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Integration of process safety engineering and fire protection engineering for better safety performance

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ABSTRACT

Since the inception of the process industries, there have been a great number of process incidents causing significant loss of life and property damage. Even the establishment and implementation of a series of rigorous regulations has not prevented the occurrence of process incidents. In order to protect people, property and the environment a more robust safety program is needed and the safety performance of process industries must continue to improve. In this work, the common ground and the unique characteristics of process safety engineering (PSE) and fire protection engineering (FPE) is reviewed to demonstrate the potential benefits of unifying the two fields or improving the coordination between them to create a more robust safety program, thereby enhancing the safety performance of process industries. Recommendations are made to facilitate and encourage continued discussion and efforts toward the integration of process safety engineering and fire protection engineering.

1. Introduction

In the preceding decades a long list of process incidents at industrial facilities involving toxic, reactive, flammable or explosive hazards have repeatedly resulted in loss of life and major property damage, sometimes totaling hundreds of millions or billions of dollars in damage and clean-up. Dozens if not hundreds of major loss events have occurred because of the mishandling of combustible dusts (U.S. Chemical Safety and Hazard Investigation Board, 2006), aerosols (Huang, 2013), reactive chemicals (U.S. Chemical Safety and Hazard Investigation Board, 2002; Han et al., 2014), and other hazardous materials. Some of the most notable and historically impactful incidents include the Flixborough incident, the Bhopal gas tragedy, the Seveso disaster, the Phillips 66 incident, the Texas City disasters of 1947 and 2005, the destruction of Piper Alpha in the British North Sea, and the Deepwater Horizon tragedy (Crowl and Louvar, 2011; Office of the Maritime Administrator, 2011).

These and other incidents, most occurring in the 1970s and 1980s, drastically changed public perceptions of industrial chemistry and the hazards it poses and have left an enduring – and periodically re-enforced – negative perception of the chemical industry and chemical manufacturers. Governments responded with a series of new regulations including OSHA's Process Safety Management (PSM) (Occupational Safety and Health Administration, 1992), the EPA's Risk Management Plan (RMP) (Environmental Protection Agency, 1994-1996) and the DHS' Chemical Facility Anti-terrorism Standards (CFATS) (U.S. Department of Homeland Security, 2007)) in the US, Control of Major Accident Hazards (CoMAH) in the United Kingdom under the Health and Safety Executive (Health and Safety Executive, 1999), and the Seveso I, II, and III Directives in the European Union (European Commission, 1982-2012).

The goal of these regulations was to protect the public by requiring companies and industrial facilities to take the necessary and reasonable steps to identify hazards and either eliminate or manage them, thereby preventing additional incidents, loss of life, and loss of property. However, these regulations effectively created a regulatory mandate for process safety engineering (PSE), a field and concept that, while not a new concept in the early 1990s when many of these regulations were being drafted, was still largely undeveloped and unexplored in industry and academia. These

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incidents, the resulting public perception, and the regulations that followed provided the necessary impetus to formalize PSE into a mainstream and necessary discipline in the industrial community.

In contrast to PSE, fire protection and fire protection engineering (FPE) traces its roots back to major historical fires including the burning of Rome in 64 AD (Eyewitness to History, 1999), the Great Fire of London in 1666 (History Learning Site, 2014), the Great Chicago Fire of 1871 (Bales, 2004), the Great Fire of Pittsburg in 1845 (Adams, 1942), the Great Boston Fire of 1872 (The Library of Congress, 2014)), and the 1906 earthquake and fire that destroyed San Francisco (Eyewitness to History, 1997). More recently, fire events such as the World Trade Center collapse in 2001 (Federal Emergency Management Agency, 2002), the Station Nightclub fire in 2003 (Belluck and Zielbauer, 2003), and the Arizona Yarnell Hill wildland fire in 2013 (Mockenhaupt, 2014) have caused a significant number of deaths and billions of dollars in damage. FPE is therefore a much older discipline than PSE with a broader mandate of protecting all of society from catastrophic fires. The pursuit of this goal has led to the creation of private and public fire brigades, fire fighter training facilities like the Brayton Fire Training Field in College Station, Texas, and a variety of state, national, and international fire and building codes. The National Fire Protection Association (NFPA) was established in 1896, with a primary objective to reduce the impact of fire and other hazards by providing and advocating consensus codes and standards, research, training, and education, and is the world's leading advocate on fire safety, developing and publishing more than 300 consensus codes and standards (National Fire Protection Association, 2014).

However, while FPE and PSE were developed at different times in history and resulted from different historical drivers, in the context of modern industrial chemical facilities, both disciplines have a common aim: to prevent loss of life and property due to incidents, accidents, and mishaps. With this common goal in mind, the two disciplines use similar processes to address similar, if not overlapping hazards. Many process safety incidents either begin with or eventually result in fires and explosions of various sizes and severities. FPE, while having a longer history as a discipline, can be reasonably treated as a single part of a comprehensive PSE program which also considers toxic release, and reactive hazards, as well as noise, air and water pollution.

In spite of this apparent synergy in goals and methods, however, the activities to integrate the older discipline of FPE into the new and broader discipline of PSE are scarce. This paper seeks to highlight the common ground between FPE and PSE, what the two fields have to learn from each other, and how the disciplines can be brought together and integrated in industrial facilities to produce better, safer processes by reducing the likelihood and severity of process incidents in the future.

2. Common ground between FPE and PSE

Based upon the characteristics of FPE and PSE, there is some common ground between them. The similarities are demonstrated in this section.

2.1. Process Hazard Analysis (PHA) and Fire Hazard Analysis (FHA)

Both FPE and PSE use hazard analysis to anticipate and manage hazards and the associated risks. Similar in name and function, the Process Hazard Analysis (PHA) and Fire Hazard Analysis (FHA) aim to identify hazards, determine possible consequences, and calculate the risk of an incident (Crowl and Louvar, 2011; Center for Chemical Process Safety, 2003).

Process Hazard Analysis (PHA) focuses on a broad set of technical issues by considering a series of different scenarios. This includes identifying potential chemical hazards related to the release of flammable and toxic materials and the potential consequences in case of a release, not only in traditional onshore settings, but also offshore processes. The scope of PHAs is enormous, making them an invaluable tool for risk management and mitigation (Crowl and Louvar, 2011).

Fire Hazard Analysis (FHA) is similar to PHA but focuses on a narrower set of technical issues, specifically fire events. FHA identifies fire hazards, assesses potential consequences of an incident, and if necessary, calculates the risk associated with the consequences (Center for Chemical Process Safety, 2003). The goal of FHAs is to define the exposure conditions that could occur in the event of ignition resulting from hypothesized fires. These include but are not limited to time–temperature curves, incident heat flux, smoke conditions and local flammable vapor concentrations. FHA results are often determined using empirical data, live fire testing, or computer modeling and later compared against various threshold levels, or performance criteria, to identify fire protection solutions in the broader performance-based design process. While PHAs include an analysis of fire hazards, they also consider large-scale releases of toxic materials, noise and auditory hazards, health hazards resulting from chronic exposures, and other hazards with the potential to harm employees or the public. However, because of the broad scope of the PHA however, fire hazards rarely receive the depth of analysis in a PHA that is expected of an FHA.

2.2. Documentation and information

Implementation of PSM elements usually generates vast amounts of information, most of which must be documented and protected for future use, including PHA documents (QRA documents), process knowledge/design documents, mechanical integrity documents, management of change documents, operating procedure documents, training documents, emergency response planning and preparedness documents, auditing documents, incident investigation documents, standards/codes/regulations documents, contractor documents, permitting system documents, and control software documents. The purpose of documentation is to ensure the information is available to personnel responsible for implementing other PSM elements. Most PSM elements are dependent on this flow of information to function properly and a PSM program will almost certainly fail without it.

For example, important information on how to safely operate a reactor identified in a PHA may be of little value unless it is communicated to the appropriate personnel through procedures and training (Center for Chemical Process Safety, 1995). Appropriate documentation will have many benefits including linking the PSM elements together, preserving the historical data throughout the life cycle of facilities, identifying deviations before incident occurrence, facilitating regulation compliance, and reducing downtime. However, the probabilities of incident occurrences are increased if the documentation is deficient. Many incidents might have been avoided if satisfactory PSM documentation had existed and been effectively used (Center for Chemical Process Safety, 1995).

Similar to PSM, fire protection programs generate a large amount of information and documentation. FPE systems are specified and drawn into building plans and facility layouts in the design phase. Other FPE documentation includes emergency response procedures, NFPA codes, standards and guidelines, fire department incident documentation, and operation manuals for all system components within the FPE design. Documentation may also include the design basis for fire protection systems if developed from a FHA. These drawings are held by project managers, construction managers, and many times the AHJ or local