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

By

Hocine Ait Mohamed, Eng

54th Canadian Chemical
Engineering Conference

Process Safety and Loss Management
Symposium

Toronto, October 17-19th, 2005

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

Hocine Ait Mohamed[1]

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, and 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 heavy users 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 a report by L.J. Moore[2], losses in the chemical processing (CPI) 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).

1. Engineering Specialist – Montreal SCR Coordinator,
FM Global, 600 De la Gauchetiere, Montréal, Québec H3B 4L8, CA.

Process Safety Management (PSM)

The interaction of reactive chemicals under normal or abnormal conditions cannot be evaluated without focused hazard analysis and full understanding of the chemistry and process conditions. These hazards can be managed through an established and comprehensive program that integrates technology, procedures and management practices. PSM has proven to be an effective system whereby safety and loss prevention programs can be developed, monitored, and measured for performance under a single program. Process Safety Management helps and has helped prevent and minimize the size of loss.

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 to further the Clean Air Act Amendments of 1990. 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[8]. 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.

An effective Process Safety Management program will include:

- Accountability
- Process Safety Knowledge
- Process Hazard Reviews
- Process Risk Management
- Mechanical Integrity
- Management of Change (MOC)
- Incident Investigation
- Training of Personnel
- Contractor Oversight
- Emergency Response Planning
- Audits and Documentation
- Standards, Codes, and Laws

Three 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 in Process Safety Management, regardless of the occupancy.

INCIDENT CASE STUDIES

Three case studies are abstracted to demonstrate root cause failures in process safety management.

Mineral Processing:

Case Study No 1:

Summary of the incident

On July 5, 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.

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;
- A lack of process hazard analyses;
- Poor mechanical integrity of pressure relief valves and piping systems;
- No management of change;and
- 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 (11)).

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 H_2SO_4 storage tanks.

  - The 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.

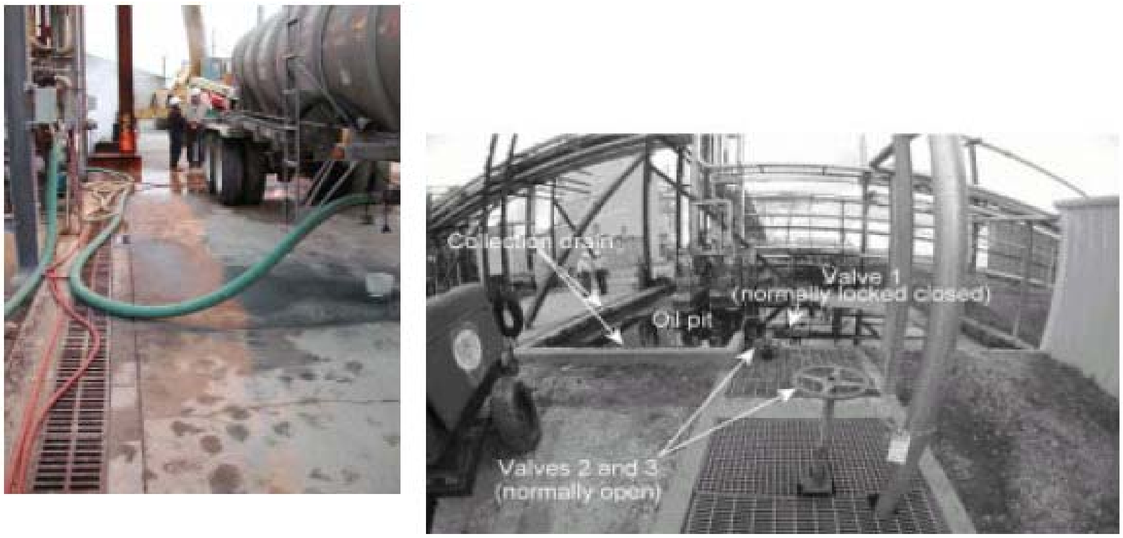
Pulp & Paper

Case Study No 3:

Summary of the incident:

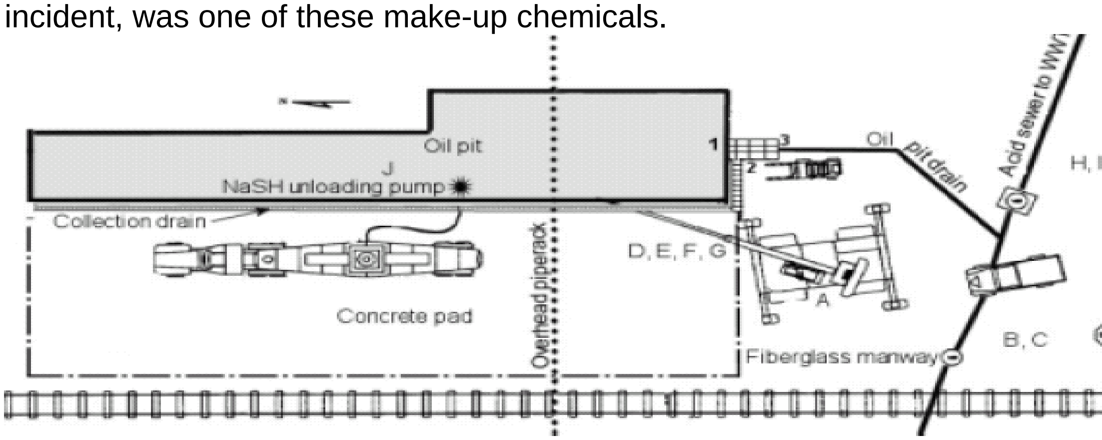
On January 16, 2002, highly toxic hydrogen sulfide gas leaked from a sewer manway at a pulp and paper mill in Pennington, Alabama. Several people working near the manway were exposed to the gas. Two contractors were killed. Eight people were injured. The County paramedics who transported the victims 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 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 arrived 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 H2S. Within 5 minutes, an invisible cloud of H2S 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[10].



Oil pit and adjacent tank truck unloading station (courtesy of CSB (10)).

The 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-(10).

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;
- Update emergency response plans

CONCLUSIONS

These three 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 Canadian 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.

REFERENCES

2. L.J. Moore, *Using Process Safety Management to manage Risk in Mineral and Metals Processing Facilities*, The Australasian Institute of Mining and Metallurgy Mining Risk Management Conference, Sydney, NSW, 9-12 September 2003

3. Process Safety Management, U.S. Department of Labor, Occupational Safety and Health Administration, OSHA 3131-2000

4. FM Global Loss Prevention Data Sheet 7-43, *Loss Prevention in Chemical Plants*, 2001, Factory Mutual Insurance Company

5. Tom Boughner, *The Discipline of Process Safety Management and how it's Relevant to the Pulp and Paper Industry*, PSM conference

6. Safety Bulletin, Sodium Hydrosulfide, U.S. Chemical Safety and Hazard

Investigation Board, November 2004

7. Orzog, *Management of Change or Change of Management*, ioMosaic Corporation

8. http://www.cheminst.ca/divisions/psm

9. Kelly H. Ferguson, *Risks and Rewards*, Risk Management-editorial supplement to Pulp & Paper

10. Investigation Report, Hydrogen Sulfide Poisoning, U.S. Chemical Safety and Hazard Investigation Board, January 16-2002.

11. Motiva Enterprises Sulfuric Acid Tank Explosion, Delaware City, DE, U.S. Chemical Safety and Hazard Investigation Board, July 17, 2001.

12. CCPS G-10, 1992, Guidelines for Technical Management of Chemical Process Safety New York, Centre for Chemical Process Safety of the American Institute of Chemical Engineers.

Appendix 1

There are many hazardous processes in the mineral and metallurgical refining industries that might benefit from a PSM oversight program[2]. Examples are:

• Air separation plants (oxygen production),

• Hydrogen reforming or electrolysis facilities,

• Ammonia refrigeration systems;

• Fuel gas combustion trains;

• Bauxite-to-alumina production plants;

• Solvent extraction – electro winning (SX-EW) plants;

• Lixiviation processes that liberate hydrogen gas by acid-metal reaction;

• Leaching using high pressure-high temperature autoclave technology;

• Carbon-in-pulp and carbon-in-leach gold recovery processes;

• Flotation reagent preparation and handling in concentrator mills;

• Heat transfer fluid systems;

• Smelting, converting, sintering and roasting furnaces and processes;

• Cooling water systems for molten metal processes;

• Sulfur burning and waste emission metallurgical acid plants; and

• Air cleaning plants;

Appendix 2

Throughout the 1960s, 1970s, and 1980s, the paper industry sustained several recovery boiler explosions. While some caused minimal impact, others caused major damage, including loss of life and lengthy mill downtime. So, in the late 1960s, as frequency of explosions increased, the industry and other concerned groups, such as insurance companies, formed the Black Liquor Recovery Boiler Advisory Committee (BLRBAC). The objective of the group, according to its bylaws, is "to promote improved safety of chemical recovery boilers and their auxiliaries through the interchange of **technical knowledge**, experience, and **data on past and any future recovery boiler incidents**." BLRBAC has helped implement formal training, engineered **process changes**, and recommended best practices.

Note the highlighted key words which are part of PSM elements (Technical knowledge, incidents investigation, management of change).

One of the hazards of a BLRB is a smelt-water explosion, which occurs when water comes into contact with hot smelt at the bottom of the boiler. This can be caused by the black liquor containing too much water or by tube leaks in the steam boiler or by other water sources. There is also the hazard of flue gas explosions as a result of burner failure when unburnt fuel gases and air form an explosive mixture. Burner failures are usually caused by salt deposits from the boiler wall dropping onto a burner or a black liquor jet hitting a burner.