1

AN OVERVIEW OF PROCESS SAFETY

"To know is to survive and to ignore fundamentals is to court disaster."
H.H. Fawcett[1]

1.0 COURTNEY'S STORY – CONTINUED

If you have not read the preface, you will not have been introduced to Courtney. If you have a few minutes take the time to go back and become familiar with Courtney. Her story will continue at the beginning of each chapter.

Carla the VP of Compliance and Regulatory Affairs, and Courtney's boss continued to explain the business aspects of the proposed acquisition of White Hot Chemicals. However Courtney's mind continued to focus on what Carla had just said, that as part of Courtney's responsibilities they wanted her to assess the state of White Hot's process safety programs as well as all other HSE related matters. In their US operations Bland's process safety matters were handled by the Asset and Operations Integrity (A&OI) group, not HSE. When Courtney raised this point, her boss explained because of the turn-around at Bland's Pasadena, TX site and the expansion at Port Arthur, TX the A&OI group didn't have anyone they could assign to the due diligence team. In fact, one of the reasons Courtney was assigned to the due diligence team was Courtney

oversaw the major hazards programs of Bland's Fawley, UK operations and was the HSE director there for three years. That plus Carla noted that White Hot's Ternuezen facility was one of the potential real 'gems' in the acquisition and they felt Courtney's previous experience with major hazard legislation in Europe would be a real plus. That is why they had every confidence Courtney could handle the process safety as well as all the other HSE related issues. Courtney thought to herself – "I wish I had that same level of confidence!"

1.1 WHY THIS GUIDELINE?

You have probably heard the adage that only 10% of an iceberg is visible above the waterline, the other 90% being submerged or hidden from view. The development and publication of this Guideline was based on similar findings of Center for Chemical Process Safety (CCPS) member companies – namely many process safety issues were found only after they had purchased a set of assets, facilities or operations. In other words, prior to the purchase and despite doing a due diligence review of the site or business, these process safety issues were 'below the waterline' only to be discovered later after the deal closed.

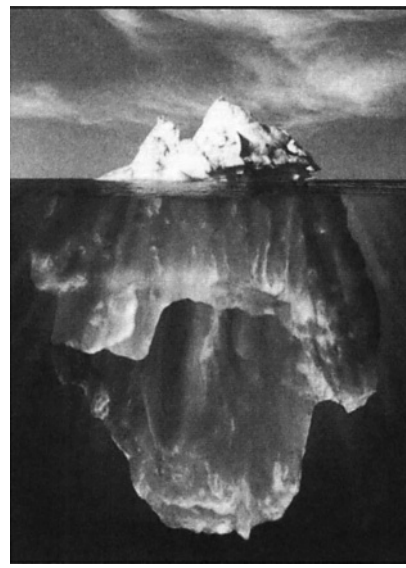

Figure 1. The Iceberg principle

This situation is not new to the health, safety and environmental community. Often in the past environmental legacy issues were not investigated prior to purchasing a site or business. Afterwards and with changing legislation many companies found they had 'inherited' significant environmental liabilities with the purchase. Sometimes these liabilities required investments of tens of millions of dollars in order to remediate or correct conditions left by the previous owners. Today, investigating environmental matters forms an integral part of the due diligence process when purchasing a facility that stores, processes, manufactures or handles hazardous materials or chemicals. The same holds for certain health issues such as those associated with asbestos. However, this practice has yet to become standard or routine when it comes to identifying and evaluating process safety or major accident hazard issues as an integral part of undertaking a due diligence investigation of a potential acquisition.

While there are a number of explanations for this, perhaps the primary reason is management not recognizing the potential costs that can accompany correcting or rectifying gaps in an operations approach to process safety or major hazard risks. Against this however, a number of the member companies of the Center for Chemical Process Safety investigated the costs they were incurring to rectify process safety issues found after they had closed on an acquisition. Arising out of their investigation they found it was common that another **ten to thirty percent** of the initial purchase price was being expended rectifying such issues. And these were not rare or extreme cases, rather they represented the average costs they were experiencing. Why so much? Examples included:

- Costs of between $30-40 Million just to build and equip a new control room, when studies found the current control room too near to major inventories of flammable materials exposing occupants to an unacceptable level of risk,
- A variety of issues with plant, equipment, control systems, etc. where on studying the issues further, the company found

the costs of 'retro-engineering' corrections amounted to almost 100 times the costs of engineering a new facility.

- Following the Texas City refinery explosion and fires, new requirements for relief and blow-down systems and the siting of occupied buildings or structures are likely to require considerable rectification and upgrading of these systems in light of changes to standards, codes and recommended practices.

In summary, one CCPS member noted:

> *"Rectifying occupational health and safety issues generally runs us hundreds of thousands of dollars. Rectifying process safety issues has been costing us in the tens of millions of dollars. It was not until we were able to prove and present these hard facts to management that process safety became an integral part of our due diligence process."*

The above is 'lesson one' of this Guideline – i.e. the need to get process safety issues onto the agenda of your company's due diligence investigations or studies.

Lesson two of this Guideline is also born out of hard experience. That integrating or merging the process safety approach or programs of two companies can be as equally challenging. This has been found even where a company acquiring a set of assets has itself, operated similar facilities or processes for a period of time. Case studies and discussions of these issues can be found later in sections 2.0 and 2.5 of Chapter 2.

As a result then, this Guideline was developed to:

- Pass some of these 'learnings' on to others to help you make a strong case to your management that process safety issues need to identified and investigated thoroughly in the M&A due diligence process,
- To provide assistance on the various types of process safety or major hazard issues that should be investigated, and

- Provide assistance with planning the process for integrating together the process programs of the two companies after the deal has closed.

1.2 UNDERSTANDING THE BASICS

This first chapter introduces basic concepts related to chemical process safety including an understanding of risk versus hazards. In addition, it is important for every organization to understand the key differences between occupational safety and chemical process safety.

When one hears the word "safety", the general reaction is to think of personal injuries and/or minor accidents, such as cuts, bruises, falls, motor vehicle accidents, or muscle sprains and strains. All of these safety issues can be very serious. However this type of safety incident is typically isolated to a single individual and is generally called occupational safety. When a hazardous materials related incident occurs it often impacts more than one person in addition to property damage and interrupting business flow(s) and possibly off site impacts as well. 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 result in multiple injuries and fatalities, as well as substantial economic, property, environmental damage, and community impact.

The current working definition for Process Safety as used by the Center for Chemical Process Safety is:

> *Process Safety – is a disciplined framework for managing the integrity of operating systems and processes handling hazardous substances by applying good design principles, engineering and operating practices. It deals with the prevention and control of incidents that have the potential to*

release hazardous materials or energy. Such incidents can cause toxic effects, fire or explosion and could ultimately result in serious injuries, property damage, lost production and environmental impact.

> *1. A discipline that focuses on the prevention and mitigation of fires, explosions, and accidental chemical releases at process facilities. Excludes classic worker health and safety issues involving working surfaces, ladders, protective equipment, etc.*
>
> *2. A discipline that focuses on the prevention of fires, explosions, and accidental chemical releases at chemical process facilities*

1.3 HAZARD VERSUS RISK – IS THERE A DIFFERENCE?

Two other terms the reader should be familiar with, as they have very distinctly different meanings, are "risk" and "hazard". Both terms are defined and discussed in numerous CCPS guidelines and materials. Below are two definitions extracted from such other material:

> *Hazard – A chemical or physical condition that has the potential for causing damage to people, property or the environment. A hazard is intrinsic to the material or to its conditions of storage or use. With respect to chemicals, "hazard" may include toxicity (acute or chronic), flammability, corrosivity or reactivity.*
>
> *Risk – A measure of potential loss (for example, human injury, environmental insult, economic penalty) in terms of the magnitude of the loss and the likelihood that the loss will occur.*

To provide an everyday example that might help explain these terms, the risk of injury in a motor vehicle accident is much higher than the risk of being fatally injured in an airplane accident. According to statistics published by the U.S. National Transportation Safety Board, the risk of being fatally injured in an aircraft accident is 0.0002 fatal injuries per one million miles flown as compared to the risk of being fatally injured in a traffic accident, which is 1.4 fatal injuries per one million miles driven or traveled. In other words within the United States, you are 7,000 times more likely to be fatally injured for every one million miles traveled in a car versus in an airplane. However, in an airplane crash more individuals are likely to be injured in a single accident. The likelihood of an event occurring causing injury to the passengers in a motor vehicle is extremely high relative to the likelihood of an airline crash causing injury to its passengers. This is an important concept when discussing chemical hazards and process safety. The public is willing to accept a large number of accidents that involve a few individuals as occur in motor vehicle accidents, but does not tolerate a single event that injures many individuals.

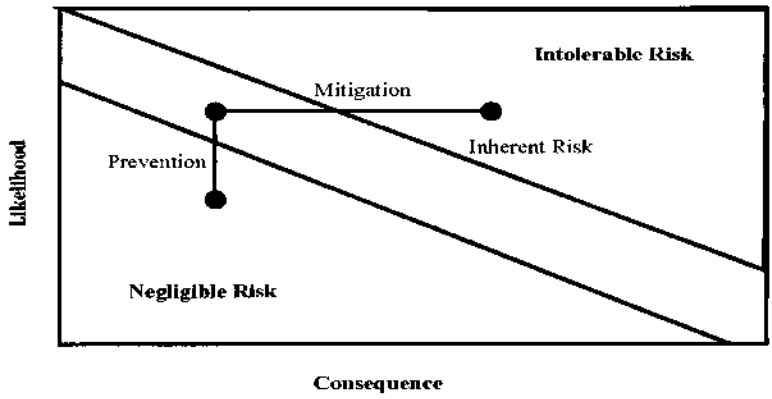

Figure 2. Risk Tolerability

Figure 2 presents the various elements that make-up risk, namely the likelihood a hazard or event might occur coupled with the potential consequences that could arise. The Figure also demonstrates that as the consequences become more severe (e.g. multiple injuries or fatalities, major environmental damage, business interruption) the acceptance of those consequences becomes decreases. The same is true for the likelihood of a particular class of accident occurring. Simply stated, when incidents or accidents increase in frequency or their consequences become more severe the acceptance or tolerability of those accidents decreases. The Figure also shows the impact various risk control measures might have on any one hazard or risk. Risk controls that help mitigate the consequences of an accident move the 'acceptability' of those consequences to the left in the chart. Preventive risk control measures on the other hand act to reduce the likelihood of a particular risk from occurring thus moving their acceptability down in this figure. Most risk control programs will work to identify the optimal combination of measures taken to reduce both the likelihood as well ways to reduce the consequences with the ideal of moving the risks into the lower left hand corner (i.e. to a tolerable if not negligible level).

Process safety accidents can impact numerous individuals both on and offsite. These low likelihood, but high consequence events cause great unease in and amongst the public. As a result, considerable resources are spent to prevent their occurrence. There are numerous techniques for assessing process hazards in new and existing facilities. A similar approach needs to be used when assessing process safety during the merger and acquisition process.

1.4 GOOD INJURY RATE DOES NOT EQUAL GOOD PROCESS SAFETY PERFORMANCE

When an acquisition or merger is being considered, a key performance metric typically requested is one that is calculated based on employee injuries and hours worked. Another common key performance metric is one associated with inspections or

violations noted by governing agencies. Neither of these metrics though is appropriate for measuring a company or facility's performance as it relates to process safety.

An example of this is based on findings in the U.S. Chemical Hazards and Safety Investigation Board's (i.e. CSB) investigation report on the BP Texas City Refinery explosion. In the CSB report the investigation panel noted BP had emphasized personal safety, and had in fact been very successful in injury reduction over the last decade. However BP did not have process safety performance metrics in place. As process safety expert Trevor Kletz notes,

> *Personal safety metrics are important to track low-consequence, high-probability incidents, but are not a good indicator of process safety performance. The lost time rate is not a measure of process safety. An emphasis on personal safety statistics can lead companies to lose sight of deteriorating process safety performance. Process safety metrics provide important information on the effectiveness of safety systems, and an early warning of impending catastrophic failure.*

CCPS has recently issued a publication defining process safety leading and lagging metrics, Process Safety Leading and Lagging Indicators and it is recommended these be used rather than personal injury statistics.[2]

In summary, the injury performance at a facility, which handles highly hazardous compounds, may not be indicative of process safety performance. However, a consistently poor injury rate can be viewed as an indicator of the level of management commitment to operating a facility safely.

1.5 UNDERSTAND THE HAZARDS OF CHEMICALS HANDLED ON SITE

When considering a merger with or acquiring a company that handles hazardous chemicals, a key first step is to identify what chemicals are handled on site, the quantities stored and how they are processed. Once it is determined there is a process hazard at a particular facility, the merger and acquisition team must examine the hazard identification techniques employed in the past, but more importantly the preventative measures currently in place.

There is no prescriptive way to identify high hazard chemicals. Every chemical can potentially be hazardous. There have been numerous efforts to make lists of highly hazardous compounds. European countries, Asia, the United States as well as many other countries have developed high hazard chemical lists. The chemicals on those lists are selected for a variety of reasons. Factors considered in developing various high hazard lists include:

- Inherent toxicity, for example - chlorine and anhydrous ammonia;
- Flammability, for example - ethanol, methanol or butane;
- Reactivity, for example - peracetic acid;
- Environmental impact, for example - chloroform;

There are even lists of highly hazardous substances, based on the potential for a chemical or substance to be used as a weapon for terrorists or sabotage. Those lists may include highly potent active pharmaceutical ingredients or items that would be utilized to make weapons of mass destruction. There are many substances on these lists because they pose multiple hazards. Ethylene oxide is a prime example of a substance that is highly toxic, highly flammable, environmentally sensitive and reactive.

With such a wide variety of potential hazards, a starting point for hazard identification is needed. One option is to obtain a master list of all chemicals handled on site and compare the list to the various

lists of hazardous chemicals developed as noted above. Keep in mind when reviewing the chemicals handled onsite that intermediates and byproducts need to be considered in addition to the raw materials and the final products. Each stage of the process must be considered to identify all highly hazardous substances handled in a process.

Each facility, which handles highly hazardous chemicals (HHCs) should have an understanding of which items are covered by process safety or major hazard accident regulations as well as any applicable industry codes and standards. Table 1 provides a summary of international process safety related standards, codes, and regulations. While extensive it is not an exhaustive or all-inclusive list of relevant codes, standards and practices.

Knowledge in this field of expertise is required to fully comprehend the requirements associated with a facility that has process safety issues. Keep in mind that these lists or regulatory requirements are only a starting point. If a facility does not handle one of the substances on one of the lists or does not exceed the threshold quantity listed for a particular chemical that in itself, does not mean a process safety hazard is not present. A prime example of this is represented by an incident that occurred in 2003 at Catalyst Systems Inc. This incident involved only 200 lbs. of benzoyl peroxide.

> *On January 2, 2003, a vacuum dryer holding nearly 200 pounds of benzoyl peroxide exploded at the Catalyst Systems Inc. production facility in Gnadenhutten, Ohio. Employees were in the process of drying granular benzoyl peroxide, which is unstable at high concentrations, when the explosion occurred.*

Once there is an understanding of the chemicals handled at the facility, individuals with a process safety background should be added to the M&A assessment team.

Table 1. Examples and Sources of Process Safety Related Standards, Codes, Regulations and Laws [3]

Various sources of process safety related information
Voluntary Industry Standards
• American Petroleum Institute Recommended Practices[4] • American Chemistry Council Responsible Care® Management System and RC 14001[5] • ISO 14001 – Environmental Management System[6] • OHSAS 18001 – International Occupational Health and Safety Management System[7] • Organization for Economic Cooperation and Development – Guiding Principles on Chemical Accident Prevention, Preparedness, and Response, 2003[8]
Consensus Codes
• American National Standards Institute[9] • American Petroleum Institute[4] • American Society of Mechanical Engineers[10] • The Chlorine Institute[11] • The Instrumentation, Systems, and Automation Society / International Electrotechnical Commission[12] • National Fire Protection Association[13]
U.S. Federal, State, and Local Laws and Regulations
• U.S. OSHA – Process Safety Management Standard(29 CFR 1910.119)[14] • U.S. Occupational Safety and Health Act – General Duty Clause, Section 5(a)(1)[15] • U.S. EPA – Risk Management Program Regulation (40 CFR 68)[16] • Clean Air Act – General Duty Requirements, Section 112(r)(1)[17] • California Risk Management and Prevention Program[18] • New Jersey Toxic Catastrophe Prevention Act[19] • Contra Costa County Industrial Safety Ordinance[20] • Delaware Extremely Hazardous Substances Risk Management Act[21] • Nevada Chemical Accident Prevention Program[22]

Various sources of process safety related information
International Laws and Regulations
• Australian National Standard for the Control of Major Hazard Facilities[23] • Canadian Environmental Protection Agency – Environmental Emergency Planning, CEPA, 1999 (section 200)[24] • European Commission Seveso II Directive[25] • Korean OSHA PSM Standard[26] • Malaysia – Department of Occupational Safety and Health (DOSH) Ministry of Human Resources Malaysia, Section 16 of Act 514[27] • Mexican Integral Security and Environmental Management System (SIASPA)[28] • United Kingdom, Health and Safety Executive COMAH Regulations[29]

Highly hazardous chemicals need to be properly controlled and contained at all times. The basic design of the equipment is critical to ensure proper containment is achieved. If the equipment is not of a proper design or is not "fit-for-purpose" the potential for a chemical release is inevitable. If the equipment is not well maintained, the results can be equally catastrophic.

There are numerous industry groups that provide guidance on process safety for specific chemicals. For example, chlorine is a common chemical that can be found in multiple locations across the U.S. Chlorine suppliers and their clients also have a history of incidents and continue to learn and establish new codes and standards that are designed to prevent a release. The Chlorine Institute is a key resource for these efforts. Due diligence teams would need to understand if prospective facilities that handle chlorine have followed the design and engineering codes established by the Chlorine Institute. Other consensus codes that address process safety are listed in the previously noted Table 1.

1.6 DON'T FORGET ABOUT THE DUST EXPLOSION HAZARD

A dust explosion hazard is present with many common solids. Quite often these solids may not historically have been considered a high hazard. Dust explosions have occurred for years, particularly in the grain handling business sectors. A recent incident should be a key reminder of the potential catastrophic hazard associated with a dust explosion. An explosion that occurred in February of 2008 was a clear indication of the power of any combustible solid material when suspended in air. On February 7, 2008 an incident at an Imperial Sugar refinery resulted in 13 fatalities (on August 22, 2008 a 14th fatality occurred after months in critical condition) and a total of 40 individuals injured.[30] The explosion was believed to have been the result of an initial 'minor' explosion followed by a larger explosion. The first minor explosion resulted in dust dislodging from various surfaces. This dust also became suspended in air resulting in a second catastrophic explosion. This scenario of a small primary explosion followed by a catastrophic secondary explosion is stereotypical of a dust hazard. The Chemical Safety Board completed a comprehensive investigation on the history of dust explosions. Their investigation was initiated after three major explosions in 2003 resulted in 14 deaths. As part of their investigation the CSB investigators researched the history of dust fires and explosions from 1980 to 2005, and identified 281 major combustible dust incidents that killed 119 workers, injured 718 others, and destroyed many of the industrial facilities.[31] The potential catastrophic result of a dust explosion necessitates the completion of a thorough assessment of this particular process safety hazard as part of the M&A process.

Many materials when suspended as a dust in air can lead to explosions. As described above sugar is one. Grain dusts have led to a number of explosions in grain handling silos. Coal dusts, of course, as well as wood dust(s) and many different metal dusts such as aluminum have also been the source of airborne-suspended dust explosions. Sites, facilities or processes with the potential to generate such dust hazards, must be evaluated to assure controls are

in place that manage the risks of an accident with potentially catastrophic consequences.

1.7 UNIQUE CONSIDERATIONS AT FACILITIES THAT HANDLE HHCS

Chapter 4 provides further detail on the issues and activities that should be carried out to assess the state of the current process safety programs as part of a due diligence investigation. However, to assist with establishing a fundamental knowledge or understanding of the management of process safety issues, a few areas aspects of an effective approach to PS are introduced here.

Process safety is an extremely broad and technical topic in itself. Just developing a basic knowledge and understanding of which codes and practices are applied to various process safety hazards is a monumental task. The codes are ever changing as the industry experiences incidents and review panels modify standards based on new knowledge. New publications are issued frequently. For example, one design standard mostly unique to the chemical, refinery and related industries is facility siting. Facility siting involves proper spacing and organization of a chemical processing complex between on site process units themselves as well as relative to its neighbor's. Industry standards have been changed recently with new requirements for locating portable buildings (API 753 – "Management of Hazards Associated with Location of Process Plant Portable Buildings" issued in June 2007[32]). These changes were made to ensure such facilities and their occupants are protected against toxic releases, fires and explosions. Facility siting assessments not only look at spacing, but also assess occupancy load and the construction of the building in question.

Facility siting involves examining potential offsite impacts as well. The scenario examined here is the proximity of buildings in the surrounding neighborhood or near to the fence line of an industrial facility that handles HHCs. This scenario is a very

difficult risk to mitigate after the fact - i.e. after construction. Noteworthy major accidents or catastrophes where neighboring residential buildings were severely damaged or members of the general public were seriously or fatally injured include:

- 1974 – The explosion at the Nypro chemical works at Flixborough, UK
- 1976 – The release of TCDD (dioxin) from the ICESMA chemical works near Seveso, Italy
- 1984 – The release of methyl isocyanate at the Union Carbide Bhopal, India chemical works,
- 2005 – The explosion and fires at the Buncefield, UK fuel storage and transfer depot.

More recently the potential magnitude of offsite impacts can be found by viewing a video available on the United State's - Chemical Safety and Hazard Investigation Board's (CSB) website entitled "A Blast Wave in Danvers"[33] and the associated incident investigation report CAI/Arnel Chemical Plant Explosion Danvers MA. This video demonstrates what results when a process safety incident occurs at a facility in close proximity to a residential area. These issues can easily increase the risk of a potential buyer when seeking to acquire a new facility or merge with a company that has multiple sites some of which are near to residential areas.

The above incidents also raise the need to investigate and evaluate facilities adjacent to a potential acquisition site or operation. This is especially true where an asset is located in the middle of an industrial complex that comprises multiple facilities storing, processing or handling highly hazardous chemicals. You may well be faced with the situation where the only thing separating the site or assets being considered from an adjacent facility are a few 'tens of feet' or meters and a chain link fence. Further, companies are acquiring specialist facilities or operations that exist in the heart of a major chemical or petrochemical complex where the whole function of that facility is providing or feeding the units around it with power, steam or possibly a unique process stream. Such acquisitions are becoming more commonplace. These purchases

involve unique issues that will need to be investigated and evaluated from a process safety standpoint as part of the due diligence process. The potential liabilities with such purchases must be well understood to ensure proper controls are in place and whether following the purchase one or multiple parties will assume the risks and associated liabilities.

While the physical features of a prospective facility are critical aspects that influence the process safety risks, the management systems that are in place play a dominant role in determining how well those risks are controlled. The chemical and petroleum industry is one where good management systems are essential to the safe operation of the various processing units and operating facilities. Examples of management system requirements include management of change, incident investigations, employee participation, control of hot work and so on. Each of these systems is a key aspect of the risk controls that will need to be examined in the due diligence portion of the merger or acquisition. Further, assuring these systems remain robust will be essential when going through the changes of a corporate re-structuring once the merger or acquisition occurs. In his book *"Still Going Wrong"* published in 2003 Professor Kletz noted that companies at that time may not be evaluating the impact of the full range of organizational changes on process safety or major hazard management programs. He went on to recommend the impact from changes such as outsourcing, major re-organizations, mergers and 'downsizing' should all be assessed by Management of Change programs.[34]

1.8 RESOURCES FOR PROCESS SAFETY

A key resource in which to find further information on process safety issues is the library of books published over the last several years by the Center for Chemical Process Safety (CCPS). The Center identifies and addresses process safety needs within the chemical, pharmaceutical, and petroleum industries. CCPS offers

over ninety titles providing current guidance for all those that produce, store, and handle flammable, explosive and reactive materials. The CCPS library of guidelines, addresses the full range of process safety challenges, from inherently safer process design, to hazard evaluation and safe design, to advanced process safety management practices, to incident investigation.

There are multiple other resources available to develop a basic knowledge of process safety (see Table 1). The CSB is an independent federal agency charged with investigating industrial chemical accidents. The "Blast Wave in Danvers" video, mentioned earlier in this Chapter is just one of various videos and associated accident reports available on CSB's website. This website is a great resource for any individual who wants to understand the risks associated with process safety incidents. The videos on this website are of high quality. They would serve as a great educational tool for a due diligence team associated with an acquisition or merger in the chemical industry.

A basic textbook on process safety is entitled - "Chemical Process Safety: Fundamentals with Applications".[35] It provides a comprehensive introduction to the essential technical fundamentals of chemical process safety. Its emphasis on fundamentals is intended to help both experts in the field of process safety as well as those desiring to obtain a basic understanding of process safety.

In addition to the CCPS the American Petroleum Institute (API) is a valuable resource for both the petroleum and chemical industries. As with the CCPS, API has developed a wide range of industry standards, recommended practices and guidelines as well as many other resources directed toward the safe production, refining and transport of petroleum based products.

Another key organization is the National Fire Protection Association (NFPA). Many NFPA codes have been adopted as regulations at the state and national level. Other NFPA codes are recognized as establishing good industry practice or Recognized and Generally Accepted Good Engineering Practice (RAGAGEP) for protection against various hazards.

These are only a few of the many resources on process safety available. However, by far the most important resource in a merger or acquisition is the technical experience and expertise of staff or consultants familiar with the chemicals being handled, and the proper safeguards and designs that are appropriate for the hazards present. Even that expertise though may be facing their first acquitision of a new company and the ensuing process for merging two possibly disparate approaches to process safety or major accident hazard prevention together. The following chapters seek then not only to assist an individual new to process safety as well as the individual who is well versed in process safety but new to an acquisiton or merger. The objective of each chapter is to help such individuals and their organizations factor process safety decisions into the various stages of an M&A in a timely and effective manner.