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1. Providing a stands of professional competence in the practicing safety and management field
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3. Encourage practicing safety management professionals to participate in a continuing program of personal and professional development

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INTRODUCTION

Scope

This training module reviews the basic element of Process Safety Management in sufficient detail to allow a safety management professional to develop and implement a process safety management program.

Process safety encompasses technical safety, operational safety and personnel safety. The processes in the plant shall be studied to understand the hazards involved in operation. The goal of process safety is to develop a systematic and comprehensive approach to safety that involves the proactive identification, evaluation, and mitigation or prevention of chemical releases that might occur as a result of issues in the process, procedures, or equipment.

Process safety management (PSM) is widely credited for reductions in major accident risk to prevent unwanted releases of hazardous chemicals and improved process industry performance. The process safety management standard targets highly hazardous chemicals that have the potential to cause a catastrophic incident. The PSM Rule describes a comprehensive management system containing 14 elements for effective control of process hazards.

An effective process safety management program requires a systematic approach to evaluating the whole process. Using this approach, the process design, process technology, operational and maintenance activities and procedures, non-routine activities and procedures, emergency preparedness plans and procedures, training programs, and other elements which impact the process are all considered in the evaluation.

The final PSM standard mainly applies to manufacturing industries - particularly, those pertaining to chemicals, transportation equipment, and fabricated metal products. Other affected sectors include natural gas liquids; farm product warehousing; electric, gas, and sanitary services; and wholesale trade.

General Design Consideration

For many years, companies focused their accident prevention efforts on improving the technology and human factors. In the mid-1980s, following a series of serious chemical accidents around the world, companies, industries, and governments began to identify management systems (or the lack thereof) as the underlying cause for these accidents. Companies were already adopting management systems approaches in regard to product quality, as evidenced by various Total Quality Management initiatives, with widely reported success.

Companies developed policies, industry groups published standards, and governments issued regulations, all aimed at accelerating the adoption of a management systems approach to process safety. Thus, the initial, somewhat fragmented, hazard analysis and equipment integrity efforts were gradually incorporated into integrated management systems. The integrated approach remains a very useful way to focus and adopt accident prevention activities. More recently, inclusion of manufacturing excellence concepts has focused attention on seamless integration of efforts to sustain high levels of performance in manufacturing activities. Done well, manufacturing excellence deeply embeds process safety management practices into a single, well-balanced process for managing manufacturing operations.

Causes of chemical process incidents can be grouped in one or more of the following categories:

- Technology failures
- Human failures
- Management system failures
- External circumstances and natural phenomena

Process safety encompasses technical safety, operational safety and personnel safety. The processes in the plant shall be studied to understand the hazards involved in operation. The plants shall be classified using commonly available risk matrices that consider the potential severity and likelihood of occurrence. Subsequently, control measures shall be implemented to eliminate or reduce the risk to an acceptable level.

The goal of process safety is to develop a systematic and comprehensive approach to safety that involves the proactive identification, evaluation, and mitigation or prevention of chemical releases that might occur as a result of failures in the process, procedures, or equipment (Kletz, 1998). Positive safety management is an evolving process, where improvements are planned, implemented, continuously monitored and acted upon to maintain a safe working environment.

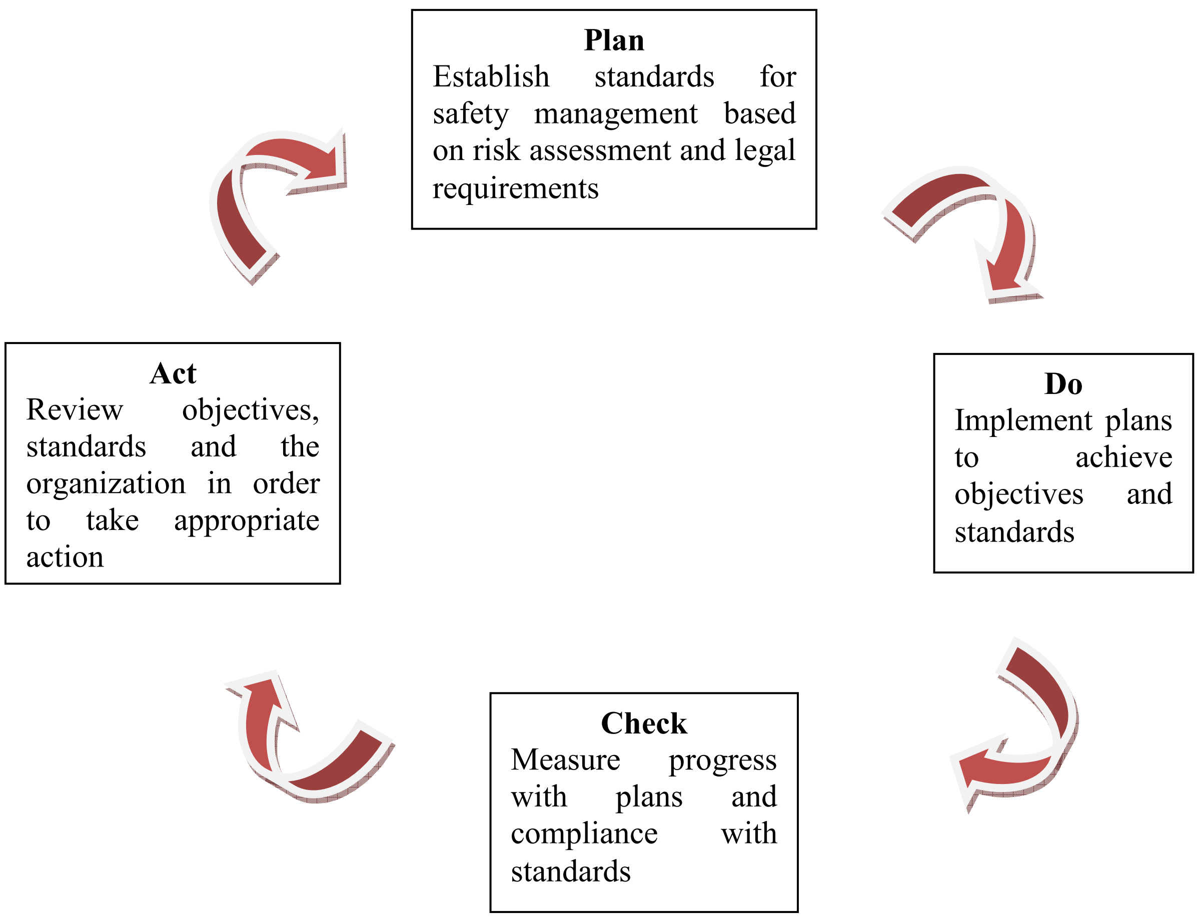

Figure 1: Process in positive safety management

In 1990, two major developments in U.S. process safety occurred: the publication of a proposed standard from the Occupational Safety and Health Administration (OSHA), titled "Process Safety Management of Highly Hazardous Chemicals," and the passage by the U.S. Congress of the Clean Air Act Amendments (CAAA) of 1990.

The CAAA provided regulatory oversight of process safety in the chemical industry to OSHA and the U.S. Environmental Protection Agency (EPA). In particular, CAAA identified 14 minimum elements that the OSHA Process Safety Management Standard must require of employers. Below are the CAAA Process Safety Management Standard Requirements

1. Develop and maintain written safety information identifying workplace chemical and process hazards, equipment used in the processes, and technology used in the processes;
2. Perform a workplace hazard assessment, including, as appropriate, identification of potential sources of accidental releases, identification of any previous release within the facility that had a potential for catastrophic consequences in the workplace, estimation of workplace effects of a range of releases, and estimation of the health and safety effects of such a range on employees;
3. Consult with employees and their representatives on the development and conduct of hazard assessments and the development of chemical accident prevention plans and provide access to these and other records required under the standard;
4. Establish a system to respond to the workplace hazard assessment findings, which shall address prevention, mitigation, and emergency responses;
5. Review periodically the workplace hazard assessment and response system;
6. Develop and implement written operating procedures for the chemical processes, including procedures for each operating phase, operating limitations, and safety and health considerations

A plant may have some process areas that are covered by the PSM Rule and others that are not. PSM provisions are invoked for covered processes only. Figure 2 provides a general logic diagram for determining the applicability of the PSM Rule

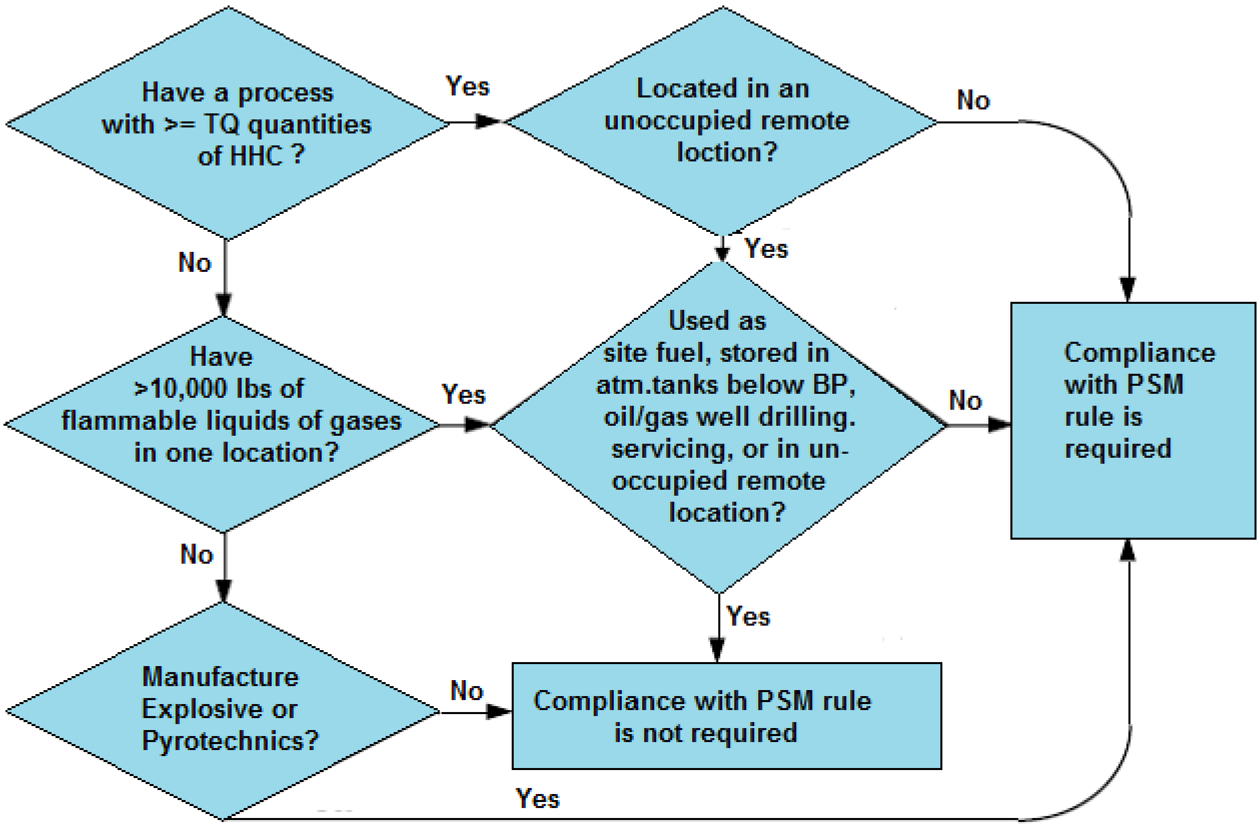

Figure 2: Applicability of the PSM rule (DOE, 1996)

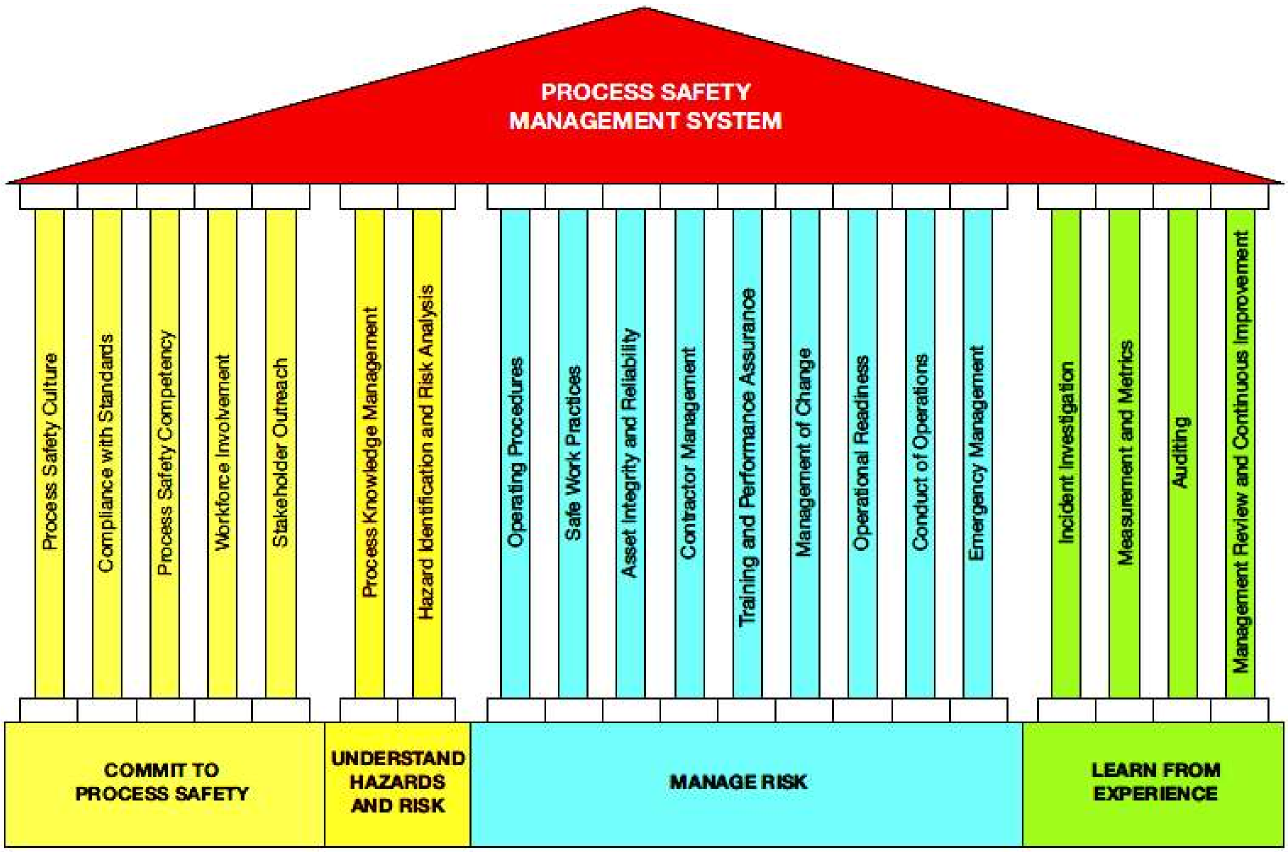

Figure 3: Pillars (Foundational Blocks) and associated Elements (CCPS)

Commitment to process safety

Authentic commitment to process safety is the cornerstone of process safety excellence. Management commitment has no substitute. Organizations generally do not improve without strong leadership and solid commitment. The entire organization must make the same commitment. A workforce that is convinced that the organization fully supports safety as a core value will tend to do the right things, in the right ways, at the right times, even when no one is looking. This behavior should be consistently nurtured, and celebrated, throughout the organization. Once it is embedded in the company culture, this commitment to process safety can help sustain the focus on excellence in the more technical aspects of process safety.

1. Process safety culture

Process safety culture has been defined as, "the combination of group values and behaviors that determine the manner in which process safety is managed". More succinct definitions include, "How we do things around here," "What we expect here," and "How we behave when no one is watching." The following four essential features will help achieve and maintain a sound process safety culture.

- Establish process safety as a core value.
- Provide strong leadership.
- Establish and enforce high standards of performances.
- Document the process safety culture emphasis and approach.

2. Compliance with standards

Standards is a system to identify, develop, acquire, evaluate, disseminate, and provide access to applicable standards, codes, regulations, and laws that affect process safety. Knowledge of and conformance to standards helps a company operate and maintain a safe facility, consistently implement process safety practices, and minimize legal liability. The following essential features help ensure that process safety management activities are executed dependably across a facility involving a variety or people and situations:

- Ensure consistent implementation of the standards system.
- Identify when standards compliance is needed.
- Involve competent personnel.
- Ensure that standards compliance practices remain effective

3. Process safety competence

Developing and maintaining process safety competency encompasses three interrelated actions: (1) continuously improving knowledge and competency, (2) ensuring that appropriate information is available to people who need it, and (3) consistently applying what has been learned. Normally, one or more of several conditions are necessary for an organization to invest in process safety competency:

- a business case describes the expected benefits and the level of resources that must be invested to achieve those benefits,
- the organization inherently values technology and places particular value on enhancing its process safety competency,
- the organization believes that decisions should be based on knowledge that is supported by facts, and any significant improvement in the body of knowledge will lead to better decisions, thereby reducing risk and improving performance.

4. Workforce involvement

Workforce involvement provides a system for enabling the active participation of company and contractor workers in the design, development, implementation, and continuous improvement of management system. When a company identifies or defines an activity to be undertaken, that company likely wants the activity to be performed correctly and consistently over the life of the facility. For the workforce involvement practice to be executed dependably across a company or facility involving a variety of people and situations, the following essential features should be considered:

- Ensure consistent implementation.
- Involve competent personnel.

5. Stakeholders outreach

Stakeholder outreach is a process for (1) seeking out individuals or organizations that can be or believe they can be affected by company operations and engaging them in a dialogue about process safety, (2) establishing a relationship with community organizations, other companies and professional groups, and local, state, and federal authorities, and (3) providing accurate information about the company and facility's products, processes, plans, hazards, and risks.

This process ensures that management makes relevant process safety information available to a variety of organizations. This element also encourages the sharing of relevant information and lessons learned with similar facilities within the company and with other companies in the industry group. Finally, the outreach element promotes involvement of the facility in the local community and facilitates communication of information and facility activities that could affect the community. In order for outreach activities to be executed dependably across a company involving a variety or people and situations, the following essential features should be considered:

- Ensure consistent implementation.
- Involve competent personnel.
- Keep practices effective.

Understand hazards and risk

Organizations that understand hazards and risk are better able to allocate limited resources in the most effective manner. Industry experience has demonstrated that businesses using hazard and risk information to plan, develop, and deploy stable, lower-risk operations are much more likely to enjoy long term success.

1. Process knowledge management

The knowledge element primarily focuses on information that can easily be recorded in documents, such as written technical documents and specifications; engineering drawings and calculations; specifications for design, fabrication, and installation of process equipment, and; other written documents such as material safety data sheets (MSDSs). The term process knowledge will be used to refer to this collection of information.

The knowledge element involves work activities associated with compiling, cataloging, and making available a specific set of data that is normally recorded in paper or electronic format. Accurate and complete process knowledge is required to thoroughly identify process hazards and analyze risk. Establishing a dependable practice to collect, maintain, and protect a company's process knowledge helps protect an important asset which simply makes good business sense. The management system should include the essential features listed below:

- Ensure consistent implementation.
- Define the scope.
- Thoroughly document chemical reactivity and incompatibility hazards.
- Assign responsibilities to competent personnel.

2. Hazard Identification and Risk Analysis (HIRA)

Hazard Identification and Risk Analysis (HIRA) is a collective term that encompasses all activities involved in identifying hazards and evaluating risk at facilities, throughout their life cycle, to make certain that risks to employees, the public, and/or the environment are consistently controlled within the organization's risk tolerance. For the risk management system to be executed dependably across a facility involving a variety of people and situations, the following essential features should be considered:

- Document the intended risk management system.
- Integrate HIRA activities into the life cycle of projects or processes.
- Clearly define the analytical scope of HIRAs and assure adequate coverage.
- Determine the physical scope of the risk system.
- Involve competent personnel.
- Make consistent risk judgments.
- Verify that HIRA practices remain effective.

Managing risk

Managing risk focuses on three issues:

- Prudently operating and maintaining processes that pose the risk.
- Managing changes to those processes to ensure that the risk remains tolerable.
- Preparing for, responding to, and managing incidents that do occur.

Managing risk helps a company or a facility deploy management systems that help sustain long-term, incident-free, and profitable operations.

1. Operating procedures

Operating procedures are written instructions (including procedures that are stored electronically and printed on demand) that (1) list the steps for a given task and (2) describe the manner in which the steps are to be performed. Good procedures also describe the process, hazards, tools, protective equipment, and controls in sufficient detail that operators understand the hazards, can verify that controls are in place, and can confirm that the process responds in an expected manner.

Procedures critical to the safe operation or maintenance of equipment should reference hazard review information (as appropriate) and include consequence of deviation warnings. Procedures should also provide instructions for troubleshooting when the system does not respond as expected. Procedures should specify when an emergency shutdown should be executed and should also address special situations, such as temporary operation with a specific equipment item out of service. Operating procedures are normally used to control activities such as transitions between products, periodic cleaning of process equipment, preparing equipment for certain maintenance activities, and other activities routinely performed by operators.

2. Safe work practices

Procedures are generally divided into three categories. (1) Operating procedures govern activities that generally involve producing a product; (2) Maintenance procedures, generally involve testing, inspecting, calibrating, maintaining, or repairing equipment; (3) Safe work procedures, which are often supplemented with permits (i.e., a checklist that includes an authorization step), fill the gap between the other two sets of procedures. Safe work practices help control hazards and manage risk associated with non-routine work.

3. Asset integrity and reliability

The asset integrity element is the systematic implementation of activities, such as inspections and tests necessary to ensure that important equipment will be suitable for its intended application throughout its life. Specifically, work activities related to this element focus on: preventing a catastrophic release of a hazardous material or a sudden release of energy and ensuring high availability (or dependability) of critical safety or utility systems that prevent or mitigate the effects of these types of events.

4. Contractor management

Contractor management is a system of controls to ensure that contracted services support both safe facility operations and the company's process safety and personal safety performance goals. This element addresses the selection, acquisition, use, and monitoring of such contracted services. In order for the contractor management practice to be executed dependably across a company or facility involving a variety of people and situations, the following essential features should be considered:

- Ensure consistent implementation.
- Identify when contractor management is needed.
- Involve competent personnel.
- Ensure that practices remain effective.

5. Training and performance assurance

Training is practical instruction in job and task requirements and methods. It may be provided in a classroom or workplace, and its objective is to enable workers to meet some minimum initial performance standards, to maintain their proficiency, or to qualify them for promotion to a more demanding position. Performance assurance is the means by which workers demonstrate that they have understood the training and can apply it in practical situations. Performance assurance is an ongoing process to ensure that workers meet performance standards and to identify where additional training is required.

6. Management of change

The MOC element helps ensure that changes to a process do not inadvertently introduce new hazards or unknowingly increase risk of existing hazards. The MOC element includes a review and authorization process for evaluating proposed adjustments to facility design, operations, organization, or activities prior to implementation to make certain that no unforeseen new hazards are introduced and that the risk of existing hazards to employees, the public, and/or the environment is not unknowingly increased. It also includes steps to help ensure that potentially affected personnel are notified of the change and that pertinent documents, such as procedures, process safety knowledge, and other key information, are kept up–to-date.

7. Operational readiness

The readiness element ensures that shut down processes are verified to be in a safe condition for re-start. This element addresses startups from all types of shut down conditions and considers the length of time the process was in the shutdown condition. Some processes may be shut down only briefly, while others may have undergone a lengthy maintenance/modification outage, or they may even have been mothballed for an extended period.

Other processes may have been shut down for administrative reasons, such as a lack of product demand; for reasons unrelated to production at all; or as a precautionary measure, for example, because of an approaching hurricane. In addition to the shutdown duration, this element considers the type of work that may have been conducted on the process (e.g., possibly involving line-breaking) during the shutdown period to help focus the readiness review prior to startup. Records should be maintained concerning readiness activities so that performance and efficiency can be periodically evaluated.

- Ensure consistent implementation.
- Determine types of and triggers for the readiness practice.
- Determine the scope of readiness reviews.
- Involve competent personnel.
- Ensure that readiness practices remain effective.

8. Conduct of operations

Conduct of operations (operations) is the execution of operational and management tasks in a deliberate and structured manner. It is also sometimes called “operational discipline” or “formality of operations”, and it is closely tied to an organization’s culture. Conduct of operations institutionalizes the pursuit of excellence in the performance of every task and minimizes variations in performance. Workers at every level are expected to perform their duties with alertness, due thought, full knowledge, sound judgment, and a proper sense of pride and accountability.

9. Emergency management

Emergency management includes: (1) planning for possible emergencies, (2) providing resources to execute the plan, (3) practicing and continuously improving the plan, (4) training or informing employees, contractors, neighbors, and local authorities on what to do, how they will be notified, and how to report an emergency, and (5) effectively communicating with stakeholders in the event an incident does occur.

Learning from experience

Learning from experience involves monitoring, and acting on, internal and external sources of information. Despite a company’s best efforts, operations do not always proceed as planned, so organizations must be ready to turn their mistakes – and those of others – into opportunities to improve process safety efforts. The most cost effective ways to learn from experience are to:

- Apply best practices to make the most effective use of available resources.
- Correct deficiencies exposed by internal incidents and near misses.
- Apply lessons learned from other organizations.

In addition to recognizing these opportunities to better manage risk, companies must also develop a culture and infrastructure that helps them remember the lessons and apply them in the future. Metrics can be used to provide timely feedback on the workings of RBPS management systems, and management review, a periodic honest self-evaluation, helps sustain existing performance and drive improvement in areas deemed important by management.

1. Incident investigation

Incident investigation is a process for reporting, tracking, and investigating incidents that includes: (1) a formal process for investigating incidents, including staffing, performing, documenting, and tracking investigations of process safety incidents and (2) the trending of incident and incident investigation data to identify recurring incidents. This process also manages the resolution and documentation of recommendations generated by the investigations. Investigations are a responsibility that is typically shared across many personnel in the company. In order to achieve consistency, investigators need a defined process and clear expectations. The more detailed the guidance provided to the teams through the program documentation and through an element expert, the greater the level of consistency that will be achieved.

2. Measurements and metrics

A combination of leading and lagging indicators is often the best way to provide a complete picture of process safety effectiveness. Outcome oriented lagging indicators, such as incident rates, are generally not sensitive enough to be useful for continuous improvement of process safety management systems because incidents occur too infrequently. Measuring process safety management performance requires the use of leading indicators, such as rate of improperly performed line breaking activities. Defining roles and responsibilities, which metrics data should be collected and how often, and the necessary technical expertise of personnel is critical to having an effective metrics system. Records should be maintained concerning metrics activities so that performance and efficiency can be periodically evaluated.

- Establish consistent implementation.
- Determine triggers for metrics collection and reporting.
- Ensure that the scope of the metrics is appropriate.
- Involve competent personnel.
- Keep metrics practices effective.

3. Auditing

The audits element is intended to evaluate whether management systems are performing as intended. The audits element comprises a system for scheduling, staffing, effectively performing, and documenting periodic evaluations as well as providing systems for managing the resolution of findings and corrective actions generated by the audits. The audits element should be documented to an appropriate level of detail in a procedure or a written program addressing the general management system aspects previously.

4. Management review and continuous improvement

Management review is the routine evaluation of whether management systems are performing as intended and producing the desired results as efficiently as possible. It is the ongoing “due diligence” review by management that fills the gap between day-to-day work activities and periodic formal audits.

The final PSM standard mainly applies to manufacturing industries—particularly, those pertaining to chemicals, transportation equipment, and fabricated metal products. Other affected sectors include natural gas liquids; farm product warehousing; electric, gas, and sanitary services; and wholesale trade. It also applies to pyrotechnics and explosives manufacturers covered under other OSHA rules and has special provisions for contractors working in covered facilities.

The process safety management standard targets highly hazardous chemicals that have the potential to cause a catastrophic incident. OSHA’s standard applies mainly to manufacturing industries–particularly those pertaining to chemicals, transportation equipment, and fabricated metal products. Other affected sectors include those involved with:

- natural gas liquids
- farm product warehousing
- food processing
- electric, gas, and sanitary services
- wholesale trade
- pyrotechnics and explosives manufacturers

The PSM standard does not apply to:

- retail facilities
- oil or gas well drilling or servicing operations
- normally unoccupied remote facilities
- hydrocarbon fuels used solely for workplace consumption as a fuel (e.g. propane used for comfort heating, gasoline for vehicle refueling), if such fuels are not a part of a process containing another highly hazardous chemical covered by this standard
- flammable liquid stored in atmospheric tanks or transferred which are kept below their normal boiling point without benefit of chilling or refrigerating and are not connected to a process

The PSM Rule describes a comprehensive management system containing 14 elements for effective control of process hazards. The word system implies the integration of all management elements with a method for assessing the efficiency and effectiveness of implementation. The elements of the PSM Rule discussed in this section are an interrelated set of management systems associated with the process, people, production, and preparedness.

The final PSM standard was promulgated in 1992 by OSHA and is enforced by that office in coordination with EPA. The standard emphasizes the management of hazards through a comprehensive program that integrates management technologies, practices, and procedures and includes 14 mandatory elements that correlate to the CAAA requirements. Under CAAA, EPA has responsibilities relating to the prevention of accidental release, inventories of chemicals, and development of risk management plans (RMP), among other things.

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

Table 1: Overview of PSM Elements (DOE, 1996)

Elements	
Process Safety Information	Maintain complete and accurate information on the process technology, process equipment, and hazardous characteristics and physical properties of all chemicals and intermediates for all covered processes.
Process Hazard Analysis	Identify and assess process hazards for each covered process, and take action to manage risk.
Operating Procedures	Provide clear written instructions for safely conducting activities at each covered process that address operating limits, safety and health considerations, and safety systems and their functions.
Training	Provide initial and refresher training with a means of

	verifying employee understanding for all employees involved in operating a covered process.
Subcontractor Safety	Ensure that subcontractor operations do not compromise the level of safety on or in the vicinity of a process using HHCs.
Mechanical Integrity	Ensure the integrity and safe operation of process equipment through inspection, testing, preventive maintenance, and quality assurance
Hot Work	A permit must be issued for hot work operations conducted on or near a covered process.
Management of Change	Establish and implement written procedures to manage changes (except for replacements in kind) to process chemicals, \ technology, equipment, and procedures, and to facilities that affect a covered process.
Incident Investigation	Using a written procedure, provide a team investigation of any incident which results in, or could reasonably result in, a catastrophic release of a highly hazardous chemical. Each investigation must be documented in a written report and findings and recommendations resolved in a timely manner.
Compliance Audits	Ensure that the PSM program is operating in an integrated and effective manner in compliance with PSM requirements.
Trade Secrets	Ensure all information is available to support the PSM Rule. When necessary, confidentiality or nondisclosure agreements may be used.
Employee Participation	Ensure that workers and their representatives are consulted and have access to information regarding all PSM elements.
Pre-Startup Safety Review	Perform safety reviews for new and modified facilities prior to operation when the modification is significant enough to require a change in the process safety information.

Emergency Planning and Response	Establish and implement an emergency action plan for the entire plant and that also addresses small releases.

DEFINITIONS

Audit (Process Safety Audit) - An inspection of a plant or process unit, drawings, procedures, emergency plan, and/or management systems by an independent team.

Catastrophic release - a major uncontrolled emission, fire, or explosion, involving one or more highly hazardous chemicals, that presents serious danger to employees in the workplace.

Change - Any alteration in process chemicals, technology, procedures, equipment, appurtenances, or facilities.

Event - An occurrence involving process, equipment, or human performance either internal or external to a system that causes system upset. In terms of accidents, an event is either a cause or contributing cause of a near miss or accident, or a response to the accident-initiating event

Facility - The plants, units, buildings, containers, or equipment that contain or include a process.

Fault-Tree Analysis - A logic model that graphically portrays the potential combinations of events, such as equipment failures, control system failures, or human errors that can lead to a major incident, as defined in this subsection.

Failure Modes and Effects Analysis (FMEA) - A systematic, tabular method for evaluating and documenting the causes and effects of known types of component failure

Hazardous Material - A substance (gas, liquid or solid) capable of creating harm to people, property or the environment (e.g. materials which are flammable, toxic, etc.).

Hazard and Operability Study (HAZOP) - A systematic method in which process hazards and potential operating problems are identified using a series of guidewords to investigate process deviations.

Highly Hazardous Chemical (HHC) - A substance possessing toxic, reactive, flammable, explosive, or other dangerous properties exposure to which could potentially result in death or serious physical harm.

Hot Work - Electric or gas welding, cutting, brazing or any similar heat, flame, or spark-producing procedures or operations.

Inherent Safety - An approach to safety that focuses on eliminating or reducing the hazards associated with a set of conditions. A process is inherently safer if it reduces or eliminates the hazards associated with materials or operations used in the process, and this reduction or elimination is permanent and inseparable from the material or operation.

Initiating Cause - An operational error, mechanical failure, or other internal or external event that is the first event in an incident sequence and marks the transition from a normal situation to an abnormal situation.

Major Change - Introduction or alteration of a process, process equipment, substance or process chemistry, or any other alteration that may introduce a hazard which has the potential to result in death or serious physical harm.

Mechanical Integrity - State or quality of process equipment, controls, and appurtenances that takes into account fabrication from the proper materials of construction, design and use for the intended purpose, proper installation, inspection, maintenance and replacement.

Near Miss - An event that did not result in an accidental release of a highly hazardous chemical, but which could have, given another “failure.” Near misses, sometimes called “precursors,”

Process - Any activity involving a highly hazardous material, including use, storage, manufacturing, handling, or on-site movement.

Process Safety Culture - The core values and behaviors resulting from a collective commitment by leaders and individuals that emphasize safety over competing goals in order to ensure protection of people and the environment.

Process Safety Management - The application of management principles to ensure the safety of chemical process facilities.

Process Hazard Analysis (PHA) - The action of identifying undesired events which could lead to the materialization of a hazard and the estimation of the magnitude and likelihood of any harmful effects resulting from this materialization.

Process Flow Diagram - A drawing showing the major equipment and design flows of a process in diagrammatic form. The drawing is intended to show the process design basis in the form of temperatures, pressures, heat balance and mass balance.

Process Hazard - A physical situation with a potential for human injury, damage to property or damage to the environment through the release of energy in the form of fire, explosion, toxicity or corrosively.

Risk - the potential for performance shortfalls, which may be realized in the future, with respect to achieving explicitly established and stated performance requirements in any one or more of the mission execution domains of safety, technical, cost, and schedule

Root Cause - Underlying reasons, such as deficiencies in management systems, which if corrected would prevent or significantly reduce the likelihood of the problem's reoccurrence.

Safeguard - A device, system or action that interrupts the chain of events following an initiating cause, or that mitigates the impacts of an incident.

Safety - defined as freedom from those hazards that can result in failure to meet one or more safety objectives by causing death, injury, or illness in humans, adversely affecting the environment, and/or causing damage to or loss of equipment or property.

Trade secret - means any confidential formula, pattern, process, device, information or compilation of information that is used in an employer's business, and that gives the employer an opportunity to obtain an advantage over competitors who do not know or use it.

NOMENCLATURES

BLEVE	boiling-liquid-expanding-vapor explosion or
BP	Boiling Point
CAAA	Congress of the Clean Air Act Amendments
EPA	Environmental Protection Agency
FMEA	Failure Modes and Effects Analysis
FTA	Fault tree analysis
HAZOP	Hazard and Operability Study
HHC	Highly Hazardous Chemicals
MI	Mechanical Integrity
MOC	Management of Change
MSDS	material safety data sheet
OSHA	Occupational Safety and Health Administration
PHA	Process Hazard Analysis
PSI	Process Safety Information
PSM	Process safety management
RMP	risk management plans
SOP	Standard Operating Procedures

THEORY

Process safety management is the proactive identification, evaluation and mitigation or prevention of chemical releases that could occur as a result of failures in processes, procedures, or equipment. Process safety management is widely credited for reductions in major accident risk to prevent unwanted releases of hazardous chemicals and improved process industry performance. Process safety practices and formal safety management systems have been in place in some companies for many years. The process safety management standard targets highly hazardous chemicals that have the potential to cause a catastrophic incident.

The processes in the plant shall be studied to understand the hazards involved in operation. The plants shall be classified using commonly available risk matrices that consider the potential severity and likelihood of occurrence. Subsequently, control measures shall be implemented to eliminate or reduce the risk to an acceptable level.

An effective process safety management program requires a systematic approach to evaluating the whole process. Using this approach, the process design, process technology, operational and maintenance activities and procedures, non-routine activities and procedures, emergency preparedness plans and procedures, training programs, and other elements which impact the process are all considered in the evaluation. The various lines of defense that have been incorporated into the design and operation of the process to prevent or mitigate the release of hazardous chemicals need to be evaluated and strengthened to assure their effectiveness at each level. Process safety management is the proactive identification, evaluation and mitigation or prevention of chemical releases that could occur as a result of failures in process, procedures or equipment.

Effective PSM helps ensure the proper development of plant systems and procedures to prevent unwanted releases which may ignite and cause toxic impacts, local fires, or explosions in plants and installations. PSM can also improve (OSHA, 2016):

- the operability, productivity, stability, and quality of the outputs of hazardous chemical processes; and
- the design and specification of safeguards against undesirable events

Effective PSM results in tangible benefits such as reduced exposure to lawsuits, OSHA penalties, public liability claims, and hikes in worker's compensation insurance premiums. Other intangible benefits include higher morale, increased trust, and an improved corporate image the community sees the company as a responsible corporate citizen.

Below are discussed each element of PSM (OSHA, 2000).

Process Safety Information (PSI)

The objective of the PSI element is to collect complete and accurate process information sufficient to conduct PHA, to support hazard communication requirements, and to document the design configuration of each process. Employers must complete a compilation of written process safety information identifying workplace chemical and process hazards, equipment used in the processes, and technology used in the processes before conducting any process hazard analysis required by the standard. The compilation of written process safety information, completed under the same schedule required for process hazard analyses, will help the employer and the employees involved in operating the process to identify and understand the hazards posed by those processes involving highly hazardous chemicals.

The information to be compiled about the chemicals, including process intermediates, needs to be comprehensive enough for an accurate assessment of the fire and explosion characteristics, reactivity hazards, the safety and health hazards to workers, and the corrosion and erosion effects on the process equipment and monitoring tools.

Information on the hazards of the highly hazardous chemicals in the process shall consist of at least the following:

- Toxicity, such as LD50/LC50 values, Threshold Limit Values (TLVs), Immediately Dangerous to Life or Health (IDLH) values, and Emergency Response Planning Guideline (ERPG) concentrations
- Permissible exposure limits,
- Physical data, such as boiling point, freezing point, density, vapor pressure, vapor density, solubility, evaporation rate, appearance, and odor
- Reactivity data, such as stability and compatibility with other families of materials including acids, bases, and water.

- Corrosively data for containment vessels, metallic, and plastics
- Thermal and chemical stability data, such as flammability limits, flash point, and auto ignition temperature, and
- hazardous effects of inadvertent mixing of different materials.

Current material safety data sheet (MSDS) information can be used to help meet this but must be supplemented with process chemistry information, including runaway reaction and overpressure hazards, if applicable.

Process technology information will be a part of the process safety information package and should include employer established criteria for maximum inventory levels for process chemicals; limits beyond which would be considered upset conditions; and a qualitative estimate of the consequences or results of deviation that could occur if operating beyond the established process limits. Employers are encouraged to use diagrams that will help users understand the process. Information on the technology of the process must include at least the following:

- A block flow diagram or simplified process flow diagram,
- Process chemistry, such as flow rates, chemical equations, chemistry of intermediates, utility systems, and exothermic/endothermic reactions.
- Maximum intended inventory for all storage tanks, reactors, and other vessels
- Safe upper and lower limits for such items as temperatures, pressures, flows or compositions for all modes of operation in all major piping segments
- An evaluation of the consequences of deviations, including those affecting the safety and health of employees.

The information pertaining to process equipment design must be documented. In other words, what codes and standards were relied on to establish good engineering practice? These codes and standards are published by such organizations

- American National Standards Institute (ANSI) establishes piping/valves/fittings/flanges and equipment design criteria, including selection of materials and standards for engineering drawings

- American Society for Testing and Materials (ASTM) establishes standard testing methods and acceptable test results, and definition of metallic and non-metallic material
- National Fire Protection Association (NFPA) establishes electrical area classifications and requirements, and fire protection design standards
- American Society of Mechanical Engineers (ASME) establishes Boiler and Pressure Vessel Code; welding materials and welder qualifications, NDT requirements, and standards; and ferrous and non-ferrous material specifications
- Institute of Electrical and Electronic Engineers (IEEE)/Instrument Society of America (ISA) establishes design and application specifications for electrical and electronic equipment, and failure rate data
- The Industry Standards recommended practices govern the design of hydrocarbon systems and facilities, including safety systems and process hazards management guidelines for petrochemical facilities.

Information on the equipment in the process must include the following:

- Materials of construction and basis for selection, such as material compatibility or corrosion resistance.
- Electrical area classification, based on flammable materials located near the process.
- Relief system design and design basis.
- Ventilation system design, including airflow, and psychometric and equipment sizing calculations.
- Design codes and standards.
- Material and energy balances. The balances must show that mass flows and heat transfers sum properly.
- Safety systems, such as control interlocks, depressurization, containment and disposal, and toxic/flammable material detection systems.
- Piping and instrumentation diagrams

A block flow diagram is used to show the major process equipment and interconnecting process flow lines and show flow rates, stream composition, temperatures, and pressures when necessary for clarity. The block flow diagram is a simplified diagram. Process flow diagrams are more complex and will show all main flow streams including valves to enhance the understanding of the process, as well as pressures and temperatures on all feed and product lines within all major vessels, in and out of headers and heat exchangers, and points of pressure and temperature control. Also, materials of construction information, pump capacities and pressure heads, compressor horsepower and vessel design pressures and temperatures are shown when necessary for clarity.

In addition, major components of control loops are usually shown along with key utilities on process flow diagrams. Piping and instrument diagrams (P&IDs) may be the more appropriate type of diagrams to show some of the above details and to display the information for the piping designer and engineering staff. The P&IDs are to be used to describe the relationships between equipment and instrumentation as well as other relevant information that will enhance clarity.

The employer must document that equipment complies with recognized and generally accepted good engineering practices.

In other words, what were the codes and standards relied on to establish good engineering practice. These codes and standards are published by such organizations as the American Society of Mechanical Engineers, American National Standards Institute, National Fire Protection Association, American Society for Testing and Materials, National Board of Boiler and Pressure Vessel Inspectors, National Association of Corrosion Engineers, American Society of Exchange Manufacturers Association, and model building code groups.

For existing equipment designed and constructed in accordance with codes, standards, or practices that are no longer in general use, the employer must determine and document that the equipment is designed, maintained, inspected, tested, and operated in a safe manner. Compiling and maintaining this information is important to provide the basis for identifying and understanding the hazards of a process, develop the process hazard analysis, comply with other provisions of PSM such as management of change and incident investigations

The PSI element is a documentation requirement. It specifies the minimum written PSI package needed to support a PSM program. It should be updated as part of the MOC element of the PSM Rule because the safety of processes depends on workers having access to accurate process safety information. PSI used to support the development of facility safety documentation or PHA should be referenced. PSI need not be located in one document or in one place. Electronic storage media may be used so long as a backup version is available at all times. PSI should be part of the facility configuration information and should be maintained for the life of a process through a configuration management system

Process Hazard Analysis (PHA)

A process hazard analysis (PHA), sometimes called a process hazard evaluation, is one of the most important elements of the process safety management program. The process hazard analysis is a thorough, orderly, systematic approach for identifying, evaluating, and controlling the hazards of processes involving highly hazardous chemicals. A PHA provides information that will assist employers and employees in making decisions for improving safety and reducing the consequences of unwanted or unplanned releases of hazardous chemicals.

The PHA focuses on equipment, instrumentation, utilities, human actions (routine and non-routine), and external factors that might affect the process. The employer must perform a workplace hazard assessment, including, as appropriate, identification of potential sources of accidental releases, identification of any previous release within the facility that had a potential for catastrophic consequences in the workplace, estimation of workplace effects of a range of releases, and estimation of the health and safety effects of such a range on employees.

Employers must perform an initial process hazard analysis (hazard evaluation) on all processes covered by this standard. The process hazard analysis methodology selected must be appropriate to the complexity of the process and must identify, evaluate, and control the hazards involved in the process.

PHA must be performed by a team. Teams can vary in size and in operational background, but must have expertise in engineering and process operations. Individuals may be full-time team members or may be part of a team for only a limited time. That is, team members may be rotated according to their expertise in the part of the process being reviewed. The ideal PHA team has an intimate knowledge of the standards, codes, specifications, and regulations applicable to the process. Team members must be compatible, and the team leader must be able to manage the team and the study.

The team conducting the PHA needs to understand the method that is going to be used. The PHA team should include:

- at least one employee who has experience with and knowledge of the process being evaluated
- one member (preferably the team leader) knowledgeable in the specific analysis methods and proper implementation of methods being used in the evaluation

The other full or part-time team members need to provide the team with expertise in areas such as:

- process technology
- process design
- operating procedures and practices
- alarms
- emergency procedures
- instrumentation
- maintenance procedures, both routine and non-routine tasks, including how the tasks are authorized
- procurement of parts and supplies
- safety and health
- any other relevant subjects

To help assure that all hazards are identified and evaluated, PHA must address the following.

- The hazards of a process. These hazards may be identified by performing a PHA.
- Previous incidents that had the potential for catastrophic consequences in the workplace.
- Engineering and administrative controls applicable to the hazards and their interrelationships.

- The consequences of failure of engineering and administrative controls.
- The influence of facility siting.
- Human factors.
- A qualitative range of possible safety and health effects on employees in the workplace caused by failure of controls.

Determining the impacts of human factors requires considering the degree to which process safety depends on human performance; whether workers can reasonably be expected to perform the tasks they are assigned; and whether procedures and training adequately guide and prepare workers to perform tasks correctly. The human factors assessment in a PHA could include listing potential human-error causes of accidents; examining the location of and access to critical safety instruments, alarms, and equipment; or reviewing critical procedures used by operators and maintenance personnel.

For critical operations, it may be necessary to perform task hazard analyses to analyze the operator/machine interface in process control rooms or other work locations to adequately evaluate human factor impacts. Addressing facility siting in a PHA means considering the physical location of covered processes within the plant property. A PHA team should consider the proximity of the covered process to workers and egress routes when evaluating the potential safety and health impacts of possible HHC releases. The team must also consider the impact of vehicle traffic and adjacent operations on the safety of the process.

To conduct an effective PHA, both operating management and the PHA team must understand their respective responsibilities. In general, the tasks breakdown is show in figure 4

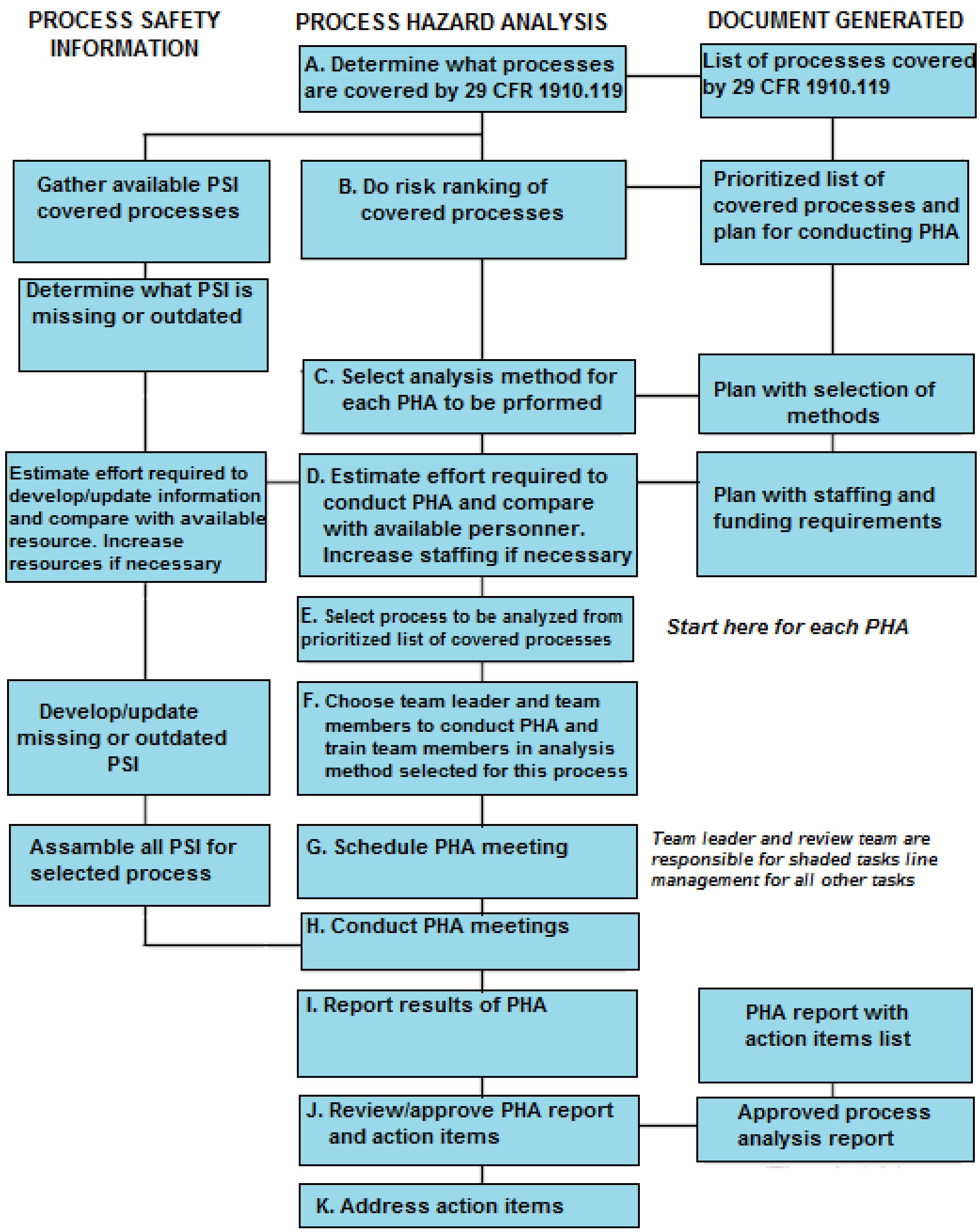

Figure 4: Process Hazard Analysis Task Structure (DOE, 1996)

The following five steps should be taken to help identify hazards:

1. List all obvious hazards. Most processes include a number of hazards that are already fully recognized, such as the flammability of propane or the inhalation toxicity of chlorine.
2. Examine the hazardous characteristics of each process chemical. Review the MSDSs, which should have information on the toxicity, flammability, and reactivity of process chemicals and on their incompatibilities with other materials.
3. Examine all process parameters. Parameters (e.g., pressure, temperature, flow rate, level, pH) that are controlled or measured in a process are good indicators of possible process hazards. Process parameters should be examined for all modes of operation, independent of process chemicals, because some hazards exist that do not involve the chemicals
4. Examine material interactions for incompatibilities. Even if process chemicals are relatively non-hazardous when considered independently, some potentially dangerous interactions may occur when materials are combined. Interactions between process chemicals, containment materials, or other materials with which the chemicals come in contact can be examined in pairs by using an interaction matrix.
5. Document the identified hazards. The PHA report should list identified hazards in tabular form and/or discuss each hazard briefly in the text.

Table 2 presents a list of hazards commonly found in process operations, grouped according to how energy is stored. It can be used as a starting point to develop a checklist for identifying process hazards.

Table 2: Processing Hazards (DOE, 1996)

Form of Energy	Associated Hazards	Typical Accidental Events
Chemical Energy	Ability to self-polymerize	Uncontrolled polymerization
	Shock-sensitivity	Detonation of solid or liquid explosive or explosive mixture
	Thermal instability	Thermal explosion following bulk self-heating and runaway reaction

Form of Energy	Associated Hazards	Typical Accidental Events
	Rearranging ability	Uncontrolled rearrangement reaction (e.g., ethylene oxide)
	Pyrophoricity	Fire upon atmospheric contact
	Flammability	• Vessel/enclosure rupture following ignition of contained vapors+air • Vapor cloud explosion • Flash fire • Pool fire
	Combustibility	• Bulk material fire • Dust explosion • Aerosol ignition and fast fire • Flash fire of vapors from heated combustible solid or liquid
	Peroxidizing ability	Contact with oxygen over time; energetic peroxide decomposition
	Water-reactivity	Release of water-reactive material and energetic reaction with water or humidity
	Oxidizing or reducing ability	• Contact of oxidizer with organic material; bulk material fire • Uncontrolled redox reaction
	Acidity or causticity	• Acid gas release (e.g., anhydrous HCl) • Corrosive liquid or solid spill • Uncontrolled acid/base reaction
	Toxicity	• Toxic vapor release • Toxic liquid or solid spill
	Other increased reactivity	Inadvertent mixing or contact with incompatible material; heat, pressure, or toxic gas generation
	Reduced chemical reactivity (inert material)	Personnel entry into confined space with reduced oxygen level
Thermal Energy	Elevated temperature	• Hot material release • Contact with hot surface • Steam explosion or equivalent • Containment rupture from thermal expansion of blocked-in fluid
	Reduced temperature	• Cryogenic material release • Fracture of embrittled containment

Form of Energy	Associated Hazards	Typical Accidental Events
Pressure-Volume Energy	Volume of compressible fluid held at elevated pressure	• Tank or enclosure rupture • High-velocity leak or spray
	Liquefied material stored under pressure	Rapid phase transition (boiling-liquid-expanding-vapor explosion or BLEVE)
	Volume of compressible fluid held under vacuum	Tank or enclosure collapse
Potential Energy	Elevation of process material above a reference level	• Toppling over of stacked drums • Shifting of granular storage piles • Fluid surge from failed container • Falling material from spill/overflow
Kinetic Energy	Moving process material	• Overpressure or over temperature by deadheaded pumping • Impingement by process material • Water hammer damage
Electro-magnetic	Elevated electromagnetic radiation levels	Unshielded laser or microwave radiation associated with process
Electrical Energy	Elevated voltage	Electrical shock from process using electricity, such as electrolysis of brine

NH_3 anhydrous ammonia	combustible; toxic vapor; cryogenic liquid spill					
Cl_2 chlorine	explosive NCl_3 formed with chlorine	oxidizer; toxic vapor; cryogenic liquid spill				
HF anhydrous hydrogen fluoride	heat generation, liberating toxic vapors	heat generation, liberating toxic vapors	strong acid; corrosive; toxic vapor and liquid			
C_4H_6 1,3-butadiene	heat generation, volent polymeriza-tion	fire, toxic gas generation	heat generation, volent polymeriza-tion	Flammable; peroxidizes; polymerizes; decomposes		
Fe etc carbon steel	none predicted	iron/chlorine fire if above 250 C (or 100 C with impurities	hydrogen blistring between steel laminations	none predicted	material construction	
H_2O 150# steam	heat generation, liberating toxic vapors	none predicted	heat generation, liberating toxic vapors	antioxidant consumed, leading to polymeriza-tion	none predicted	**elevated pressure, temperature**
combine with.....	**NH_3 anhydrous ammonia**	**Cl_2 chlorine**	**HF anhydrous hydrogen fluoride**	**C_4H_6 1,3-butadiene**	**Fe etc carbon steel**	**H_2O 150# steam**

Figure 5: Example Interaction Matrix for Identifying Process Hazards (DOE, 1996)

Incidents can indicate what could happen if protection systems, which are not totally reliable, do not work. Thorough incident investigations may also indicate root causes of initiating events and protective system failures and thus suggest action items to improve safety-management systems. Incident records also help show the likelihood of failures and operational errors. The parts of an accident event involving a process operation are shown in Figure 6. Each sequence of failures and conditions leading to an accident is a unique scenario. Every accident scenario starts with an initiating event or cause, which is a mechanical failure, operational error, external event, or other condition that causes normal operation to be interrupted or changed. Initiating events can lead to process deviations.

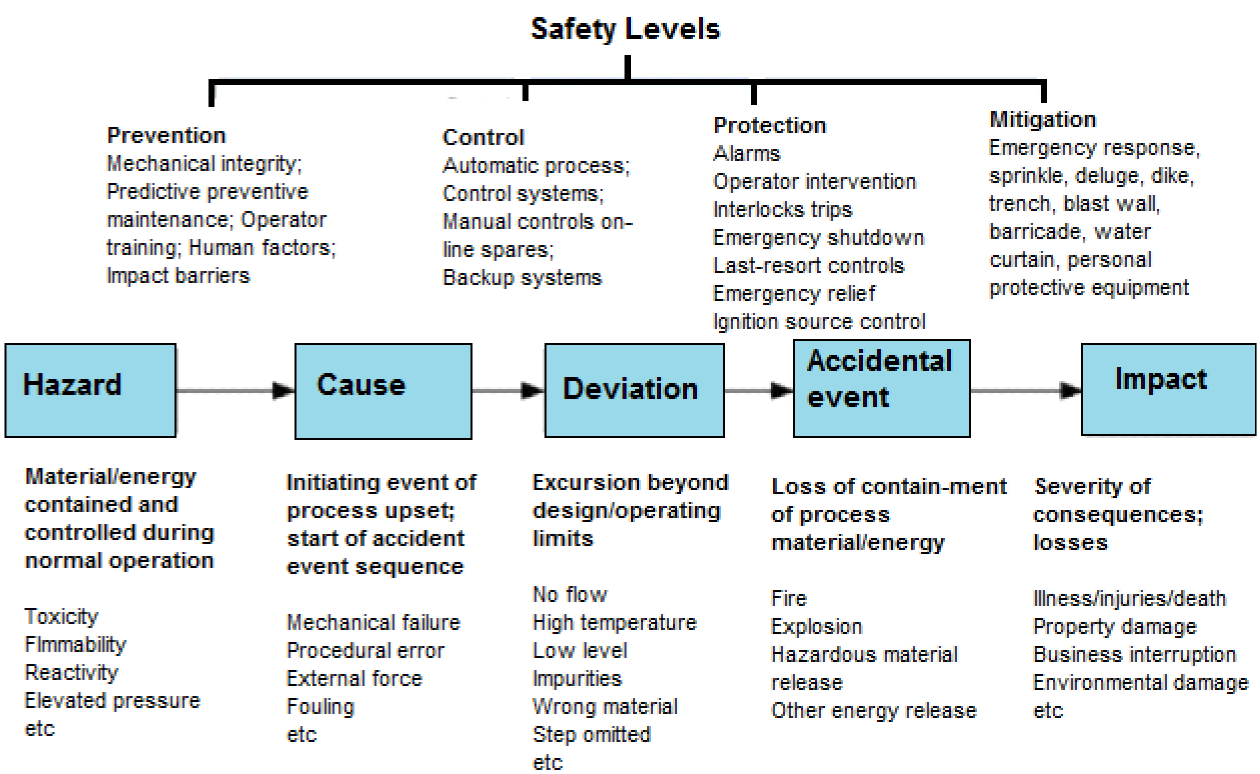

Figure 6: Anatomy of an accident

The selection of a PHA methodology or technique will be influenced by many factors including the amount of existing knowledge about the process. The employer must use one or more of the following methods, as appropriate, to determine and evaluate the hazards of the process being analyzed:

1. What-if,

   This approach uses a multi-skilled team to create and answer a series of “what-if” type questions. This method has a relatively loose structure and is only as effective as the quality of the questions asked and the answers given. What-If analyses are intended to identify hazards, hazardous situations, or accident scenarios. The team of experienced people identifies accident scenarios, consequences, and existing safeguards, then suggests possible risk reduction alternatives. The method can be used to examine deviations from design, construction, modification, or operating intent. It requires a basic understanding of the process and an ability to combine possible deviations from design intent with outcomes. A What-If usually reviews the entire process, from the introduction of the chemicals to the end. The analysis may focus on particular consequences of concern.

2. Checklist,

   This method uses established codes, standards and well-understood hazardous operations as a checklist against which to compare a process. A good checklist is dependent on the experience level and knowledge of those who develop it. Checklists are created by taking the applicable standards and practices and using them to generate a list of questions that seek to identify any differences or deficiencies. If a checklist for a process does not exist, an experienced person must develop one based on standards, practices, and facility or equipment experience. A completed checklist usually provides “yes,” “no,” “not applicable,” and “need more information” answers to each item. A checklist analysis involves touring the process area and comparing equipment to the list.

3. What-if/checklist

   The purpose of a What-If/Checklist is to identify hazards and the general types of accidents that could occur, evaluate qualitatively the affects of the effects, and determine whether safeguards are adequate. The What-If part of the process can help the team identify hazards and accident scenarios that are beyond the experience of the team members. The checklist provides a more detailed systematic approach that can fill in gaps in the brainstorming process. The technique is generally used to identify the most common hazards that exist in a process.

4. Hazard and operability study (HAZOP),

   A structured, systematic review that identifies equipment that is being used in a way that it was not designed to be, and which might create hazards or operational problems. The purpose of a HAZOP is to review a process or operation systematically to identify whether process deviations could lead to undesirable consequences. HAZOPs are usually conducted by a multi-skilled team that studies piping and instrument diagrams. Each pipeline and vessel is evaluated for certain limitations and deviations in flow, temperature, pressure, etc.

   HAZOPs usually require a series of meetings in which, using process drawings, the team systematically evaluates the impact of deviations. The team leader uses a fixed set of guide words and applies them to process parameters at each point in the process. Guide words include “No,” “More,” “Less,” “Part of,” “As well as,” “Reverse,” and “Other than.” Process parameters considered include flow, pressure, temperature, level, composition, pH, frequency, and voltage. As the team applies the guide words to each process step, they record the deviation, with its causes, consequences, safeguards, and actions needed, or the need for more information to evaluate the deviation.

5. Failure mode and effects analysis (FMEA),

   A systematic study of the consequences of failure (breakdown) of certain operational hardware such as transmitters, controllers, valves, pumps, etc. An FMEA produces a qualitative, systematic list of equipment, failure modes, and effects. The analysis can easily be updated for design or system changes. The FMEA usually produces a table that, for each item of equipment, includes a description, a list of failure modes, the effects of each failure, safeguards that exist, and actions recommended to address the failure. For example, for pump operating normal, the failure modes would include fails to stop when required, stops when required to run, seal leaks or ruptures, and pump case leaks or ruptures. The effects would detail both the immediate effect and the impact on other equipment. An FMEA requires an equipment list or P&ID, knowledge of the equipment, knowledge of the system, and responses to equipment failure

6. Fault tree analysis,

   This method draws a picture (model) that shows what undesirable outcomes might result from a specific initiating event (for example, a pipe rupture in a pipe rack). It uses graphics and symbols to show the possible order of events which might result in an accident. This method is sometimes used in accident investigations to determine probable cause. FTA is often used when another technique has identified an accident that requires more detailed analysis.

   The FTA looks at component failures (malfunctions that require that the component be repaired) and faults (malfunctions that will remedy themselves once the conditions change). Failures and faults are divided into three groups: primary failures and faults occur when the equipment is operating in the environment for which it was intended; secondary failures and faults occur when the system is operating outside of intended environment; and command faults and failures are malfunctions where the equipment performed as designed but the system that commanded it malfunctioned. An FTA requires a detailed knowledge of how the plant or system works, detailed process drawings and procedures, and knowledge of component failure modes and effects.

7. An appropriate equivalent methodology.

All PHA methodologies are subject to certain limitations. For example, the checklist methodology works well when the process is very stable and no changes are made, but it is not as effective when the process has undergone extensive change. The checklist may miss the most recent changes and consequently the changes would not be evaluated. Another limitation to be considered concerns the assumptions made by the team or analyst. AIChE list the better suited the use of methodologist.

- FMEA efficiently analyzes the hazards associated with computer and electronic systems; HAZOPs do not work as well with these.
- Processes or storage units designed to industry or government standards can be handled with checklists.
- What-If, What-If/Checklist, and HAZOP as better able to handle batch processes than FTA or FMEA because the latter do not easily deal with the need to evaluate the time-dependent nature of batch operations.
- Analysis of multiple failure situations is best handled by FTA. Single-failure techniques, such as HAZOP and FMEA, are not normally used to handle these although they can

be extended to evaluate a few simple accident situations involving more than one event.

- When a process has operated relatively free of accidents for a long time, the potential for high consequence events is low, and if there have been few changes to invalidate the experience base, the less exhaustive techniques, such as a Checklist, can be used. When the opposite is true, the more rigorous techniques are more appropriate.

Table 3: Applicability of PHA Techniques

Particular Phases in Process Design and Operation	Checklist	What-if	What-if/ Checklist	HAZOP	FMEA	FTA
R&D		✓				
Design	✓	✓	✓			
Pilot Plant Operation	✓	✓	✓	✓	✓	✓
Detailed Engineering	✓	✓	✓	✓	✓	✓
Construction/Startup	✓	✓	✓			
Routine Operation	✓	✓	✓	✓	✓	✓
Modification	✓	✓	✓	✓	✓	✓
Incident Investigation		✓		✓	✓	✓
Decommissioning	✓	✓	✓			

Whichever method(s) are used, the process hazard analysis must address the following:

- The hazards of the process;
- The identification of any previous incident that had a potential for catastrophic consequences in the workplace;
- Engineering and administrative controls applicable to the hazards and their interrelationships, such as appropriate application of detection methodologies to provide early warning of releases. Acceptable detection methods might include process monitoring and control instrumentation with alarms, and detection hardware such as hydrocarbon sensors;
- Consequences of failure of engineering and administrative controls;
- Facility siting;
- Human factors; and

- A qualitative evaluation of a range of the possible safety and health effects on employees in the workplace if there is a failure of controls.

Once hazards have been identified, the risks are estimated from the potential consequences and the likelihood of occurrence, using qualitative and/or quantitative methods such as Fault Tree, Event Tree, Risk Indices, etc. The total risk is then evaluated by comparing against criteria for Acceptability. Following risk evaluation, steps must be taken to reduce those risks which are deemed unacceptable. Such steps might include:

- inventory reduction,
- alternative processes,
- alternative materials,
- improved training and procedures,
- protective equipment, ensuring that items identified from hazard and risk analysis are closed off.

Inherent safety is an approach that eliminates or greatly reduces hazards by design of the process. Strategic decisions typically must be implemented early in the process design, but are inherent, passive and thus less prone to failure. Tactical decisions can be implemented late in process design, but are characterized by repetition and high costs. Being active and procedural in nature, they need continuous supervision to remain effective. Inherent safety is therefore best applied in a hierarchy:

- Minimize: Use smaller quantities of hazardous substances.
- Substitute: Replace a material with a less hazardous substance.
- Moderate: Use less hazardous conditions, a less hazardous form of a substance, or facilities which minimize the impact of the release of hazardous material or energy.
- Simplify: Design processes and facilities which eliminate unnecessary complexity and are forgiving of operating errors.

Resolution of Recommendations Process hazard analysis is not an end in itself. It is a method to identify areas of excessive risk. Therefore, a tracking system must be in place to ensure that the findings and recommendations of the PHA team are resolved in a timely manner, that actions taken are documented, and that all affected operating and maintenance workers are made aware of these actions. This system must ensure that:

- findings and recommendations are addressed promptly
- recommendations are resolved and documented
- actions are completed as soon as possible
- a schedule for all resolutions is established and followed
- actions are communicated to employees affected by any changes.

At least every five years after the completion of the initial process hazard analysis, the process hazard analysis must be updated and revalidated by a team meeting the standard's requirements to ensure that the hazard analysis is consistent with the current process. Employers must keep on file and make available to OSHA, upon request, process hazard analyses and updates or revalidation for each process covered by PSM, as well as the documented resolution of recommendations, for the life of the process.

Where a PHA recommendation is rejected, the employer must communicate this to the team, and expeditiously resolve any subsequent recommendation of the team. An employer can justifiably decline to adopt a recommendation where the employer can document in writing and based upon adequate evidence that one or more of the following conditions exist (OSHA, 1994):

1. The analysis upon which the recommendation is based contains material factual errors.

2. The recommendation is not necessary to protect the health and safety of the employer’s own employees or the employees of contractors.

3. An alternative measure would provide a sufficient level of protection.

4. The recommendation is infeasible.

A joint labor-management health and safety committee can review the implementation of recommendations.

Operating Procedures

Operating procedures are an important tool for achieving safe, consistent, and efficient process operation. Process procedures differ from many procedures because they cover all phases of operations. Operating procedures provide specific instructions or details on what steps are to be taken or followed in carrying out the stated procedures. The specific instructions should include the applicable safety precautions and appropriate information on safety implications.

Procedures must address normal, abnormal, and emergency conditions to prepare workers for any event that may reasonably occur. Administrative and special engineering control measures, as well as required monitoring and surveillance equipment must be described. Procedures must be clearly written, with easy-to-follow steps for each operating phase. They should be written at an education level that all process workers can understand.

The employer must develop and implement written operating procedures for the chemical processes, including procedures for each operating phase, operating limitations, and safety and health considerations; Operating procedure that addresses the safe operation of the plant must be documented and available to personnel that require it. PSM operating procedures describe:

- tasks to be performed
- data to be recorded
- operating conditions to be maintained
- samples to be collected
- safety and health precautions to be taken

Steps for each operating phase:

- Initial startup;
- Normal operations;
- Temporary operations;
- Emergency shutdown, including the conditions under which emergency shutdown is required, and the assignment of shut-down responsibility to qualified operators to ensure that emergency shutdown is executed in a safe and timely manner;

- Emergency operations;
- Normal shutdown; and
- Startup following a turnaround, or after an emergency shutdown.

Operating procedures and instructions are important for training operating personnel. The operating procedures are often viewed as the standard operating practices (SOPs) for operations. Control room personnel and operating staff, in general, need to have a full understanding of operating procedures. If workers are not fluent in English, then procedures and instructions need to be prepared in a second language understood by the workers.

In addition, operating procedures need to be changed when there is a change in the process as a result of the management of change procedures. The consequences of operating procedure changes need to be fully evaluated and the information conveyed to the personnel.

For example, mechanical changes to the process made by the maintenance department (like changing a valve from steel to brass or other subtle changes) need to be evaluated to determine if operating procedures and practices also need to be changed. All management of change actions must be coordinated and integrated with current operating procedures and operating personnel must be oriented to the changes in procedures before the change is made. When the process is shutdown in order to make a change, then the operating procedures must be updated before startup of the process.

These operating procedures have to be clearly written instruction and consistent with the process safety information. The operating procedures must be reviewed as often as necessary to ensure that they reflect current operating practices, including changes in process chemicals, technology, and equipment, and facilities. The procedures have to take into consideration both general and special hazards of the chemical involved in the process, hazards of exceeding operational limits, appropriate response to upset conditions, safety and health information, and emergency operations. Up to date and reliability of the operating procedures must be performed frequently.

Operating limits:

- Consequences of deviation, and
- Steps required to correct or avoid deviation.

Safety and health considerations:

- Properties of, and hazards presented by, the chemicals used in the process;
- Precautions necessary to prevent exposure, including engineering controls, administrative controls, and personal protective equipment;
- Control measures to be taken if physical contact or airborne exposure occurs;
- Quality control for raw materials and control of hazardous chemical inventory levels; and
- Any special or unique hazards.
- Safety systems (e.g., interlocks, detection or suppression systems) and their functions.

Procedures should include a graded approach to highlighting dangers, such as the military system of notes, cautions, and warnings. (Notes indicate that care is required. Cautions indicate that incorrect operation may lead to injury or equipment damage. Warnings indicated that incorrect operation may lead to serious injury or major equipment damage).

Seven steps are suggested for developing procedures (DOE, 2004):

1. Determine the tasks involved in operating a process unit, the relationship between the tasks, and the order in which they are to be carried out. Use Job Safety Analyses to identify and discuss hazards associated with each task.
2. Analyze each task and reach consensus on how it should be carried out. The analysis should be done by senior operators and supervisors, with input from management and technical staff. Task analysis is often beneficial because it illuminates inconsistencies in the way tasks are performed by different workers on different shifts.
3. Write the procedures based in interviews or personal experience, and follow the logic developed in the task analysis.
4. Distribute written procedures to operators for comment and discussion.

5. Perform a PHA for the procedures. The PHA team thoroughly reviews the procedures and generates the safety and health information to be incorporated.
6. Ensure that users receive the proper training.
7. Ensure that procedures are written and structured so that they can be updated regularly to reflect changes. Note that MOC procedures identify activities that lead to changes in operating procedures.

Operating procedures must be readily accessible to employees who work in or maintain a process to make sure that a ready and up-to-date reference is available and to form a foundation for needed employee training. The operating procedures must be reviewed as often as necessary to ensure that they reflect current operating practices, including changes in process chemicals, technology, and equipment, and facilities.

Training in how to handle upset conditions must be accomplished as well as what operating personnel are to do in emergencies such as when a pump seal fails or a pipeline ruptures. Communication between operating personnel and workers performing work within the process area, such as non-routine tasks, also must be maintained. The hazards of the tasks are to be conveyed to operating personnel in accordance with established procedures and to those performing the actual tasks. When the work is completed, operating personnel should be informed to provide closure on the job.

Training

All employees, including maintenance and contractor employees, involved with highly hazardous chemicals need to fully understand the safety and health hazards of the chemicals and processes they work with for the protection of themselves, their fellow employees and the citizens of nearby communities. The implementation of an effective training program is one of the most important steps that an employer can take to enhance employee safety. Provide written safety and operating information for employees and employee training in operating procedures, by emphasizing health hazards of the process, emergency operations including shutdown, and other safe work practices and safe practices that must be developed and made available.

Training serves as a method of communicating process operation information, communicating skills in performing operating and emergency procedures, communicating hazards related to the process and many other aspects of process operation and maintenance to plants personnel. A comprehensive integrated environmental, health and safety training program is a key element in providing a cost-effective means to meet the training requirements for personnel who handle chemicals.

In establishing their training programs, employers must clearly define the employees to be trained and what subjects are to be covered in their training. Employers in setting up their training program will need to clearly establish the goals and objectives they wish to achieve with the training that they provide to their employees. The learning goals or objectives should be written in clear measurable terms before the training begins. These goals and objectives need to be tailored to each of the specific training modules or segments. Employers should describe the important actions and conditions under which the employee will demonstrate competence or knowledge as well as what is acceptable performance.

Training must result in employees understanding:

- chemical hazards and the controls;
- proper procedures;
- safe operating limits and how to avoid unsafe conditions;
- how to respond to upset and emergency conditions; and
- opportunities available for employees to contribute to process safety improvements.

Training programs should have the following elements:

- Written training plans and schedules.
- Qualified trainers.
- Training materials on the process tasks.
- Methods to ensure that competencies are developed (e.g., testing appropriate to the complexity of the operations and the hazards involved).
- Periodic review of operations/activities to ensure that operators follow procedures and competencies are maintained.

At least every three years, and more often if necessary, refresher and supplemental training shall be provided to each operating or maintenance employee and other employees in order to ensure safe operation of the facility. The employer, in consultation with employees involved in operation or maintenance of a process, shall determine the appropriate frequency and content of refresher training. Both employees and contractors must be trained to understand and use site safety systems.

Initial and refresher training (every three years or more) frequently as needed are required. Initial training for new process operators or operators new to a process must emphasize:

- safe work practices, including startup, normal operations, and temporary operations procedures;
- hazardous chemicals and specific safety and health hazards and precautions for preventing exposure;
- emergency procedures, including shutdown and startup procedures;
- Standard Operating Procedures (SOPs) and Job Hazard Analyses (JHAs);
- accidents and near misses;
- operating limits, the consequences of deviations, and the steps required to avoid deviations;
- equipment and process parameters, such as pressure, flow, and temperature.

Hands-on-training where employees are able to use their senses beyond listening, will enhance learning. For example, operating personnel, who will work in a control room or at control panels, would benefit by being trained at a simulated control panel or panels. Upset conditions of various types could be displayed on the simulator, and then the employee could go through the proper operating procedures to bring the simulator panel back to the normal operating parameters.

A training environment could be created to help the trainee feel the full reality of the situation but, of course, under controlled conditions. This realistic type of training can be very effective in teaching employees correct procedures while allowing them to also see the consequences of what might happens if they do not follow established operating procedures. Other training techniques using videos or on the job training can also be very effective for teaching other job tasks, duties, or other important information. An effective training program will allow the employee to fully participate in the training process and to practice their skill or knowledge.

Particular areas which should be covered include:

- General safety rules;
- Permit to work procedures;
- Use of personal protective equipment;
- Emergency procedures;
- Specific hazards of the area in which they will be working; and
- Specific hazards of the materials which they may encounter.

Employers need to periodically evaluate their training programs to see if the necessary skills, knowledge, and routines are being properly understood and implemented by their trained employees. A competency test should be administered to employees and contractors to ensure the information given has been understood. It is especially important that people supervising contractors understand the training given. If, after the evaluation, it appears that the trained employees are not at the level of knowledge and skill that was expected, the employer will need to revise the training program, provide retraining, or provide more frequent refresher training sessions until the deficiency is resolved. Those who conducted the training and those who received the training should also be consulted as to how best to improve the training process. If there is a language barrier, the language known to the trainees should be used to reinforce the training messages and information.

A consistent and properly scheduled training program is critical because they determine the effectiveness of the training presented. Industry codes and government regulations recommend, and, in some cases, require specific trainings for plant workers. Consequently, PSM programs need to identify and document training requirements covering all levels of management and employees, including contractor personnel, who manage, operate, maintain, and support the process units.

The employer shall ensure that each employee involved in the operation or maintenance of a process has received, understood and successfully completed training as specified by this subsection. The employer, after the initial or refresher training, shall prepare a certification record containing the identity of the employee, the date(s) of training, the means used to verify that the employee understood the training, and the signature(s) of the person administering the training. Training needs to be conducted by qualified and authorized instruction who can issue required certifications.

Contractors

Employers who use contractors to perform work in and around processes that involve highly hazardous chemicals, will need to establish a screening process so that they hire and use contractors who accomplish the desired job tasks without compromising the safety and health of employees at a facility. For contractors, whose safety performance on the job is not known to the hiring employer, the employer will need to obtain information on injury and illness rates and experience and should obtain contractor references. Additionally, the employer must assure that the contractor has the appropriate job skills, knowledge and certifications (such as for pressure vessel welders). Contractor work methods and experiences should be evaluated.

PSM applies to contractors performing maintenance or repair, turnaround, major renovation, or specialty work on or adjacent to a covered process so they can taking care that they do nothing to endanger those working nearby who may work for another employer. PSM ensure contractors and contract employees are provided with appropriate information and training.

When selecting a contractor, the employer must obtain and evaluate information regarding the contract employer's safety performance and programs. The employer also must:

- Inform contract employers of the known potential fire, explosion, or toxic release hazards related to the contractor's work and the process.
- Explain to contract employers the applicable provisions of the emergency action plan
- develop and implement safe work practices to control the presence, entrance, and exit of contract employers and contract employees in covered process areas
- evaluate periodically the performance of contract employers in fulfilling their obligations
- Maintain a contract employee injury and illness log related to the contractor's work in the process areas.

Contract employees must perform their work safely. Considering that contractors often perform very specialized and potentially hazardous tasks such as confined space entry activities and non-routine repair activities it is quite important that their activities be controlled while they are working on or near a covered process. A permit system or work authorization system for these activities would also be helpful to all affected employers.

The use of a work authorization system keeps an employer informed of contract employee activities, and as a benefit the employer will have better coordination and more management control over the work being performed in the process area. A well run and well maintained process where employee safety is fully recognized will benefit all of those who work in the facility whether they be contract employees or employees of the owner.

Contractor responsibilities.

- The contractor shall ensure that all of its employees are trained in the work practices necessary to safely perform their jobs, including in applicable provisions of the emergency action plan.
- The contractor shall ensure that all of its employees are instructed in the potential hazards related to their jobs and the process, including but not limited to, fires, explosions, loss of containment, hazardous materials exposures and high temperatures and pressures.
- The contractor shall document that each of its employees has successfully completed the training required by this subsection by maintaining a record identifying: (i) each employee who has received training; (ii) the date(s) and subject(s) of training each employee has received; and (iii) the means used to verify that the employee understood the training received.
- The contractor shall ensure that each of its employees understands and follows the safety and health procedures of the employer and the contractor.
- The contractor shall advise the employer of any unique hazards presented by the contractor's work, as well as any hazards identified by the contractor while performing work for the employer.

Mechanical Integrity

The purpose of the mechanical integrity element is to ensure the integrity and safe operation of process equipment through inspection, testing, preventative maintenance, and quality assurance. The employer must be establishing maintenance systems for critical process related equipment, including written procedures, employee training, appropriate inspections, and testing of such equipment to ensure ongoing mechanical integrity. Inspection and testing must be performed on process equipment, using procedures that follow recognized and generally accepted good engineering practices. Each inspection and test on process equipment must be documented, identifying the date of the inspection or test, the name of the person who performed the inspection or test, the serial number or other identifier of the equipment on which the inspection or test was performed, a description of the inspection or test performed, and the results of the inspection or test.

The objective of MI is to ensure equipment does not fail in a way that causes a release of chemicals. Equipment means hardware that helps contain the chemicals in the process. MI covers the proper design, fabrication, construction/installation and operation of equipment throughout the entire process life cycle. PSM mechanical integrity requirements apply to the following equipment:

- Pressure vessels and storage tanks;
- Piping systems (including piping components such as valves);
- Relief and vent systems and devices;
- Emergency shutdown systems;
- Controls (including monitoring devices and sensors, alarms, and interlocks); and
- Pumps.

The applicable codes and standards provide criteria for external inspections for such items as foundation and supports, anchor bolts, concrete or steel supports, guy wires, nozzles and sprinklers, pipe hangers, grounding connections, protective coatings and insulation, and external metal surfaces of piping and vessels, etc. These codes and standards also provide information on methodologies for internal inspection, and a frequency formula based on the corrosion rate of the materials of construction.

Also, erosion both internal and external needs to be considered along with corrosion effects for piping and valves. Where the corrosion rate is not known, a maximum inspection frequency is recommended, and methods of developing the corrosion rate are available in the codes. Internal inspections need to cover items such as vessel shell, bottom and head; metallic linings; nonmetallic linings; thickness measurements for vessels and piping; inspection for erosion, corrosion, cracking and bulges; internal equipment like trays, baffles, sensors and screens for erosion, corrosion or cracking and other deficiencies.

The program to ensure the mechanical integrity of process equipment should contain:

- written maintenance procedures
- inspection and test procedures;
- trained process maintenance personnel;
- scheduled inspection, testing, and maintenance of process equipment;
- a quality assurance (QA) program to verify that
  - ✓ for new construction, equipment is suitable for its intended use and is properly installed according to design specifications and manufacturer's recommendations;
  - ✓ replacement parts and maintenance materials are suitable for the process application in which they will be used;
- a preventive maintenance program

The quality assurance program is an essential part of the mechanical integrity program and will help to maintain the primary and secondary lines of defense that have been designed into the process to prevent unwanted chemical releases or those which control or mitigate a release. "As built" drawings, together with certifications of coded vessels and other equipment, and materials of construction need to be verified and retained in the quality assurance documentation.

Equipment installation jobs need to be properly inspected in the field for use of proper materials and procedures and to assure that qualified craftsmen are used to do the job. The use of appropriate gaskets, packing, bolts, valves, lubricants and welding rods need to be verified in the field. Also, procedures for installation of safety devices need to be verified, such as the torque on the bolts on ruptured disc installations, uniform torque on flange bolts, proper installation of pump seals, etc. If the quality of parts is a problem, it may be appropriate to conduct audits of the equipment supplier's facilities to better assure proper purchases of required equipment which is suitable for its intended service. Any changes in equipment that may become necessary will need to go through the management of change procedures.

Quality assurance should include a materials control system which ensures installed equipment:

- Meets the requirements of the design specification;
- Is traceable to its manufacturer;
- Has met all required testing, with test results available on site; and
- Is labelled to be clearly identifiable to those doing installation.

Subsequent inspection and testing of process equipment should then be:

- According to good engineering practices;
- At a frequency determined by applicable codes and standards, or more frequently if operating experience suggests this is necessary;
- With a system to ensure corrective action is taken when results fall outside of acceptable limits; and
- With documentation that includes:
  - ✓ Date of inspection;
  - ✓ Name of inspector;
  - ✓ Serial number or other equipment identifier;
  - ✓ Description of the tests done;
  - ✓ Results of the inspection or test, and
  - ✓ Recommended action.

Non-routine Work Authorizations (Hot Work)

Work authorizations are required to ensure that appropriate safety measures are taken any time non-routine operations are performed on or near covered processes. Non-routine work authorizations important to safety include hot work permits, radiation work permits, and confined space entry permits. Typical authorizations address procedures, special administrative and engineering controls, and monitoring and surveillance requirements. Safe work practices provide a generic approach for conducting many non-routine activities and are typically found in safety-related manuals. Hot work permits address welding, cutting, and other spark-producing operations.

Non-routine work which is conducted in process areas needs to be controlled by the employer in a consistent manner. The hazards identified involving the work that is to be accomplished must be communicated to those doing the work, but also to those operating personnel whose work could affect the safety of the process. A permit must be issued for hot work operations conducted on or near a covered process. A work authorization notice or permit must have a procedure that describes the steps the maintenance supervisor, contractor representative or other person needs to follow to obtain the necessary clearance to get the job started.

The permit must document that the fire prevention and protection requirements in OSHA regulations have been implemented prior to beginning the hot work operations; it must indicate the date(s) authorized for hot work; and identify the object on which hot work is to be performed. The permit must be kept on file until completion of the hot work. The work authorization procedures need to reference and coordinate, as applicable, lockout/tagout procedures, line breaking procedures, confined space entry procedures and hot work authorizations. This procedure also needs to provide clear steps to follow once the job is completed in order to provide closure for those that need to know the job is now completed and equipment can be returned to normal.

The work associated with the preparation and issuing of a work permit covers:

- description of the work to be carried out
- review of documentation
- risk assessment and assignment of authorization level
- preparation of special permits (e.g. excavation, confined space entry)
- safe job analysis with the preparation of safe work procedures and identification of safety precautions.

Jobs that require a work permit include, but are not limited to:

- working in potential oxygen deficiency or enrichment
- working in potential flammable / explosive atmosphere
- working at potential high temperature / pressure

- potential exposure to hazardous chemicals (e.g. toxic, reactive, acid, caustic)
- working in confined space, elevated work, work at height
- bypassing, removing or altering safety devices and equipment
- electrical troubleshooting or repair of electrical circuit
- maintenance or repairs in areas, or to equipment or lines, containing or supposed to contain hazardous materials or conditions
- manual or powered excavations
- use of mobile cranes
- exposure to moving and/or rotating machinery

The Hot Work Standard minimizes the potential of fire or explosion in classified areas and all modules within a production operational area (e.g. water flood, utilities, etc.) by requiring a Hot Work Permit. This applies but is not limited to:

1. Open flame, welding, burning/cutting, or grinding within 75 feet of a classified area.
2. The use of non-intrinsically safe electrical tools and instruments in a classified area.
3. Work on electrical circuits including the opening of explosion proof boxes or junction boxes in a classified area.
4. Hot work on portable and mobile containers which contain or have contained flammable or combustible materials.
5. Impedance thawing.
6. Stress relieving of piping.
7. The use of spark producing devices in a classified area.

A Hot Work Permit is required for mobile heaters, stationary trucks, cranes, and other mobile equipment operating within a classified area. A classified area extends 10 feet beyond the exterior wall or roof of a building, fan exhaust, vent, low point drain, high point vent, or flanges.

Hot work permits must:

- include the date authorized for hot work;
- include the object on which the hot work is to be performed;
- identify openings, cracks, and holes where sparks may drop to combustible materials below;
- describe fire extinguishers required to handle fires that are of incipient type;
- assign fire watchers for locations where more than a minor fire could potentially develop;
- describe precautions associated with combustible materials on floors, walls, partitions, ceilings, or roofs of combustible construction;
- prohibit welding or cutting in unauthorized areas, in buildings with sprinkler systems while such protection is impaired, in explosive atmospheres, and in storage areas for large quantities of readily ignitable materials;
- require relocation of combustibles where practicable and cover with flame-proofed covers where not practicable;
- identify for shutdown any ducts or conveyors systems that may convey sparks to distant combustibles.

Management of Change (MOC)

OSHA believes that contemplated changes to a process must be thoroughly evaluated to fully assess their impact on employee safety and health and to determine needed changes to operating procedures. All changes should be identified and reviewed prior to their implementation, and the impact of design, operational, and procedural changes on process safety should be addressed and managed. A process change is defined as any alteration, whether temporary or permanent, that could affect the control or integrity of a system covered by the PSM Rule. This element is a critical part of the PSM Rule because it helps to integrate many of the other elements of the Rule. Process changes include:

- changes in process technology such as raw materials, process chemistry, process control systems, equipment design, and piping and equipment specifications;

- addition or removal of process equipment or piping;
- changes in process parameters;
- changes in utilities;
- changes in procedures;
- changes in facilities; and
- personnel changes

Written procedures to manage changes (except for “replacements in kind”) to process chemicals, technology, equipment, and procedures, and change to facilities that affect a covered process, must be established and implemented. These written procedures must ensure that the following considerations are addressed prior to any change:

- The technical basis for the proposed change,
- Impact of the change on employee safety and health,
- Modifications to operating procedures,
- Necessary time period for the change, and
- Authorization requirements for the proposed change

Management of change covers such as changes in process technology and changes to equipment and instrumentation. Changes in process technology can result from changes in production rates, raw materials, experimentation, equipment unavailability, new equipment, new product development, change in catalyst and changes in operating conditions to improve yield or quality. Equipment changes include among others change in materials of construction, equipment specifications, piping prearrangements, experimental equipment, computer program revisions and changes in alarms and interlocks. Employers need to establish means and methods to detect both technical changes and mechanical changes.

The change management process includes:

- An assessment of hazards, risks and necessary control measures
- Development of a project/work plan that specifies timescales, control measures and responsibilities

- Design of the change
- Training and communication needs
- Formal authorization
- Pre start-up safety review

A system to manage change is critical to the operation of any facility. A written procedure should be required for all changes except replacement in kind. The system should address:

- A clear definition of change (scope of application);
- A description and technical basis for the proposed change;
- Potential impact of the proposed change on health, safety and environment;
- Authorization requirements to make the change;
- Training requirements for employees or contractors due to the change;
- Updating of documentation including: drawings, process safety information, operating procedures, maintenance procedures, alarm and interlock settings, fire protection systems, etc.;
- Contingencies for "emergency" changes.

The employer shall develop, implement and maintain written procedures to manage organizational changes prior to reducing staffing levels or making other changes that could affect the occupational safety and health. The areas to which these procedures shall apply include, but are not be limited to, operations, engineering, maintenance, health and safety, and emergency response. This requirement shall also apply to employers using contractors in permanent positions.

Employees who operate a process and maintenance and contract employees whose job tasks will be affected by a change in the process must be informed of, and trained in, the change prior to startup of the process or startup of the affected part of the process. If a change covered by these procedures results in a change in the required process safety information, such information also must be updated accordingly. If a change covered by these procedures changes the required operating procedures or practices, they also must be updated.

The procedures shall include a Management of Organizational Change assessment, which addresses the following:

- The experience levels of employees involved in the process before and after the proposed change, in order to ensure that the change will not compromise employee health and safety; the safety of operations and maintenance; and the effectiveness of emergency operations and response.
- A description of the change being proposed; the makeup of the team responsible for assessing the proposed change; the factors to be evaluated by the team; the rationale for the team's decision to implement or not implement the change; and the actions required to make the change.

While process changes occur for several reasons, it is essential that these changes do not compromise process safety. Changes must always be under proper control. Variance procedures should ensure proposed operation outside current operating limits is subject to prior review and approval by qualified personnel, who must be available if authority is needed at short notice. Equipment changes may introduce additional hazards or increase risk. A management of change system should therefore include an assessment of hazards and risks associated with the change. Procedures should also be used for smaller changes, since major hazards can be introduced by minor changes, e.g. across connection or instrumentation change. The procedure should be simple, but require approval by qualified personnel

Incident Investigation

Incident investigation is the process of identifying the underlying causes of incidents and implementing steps to prevent similar events from occurring. The intent of an incident investigation is for employers to learn from past experiences and thus avoid repeating past mistakes. Investigation of incidents, including near misses/abnormal events, is a vital part of PSM. PSM requires the investigation of each incident that resulted in, or could reasonably have resulted in, a catastrophic release of a highly hazardous chemical in the workplace. Such an incident investigation must be initiated as promptly as possible, but not later than 48 hours following the incident. The investigation must be by a team consisting of at least one person knowledgeable in the process involved, including a contract employee if the incident involved the work of a contractor, and other persons with appropriate knowledge and experience to investigate and analyze the incident thoroughly.

The incident investigation team should vary according to the type of incident. A typical team may include management personnel from the facility where the incident occurred; engineering and/or maintenance personnel; facility and/or operations personnel; ES&H personnel; and technical and/or research personnel. Incident investigation teams must include at least one person knowledgeable in the process involved in the incident. If the incident involved the work of a subcontractor, at least one subcontractor employee must be included on the investigation team.

Other members should have the appropriate knowledge and experience to support the investigation. The team chairperson must effectively control the scope of team activities by identifying the lines of investigation to be pursued; assigning tasks and establishing timetables; and keeping facility management advised of the progress of the investigation

Investigations should include a visit to the incident scene; preparation of visual aids, such as photos and field sketches; eyewitness interviews, conducted privately and individually; observation of any mechanical equipment involved; review of as-built drawings, operating logs, recorder charts, previous reports, procedures, equipment manuals, design data, laboratory tests, and other potentially useful information; and documentation of the sources of information for the incident report. Incident investigations should analyze for root causes that will lead to recommendations for corrective actions.

Recommendations should include the actions to prevent a recurrence of the incident, the identification of the person responsible for completing the actions, and the schedule for completion. Corrective actions should be aimed primarily at preventing or controlling the underlying causes of an incident rather than the surface manifestations

Minimum requirements for incident investigation include:

- Determining the investigator (high severity incidents require independent investigation)
- A clear definition of what is meant by “major incident” and any other categories used for classification;
- Collecting information
- Investigation of every actual or potential process-related incident;

- Analyzing, evaluating and organizing information. Many methods of getting to the root causes, such as “ask why five times” and “fish-bone analysis”, are readily available
- Investigation done promptly by a team with at least one person knowledgeable in the process
- Preparing the draft investigation report
- A report to management following the investigation stating:
  - ✓ Incident date;
  - ✓ Incident description;
  - ✓ Factors which contributed to the incident; and
  - ✓ Recommendations to prevent recurrence.

Incident investigation report findings and recommendations must be implemented and documented promptly. An investigation report must be prepared including at least:

- Date of incident,
- Date investigation began,
- Description of the incident,
- Factors that contributed to the incident, and
- Recommendations resulting from the investigation.

A system must be established to promptly address and resolve the incident report findings and recommendations. Resolutions and corrective actions must be documented and the report reviewed by all affected personnel whose job tasks are relevant to the incident findings (including contract employees when applicable). The employer must keep these incident investigation reports for 5 years.

Investigating incidents is of little use unless accompanied by follow-up. The follow-up system should address the recommendations made in the report and ensure timely implementation of corrective actions. Key results of the investigation should be shared, as appropriate, with other parts of the plant, the organization, and the process industry and other industries where the lessons learned could usefully be applied.

Compliance Audits

Employers need to select a trained individual or assemble a trained team of people to audit the process safety management system and program. A small process or plant may need only one knowledgeable person to conduct an audit. The purpose of safety audits is to determine the status and effectiveness of safety management efforts versus goals and also the progress toward those goals.

PSM compliance auditing is a unique and evolving process in each company. An experienced auditor should scrutinize the Standard Operating Procedures (SOPs) at a facility looking for PSM Program discrepancies in content and format. Special attention should be given to process safety information, mechanical integrity, and contractor qualifications.

The selection of effective audit team members is critical to the success of the program. Team members should be chosen for their experience, knowledge, and training and should be familiar with the processes and with auditing techniques, practices and procedures. The size of the team will vary depending on the size and complexity of the process under consideration.

For a large, complex, highly instrumented plant, it may be desirable to have team members with expertise in process engineering and design, process chemistry, instrumentation and computer controls, electrical hazards and classifications, safety and health disciplines, maintenance, emergency preparedness, warehousing or shipping, and process safety auditing. The team may use part-time members to provide for the depth of expertise required as well as for what is actually done or followed, compared to what is written.

A Safety Audit should cover:

- Compliance with all relevant legislation
- All departments within an organization
- All health and safety policies and procedures, including review of outcomes from the internal monitoring of the safety management system
- Identification of (and advice on) reasonable. Practical measures to control workplace risks

- Reinforcement of the organization’s commitment to continual improvement of health and safety

Management systems audits verify that the systems are effective in ensuring company/plant policies and procedures are being implemented. They also identify opportunities where systems may be strengthened. Process safety audits provide increased assurance that facilities are being operated and maintained in a way which properly protects the safety and health of those on site, the environment, the surrounding community, plant assets and continuity of operations.

An effective audit includes

- a review of the relevant documentation and process safety information,
- inspection of the physical facilities, and interviews with all levels of plant personnel.
- Utilizing the audit procedure and checklist developed in the preplanning stage,
- systematically analyze compliance with the provisions of the standard and any other corporate policies that are relevant.

An audit is a technique used to gather sufficient facts and information, including statistical information, to verify compliance with standards. Auditors should select as part of their preplanning a sample size sufficient to give a degree of confidence that the audit reflects the level of compliance with the standard. The audit team, through this systematic analysis, should document areas which require corrective action as well as those areas where the process safety management system is effective and working in an effective manner. This provides a record of the audit procedures and findings, and serves as a baseline of operation data for future audits. It will assist future auditors in determining changes or trends from previous audits.

Planning in advance is essential to the success of the auditing process. Each employer needs to establish the format, staffing, scheduling and verification methods prior to conducting the audit. The format should be designed to provide the lead auditor with a procedure or checklist which details the requirements of each section of the standard. The names of the audit team members should be listed as part of the format as well. The checklist, if properly designed, could serve as the verification sheet which provides the auditor with the necessary information to expedite the review and assure that no requirements of the standard are omitted. This verification sheet format could also identify those elements that will require evaluation or a response to correct deficiencies. This sheet could also be used for developing the follow-up and documentation requirements.

The compliance audit must be conducted by at least one person knowledgeable in the process and a report of the findings of the audit must be developed and documented noting deficiencies that have been corrected. The two most recent compliance audit reports must be kept on file.

A common mistake in a compliance auditing program is using a company employee who is responsible for the PSM program at the facility. An internal auditor is typically too familiar with the program components, documentation, and implementation methods which may lead to a false sense of security in the effectiveness of the PSM program.

- The compliance audit must be conducted by at least one person knowledgeable in the process and a report of the findings of the audit must be developed and documented noting deficiencies that have been corrected.
- The two most recent compliance audit reports must be kept on file

Trade Secrets

The trade secrets provision of PSM requires that the employer provide all information necessary to comply with PSM to all persons who need it. This does not preclude the employer from taking steps necessary to safeguard the integrity of any information disclosed. It merely prohibits the employer from using trade secrets as an excuse not to provide information to either employees or contractors. When necessary, confidentiality or nondisclosure agreements are recommended to ensure that personnel having access to trade secrets do not disclose that information.

Many of the programs and resources developed by professional and trade associations can be useful for enhancing process safety knowledge, as tools and support may have been adapted for the specific needs of an industry or sector. Companies should therefore encourage participation in such bodies, so that they can monitor developments, communicate relevant information to those within the company who could benefit from it, and also provide input to those external bodies. Information covered by trade secrets must be available to support development of PSI, PHA, operating procedures, and incident investigations.

Employers must make available all information necessary to comply with PSM to those persons responsible for:

- compiling the process safety information,
- developing of the process hazard analysis and operating procedures, and
- incident investigations, emergency planning and response, and compliance audits.

Employee Participation

Employers must develop a written plan of action to implement the employee participation required by PSM. Under PSM, employers must consult with employees and their representatives on the conduct and development of process hazard analyses and on the development of the other elements of process management, and they must provide to employees and their representatives access to process hazard analyses and to all other information required to be developed by the standard.

Employees with a working understanding of chemical processes should serve as informational resources in the development of chemical process accident prevention plans, the performance of PHAs, and the conduct of incident investigations and audits. The effectiveness of PSM programs depends on the employees' sense of ownership and accountability.

Table 4: Areas where employees can participate in PSM

▪ Development and gathering of process safety information	▪ Safety meetings
▪ Process Hazard Analysis	▪ Mechanical integrity procedure development
▪ Training	▪ Audits
▪ Management of change	▪ Incident investigation
▪ Developing and evaluating operating procedures	▪ Emergency preparedness
▪ Evaluating contractor safety performance	▪ Pre-startup safety review

Many employers, under their safety and health programs, have already established means and methods to keep employees and their representatives informed about relevant safety and health issues and employers may be able to adapt these practices and procedures to meet their obligations under this standard. Employers who have not implemented an occupational safety and health program may wish to form a safety and health committee of employees and management representatives to help the employer meet the obligations specified by this standard. These committees can become a significant ally in helping the employer to implement and maintain an effective process safety management program for all employees.

Employees operate the equipment, use the tools, and do the tasks that expose them to hazards, so it makes sense to involve them in the day-to-day effort to keep the workplace safe. In fact, you can't establish a strong safety foundation without employee involvement. The employees can participate in (US EPA, 2008):

- Developing safety policy. Employees' suggestions can help develop a new policy or improve an existing one.

- Allocating safety resources. Employees' suggestions and safety committee recommendations can help determine what resources are necessary to achieve safety goals.
- Emphasizing safety training. Employees can recommend training topics and develop training plans, suggest who should do the training, train co-workers, and evaluate training sessions.
- Identifying and controlling hazards. Employees and a management representative need to inspect the workplace frequently and document hazards; they must report new hazards to the person responsible for correcting them. Employees must maintain their equipment, keep work areas clean, and use personal protective equipment properly. Employees should also have a way to make safety suggestions.
- Evaluating the safety-and-health effort. Employees can help evaluate yearly trends in accidents and near misses, evaluate the effectiveness of emergency procedures, and review the past year's strengths and weaknesses. Using evaluation results, employees can develop goals for achieving a safer workplace.
- Membership in Safety Committee. A safety committee is one of the best ways to involve employees. It's the perfect setting for getting together and working out safety and health concerns. Employees can volunteer for the committee or be elected by their peers.

Pre-startup Safety Review

PSRs are important in MOC procedures after a process has been modified or shut down for process safety-related reasons. For new processes, the employer will find a PHA helpful in improving the design and construction of the process from a reliability and quality point of view. The safe operation of the new process will be enhanced by making use of the PHA recommendations before final installations are completed. P&IDs are to be completed along with having the operating procedures in place and the operating staff trained to run the process before startup.

The initial startup procedures and normal operating procedures need to be fully evaluated as part of the pre-startup review to assure a safe transfer into the normal operating mode for meeting the process parameters.

It is important that a safety review takes place before any highly hazardous chemical is introduced into a process. PSM, therefore, requires the employer to perform a pre-startup safety review for new facilities and for modified facilities when the modification is significant enough to require a change in the process safety information. The Pre-Start Up Safety Review shall involve employees with expertise in process operations and engineering. These employees shall be selected by employees and their representatives on the basis of their level of experience with and knowledge of the process systems being evaluated.

A qualified team should be assembled to conduct each PSR. This team, at a minimum, should include individuals with design and process safety expertise. The team must conduct a physical examination of the plant, process, or equipment that is new or modified, or that has been shut down for safety reasons. The physical examination is to verify that the plant or process was built according to design, and that all necessary safety features are included and functioning. This examination must include interviews with key personnel and reviews of documentation, such as specifications and drawings, to verify that the design criteria are met.

Pre-startup safety reviews should be conducted before commissioning a new or modified process, replacing equipment or recommissioning mothballed equipment. The review should cover both equipment and operating procedures to ensure that all elements are in place and functional. Prior to the introduction of a highly hazardous chemical to a process, the pre-startup safety review must confirm that the following:

- Construction and equipment are in accordance with design specifications;
- Safety, operating, maintenance, and emergency procedures are in place and are adequate;
- A process hazard analysis has been performed for new facilities and recommendations have been resolved or implemented before startup, and modified Facilities meet the management of change requirements; and
- Training of each employee involved in operating a process has been completed.

The level or depth of a PSR should be consistent with the level of hazard of the process or the reason for shutdown. A written action plan must be developed for each PSR. As a minimum, all plans must include the scope of the PSR, names of the PSR team members and their qualifications, the PSR objectives, the action items, and the individuals responsible for the action items.

Emergency Planning and Response

All operations should establish an emergency response plan that defines local emergency coordination teams and routines for reporting and handling emergencies. If, despite the best planning, an incident occurs, it is essential that emergency preplanning and training make employees aware of, and able to execute, proper actions. For this reason, an emergency action plan for the entire plant must be developed and implemented in accordance with the provisions of other OSHA rules. In addition, the emergency action plan must include procedures for handling small releases of hazardous chemicals. Employers covered under PSM also may be subject to the OSHA hazardous waste and emergency response regulation.

Employers at a minimum must have an emergency action plan which will facilitate the prompt evacuation of employees when an unwanted release of highly hazardous chemical. This means that the employer will have a plan that will be activated by an alarm system to alert employees when to evacuate and, that employees who are physically impaired, will have the necessary support and assistance to get them to the safe zone as well. The intent of these requirements is to alert and move employees to a safe zone quickly. Delaying alarms or confusing alarms are to be avoided. The use of process control centers or similar process buildings in the process area as safe areas is discouraged. Recent catastrophes have shown that a large life loss has occurred in these structures because of where they have been sited and because they are not necessarily designed to withstand overpressures from shockwaves resulting from explosions in the process area.

Since risk cannot be completely eliminated, plans are needed to control the residual risk of incident occurrence within acceptable limits and mitigate effects should an incident occur. It is vital to document the rationale and resolution of all recommendations. There should be a written emergency response plan containing, as a minimum:

- Emergency escape routes and evacuation procedures;
- Procedures for those required to operate critical systems;
- Procedures to account for people following an evacuation (headcount);

- Identify roll call and evacuation procedures
- Rescue and medical duties;
- Emergency reporting procedures;
- Emergency response procedures (fire suppression, spill control, etc.);
- Organizational responsibilities during an emergency
- Set the standard for testing the emergency plan
- Describe the communication procedures internally in the event of an emergency arising
- Describe the communication procedures with external resources such as the emergency services and local authorities

Each site should have a site wide alarm and/or communication system which:

- Has distinctive alarms to indicate alert, evacuate and "all clear";
- Has an easily remembered means of activation (e.g. a special telephone number);
- Is regularly tested and maintained.

If the employer wants specific employees in the release area to control or stop the minor emergency or incidental release, these actions must be planned for in advance and procedures developed and implemented. Preplanning for handling incidental releases for minor emergencies in the process area needs to be done, appropriate equipment for the hazards must be provided, and training conducted for those employees who will perform the emergency work before they respond to handle an actual release.

The employer's training program, including the Hazard Communication standard training is to address the training needs for employees who are expected to handle incidental or minor releases. Employees should be trained in the use of the emergency plan and regular drills carried out to test its effectiveness. Copies of the plan should be easily available to all employees. In addition to the minimum requirements, a good plan will contain:

- Coordination with local community fire department and/or other response personnel;

- Provisions for visitors, contractors and the handicapped;
- Designated assembly areas with alternatives if needed;
- Establishment of an emergency control centre sited in a safe area;
- Internal and external communications.

Preplanning for releases that are more serious than incidental releases is another important line of defense to be used by the employer. When a serious release of a highly hazardous chemical occurs, the employer through preplanning will have determined in advance what actions employees are to take. The evacuation of the immediate release area and other areas as necessary would be accomplished under the emergency action plan.

If the employer wishes to use plant personnel such as a fire brigade, spill control team, a hazardous materials team, or use employees to render aid to those in the immediate release area and control or mitigate the incident. Where emergencies could result in serious offsite impacts, vigilance should be maintained on land use developments in the surrounding area to ensure buffer zones are sufficient for present and potential future site activities. Plans should cover management of both the process where the emergency occurs and also other processes which interact with or are near to that process. The purpose of this step is to minimize the risks of incidents at upstream/downstream facilities and while materials are being transported between sites. This will help reduce incidents, ensure continuity of production and avoid litigation.

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