GUIDELINES FOR
Fire Protection in Chemical, Petrochemical, and Hydrocarbon Processing Facilities

Center for Chemical Process Safety
of the
American Institute of Chemical Engineers
3 Park Avenue, New York, NY 10016-5991
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The American Institute of Chemical Engineers (AIChE) has helped chemical plants, petrochemical plants, and refineries address the issues of process safety and loss control for over 30 years. Through its ties with process designers, plant constructors, facility operators, safety professionals, and academia, the AIChE has enhanced communication and fostered improvement in the high safety standards of the industry. AIChE's publications and symposia have become an information resource for the chemical engineering profession on the causes of incidents and means of prevention.

The Center for Chemical Process Safety (CCPS), a directorate of AIChE, was established in 1985 to develop and disseminate technical information for use in the prevention of major chemical accidents. The CCPS is supported by a diverse group of industrial sponsors in the chemical process industry and related industries who provide the necessary funding and professional guidance for its projects. The CCPS Technical Steering Committee and the technical subcommittees oversee individual projects selected by the CCPS. Professional representatives from sponsoring companies staff the subcommittees and a member of the CCPS staff coordinates their activities.

Since its founding, the CCPS has published many volumes in its "Guidelines" series and in smaller "Concept" texts. Although most CCPS books are written for engineers in plant design and operations and address scientific techniques and engineering practices, several guidelines cover subjects related to chemical process safety management. A successful process safety program relies upon committed managers at all levels of a company who view process safety as an integral part of overall business management and act accordingly.

A team of fire protection experts from the chemical industry drafted the chapters for this guideline and provided real world examples to illustrate some
of the tools and methods used in their profession. The subcommittee members reviewed the content extensively and industry peers evaluated this book to help ensure it represents a factual accounting of industry best practices.
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Siegfried Fiedler, BASF Corporation
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Duncan L. Hutcheon, ExxonMobil
Joel Krueger, BP Amoco
John Sepahpur, ChevronTexaco Energy Research & Technology Company
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Jeffrey Yuill, Starr Technical Risks Agency, Inc.

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Tim McNamara

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<td>ALARP</td>
<td>As low as reasonably practical</td>
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<tr>
<td>AiChE</td>
<td>American Institute of Chemical Engineers</td>
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<tr>
<td>AISC</td>
<td>American Institute of Steel Construction</td>
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<tr>
<td>AHJ</td>
<td>Authority Having Jurisdiction</td>
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<td>ANSI</td>
<td>American National Standards Institute</td>
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<td>API</td>
<td>American Petroleum Institute</td>
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<tr>
<td>BI</td>
<td>Business Interruption</td>
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<td>BLEVE</td>
<td>Boiling Liquid Expanding Vapor Explosion</td>
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<td>CCPS</td>
<td>Center for Chemical Process Safety</td>
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<tr>
<td>CFD</td>
<td>Computational Fluid Dynamics</td>
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<td>CFR</td>
<td>Code of Federal Registry</td>
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<td>CMPT</td>
<td>Center for Marine and Petroleum Technology</td>
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<td>DCS</td>
<td>Distributed Control System</td>
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<td>DOT</td>
<td>Department of Transportation</td>
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<td>EANS</td>
<td>Emergency Alarm Notification System</td>
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<td>EHS</td>
<td>Environmental, Health, and Safety</td>
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<td>EOC</td>
<td>Emergency Operations Center</td>
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<td>EPA</td>
<td>Environmental Protection Agency</td>
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<td>ERP</td>
<td>Emergency Response Plan</td>
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<td>ERT</td>
<td>Emergency Response Team</td>
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<td>FCC</td>
<td>Fluid Catalytic Cracking (Unit)</td>
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<td>FHA</td>
<td>Fire Hazard Analysis</td>
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<td>FMEA</td>
<td>Failure Mode and Effects Analysis</td>
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<td>FM</td>
<td>Factory Mutual</td>
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<td>FPS</td>
<td>Fire Protection Strategy</td>
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<td>FRP</td>
<td>Fiberglass Reinforced Plastic</td>
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<td>GRP</td>
<td>Glass Reinforced Plastic</td>
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<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>HVAC</td>
<td>Heating, Ventilating, and Air Conditioning</td>
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<td>HAZID</td>
<td>Hazard Identification</td>
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<td>HAZOP</td>
<td>Hazard and Operability Study</td>
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<tr>
<td>HSSD</td>
<td>High Sensitivity Smoke Detection</td>
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<tr>
<td>HAZMAT</td>
<td>Hazardous Material</td>
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<tr>
<td>ICS</td>
<td>Incident Command System</td>
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<td>IEEE</td>
<td>Institute of Electrical and Electronic Engineers</td>
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<td>I/O</td>
<td>Input/Output</td>
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<td>IR</td>
<td>Industrial Risk</td>
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<td>LEPC</td>
<td>Local Emergency Planning Committee</td>
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<td>LFL</td>
<td>Lower Flammability Limit</td>
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<td>LOPA</td>
<td>Layer of Protection Analysis</td>
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<td>LPG</td>
<td>Liquefied Petroleum Gas</td>
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<td>MERITT</td>
<td>Maximizing EHS Returns by Integrating Tools and Talents</td>
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<td>MFL</td>
<td>Maximum Foreseeable Loss</td>
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<td>MOC</td>
<td>Management of Change</td>
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<td>MSDS</td>
<td>Material Safety Data Sheet</td>
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<td>NICET</td>
<td>National Institute for Certification in Engineering Technologies</td>
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<td>NFPA</td>
<td>National Fire Protection Association</td>
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<td>NLE</td>
<td>Normal Loss Estimate</td>
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<td>NOAA</td>
<td>National Oceanic and Atmosphere Administration</td>
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<td>OSHA</td>
<td>Occupational Safety Hazard Association</td>
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<td>P&amp;ID</td>
<td>Piping and Instrumentation Drawing</td>
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<td>PC</td>
<td>Personal Computer</td>
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<td>PDA</td>
<td>Personal Digital Assistant</td>
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<td>PE</td>
<td>Professional Engineer</td>
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<td>PHA</td>
<td>Process Hazard Analysis</td>
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<td>PML</td>
<td>Probable Maximum Loss</td>
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<td>Process Flow Diagrams</td>
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<td>Process Safety Management</td>
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<tr>
<td>PVC</td>
<td>Polyvinyl Chloride</td>
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<tr>
<td>RMS</td>
<td>Risk Management System</td>
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<tr>
<td>RP</td>
<td>Recommended Practice</td>
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<td>RVP</td>
<td>Reid Vapor Pressure</td>
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<td>SFPE</td>
<td>Society of Fire Protection Engineers</td>
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<tr>
<td>SI</td>
<td>Standard Instrumentation</td>
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<td>SIS</td>
<td>Safety Instrumented System</td>
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<td>UFL</td>
<td>Upper Flammability Limit</td>
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<tr>
<td>UL</td>
<td>Underwriters Laboratories</td>
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<tr>
<td>UK</td>
<td>United Kingdom</td>
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<td>VCE</td>
<td>Vapor Cloud Explosion</td>
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INTRODUCTION

This Guideline provides tools to develop, implement, and integrate a fire protection program into a company's or facility's Risk Management System. Figure 1-1 highlights the guidance provided in this Guideline.

For the thirty-year period of 1970 through 1999, 116 fires resulted in large-scale property damage (greater than $10MM) in the hydrocarbon and petrochemical onshore industries, and totaled over 4.5 billion dollars adjusted for year 2000 dollars (Marsh Risk Consulting, 2001). This is an average of approximately 39 million US dollars per occurrence, and includes losses in refineries, petrochemical plants, gas plants, marine terminals, and offshore oil and gas operations. Consequential business losses are two to three times property damage losses.

During the five-year period of 1995 to 2000, 50 large-scale fire losses have resulted in losses totaling approximately 2 billion dollars, or an average of 40 million dollars per occurrence. These numbers indicate that although the average dollar loss per occurrence is about the same for both time frames, the number of large losses is increasing. These incidents reinforce the importance of utilizing a systematic approach for addressing fire hazards in the hydrocarbon and petrochemical industries.

A Risk Management System (RMS)\(^1\) is vital for effective loss prevention. Fire protection is an essential part of an RMS. Appropriately designed, installed, and maintained fire protection systems are paramount to mitigating the direct consequences, and preventing the escalation, of fires in processing facilities.

\(^1\) Some companies use the term Hazard Management System or HSE Management System.
1. Introduction

Figure 1-1. Fire Protection Guidance in This Guideline

1.1. Scope

Information on fire protection codes and standards are available from several sources, including the National Fire Protection Association (NFPA), the Society of Fire Protection Engineers (SFPE), the Fire Suppression Systems Association (FSSA), and the American Petroleum Institute (API). Jurisdictions that provide requirements for fire protection include federal, state, and local agencies. This Guideline bridges the regulatory requirements and industry standards with practical application and provides:

- A useful tool for making fire protection decisions
- Specific examples of fire protection criteria

While life safety issues are not a primary focus of this Guideline, they are an integral part of good fire protection design.²

There is a very close relationship between fires and explosions. In many instances, an explosion is the initial event, followed by a significant fire. Sometimes the fire can be the trigger that causes the explosion, such as a Boiling Liquid Expanding Vapor Explosion (BLEVE). This Guideline does not address the prevention of explosions, methods to quantify the severity of explosion, or explosion suppression techniques. Explosions are specifically addressed in

² For additional information on life safety issues, refer to NFPA 101.
Guidelines for Evaluating the Characteristics of Vapor Cloud Explosions, Flash Fires, and BLEVEs (CCPS, 1994) and Understanding Explosions (CCPS, 2003a).

1.2. Who Will Benefit from This Guideline?

Because fire protection is an important aspect of risk management and loss prevention, this Guideline will benefit many different people within an organization.

- Corporate Leadership—Senior executives define the basis for the development of fire protection philosophies. Their commitment and recognition of the value of fire protection is vital to integration into an RMS and implementation of fire protection strategies.

- Site Managers—Site Managers are responsible for developing and maintaining the facility’s fire protection philosophy and strategies.

- Line Management—Line Managers are responsible for maintaining fire protection systems and for assuring personnel are trained on their use. Line Managers are the champions of a facility’s entire RMS. They ensure that policies and procedures, including fire protection, are integrated and implemented. They also ensure that fire protection systems are tested and maintained.

- Project Managers—Project Managers are responsible for executing projects, usually from design through startup and commissioning. A Project Manager is responsible for determining the basic fire protection design concepts to apply in the execution of a project. The Project Manager is responsible for implementing the decisions and abiding by the project procedures associated with amending and adding to the fire protection system.

- Engineers—Engineers are responsible for specifying and designing fire protection systems that meet their company’s fire protection requirements. This still leaves room for making decisions when designing fire protection systems and knowledge of performance vs. prescriptive methods is beneficial.

- HSE Professionals—Health, Safety, and Environmental (HSE) Professionals provide technical guidance to engineers and typically are in an assurance role for fire protection systems.

All fire protection decision makers will benefit from this Guideline.

Figure 1-2 provides an overview of the contents of this Guideline and also provides examples of how each Chapter can assist in establishing fire protection programs, fire protection decision making, design, installation, etc.
1.2.1. What Is Fire Protection?

This Guideline focuses on fire protection. For the purpose of this Guideline, fire protection and fire prevention are defined as:

- **Fire Protection**—The science of reducing loss of life and property from fire by control and extinguishment. Fire protection includes fire prevention, detection of a fire, providing systems to control or mitigate the fire, and providing manual firefighting capabilities.

- **Fire Prevention**—Activities whose purpose is to prevent fires from starting. Fire protection and fire prevention go hand-in-hand. All fire protection programs include a fire prevention program. For example, control of ignition sources is very important in minimizing the risk of fire, but does not meet the definition of fire protection in this Guideline.

Much of process safety deals with the prevention of catastrophic events, such as fires and explosions. This is accomplished by containing hazardous materials within the process system. The Center for Chemical Process Safety (CCPS) has developed many Guidelines that assist companies in this effort (see Section 1.3 and References).

1.2.2. Examples

Fire protection is often driven by the likelihood of potential consequences. Examples of incidents resulting in fire are provided in Table 1-1.

1.3. Relation to Other CCPS Guidelines and Resources

Other CCPS Guidelines provide additional resources for topics discussed in this Guideline. Some of these include:

- **Guidelines for Engineering Design for Process Safety**
- **Guidelines for Evaluating the Characteristics of Vapor Cloud Explosions, Flash Fires, and BLEVES**
- **Guidelines for Facility Siting and Layout**
- **Guidelines for Technical Planning for Onsite Emergencies**
- **Guidelines for Integrating Process Safety Management, Environment, Safety, Health and Quality**
- **Guidelines for Technical Management of Process Safety**
- **Guidelines for Safe Warehousing of Chemicals**
Table 1-1
Examples of Major Fire Incidents

<table>
<thead>
<tr>
<th>Year / Location</th>
<th>Incident Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1984</td>
<td>LPG Terminal—a major fire and series of catastrophic Boiling Liquid Expanding Vapor Explosions (BLEVEs) killed 500 people and destroyed the LPG terminal.</td>
</tr>
<tr>
<td>Mexico City, Mexico</td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>Process Facility—a fire originated in the feed heater of a hydrocracker and resulted in one fatality and significant damage to a Hydrocracking Unit.</td>
</tr>
<tr>
<td>New Brunswick, Canada</td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>Terminal—16 tanks, containing approximately 30,000 barrels of crude oil each, caught fire after being struck by lightning.</td>
</tr>
<tr>
<td>Ras Gharib, Egypt</td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>Process Facility—a fire in a process unit resulted in three fatalities, significant downtime, and public scrutiny of refinery operations.</td>
</tr>
<tr>
<td>California, USA</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>Warehouse—a pharmaceutical warehouse fire resulted in damage to adjacent warehouses and a total property loss of 100 million dollars.</td>
</tr>
<tr>
<td>Ohio, USA</td>
<td></td>
</tr>
</tbody>
</table>

Additional resources include the National Fire Protection Association (NFPA), the Society for Fire Protection Engineers (SFPE), Fire Suppression Systems Association (FSSA), and the American Petroleum Institute (API). Refer to the References section of this Guideline for specific resources.
MANAGEMENT OVERVIEW

Fire protection is a science that stretches as far back as the Roman Empire. The aqueducts and the Corp of Vigilantes gave the Romans what they needed for fire protection and control. Through the years, the practice of fire protection has evolved from a problem-solving approach to a mature, systematic discipline.

Most processing facilities, due to the materials being handled, have a high potential for loss due to fire. Management teams (like individuals) tend to believe that major incidents, such as fires, are unlikely to occur at their facility. This perception is not accurate. The statistics related to the number of fires do not vary widely year-to-year and losses continue to occur. To effectively implement a fire protection program, it is important to understand that a significant loss is possible. Top management personnel should view fire protection as a benefit - an integral part of the recovery of operations after an incident - and not just as a cost.

This book will assist organizations in making informed, risk-based decisions to determine the appropriate level of fire protection.

2.1. Management Commitment

All responsible organizations will have a fire protection program to protect their assets. For some, it may be fire extinguishers in the warehouse; while for others it is a department of professionals supplementing numerous automatic fire detection and suppression systems. Due to the nature of the program, it is often necessary to involve several individuals, each having a specific, assigned responsibility.
Management commitment to support the fire protection program is necessary if fire protection is to be available when needed. The commitment includes ensuring adequate staffing, resources, and technical support is provided. While fire protection is included with new capital projects, sufficient resources to maintain these systems must be included in the facility’s budget for maintenance.

Management has a responsibility to fully define the roles and responsibilities of each individual. These duties should not be assigned as an add-on or left to chance as this creates the impression that fire protection is not a priority issue. No matter the size of the organization nor the complexity of the program, the need for an effective fire protection program is always present.

2.2. Integration with Other Management Systems

While the implementation of risk management systems may vary from company to company, they are a fundamental activity in the chemical, petrochemical, and hydrocarbon processing industries. A company’s approach to risk management reflects its beliefs and values.

An organization needs to develop a strategy for fire protection. This allows for cost-effective and efficient implementation and continuous improvement in fire protection systems. This strategy must be reviewed and updated periodically because of the many changes that take place within processing industries.

A strategy for fire protection is only one part of an overall framework of guidance to allow consistent, methodical evaluation and management of hazards and risk. There are many ways to approach risk management; however, a strategy and procedures for fire protection must be established and followed.

2.3. Balancing Protection

Three factors contribute to the extent of any fire loss. The first involves an act, omission, or system failure allowing an ignition source and fuel to combine. The second involves the potential for continued fire growth and escalation. The third factor is extinguishment.

Providing the right level of protection can be a delicate balancing act. Overprotection results in unnecessary capital expenditure and higher ongoing costs. The larger the system and the more complex its components, the more capital will need to be invested and the greater the requirements for training on fire protection system operations, testing, and maintenance. Overprotection may result in an overconfidence in the ability of the system to address all situations and a subsequent deterioration in readiness. There are minimum require-