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A Simplified PSM Guidance for Smaller Facilities using a Risk Based Approach

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Abstract

"Safety matters at all levels", even for small companies that may not be OSHA's PSM level facilities, as long as they use highly hazardous chemicals which may be toxic, reactive, flammable, or explosive. Incidents aren't restricted to "large" companies and the fallout from an incident - having to deal with loss of life and property, OSHA/CSB investigations and possible fines and legal ramifications, can actually have a more significant impact on a smaller company. That's why a robust PSM program (Process Safety Management) is important. It will drive the development of a safety culture among plant personnel to have safer operating facilities free of incidents. Smaller facilities face major challenges in providing financing and resourcing to implement a standard PSM program. This paper presents a risk based approach towards a simplified PSM program that is not a drain on company resources and is feasible to implement in practice. A combination of CCPS Risk-Based Process Safety approach with an organization's own risk tolerance for various factors and data from OSHA NEP citations (National Emphasis Program) is used as a basis to suggest a simplified PSM guidance by prioritizing specific elements.

Introduction

Unexpected releases of toxic, reactive, or flammable liquids and gases in processes involving highly hazardous chemicals have been reported for many years, in various industries using chemicals. Regardless of the industry there is a potential for an accidental release any time they are not properly controlled, creating the possibility of disaster. To help ensure safe and healthful workplaces, OSHA has issued the Process Safety Management of Highly Hazardous Chemicals standard (29 CFR 1910.119), which contains requirements for the management of hazards associated with processes using highly hazardous chemicals. Process Safety Management (PSM) is addressed in specific standards for the general and construction industries. OSHA's standard emphasizes the management of hazards associated with highly hazardous chemicals and establishes a comprehensive management program that integrates technologies, procedures, and management practices. Process Safety Management is the application of management principles and systems to the identification, understanding and control of process hazards to protect employees, facility assets and the environment.

The following are the 14 elements of the PSM standard:

1. Process Safety Information
2. Process Hazard Analysis
3. Operating Procedures
4. Training
5. Contractors
6. Mechanical Integrity
7. Hot Work
8. Management of Change
9. Incident Investigation
10. Compliance Audits
11. Trade Secrets
12. Employee Participation
13. Pre-startup Safety Review
14. Emergency Planning and Response

The two major industry accidents brought to light the need for a PSM program and the push for the enforcement of the standard. Below is a brief overview of these significant accidents:

1. Bhopal, India (December 1984)

On the night of December 23, 1984, a dangerous chemical reaction occurred in the Union Carbide pesticide plant at Bhopal, India, when a large amount of water got into the MIC storage tank # 610. The leak was first detected by workers about 11:30 p.m. when their eyes began to tear and burn. They informed their supervisor who failed to take action until it was too late. In that time, a large amount, about 40 tons of Methyl Isocyanate (MIC), poured out of the tank for nearly two hours and escaped into the air, spreading within eight kilometers downwind, over the city of nearly 900,000. Thousands of people were killed (estimates ranging as high as 4,000) in their sleep or as they fled in terror, and hundreds of thousands remain injured or affected (estimates range as high as 400,000) to this day. At least 200,000 people fled Bhopal during the week after the accident. Estimates of the damage vary widely between $350 million to as high as $3 billion. The Bhopal disaster was the result of a combination of legal, technological, organizational, and human errors. The immediate cause of the chemical reaction was the seepage of water (500 liters) into the MIC storage tank. The results of this reaction were exacerbated by the failure of containment and safety measures and by a complete absence of community information and emergency procedures. The long term effects were made worse by the absence of systems to care for and compensate the victims. Furthermore, safety standards and maintenance procedures at the plant had reportedly been deteriorating and ignored for months.

2. Texas City, Texas (March 2005)

At approximately 1:20 p.m. on March 23, 2005, a series of explosions occurred at the BP Texas City refinery during the restarting of a hydrocarbon isomerization unit. Fifteen workers were killed and 180 others were injured. Many of the victims were in or around work trailers located near an atmospheric vent stack. The explosions occurred when a distillation tower flooded with hydrocarbons and was over pressurized, causing a geyser-like release from the vent stack.

National Emphasis Programs (NEP)

After the Texas City incident OSHA introduced the National Emphasis Programs (NEP) to provide uniform procedures for any unprogrammed inspection within these industries, and for any regional or State Plan emphasis program within these industries that may be voluntarily implemented. This National Emphasis Program (NEP) was developed to focus OSHA resources on the workplace health issue of occupational exposure to hazardous chemicals. This program combines enforcement and outreach efforts to raise awareness of employers, workers, and safety and health professionals of the serious health effects associated with occupational exposure to hazardous chemicals. It provides for planned inspections in high hazard industries, focusing efforts on specific hazards. There are two types of these programs:

- Refinery NEP focuses on implementation of PSM in Refineries
- Chemical NEP focuses on implementation of PSM in all other PSM covered facilities

Various citations issued by OSHA as part of the NEP implementation are shown below:

Comparison of Refinery and Chemical NEP's (as per OSHA 2012 report)

Type of PSM Inspection Program	**Citation Per Inspection**	**Penalty Per Inspection**
Refinery NEP	**11.2**	**$ 76,800**
Chemical NEP	**8.4**	**$ 31,600**

Top 1910 Standards violated (as per OSHA 2012 report)

Standard	**Description**	**Number**	**%**
1910.119	**Process Safety Management**	**891**	**59.9 %**
1910.147	**Lockout / Tagout**	**55**	**3.7 %**
1910.120	**Hazardous Waste & Emergency Response**	**47**	**3.2 %**
1910.134	**Respiratory Protection**	**36**	**2.4 %**

Top Refinery NEP Cited PSM Elements (as per OSHA 2012 report)

Element	Description	Number	%
j	Mechanical Integrity	198	19.5%
d	Process Safety Information	177	17.4 %
f	Operating Procedures	174	17.1 %
e	Process Hazard Analysis	168	16.5 %
i	Management of Change	92	9 %

Top Chemical NEP Citations by PSM Element (as per OSHA 2012 report)

Element	Description	Number	%
j	Mechanical Integrity	207	23.2%
d	Process Safety Information	186	20.9 %
e	Process Hazard Analysis	141	15.9 %
f	Operating Procedures	125	14 %
i	Management of Change	49	5.5 %

CCPS Risk-Based Process Safety (RBPS)

Process Safety Management is credited for reductions in major accident risk in the chemical industry. However, in an environment of increasingly tightening budgets, organizations face continual challenges to allocate sufficiently experienced resources to implement and maintain an effective PSM program. Furthermore, PSM is sometimes implemented as a one-time program rather than a continuous process. As a consequence the program tends to not be well integrated into an organization’s overall management system. This may result in the stagnation a PSM program and adversely affect the overall safety culture of a company

In order to help organizations run a PSM program effectively, the Center for Chemical Process Safety (CCPS) initiated the Risk-Based Process Safety (RBPS) framework. These guidelines provide methods to not only design a process safety management program but also to effectively operate and improve upon an existing PSM program. The RBPS approach is based on the recognition that not all hazards and risks are equal; as such, more focus is placed upon greater hazards and higher risks. Using a risk-based approach enables a company with limited resources to optimally assign resources to address higher risk activities, and avoid unwarranted resource concentration on lower risk tasks.

In the CCPS RBPS approach, twenty risk-based process safety elements are addressed within four main accident prevention pillars: Commitment to Process Safety, Understand Hazards and Evaluate Risks, Manage Risk, Learn from Experience. The process safety elements in each pillar are shown below:

1. Safety Commitment
    - Process Safety
    - Process Safety Culture
    - Compliance with Standards
    - Process Safety Competency
    - Workforce Involvement
    - Stakeholder Outreach

2. Understand Hazards and Risk
    - Process Knowledge Management
    - Hazard Identification and Risk Analysis

3. Manage Risk
    - Operating Procedures
    - Safe Work Practices
    - Asset Integrity and Reliability
    - Contractor Management
    - Training and Performance Assurance
    - Management of Change
    - Operational Readiness
    - Conduct of Operations
    - Emergency Management

4. Learn from Experience
    - Incident Investigation
    - Measurement and Metrics
    - Auditing
    - Management Review and Continuous Improvement

Combination of RBPS with an organization's own risk analysis

The CCPS Risk-Based Process Safety approach is a good guide to either developing a PSM program or improving an existing program. However, each organization faces its own challenges in implementing an effective and a successful PSM program due to factors such as budget or resource constraints, hazards and risks unique to that organization, the organization's risk tolerance and a general process safety culture.

Often smaller companies are more resource constrained. So the successful implementation and continued support of a PSM program with daunting magnitude of the tasks involved can be an issue. Some elements of the PSM program may be already in place in the organization, and other areas may need a lot of work towards having an effective program. OSHA's PSM standard contains requirements for each of the 14 PSM elements. Furthermore, the non-mandatory Appendix C of the 1910.119 standard provides compliance guidelines and recommendations for PSM. We propose in this paper a combination of the CCPS Risk-Based Process Safety approach with an organization's own analysis of risk by evaluating the existing state of each of the PSM elements as compared to the requirements of the standard and the compliance guidelines. First, the organization may attempt to tackle the overall problem of implementing an effective PSM program by dividing it into phases. We propose that the 14 PSM elements be grouped into four implementation phases, using the CCPS RBPS accident pillars as a guide. The proposed division of the PSM elements into phases is shown below:

Phase 1 – Safety Commitment

- Employee Participation
- Emergency Planning and Response
-

Phase 2 – Understand Hazards and Risk

- Process Safety Information
- Process Hazard Analysis

Phase 3 – Manage Risk

- Operating procedures
- Training
- Contractor Safety
- Pre-Startup Safety Review
- Mechanical Integrity
- Hot Work Permit
- Management of Change
- Trade Secrets

Phase 4 – Learn from Experience

- Incident Investigation
- Compliance Audits

For each phase, the existing state of each PSM element could be evaluated compared to the requirements of the PSM standard and OSHA compliance guidelines. Once the existing state is evaluated, risk analysis could be performed to prioritize one element over the other, for implementation within each phase. The organization's own risk tolerance could be assessed by considering factors such as the time, resources and other costs required to bring the program up to the desired level. A risk score, on a scale of 1-5 for example, could be assigned to each of the factors considered, with a higher score assigned for a higher risk. An overall score could be developed for each PSM element after consideration of the current status and also all other risk factors for the organization. The overall score can then be used in prioritization in order to start the implementation plan of one element over the other, and also to plan and allocate resources and budgets. This process would also help in understanding how long the implementation of some of elements would take, the costs that could be involved etc., so that effective implementation plans could be developed. A sample matrix for the methodology is shown below:

	Phase 1		Phase 2		Phase 3								Phase 4	
PSM Elements ---------------- Factors	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Current Status														
Time taken														
Total Cost														
Resources														
Safety Risk														
Overall Rank														

The risk analysis procedure and the thought process of the matrix is illustrated by taking the example of two PSM elements, Mechanical Integrity and Process Hazard Analysis.

Mechanical Integrity

This element pertains to process equipment like Pressure Vessels, Piping Systems, Relief and Effluent Systems etc. The PSM standard contains the following requirements for the Mechanical Integrity element:

- Provide written procedures to maintain integrity of equipment
- Train employees involved in maintaining integrity of equipment
- Perform periodic inspection, testing and maintain records
- Correct deficiencies in equipment
- Assure that equipment is suitable and properly installed
- Assure that maintenance materials, spare parts and equipment are suitable and correct for use in the process.

Using the above requirements, the existing state of Mechanical Integrity could be evaluated as a first step. The farther the existing program is from the requirements, the higher a risk rank that could be assigned. Let us say that there are some written procedures in place, and the employees are trained to a certain extent. However, there are no plans for periodic inspections. This factor, then, may be assigned a higher risk rating of 3, out of 5.

Now that the existing status has been evaluated and a risk factor assigned, other factors in the matrix could be looked at. As previously mentioned, this process could also be used to simultaneously develop a good understanding of the effort and the timing needed to ultimately achieve an effective PSM program for the element. Preliminary estimates could be obtained on the time needed to bring the program to a certain level, and also the costs involved, such as, if the implementation work can be performed in-house or an external contractor needed, and also requirements like if any RBI (Risk Based Inspection) type software need be purchased. Let us say that the required inspections and addressing of deficiencies takes 3 years, also that an external contractor would be used, thus increasing the cost but without a large demand from internal resources. Based on these, risk factors of 3 for timing, 4 for cost and 1 for resources could be assigned. A general safety risk factor of 2 could be assigned for all the elements, with a higher risk for any unique processes, or for highly aged infrastructures. With all this done, the overall risk rating for the Mechanical Integrity element comes to 13. This can then be compared with overall risk factors for other elements, in deciding which elements to spend time, resources and budget on.

Process Hazard Analysis (PHA)

This element pertains to identifying, evaluating and controlling hazards of a process. PSM standard requirements for Process Hazard Analysis (PHA) are:

- Develop a priority order for conducting PHAs and do the most important ones first
- Set a timetable for requirements
- Use one of listed methods (What-if, Checklist, Hazard and Operability Study HAZOP, Failure Mode and Effects Analysis FMEA, Fault Tree Analysis) or equivalent methodology
- Outline what must be covered in a PHA
- Establish a team to do the PHA
- Set up a tracking system to assure that the team’s findings and recommendations are addressed and resolved in a timely manner
- Update the PHAs every five years and keep the records throughout the life of the process

Following the similar methodology of assigning risk scores for various factors, as shown above for Mechanical Integrity, let us say the overall score for the PHA element is 6. This would then mean that the PHA element is in a much better condition compared to Mechanical Integrity, and the process owners can allocate more resources and budget towards Mechanical Integrity. There could be a scenario where the PHA score could be 12, which means that the risk score is similar to that of Mechanical Integrity. In the process of arriving at the score, the risk factor matrix would have considered the risks involved, so that budget holders could make informed decisions in allocating resources and costs, based on factors like immediate availability of expertise, any past history of incidents/failures etc. One of the facilitators for prioritizing could also be the NEP violations and citations issued by OSHA. The higher a PSM element cited by OSHA across the industry, the more that particular PSM element could be prioritized.

Maintaining an existing PSM program using OSHA audit guidelines

Developing a PSM program is only one of the first steps in the safety journey. An effective safety culture requires properly maintaining an existing PSM program. OSHA directive CPL 02-02-045 provides compliance guidelines and enforcement procedures for Process Safety Management. Appendix A of the directive contains audit guidelines intended to assist a CSHO in investigating an employer’s compliance. While detailed and complex programs could be developed for maintaining a PSM program, a smaller organization with limited resources could use these OSHA compliance and audit guidelines to assess and maintain their PSM programs, without constraining resources.

Conclusion

The proposed approach of combining the CCPS Risk-Based Process Safety together with an organization's own analysis of various risk factors helps smaller companies better allocate resources and budgets towards the development and implementation of an effective PSM program. The elements shown in the proposed matrix are examples of some kinds of risks companies could analyze in making informed decisions; however, the risk elements may not be limited to those shown. Companies could formulate the matrix with elements unique to their processes or hazards, and yet use the proposed approach to consistently evaluate and develop all the PSM elements in a structured way, making informed decisions along the way. A PSM program developed in this way could then be maintained using OSHA's own compliance and audit guidelines, thus paving way for an effective PSM program and a safer workplace for employees.

References:

1. Chemical Safety and security training by Nancy B. Jackson
2. Occupational Safety and Health Administration (OSHA), 29 CFR Part 1910.119, Process Safety Management of Highly Hazardous Chemicals.
3. Occupational Safety and Health Administration (OSHA), Instruction CPL 02-02045, Process Safety Management of Highly Hazardous Chemicals - Compliance Guidelines and Enforcement Procedures.
4. American University, The School of International Service, Trade & Environment Database (TED) case study #233
5. Center for Chemical Process Safety, *Guidelines for Risk Based Process Safety*, Hoboken, NJ: John Wiley and Sons.
6. Steve Arendt, William Bradshaw and Jack McCavit *Overview of risk-based process safety — The next generation PSM*, Inside Industry