INTRODUCTION

The Center for Chemical Process Safety (CCPS) has published a number of guidelines that focus on the evaluation and mitigation of risks associated with catastrophic events in process facilities. Originally published in 1993, the purpose of Guidelines for Mechanical Design for Process Safety was to shift the emphasis on process safety to the earliest stage of the design where process safety issues could be addressed at the lowest cost and with the greatest effect. Almost 20 years later, this 2nd edition of Guidelines for Mechanical Design for Process Safety continues to stress the importance of minimizing process safety events during Front-End Engineering and Design (FEED) to achieve the greatest risk reduction at the lowest cost — and also emphasizes the benefits of diligence in process safety design issues through the life of the facility. This updated book also incorporates material from Guidelines for Design Solutions for Process Equipment Failures, which was originally published by CCPS in 1993 (Ref. 1.1).

This book focuses on process safety issues in the design of chemical, petrochemical, and hydrocarbon processing facilities. Although information is provided on each topic to ensure that the reader understands:

- The conceptual issues
- The design approach for process safety
- Areas of concern
- Where to go for detailed information

The scope of this book includes avoidance and mitigation of catastrophic events that could impact people and facilities in the plant or surrounding areas. The scope is limited to excluding inappropriate designs or processes that mitigate the release of flammable or toxic materials that could lead to a fire, explosion, and impact on personnel and the community. Process safety issues affecting operations and maintenance are limited to causes where design choices impact system reliability. These Guidelines are intended to be applicable to the design of a new facility, as well as modifications of an existing facility.

The scope included:

- Transportation safety
- Reaction environmental control
- Process safety and industrial hygiene practices
- Emergency response
- Detailed design
- Operations and maintenance
- Security issues unrelated to process safety
These Guidelines highlight safety issues in design documents. For example, Section 7.1.1, "Identification and Classification of Hazards", addresses the need to ensure the proper application of hazardous substances in the process environment to prevent safety and health hazards. The Guidelines also emphasize the importance of electrical supply and distribution systems, which are required to operate the facility.

It is clear that choices made early in design can reduce both the potential for large releases of hazardous materials and the severity of such releases, if they should occur.

1.1 Engineering Design for Process Safety through the Life Cycle of the Facility

Engineering design for process safety must be an integral part of the life cycle of a facility. Process safety has been defined in previous publications as:

A discipline that focuses on the prevention and mitigation of fires, explosions, and other hazardous chemical releases at process facilities. It includes the entire life cycle of a facility, from design, construction, and operation (Ref. 1.2).

Hazard evaluations are one method used to identify, evaluate, and control hazards involved in chemical processes. Hazards can be defined as characteristics of systems, processes, or plants that must be controlled to prevent occurrence of specific unwanted events. Hazard evaluation is a technique that is applied repeatedly throughout the design, construction, and operation phases of a facility (Ref. 1.3). Engineering design for process safety should be considered within the framework of a comprehensive process safety management program as described in "Process Guidelines for Technical Management of Chemical Process Safety" (Ref. 1.3).

Hazard analysis is synonymous with process hazard analysis and process safety reviews. From conceptual design to detailed design, a single method of hazard evaluation applies to all the stages of a project. Different methods are required for different stages of a project, such as research and development, conceptual design, detailed design, and operations. Table 1.1 presents some of the stages of facility life cycle and typical corresponding process hazard evaluation objectives. An objective shown for each stage may be applicable to another.

As illustrated in Table 1.1, different types of hazards can be identified during the stages of a facility's life cycle. Findings from the Houston Panel report (Ref. 1.4) and associated with the 2005 Texas City refinery explosion illustrate the importance of engineering design for process safety.

Not all refining hazards are caused by the same factors or involve the same degree of potential damage. Process or occupational safety hazards: fire risk to incident such as leaks, fires, and vehicle accidents that primarily affect one individual worker for each occurrence. Process safety hazards can give rise to major accidents involving the release of potentially dangerous materials, the release of energy (such as fires and explosions), or both. Process safety incidents can also cause environmental effects and can result in multiple injuries and fatalities, as well as substantial economic, property, and environmental damage. Process safety refinery incidents can affect workers inside the refinery and members of the public who reside nearby. Process safety in a refinery involves the prevention of leaks, spills,
equipment malfunctions, over-pressures, excessive temperatures, corrosion, metal fatigue, and other similar conditions. Process safety programs focus on the design and engineering of facilities, hazard assessment, management of change, inspection, testing, and maintenance of equipment, effective alarm, effective process control, procedures, training of personnel, and human factors. The Taconite Harbor tragedy in March 2008 was a process safety accident. (Sec. 1-4).

Figure 4.1: Identifying Hazards Through the Facility Life Cycle.
<table>
<thead>
<tr>
<th>Stage of Facility Life Cycle</th>
<th>Example Hazard Evaluation Objectives</th>
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| Research and Development    | • Identify chemical interactions that could cause runaway reactions, fires, explosions, or toxic gas releases  
• Identify process safety data needs |
| Conceptual Design            | • Identify opportunities for inherent safety  
• Compare the hazards of potential sites |
| Pilot Plant                  | • Identify ways for toxic gas to be released to the environment  
• Identify ways to deactivate the catalyst  
• Identify potentially hazardous operator interfaces  
• Identify ways to minimize hazardous wastes |
| Engineering                  | • Identify ways to prevent flammable mixtures inside process equipment  
• Identify how a loss of containment might occur  
• Identify which process control malfunctions will cause runaway reactions  
• Identify ways to reduce hazardous material inventories  
• Identify safety-critical equipment that must be regularly tested, inspected, or maintained  
• Identify operating conditions that affect selection of materials of construction (e.g., corrosivity)  
• Identify incompatibility / reactivity issues  
• Identify relief system and discharging location impact |
| Construction and Startup     | • Identify error-likely situations in startup and operating procedures  
• Verify that all issues from previous hazard evaluations were resolved satisfactorily and that no new issues were introduced  
• Identify hazards that adjacent units may create for construction and maintenance workers  
• Identify hazards associated with the vessel-cleaning procedure  
• Identify any discrepancies between the as-built equipment and the design drawings |
| Routine Operation            | • Identify employee hazards associated with the operating procedures  
• Identify ways an overpressure transient might occur  
• Identify hazards associated with out-of-service equipment |
| Process Modification or Plant Expansion | • Identify whether changing the feedstock composition will create any new hazards or make any existing hazards more severe  
• Identify hazards associated with new equipment |
| Decommissioning              | • Identify how demolition work might affect adjacent units  
• Identify any fire, explosion, or toxic hazards associated with the residues left in the unit after shutdown |
1.2 Regulatory Review / Impact on Process Safety

This document presents many recent innovations to replace regulations, codes, or technical standards with guidelines and recommended practices. Specifically, implementation of these guidelines requires the application of sound engineering judgment because they concepts may not be applicable in all cases.

Identifying and applying relevant process safety standards, codes, regulations, and laws over the life of a process is one of the three elements in the Risk-Based Process Safety Pillar of Commodity: Process Safety (Ref. 1.6). Companies should establish a process for maintaining adherence to applicable standards, codes, regulations, and laws. Guidelines for Risk-Based Process Safety (Ref. 1.6) recommends establishing a standards system to achieve this objective, including:

- Establishing a system to identify, develop, acquire, evaluate, disseminate, and provide access to applicable standards, codes, regulations, and laws that affect process safety.
- Promoting consistent interpretations, implementation, and enforcement in the initial identification of new requirements and ongoing reevaluation of changes in standards.

Safe operation and maintenance of facilities that manufacture, store, or otherwise use hazardous chemicals require robust process safety management systems. The primary objectives of establishing a standards system is to ensure that a facility remains in conformance with applicable standards, codes, regulations, and laws, including voluntary ones adopted by the company over the life of the facility. Long-term conformity to基准-standards of care helps ensure that the facility is operated in a safe and legal fashion. Key principles and essential features of maintaining a dependable standards system include:

- Periodic examination and implementation of the standards system.
- Identifying any standards compliance issues.
- Involving competent personnel.
- Evaluating that standards compliance practices remain effective.

The PSMR seven elements for implementation of compliance with maintenance of good engineering practices and a comprehensive safety management system that supports and improves process safety performance (Ref. 1.6).

I’ve detailed information on establishing a system to comply with standards, codes, and regulations in Chapter 6. Complaince with Standards, Code Compliance and Guidelines for Risk-Based Process Safety (Ref. 1.6).

Table 1.2 provides some examples of the types of process safety standards, codes, and regulations that many facilities comply with.


Table 1.2: Examples and Sources of Process Safety (Related) Standards, Codes, Regulations, and Laws

**Voluntary Industry Standards**
- American Chemistry Council Responsible Care® Management System (Ref. 1-6)
- European Chemical Industry Council (ECIC) Responsible Care (Ref. 1-6)
- American Petroleum Institute Recommended Practice (Ref. 1-6)

**Commercial Codes**
- American National Standards Institute (Ref. 1-6)
- American Petroleum Institute (Ref. 1-4)
- American Society of Mechanical Engineers (Ref. 1-10)
- The Instrumentation, Systems and Automation Society (International Electrotechnical Commission (Ref. 1-11)
- National Fire Protection Association (Ref. 1-12)

**U.S. Federal, State, and Local Laws and Regulations**
- U.S. OSHA
- Public General Industry & Public Safety Management National Revisions Program (Ref. 1-14)
- U.S. EPA Risk Management Program Regulations (40 CFR 68) (Ref. 1-37)
- California Occupational Hazard Prevention Program (Ref. 1-38)
- California Central County Occupational Safety Ordinance (Ref. 1-39)
- California Environment Health Protection Risk Management Act (Ref. 1-39)
- Delaware Chemical Accident Prevention Program (Ref. 1-27)
- Iowa Air Quality Control Board: Prevention Act (Ref. 1-27)

**International Laws and Regulations**
- Australian National Standard for Control of Hazardous Substances (Ref. 1-25)
- Canadian Environmental Protection Act, Environmental Emergency Planning (Sec. 8000) (Ref. 1-50)
- October, Department of Occupation Safety and Health Ministry of Human Resources Malaysia, Notice 15 of Act 314 (Ref. 1-25)
- United Kingdom, Health and Safety Executive COSHH Regulations (Ref. 1-25)

It is important to note that regional or local laws and regulations sometimes mandate beyond requirements than similar federal regulations. For example, the State of California’s Accidental Release Prevention Program requires compliance by facilities with over a threshold quantity of 100,000 lb of chlorine, whereas the U.S. EPA Risk Management Program’s threshold quantity for compliance is 25,000 lb of chlorine.
Different global, federal, and regional requirements pose challenges for facilities that operate in different geographical locations.

1.3 WHAT WILL BE ENFORCED FROM THESE GUIDELINES?

Process safety is an important part of risk management and loss prevention. Although these Guidelines do not provide all the “answers,” they do highlight the process safety issues that cannot be addressed in all stages of design. These Guidelines will be useful many different people within an organization:

- **Corporate Leadership:** Senior executives define the needs for the development of design philosophies. Their commitment and recognition of the value of incorporating process safety at all levels of the design process is essential.

- **Project Managers:** Project Managers are responsible for executing projects, usually chosen design through studies and commissioning. A Project Manager is responsible for determining the basic protection design concepts to apply in the execution of a project. The Project Manager is responsible for implementing the decisions and authoring the process safety systems associated with the design.

- **Engineers:** Engineers are responsible for specifying and designing process units and protection systems that meet the company's requirements. They still make decisions for varying design criteria when designing process units and protection systems.

- **HSE Professionals:** Health, Safety, and Environmental (HSE) Professionals provide technical guidance to engineers and typically act as an assurance role for process safety systems.

1.4 ORGANIZATION OF THIS BOOK

This document provides an overview of all the contents of these Guidelines and also provides the examples of how each chapter can assist in integrating process safety throughout the entire process. Each chapter has been updated to include recent studies and information, industry experience, and references to other HSE publications.

Specific references and applicable industry standards are listed at the end of each chapter. It is not the intent of this book to provide specific design recommendations, but to provide a general source of information where the reader can obtain more detailed information.
Figure 1.2: Overview of Guideline Contents

Guideline Chapter

Chapter 1
Introduction

Chapter 2
Foundational Concepts

Chapter 3
Basic Physical Properties / Thermal Stability Data

Chapter 4
Analysis Techniques

Chapter 5
General Design

Chapter 6
Equipment Design

Chapter 7
Protection Layers

Chapter 8
Documentation to Support Process Safety

Questions This Chapter Will Answer

- What is process safety?
- How can this book help me?
- Where is process safety incorporated into engineering design?

- Why is incorporating process safety into a facility's design important?
- What is engineering design that incorporates process safety?
- How are inherently safer options included in the design?

- What basic physical properties do I need to know before designing?
- What material data do I need to understand?
- What chemical property data do I need to know?
- What is the impact of hazards on people?

- Why conduct hazard assessments during engineering design?
- What techniques do I use for hazard identification?
- How does risk assessment influence engineering design?

- What are inherent safety strategies?
- How does process safety influence our plant design?
- What methods of construction and layout can I use to prevent accidents?

- How does process safety influence equipment design?
- What are typical failure mechanisms for different types of equipment?
- What are common equipment design flaws?

- How do I recognize the differences between prevention and protection?
- What are preventative design features?
- What are protective design features?

- What do I need to document?
- How can this documentation help my facility?
1.6 OTHER OCPS RESOURCES

Other OCPS Guidelines provide additional resources for topics discussed in these Guidelines. Some of these include:

- Continuous Monitoring for Hazardous Material Releases
- Containment and Containment Flume Operations
- Guidelines for Mechanical Integrity Systems
- Guidelines for Analyzing and Managing the Security Vulnerabilities of Fixed Chemical Sites
- Guidelines for Chemical Reactivity Information and Application in Process Design
- Guidelines for Developing Quantitative Safety Risk Criteria
- Guidelines for Facility Siting and Layout
- Guidelines for Fire Protection in the Chemical, Petrochemical and Other Process Industries
- Guidelines for Integrating Process Safety Management, Environment, Safety, Health and Quality
- Guidelines for Pressure Relief and Relief Handling Systems
- Guidelines for Preventing Human Error in Process Safety
- Guidelines for Process Safety Documentation
- Guidelines for Process Safety in Reactor Systems
- Guidelines for Risk-Based Process Safety
- Guidelines for Safety and Reliable Instrumentation Protection Systems
- Guidelines for Safe Handling of Pressure and Bulk Metals
- Guidelines for Safe Storage and Handling of Reactive Materials
- Interchangeability of Chemical Processors; a Life Cycle Approach, Second Edition
- Plant Guidelines for Technical Management of Chemical Process Safety
- Safe Operations of Processes, Waste and Handling Control Systems

Additional information on these publications can be found at www.cashtech.org/ocps/.
REFERENCES:


1.7. European Chemical Industry Council (CIC), Avenue H. van Mierlohuysen, 4, Box 1, 1000 Brussels. www.cic.be


1.10. American Society of Mechanical Engineers, Three Park Avenue, New York, NY, 10016. www.asme.org


1.15. PHMSA Covered Chemical Facilities National Emphasis Program, OSHA Notice, 08-02 (CFR 910.05), U.S. Occupational Safety and Health Administration, July 2009. www.osha.gov


