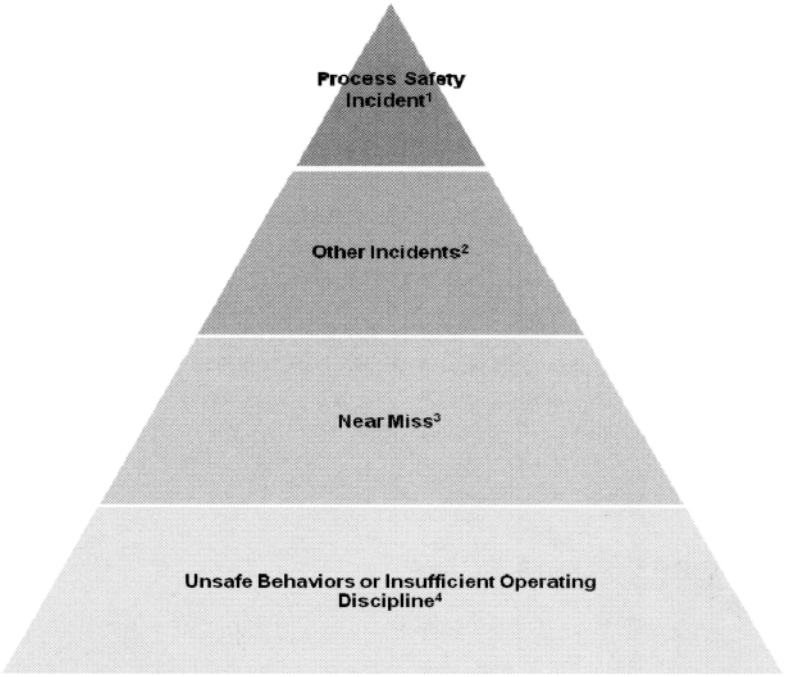
Process safety metrics provide a means to measure activity, status, or performance against requirements and goals. Monitoring and analyzing such performance enables organizations to identify and track not only current performance but also trends, both improvements and degradations, so that corrective actions are taken as needed. An organization that expects and maintains performance within operating specifications and that monitors activities or behaviors critical to overall safety operations (e.g., training, management of change) is more likely to avoid major failures, including catastrophic events. In the event of an incident, process safety metrics can provide critical information to identify contributing and root causes of the failures and a system to track subsequent system improvements. The need to monitor behavior includes the behavior of engineers and managers, not just operators. Unsafe behavior includes things like the unit manager deciding that he can delay a required safety inspection to save money on his maintenance budget or to avoid a plant shutdown, or an engineer deciding that he does not need to do a management of change review of a piping modification.

1.2 PURPOSE OF THIS BOOK

This book has many purposes, including the following:

- To provide guidelines and examples of effective practices for the development and use of process safety leading and lagging metrics;
- To provide the reader with summaries and references to other useful resources;
- To convey basic information about performance indicators such as the what, when, where, why, and to whom they are useful;
- To provide guidance to companies on how to collect, evaluate, and communicate process safety metrics;
- To provide guidance to companies at corporate and site levels on how to use performance metrics effectively to improve process safety performance;
- To provide sufficient examples such that readers gain an understanding of how performance metrics can be successfully applied over the short and long term; and
- To encourage the adoption of a set of consensus process safety metrics comparable to occupational safety metrics.

Figure 1.2 Process Safety Pyramid (CCPS, 2007b)



1. Incidents which meet the threshold of severity which should be reported as part of the process safety metric.
2. Incidents which didn't meet the definition of PS incident metric (e.g., all other Loss of Primary Containment or fire).
3. System failures which could have led to an incident (e.g., instrument had failed, pipe wall thickness is low).
4. Other Process Safety Factors, e.g., Equipment Selection, Engineering Design, Specification of Inspection Frequency and Technique, Unsafe Behaviors and Insufficient Operating Discipline.

1.3 KEY AUDIENCES FOR THE GUIDELINES

This book is primarily written for those within the chemical process and allied industries responsible for process safety including:

- *Process Safety Specialists*—those at the corporate and facility levels responsible for the process safety system including tailoring the system to specific facilities and using metrics to monitor and maintain or improve process safety performance.
- *Line Management (area managers, unit managers)*—those responsible for collecting metrics data and ensuring that the behaviors in the work area are consistent with the expectations of the process safety system.
- *Site Management (site managers, plant managers, facility managers, health safety, and environmental (HSE) managers)*—those who set site performance goals based on management expectations and use metrics data to measure and improve the process safety performance at a given site.
- *Corporate Leaders*—those providing the leadership commitment, setting the expectations, for a process safety performance and the supporting metrics system including the resources necessary to develop and implement such a program throughout the corporation to improve process safety.

Other audiences and stakeholders interested in improving process safety are also likely to find this book useful and informative and may include:

- Production personnel (operators), including representatives of labor, who are concerned with the safety of the operators
- Those within a company who wish to make comparisons between sites with process safety programs
- Personnel responsible for mechanical integrity (MI), management of change (MOC), and other elements of the process safety system who can use metrics to measure the performance of their systems;
- Corporate communicators responsible for communicating the company's safety performance within the company and to the public
- Industry trade groups that want to promote the safety of the industries they represent and show progress towards sustainable process safety improvement;
- Government regulators and analysts who are concerned with regulating or analyzing companies and industries, including those in the fields of public health, emergency response, and local land-use planning
- Non-governmental organizations (NGOs) addressing environmental, public safety, and other chemical-related issues
- Members of the public, especially those near a process industry facility, who could be affected in the event of a major or catastrophic accident

The scope of this book is intended to be globally applicable, and the concepts and approaches will be useful to all companies seeking to continuously improve their process safety performance. However, many of the references and examples are based on U.S. conditions and programs.

1.4 AN ORGANIZATION'S PERSONNEL HIERARCHY

Throughout these guidelines, references will be made to an organizational personnel hierarchy – the levels of the organization generally spanning operating and maintenance personnel to the board of directors – each have different responsibilities, needs, and interests with respect to process safety metrics. Different organizations may have different terms for different personnel levels, but for the purpose of the book the following descriptions will be used:

- *Operating and Maintenance Personnel (operators, mechanics, craft personnel)*—individual contributors who carry out specific tasks and/or procedures
- *Supervisors (foremen, first-line leaders)* – individuals who provide direct supervision for the operating, maintenance, and craft personnel – could be seen as first level of line management
- *Line Management (area managers, unit managers)*—individuals who have management responsibility for organizational units of process operating facilities and maintenance organizations, normally situated in a single plant site or operating area
- *Site Management (site managers, plant managers, facility managers)*—individuals who have management responsibility for an entire site, usually based upon geographical boundaries, and may include multiple production units on the site
- *Business Leaders*—individuals who have management responsibility for a business unit or portion of a company, including oversight for a manufacturing plant(s) associated with business; budget approval for operations; and oversight of marketing, sales, and other functional areas that generate the production demand
- *Corporate Leaders*—individuals who have responsibility at the highest levels of a company for business and/or company support functions; focus upon the strategic issues and planning for the enterprise; often have overall management responsibility for a business or groups of businesses; and usually do not have day-to-day operational responsibility
- *Board of Directors*—body of appointed persons, including company officers and outside directors, who jointly oversee the activities of an enterprise including ensuring that the enterprise is managing risks properly

1.5 ORGANIZATION OF THIS GUIDELINE

This book is organized in a logical flow for developing and implementing a process safety metrics program. Because some readers may read the book from beginning to end while others may select specific chapters, the chapters have been written to stand alone as well as part of the book as a whole.

- Chapter 2—***Why Implement Process Safety Metrics***, especially the role of metrics in management
- Chapter 3– ***Process Safety Management Metrics*** commonly used in process safety management systems including leading, lagging, and near miss; and activity and outcome, external and internal metrics as well as characteristics of successful metrics
- Chapter 4 ***Choosing Appropriate Metrics*** based on identified process safety goals and objectives
- Chapter 5—***Implementing a Metrics Program***, including implementation strategy and framework, analyses, and program rollout
- Chapter 6—***Communicating Results*** to various internal and external audiences and tools for reaching those audiences
- Chapter 7– ***Using Metrics to Drive Performance Improvements*** through identification of system strengths and weaknesses, holding responsible parties accountable, engaging the public, conducting management reviews, cultivating a positive process safety culture, and communicating successes
- Chapter 8—***Improving Industry-Wide Performance*** through the adoption of common process safety metrics and definitions within companies and industry sectors, and across the processing industries
- Chapter 9—***Future Trends in the Development and Use of Process Safety Metrics*** for improving process safety performance and broader societal interests

The guidelines include examples of metrics and how to establish, use, and update them. These examples are garnered from several sources including the recently published CCPS "Process Safety Leading and Lagging Metrics" brochure, which is included on the accompanying CD, and the CCPS *Guidelines for Risk Based Process Safety*. Every attempt is made to be consistent with other published guidelines from CCPS while reflecting growth and change in the development and use of process safety metrics.

1.6 USING THIS GUIDELINE

It is hoped that process safety performance throughout the process industries will improve as an increasing number of companies adopt more extensive and more rigorous process safety metrics as part of their process safety management systems. Companies and facilities that do this should ultimately see improvement

in their process safety performance, which improves the performance of the sector more broadly. In addition, benchmarking and other comparisons can be made within and across sectors when companies adopt common public-facing metrics. Such public comparisons both acknowledge high performers and provide improvement incentives for all.

REFERENCES

Center for Chemical Process Safety, *Guidelines for Process Safety in Batch Reaction Systems*, American Institute of Chemical Engineers, New York, 1999

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Reason, J., *The contribution of latent human failures to the breakdown of complex systems*, Philosophical Transactions of the Royal Society (London), series B. 327: 475–84 (1990)