1 INTRODUCTION

1.1 PURPOSE AND SCOPE OF THE BOOK

This book provides resources for supervisors and operators/technicians in industrial processes, whose correct and timely intervention is often crucial, either to prevent abnormal situations from escalating into a major event, or to mitigate the consequences if an event occurs. Operations management and support services personnel (such as those in maintenance, engineering, and process safety), who read this book will be able to develop relevant training and support material to prevent or mitigate abnormal situations from occurring at their facility. This book includes the historical development of principles and procedures for managing abnormal situations as well as a summary and review of available resources for addressing them. It also provides guidance for management and engineers to develop appropriate training and procedures, and demonstrates how to institutionalize these into process operations.

Since many of the principles and practices of managing abnormal situations are transferable across industries, this book provides some guidance and suggestions on sharing knowledge and learning from a variety of industries and disciplines that are leaders in such management. With that in mind, example incidents (brief examples) and case studies (detailed studies) are included for front line staff as training aides.

As part of the development of this book, five online training modules were developed relating to abnormal situations. These training modules can be used by supervisors, plant engineers, and trainers to help train operating teams in diagnosing an abnormal situation. The modules allow the trainer to step through specific abnormal situations and discuss diagnosis, actions to be taken, learning, and relevance to their operation with the team members who are being trained. Details on how to access this material is provided in Appendix A.

1.2 WHAT ARE ABNORMAL SITUATIONS?

Abnormal situations in the process industries occur when conditions deviate from their normal state or operating range, such that basic process control systems are unable to restore normal conditions. Some examples of the early stages of an abnormal situation that could develop into a major incident, if not corrected, include:

- A tank level rises above safe operating limit because a control valve has seized.
- A tank level falls below safe operating limit because a level sensor has failed.
- A batch reactor temperature increases above safe limits because the wrong amount of one ingredient was added.
- Pressure starts to fall because a relief valve has lifted and has stuck open.
- The startup conditions are wrong because a key step was missed or delayed.
- A valve starts to close due to a leak of instrument air.

A typical intervention would be a response from a process operator, ranging from changing a set point on a control loop to bring the conditions back to normal, to a decision to carry out a controlled shutdown, or even to initiate an emergency shutdown of the process. Failure to respond adequately to an abnormal situation could lead to a worsening situation that could develop into a major incident, such as those described in Section 1.3.

Other commercial enterprises, such as the aviation and rail sectors of the transportation industry, also encounter abnormal situations, such as equipment failures, faulty warning signals or other unexpected safety events that must be managed. This book includes some example incidents and case studies from the aviation sector and examines their relevance to the chemical process industries. A useful example from the rail sector involves a runaway train at Lac-Mégantic (Transportation Safety Board of Canada Report 2014).

An Abnormal Situation, as defined by CCPS (CCPS Glossary):

"A disturbance in an industrial process with which the basic process control system of the process cannot cope."

A detailed definition of Abnormal Situation is included on the ASMC website (Abnormal Situation Management® Consortium) as follows:

- A disturbance or series of disturbances in a process that cause plant operations to deviate from their normal operating state.
- The nature of the abnormal situation may be of minimal or catastrophic consequence. It is the job of the operations team to identify the cause of the situation and execute compensatory or corrective actions in a timely and efficient manner.
- A disturbance may cause a reduction in production; in more serious cases it may endanger human life.
- Abnormal situations extend, develop, and change over time in the dynamic process control environments increasing the complexity of the intervention requirements.

User Centered Design Services (UCDS) Inc. describes abnormal situations as encompassing:

- "a range of events outside the 'normal' plant operating modes, i.e., trips, fires, explosions, toxic releases, human error, or just failing to reach planned targets" (UCDS website).

UCDS defines abnormal situation management as:

- A comprehensive process for improving performance, which addresses the entire plant population. It promotes effective utilization of all available resources—i.e., hardware, software, and people, to achieve safe and efficient operations.

Abnormal situations can be characterized as unplanned transitions or events that may occur during normal or routine operation, although they often take place during transient operations, such as startup, shutdown, switching to different products, or catalyst regeneration. These situations do not provide an opportunity for planning, training, and procedures to be developed to respond to them as they are occurring. Procedures and practices to manage abnormal situations should be established before an abnormal situation occurs. Operating personnel must be able to recognize

the occurrence of an abnormal situation, identify its source, and take corrective action quickly and efficiently. However, in a dynamic process control environment, the situation can develop and change rapidly, making it difficult to determine the nature of the intervention that is required.

For optimal management of abnormal situations, the methodologies, tools, processes, and training should be established prior to the occurrence of such an event. This would help personnel recognize abnormal situations so they can either safely restore normal operations as quickly and efficiently as possible or take the process to a safe state, and subsequently to capture lessons learned to prevent similar situations from occurring in the future.

1.3 THE BUSINESS CASE FOR MANAGING ABNORMAL SITUATIONS

The consequences of a failure to provide the right intervention during an abnormal situation could ultimately lead to a major disaster such as a fire, explosion, toxic release, leading to environmental damage, injury and fatalities. Opportunities for early identification, allow corrective action to be taken before the abnormal situation escalates.

Examples of abnormal situations in order of increasing significance and consequences are included in this chapter. The relationship between abnormal situations and process safety events is provided in Figure 2.1 in Chapter 2.

- Loss of product quality.
- Reduction in operating efficiency/ increased processing costs.
- Deterioration of equipment (e.g., pump bearings, rates of corrosion), potentially leading to damage to the pressure envelope.
- Loss of containment of hazardous substances due to overpressure or overfilling, potentially leading to major events such as fire, explosion, toxic release, environmental damage, and fatalities.

Most of these consequences include a cost component such as lost production, equipment damage, injuries, or personnel costs including investigation and rectification work; as well as indirect consequences, such as damage to the environment, fines, and community complaints, even if the situations are managed well.

In addition, reputational damage tends to occur following a major incident, especially since most events are now broadcast widely via social media. Consequences of such incidents can negatively impact the surrounding community, to the point that some companies have shut down, as a result of major events. One example is the Philadelphia Energy Solutions refinery that was permanently closed after corrosion in a piping dead-leg led to a loss of containment, fire, and explosion in June 2019.

The benefits of adopting process safety principles are clearly outlined in the CCPS document, *The Business Case for Process Safety*, 4th edition (CCPS 2018b).

The cost to set up a management system that mitigates an Abnormal Situation is a fraction of the cost of the aftermath of process incidents. Trevor Kletz, renowned process safety expert and author, often remarked:

"If you think safety is expensive, try an accident" (Kletz/O'Connor PSC).

1.4 CONTENT AND ORGANIZATION OF THE BOOK

The chapter summaries provide an overview of the content and organization of this book, enabling the reader to locate a particular area of interest. Example incidents are embedded throughout the book to illustrate the points that are being made; some example incidents are used more than once where different aspects are relevant. Chapter 7 presents detailed Case Studies.

Chapter 2 – Process Safety and Management of Abnormal Situations

Chapter 2 discusses why the management of abnormal situations is important to process safety and uses example incidents to illustrate the impact that abnormal situations, if unchecked, can have on operating facilities. It discusses some of the key elements of Risk Based Process Safety (RBPS) (CCPS 2007a) that are directly related to the management of abnormal situations, including: Hazard Identification and Risk Analysis (HIRA), Operating Procedures, Training and Performance Assurance, Asset Integrity and Reliability, Conduct of Operations, and Process Safety Culture.

The chapter makes the case for proactive management of abnormal situations; to avoid or mitigate an incident before it escalates into a more dangerous and costly event that can include downtime, lost production, equipment damage, injuries, and external / environmental and reputational

damage. It reviews the consequences of a failure to manage abnormal situations, including an overview of some cases that demonstrate some of the principles discussed.

The chapter includes a more detailed discussion about the management of training for abnormal situations and the key issue of process safety culture. The latter includes the interaction between process safety culture, human factors, and the performance of individuals in stressful situations, including pressure to continue operations versus shutting down a facility. Process safety leadership is a strong influencer of culture, and this key issue is discussed in some depth.

Chapter 3 – Abnormal Situations and Key Relevance to Process Plant Operations

Chapter 3 discusses subjects regarding management of abnormal situations that are relevant to process plant operations, explaining their relevance to operating personnel. It also includes plant design aspects, with separate focus points on new plant design and retrofits to existing plants. It includes a section on writing plant procedures and plant policies so that they incorporate the principles of managing abnormal situations.

Content topics explain basic theoretical knowledge, practical application of the theory in general, and its specific link and application to some of the 20 elements of Risk Based Process Safety that would apply to any industry. Practical strategies for implementation are also included, along with practices that impact the effectiveness of addressing abnormal situations to help improve safety, reliability, and efficiency of process operations.

This chapter also covers how to include and structure into existing procedures the best practices for managing abnormal situations, to help operating personnel make the right decisions during periods of abnormal situations. It also addresses how abnormal situations can occur during transient modes including startup, shutdown, or changes in operating modes and product grades, which can result in incidents.

Chapter 4 – Education for Managing Abnormal Situations

Chapter 4 builds on Chapter 3 content to provide training on how to manage abnormal situations, with guidance on presenting the information to specific target populations. This includes advice, tools, and techniques for such training, both in the classroom and using DCS simulators or “digital

twins" and E-Learning, and some computer-based training materials developed in conjunction with this book.

The primary target populations for this information are front line operators, operations managers, plant engineers, process safety engineers, technical experts, and others who could benefit from it. This chapter provides guidance to organizations in the process industries about organizing and structuring training on management of abnormal situations, including advice on trainer competencies, training programs, and assessment of required skills.

Chapter 5 – Tools and Methods for Managing Abnormal Situations

Chapter 5 provides a brief summary of the relevant management tools that are currently available for recognition and management of abnormal situations; specifically, tools that illustrate the principles described in Chapter 3, and some worked examples of how to use them.

Hazard Identification and Risk Analysis is also addressed, including a list of scenarios that Process Safety Engineers can use during HIRAs to address abnormal situations.

Chapter 6 – Continuous Improvement for Managing Abnormal Situations

Chapter 6 includes detailed descriptions of the available metrics related to managing abnormal situations that can be used for improvement, as well as the impact on incident investigations related to complex system issues, including lower-level incidents such as near-misses. The chapter also provides guidance on identifying the system and conditions that caused the incident and how to fix the system in order to prevent future incidents.

Chapter 7 – Case Studies/Lessons Learned

Throughout the book, brief example incidents are used to illustrate specific issues in managing abnormal situations. Chapter 7 focuses on three case studies in more detail to illustrate topics discussed in earlier chapters.

The case studies address general as well as specific information regarding abnormal situations that have occurred both within and outside the process industry and how these events were handled from the perspective of management of abnormal situations. Both positive and negative examples are included in concise summaries.