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Process Safety Management to Manage Risk in Occupancies other than Chemical Process Industries

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Abstract

Process Safety Management (PSM), as a loss prevention management system, has been used for many years to limit and control risks in the Chemical Process Industries (CPI). Losses at chemical and petrochemical facilities are characterized by high energy fire and explosions which in many cases have received large press coverage. Most CPI fires and explosions happened in organic hydrocarbon processes originating from mechanical integrity failures. Mineral, metallurgical refining and pulp and paper processes, on the other hand, feature seemingly benign and often non combustible chemicals. Corrosion in acid plants, physical explosions of digesters, autoclaves, and black liquor recovery boilers have been more common than fires or combustion explosions.

This paper presents case studies of incidents in several non-chemical occupancies and efforts made by some companies in Eastern Canada to incorporate elements of PSM as a tool for loss prevention and risk management.

Introduction

The chemical, pulp and paper, and mineral processing industries are capital intensive, labor intensive and are a heavy user of natural resources. There are many methods to manage risk in these industries. Risk can be transferred through insurance, it can be eliminated by abandoning a high risk process, or it can be managed and minimized by a more thoughtful, *systematic* approach.

According to Moore[1], losses in the chemical processing and metallurgical refining are often characterized by failures of mechanical systems that release high energy flammable, toxic or corrosive materials. In conventional industrial plants, hazards usually can be observed visually and evaluated according to established, prescriptive exposure-identification procedures and guidelines. Due to the nature and complexity of the CPI, metallurgical refining, and pulp and paper occupancies, most potential loss exposures or event scenarios are not discovered readily through the usual field methods and intuitive techniques. This can only be done by a systematic approach using Process Safety Management (PSM).

Process Safety Management (PSM)

Process Safety Management is a U.S. Occupational Safety and Health Administration (OSHA) regulation that is intended to prevent an incident like the 1984 toxic gas release in Bhopal, India[2]. The process Safety Management of Highly Hazardous Chemical standard, 29 CFR 1910.19, is intended to prevent or minimize the consequences of a catastrophic release of toxic, reactive, flammable or explosive hazardous chemical from a process. PSM has been developed over many years to guide the chemical process industry toward safer facilities before being adopted by various regulatory agencies. It is considered the foundation of all loss prevention activities[3].

Earliest PSM efforts started in Europe in the 1960s. It got larger application following significant incidents and passage of the European Economic Council's (EEC) Directive 82/501/EEC (also known as the "Seveso Directive"), with revisions in 1997 known as "Seveso II". Application of PSM in the United States was limited to a few progressive chemical companies until the Occupational Safety and Health Administration (OSHA) rule "Process Safety Management of Highly Hazardous Chemicals" (29 CFR Part 1910) was promulgated in 1992. This law was passed following publicity from a series of severe fire and explosion incidents.

Canada has no formal or mandatory PSM regulations and instead, relies on high-hazard industries to voluntarily regulate themselves through chemical trade organizations and programs, such as Responsible Care. These voluntary programs have key elements inherent in a PSM program. Until 1999, the Major Industrial Accidents Council of Canada (MIACC) brought together representatives from the Canadian industrial sectors for the purpose of reducing the frequency and severity of major industrial accidents[4]. MIACC has initiated programs, such as Partnerships toward Safer Communities, Process Safety Management, and the Ideal Emergency Response System (ER2000)[5]. Presently, the Process Safety Management Division, part of the Canadian Society for Chemical Engineering (CSChE) is a continuation of work started in 1990 under MIACC. More information can be obtained in the division website: http://www.cheminst.ca/divisons/psm

PSM is a guide to applying chemical engineering discipline and methodology to increasing the performance efficiency of a process operation, in all its aspects.

Traditional workplace health and Safety:

1. Focuses on individual actions while considering interaction with equipment
2. Occupational health exposures
3. Significant legal and regulatory mandate

The objective is to eliminate injuries and illnesses to personnel.

Process safety management:

1. Focuses on process: materials, equipment and systems
2. Individuals and procedures are considered part of the system

The objective is to eliminate process-related incidents.

An effective Process Safety Management program will include[6]:

1. Accountability
2. Process Safety Knowledge
3. Process Hazard Reviews
4. Process Risk Management
5. Mechanical Integrity
6. Management of Change
7. Incident Investigation
8. Training of Personnel
9. Contractor Oversight
10. Emergency Response Planning
11. Audits and Documentation
12. Standards, Codes, and Laws

Incidents in mineral, chemical, and pulp and paper industries are presented in this paper. The objective is to show that contributing factors are due to a lack of or a breakdown of Process Safety Management, regardless of the industry type.

Incident Case Studies

Case Study No 1:

Summary of the incident

On 5 July 1999, an explosion occurred at the Gramercy Works Plant operated by Kaiser Aluminium and Chemical Corporation in Gramercy, Louisiana, injuring 29 persons, as reported by US MSHA (1999). The plant processed bauxite ore into alumina using the 'Bayer Process', which involves the caustic leaching of bauxite at elevated temperature and pressure. The plant processed about 9000 tons of bauxite ore each day, producing 3200 tons of alumina.

An unplanned electrical power failure occurred approximately 34 minutes before the explosion. This caused all electrically powered processes to stop, including slurry pumps. Gas-fired boilers continued to deliver high-pressure steam to pressure vessels in the digestion area. Many relief valves failed to function because they were shut off and some relief piping was clogged with scale. An explosion occurred in several vessels. There were no combustible liquids and no fires resulted. The pressure wave from the exploding pressure vessels destroyed the plant. It took almost two years to rebuild.

Photo of damage to bauxite plant following pressure vessel failure (courtesy MSHA).

Mine Safety and Health Administration (MSHA) Investigators determined that the explosion occurred as a result of a build-up of excessive pressure within vessels in the digestion area and the subsequent rupture of the vessels. Rupture of the vessels exposed the superheated liquid contents to atmospheric pressure resulting in a boiling liquid expanding vapor explosion (BLEVE).

During the MSHA investigation, it was determined that:

- The pressure relief safety system installed to relieve excessive pressure in several flash tanks was inoperative;
- Sections of the pressure relief piping designed to vent excessive pressures for the digestion flash tanks were partially blocked, and, in at least one case, was totally blocked with scale;
- The mine operator routinely allowed the digestion process to be operated while pressure in one or more pressure vessels exceeded the design capacity intended by the manufacturer; and
- Digestion operators had not been adequately trained in the safety and health aspects and safe operating procedures.

There are many representative PSM failures associated with this incident including:

- No formal oversight PSM program in place;
- Process hazard analyses not conducted;
- Poor mechanical integrity of pressure relief valves and piping systems;
- No management of change;
- Inexperienced operators.

Case Study No 2:

Summary of the incident

On July 17, 2001, an explosion involving sulfuric acid occurred in Delaware City, Delaware. A work crew had been repairing a catwalk above a sulfuric acid storage tank farm when a spark from their hot work ignited flammable vapors in one of the tanks. This tank had holes in its roof and shell due to corrosion. The tank collapsed, and one the contract workers was killed; eight others were injured. A significant volume of sulfuric acid was released to the environment.

Large sulfuric acid storage tank collapsed after an explosion (Courtesy CSB[7]).

The root causes were determined to be:

- The company did not have an adequate mechanical integrity management system to prevent and address safety and environmental hazards from the deterioration of H2SO4 storage tanks.

- Repeated recommendations for an internal inspection were not taken in consideration.

- A leak in the shell of tank, observed in May 2001, was not repaired. Instead, the tank remained in service.

- MOC systems inadequately addressed conversion of the tanks from fresh to spent acid service.

  - No engineering calculations were made to determine proper sizing for the inerting system.
  - The tank conversion was completed without review of changes by technical experts, process hazard analyses, or prestartup safety reviews–all elements of a proper MOC program.

- Hot work program was inadequate.

Case Study No 3:

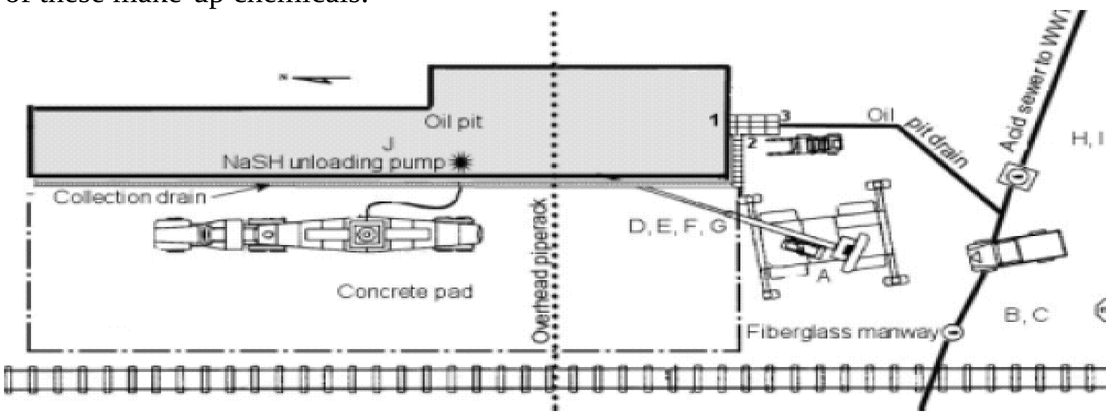
Summary of the incident

On January 16, 2002, highly toxic hydrogen sulfide gas leaked from a sewer manway at pulp and paper mill in Pennington, Alabama[8]. Several people working near the manway were exposed to the gas. Two contractors were killed. Eight people were injured. The County paramedics who transported the victims to hospitals reported symptoms of hydrogen sulfide exposure.

Sodium hydrosulfide (NaSH) was being unloaded on January 15–16. The unloading station consists of a large concrete pad sloped to a collection drain. The pit–commonly referred to as the oil pit–collects rainwater, condensate, and occasionally spilled chemicals from the unloading station. The job required contractor employees to work in or near the oil pit, which–at the time of the incident on January 16–contained liquid. It estimated that it was typical for approximately 5 gallons of NaSH to collect in the oil pit from various sources (pump leaking, flushing unloading lines, etc.) during each offloading of a tank truck. Fifteen tank trucks of NaSH had unloaded in the 24 hours prior to the incident. To avoid having the construction crew stand in the fluid-filled pit, an operator opened a valve to drain the oil pit. The valve was then closed and relocked. In the same area, three Transport tank trucks carrying NaSH. With the assistance of plant operators, one of the truck drivers connected his vehicle to the unloading hose. Witnesses estimated that when the connection was made, up to 5 gallons of NaSH spilled to the collection drain. On the day of the incident, sulfuric acid was being added to the acid sewer to control pH downstream in the effluent area. NaSH from the oil pit and the collection drain drained to the sewer and reacted with the sulfuric acid to form H_2S. Within 5 minutes, an invisible cloud of H_2S gas leaked through a gap in the seal of a manway. This incident is a reactive chemical incident as defined in the U.S. Chemical Safety and Hazard Investigation Board (CSB) reactive chemical hazard investigation.

Oil pit and adjacent tank truck unloading station (courtesy of CSB[8]).

The paper mill uses the Kraft process to produce pulp. Pulp is a material derived from wood chips. It is the main raw material in making paper. In this process, a mixture of chemicals called the pulping liquor is used to treat wood chips that will be processed into pulp. The pulping liquor is made of sodium hydroxide and sodium sulfide. This pulping liquor is recycled through the process and occasionally fresh chemicals are added to the liquor in order to maintain proper liquor chemistry. Sodium hydrosulfide, or NaSH, which was involved in this incident, was one of these make-up chemicals.



Approximate locations of the 10 victims ("A" through "J")-courtesy of CSB[8]).

Recommendations include the following:

- Apply good engineering and process safety principles to process sewer systems;
- Evaluate process sewers where chemicals may collect and interact, and identify potential hazardous reaction scenarios;
- Identify areas where hydrogen sulfide could be present, institute safeguards to limit exposure and require appropriate training (process safety knowledge and training of personnel); and
- Update emergency response plans (emergency response planning).

Conclusions

These incidents at widely differing industrial plants emphasize how important it is to properly implement and adhere to PSM. The cost of not implementing effective incident prevention can be very high. These incidents caused loss of life, impact to the environment, property damage and business interruption. All could have been avoided if management systems such as PSM had been in place or more effective.

According to Kelly H. Ferguson[9], a study by FM Global shows that a breakdown in PSM is the root cause of nearly all losses in the CPI and other industries with chemical processes. The study concludes that facilities with culturally embedded and effectively implemented PSM programs are significantly less likely to suffer a high-impact loss.

Hopefully the case studies presented in this paper will help promote awareness, understanding, and use of Process Safety Management tools, and techniques within non-chemical processing facilities. The widespread use of PSM can be a valuable tool for the mining and pulp and paper industries to eliminate or mitigate process related incidents. Further development of PSM ideas for implementation and best practices in occupancies other than chemical is strongly encouraged.

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