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# Process Safety Management Standard

1st Edition

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### Foreword

This standard was prepared by the Process Safety Management (PSM) Subject Division of the Canadian Society for Chemical Engineering (CSChE). It is believed that application of the Elements contained in this document will enhance the safety record for the process industries of Canada.

The PSM Guide, upon which this standard is based, was developed through the Major Industrial Accidents Council of Canada (MIACC), a voluntary alliance of interested parties dedicated to reducing the frequency and severity of major industrial accidents. From 1987 until its dissolution in 1999, this partnership included the federal, provincial and municipal governments, industry, labour, emergency response groups, public interest groups and academia. On the dissolution of MIACC, the process safety management aspects of this initiative were transferred to the new subject division of the CSChE formed for this purpose.

The material in the PSM Guide is based on the approach developed by the U.S. Center for Chemical Process Safety (CCPS). The CCPS was established in 1985 as a Directorate of the American Institute of Chemical Engineers to focus on engineering practices that will help prevent or mitigate catastrophic process safety accidents. Its dynamic program of publications, seminars, training courses and research has made CCPS a powerful voice in the international community of those committed to engineering practices that can prevent or mitigate catastrophic accidents in chemical processing.

For more information on PSM or publications available on this and related subjects, please contact:

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### Disclaimer

The proposed application of this publication is stated in the Introduction. While the information presented in this document is intended to assist users in the safe design and operation of facilities handling, using, processing or storing hazardous materials, the user is advised that neither the Canadian Society for Chemical Engineering (CSChE) nor persons involved in producing this publication warrant to represent, expressly or implicitly, the correctness or accuracy of the information presented herein. This publication is intended to be a general guidance and not advice for specific situations, nor is it to constitute a legal standard of care.

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## Introduction

*Expressions appearing in **boldface** in the text are explained in the Glossary*

This Standard identifies the requirements of a **management system** that will address the scope of issues covered by **Process Safety Management (PSM)** for facilities handling or storing potentially hazardous materials. It should be used in conjunction with the *PSM Guide*, which briefly explains the meaning of the elements and components. The approach incorporated in both the *PSM Standard* and the *PSM Guide* is based on that developed by the U.S. Center for Chemical Process Safety (CCPS), based in New York, N.Y. This approach was selected after reviewing several currently available alternatives, and was chosen because it was comprehensive; well-supported by reference materials, tools and an organizational infrastructure; and based on a benchmark of leading or good industry practice rather than on a minimum standard.

Organizations already practising PSM but using a different approach do not necessarily need to switch to the approach given here; however, they should be aware of any items that may not be addressed under their present PSM approach (e.g. human factors) and should be able to demonstrate that they have alternative measures in place that are equivalent in scope and content for proper control of those items. For more information, users should refer to the CCPS book *Guidelines for the Technical Management of Chemical Process Safety* and supporting publications. These are listed in the references given in the *PSM Guide*, which can be found on the PSM page of the Canadian Society for Chemical Engineering website ([www.cheminst.ca/PSM](http://www.cheminst.ca/PSM)).

## Purpose

The overarching purpose of this Standard is to identify the performance requirements that can be audited by an organization or a third party to recognize and address gaps that may exist in the overall management system. This Standard identifies the various policies, practices and procedures that will help to ensure the organization achieves the desired results; however, it is not the intent of this Standard to lay out prescriptive solutions that will meet the needs of every organization. Each facility is unique and the user of this Standard will find that a particular policy, practice or procedure that is effective at one site may need to be modified or rewritten for it to be fully effective at another site.

## Scope

PSM is the application of management principles and systems to the identification, understanding and control of process hazards to prevent process-related injuries and incidents. This Standard defines the minimum requirements that must be in place to ensure deficiencies are adequately addressed. Such deficiencies can lead to unacceptable risks to safety, health and the environment or losses of assets and/or production. An organization could include the minimum requirements in an integrated health, safety, environmental and risk management program or in a stand-alone PSM program that will be effective in preventing incidents at facilities that manufacture, store, handle or otherwise use potentially hazardous materials.

The PSM system originally suggested by CCPS consists of 12 elements. These elements are shown in Table 1 and are intended to work in conjunction with traditional occupational health and safety programs and applicable federal/provincial/territorial legislation or municipal regulations. A complete framework of PSM elements is recommended for each facility even though some elements or components of PSM may be less applicable to some facilities than to others, depending on the nature and degree of potential hazards involved. A facility should evaluate the applicability of each item before assuming that it does not apply.

**Table 1: Elements and Components of PSM<sup>1</sup>**

**1. Accountability: Objectives and Goals**

Continuity of operations  
Continuity of systems  
Continuity of organization  
Quality process  
Control of exceptions  
Alternative methods  
Management accessibility  
Communications  
Company expectations

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Protective systems  
Normal and upset conditions  
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Reduction of risk  
Residual risk management  
Process management during emergencies  
Encouraging client and supplier companies to adopt similar risk management practices  
Selection of businesses with acceptable risk

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Design of operating and maintenance procedures  
Initial qualifications assessment  
Selection and development of training programs  
Measuring performance and effectiveness  
Instructor program  
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Ongoing performance and refresher training

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Major incidents  
Third party participation  
Follow-up and resolution  
Communication  
Incident recording, reporting and analysis  
Near-miss reporting

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External codes/regulations  
Internal standards

**11. Audits and Corrective Actions**

PSM systems audits  
Process safety audits  
Compliance reviews  
Internal/external auditors  
Corrective actions

**12. Enhancement of Process Safety Knowledge**

Quality control programs and process safety  
Professional and trade association programs  
Technical association programs  
Research, development, documentation and implementation  
Improved predictive system  
Process safety resource centre and reference library

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<sup>1</sup> The PSM system described here was originally developed by the CCPS of the American Institute of Chemical Engineers (AIChE). This material is copyright 1989 by the AIChE and is reproduced by permission of the CCPS. In 2007 the CCPS moved from the twelve-element system to a risk-based approach using a different set of categories from those shown in this framework, as facilities in the U.S. were generally familiar with PSM due to regulation by the Occupational Safety and Health Administration (OSHA) and various state authorities; however, the CSE PSM Division decided to retain the original CCPS system for use in Canada, where PSM is not regulated, as it is more self-explanatory for site operators who may be unfamiliar with what PSM comprises.

## **ELEMENT 1 - ACCOUNTABILITY: OBJECTIVES AND GOALS**

### **A. INTRODUCTION**

Leadership commitment at all levels of an organization is key to achieving excellence in PSM and establishing the process safety culture. Management must be visible and must demonstrate this commitment in the activities undertaken. Their commitment must be unequivocal and leave no doubt as to their expectations.

### **B. REQUIRED ELEMENTS**

Each company/business/facility shall:

- a) Establish process safety goals and objectives;
- b) Ensure that process safety goals and objectives, which address worker, public, environmental and financial risks, are visible to and understood by all relevant employees;
- c) Establish company objectives that demonstrate the priority of process safety compared to other business objectives like production and cost;
- d) Clearly identify accountability for process safety in roles, responsibilities, and position descriptions;
- e) Ensure that appropriate resources are available to meet the process safety goals and objectives; and
- f) Identify expected results that demonstrate management commitment to process safety at all levels of the organization (e.g. a directive that states uncontrolled process fires must be eliminated).

#### **1.1 Continuity of operations**

Each business/facility shall establish:

- a) A policy that makes it clear when operations personnel have the authority to shut down operational units or a facility if they are concerned that it may be unsafe to operate;
- b) Procedures or guidelines to help personnel determine when operational units or the facility should be shut down or output should be reduced for planned or unplanned maintenance or modifications;
- c) A system to identify the need for spare and redundant equipment at the design stages of a project so the facility can reduce the need for a complete shutdown;
- d) A system to identify when to segregate parts of a facility so that small sections of the facility can be shut down without shutting down the complete operation; and
- e) A system to identify when there is a need to install multiple lines rather than rely on single stream operation.

#### **1.2 Continuity of systems**

Each business/facility shall establish a system to:

- a) Ensure that resources are allocated based on the process hazards and risks rather than just by the economic viability of the process; and
- b) Allocate adequate resourcing of supporting job functions or units for each phase of the life cycle of the process.

#### **1.3 Continuity of organization**

Each business/facility shall:

- a) Clearly define PSM responsibilities as part of position or job descriptions;
- b) Establish a system to ensure that PSM responsibilities are maintained during changes in organizational structure; and
- c) Ensure accountability for PSM is flexible enough to accommodate organizational changes while ensuring that process safety tasks are properly assigned and performed throughout the change.

#### **1.4 Quality process**

Each business/facility shall:

- a) Ensure that employees understand the scope of issues involved in PSM;
- b) Maintain monitoring programs to track the status of process safety;
- c) Establish goals, targets and **key performance indicators** (KPI) for measuring process safety performance;
- d) Ensure that guidance is in place to address deviation from this performance; and
- e) Establish a quality assurance system for all aspects of work that includes checking, verification, validation, documentation and configuration management, as appropriate.

#### **1.5 Control of exceptions**

Each business/facility shall ensure a system is in place to deal with situations that are outside the defined elements of the existing management systems, and to manage exceptions with appropriate controls, by assigning accountability to qualified personnel, in the following areas:

- a) Engineering designs;
- b) Construction, commissioning and decommissioning of facilities;
- c) Operating procedures;
- d) Maintenance practices and procedures;
- e) Purchasing practices and procedures; and
- f) Qualifications of operating personnel.

#### **1.6 Alternative methods**

Each business/facility shall:

- a) Establish a system to ensure accountability and responsibility are assigned when practices and procedures are implemented in compliance with performance standards. (Performance-based standards are those which identify desired outcomes without specifying the methods to be used.); and
- b) Establish a system to ensure, in an instance where more than one method is available for a given task (e.g. process hazard reviews), the method selected is effective in completing the task.

#### **1.7 Management accessibility**

Each business/facility shall:

- a) Establish a system to ensure management is available to assist in the decision-making process; and
- b) Ensure leadership is available to resolve conflicting views among safety, engineering, maintenance, production and business managers.

#### **1.8 Communications**

Each business/facility shall ensure:

- a) Senior management communicates their understanding of process safety accountability for their area of responsibility and individuals within it; and

- b) Overlapping responsibilities between individuals/areas are clearly defined and communicated so that no gaps or conflicts exist.

### **1.9 Company expectations**

Each company shall ensure:

- a) That the Board of Directors and the executive management team communicate their expectations regarding process safety performance;
- b) That the process safety goals are consistent with other aspects of the organizational vision or strategic plan;
- c) Broad process safety goals are established by management;
- d) A system is in place to measure process safety performance and take the required action;
- e) Process safety goals address the long-term aims of the company as well as detailed short-term targets; and
- f) Adequate resources are available to achieve the process safety goals.

### **C. RECOMMENDED GUIDELINES**

#### **Control of exceptions**

- 1. Each business/facility should identify the minimum operating complement and ensure there are appropriate controls in place to deal with situations where the minimum operating complement is not met.

#### **Management accessibility**

- 2. Each business/facility should ensure there is a system in place for conflict resolution on issues that include process safety.

#### **Company expectations**

- 3. Each business/facility should establish key leading and lagging indicators to measure process safety performance (e.g. Process safety-related incidents should be included as a lagging metric.).
- 4. Each company/business/facility should benchmark their organization to ensure the best practices are being employed.

## **ELEMENT 2 - PROCESS KNOWLEDGE AND DOCUMENTATION**

### **A. INTRODUCTION**

Safe operation depends on individuals working in the facility having the knowledge to address planned and unplanned changes that may occur. Those individuals require a full understanding of the material properties, the equipment design and the safeguards that have been provided in the facility. A proper system for documenting this information is required to ensure the knowledge is maintained as the facility matures and changes.

### **REQUIRED ELEMENTS**

1. Each business/facility shall:

- a) Ensure the information necessary for the safe design, operation, maintenance and decommissioning of the facility is written, reliable, current and easily accessible by people who need to use it; and
- b) Identify the specific location(s) where such information for the facility is stored.

### **2.1 Chemical and occupational health hazards**

2. Each business/facility shall ensure:

- a) **Material Safety Data Sheets** (MSDS) or equivalent for every potentially hazardous material used, stored or produced at the site are available and kept current; and
- b) Information on the reactivity and the chemical and physical properties of all materials, including process and utility streams and materials of construction, is readily available for those involved in:
  - i. Process development and design; and
  - ii. Operation and maintenance of the facility.

Note: These information requirements may not be the same for both groups.

### **2.2 Process definition/design criteria**

3. Each facility shall have up-to-date and available:

- a) Process flow diagrams;
- b) Data on relevant operating envelopes and safe operating limits (e.g. levels, temperatures, pressures, flows, time, cycles and compositions);
- c) Data for evaluation of the effects of operating outside the safe upper and lower limits on health, safety and the environment;
- d) Data on process chemistry including process stability and chemistry of side reactions, by-products and contaminants;
- e) Specifications on the maximum intended inventory; and
- f) Material and energy balances.

### **2.3 Process and equipment design**

4. Each facility shall have up-to-date and available:

- a) Piping and instrumentation diagrams (P&IDs);
- b) Data regarding materials of construction and their suitability in handling process materials;
- c) Data regarding process control systems, including software integrity;
- d) Data regarding ventilation system design;
- e) Data regarding critical alarms and systems;
- f) Data regarding design codes and standards employed;
- g) Electrical area classification drawings; and



h) Plot plan.

## **2.4 Protective systems**

5. Each facility shall have up-to-date and available data regarding:

- a) **Critical interlocks;**
- b) Pressure relief and venting systems;
- c) Relief system design and design basis;
- d) Fire detection and protection equipment;
- e) Emergency isolation valves; and
- f) Effluent treatment systems (e.g. scrubbers, quench tank).

## **2.5 Normal and upset conditions (operating procedures)**

6. Each facility shall ensure:

- a) Operating procedures are in place and readily accessible to workers involved with the process;
- b) There is a system for regularly verifying that procedures are current and accurate;
- c) There is a system for updating procedures to incorporate changes in operating practice including changes of process chemistry, technology, equipment, facilities or organization;
- d) Operating procedures address steps for each operating phase, including:
  - i. Initial start up of a new facility;
  - ii. Normal and temporary operations;
  - iii. Emergency shutdown, including identification of conditions which require shutdown;
  - iv. Normal shutdown; and
  - v. Start-up following an emergency or normal shutdown.
- e) Operating procedures address steps required to correct or avoid a deviation beyond operating limits; and
- f) Operating procedures address safety systems and their functions.

## **2.6 Process risk management decisions**

7. Each company/business/facility shall ensure:

- a) There is a system for making risk management decisions on an ongoing basis; and
- b) Risk management decisions are documented, showing the decisions made and the basis on which they were made.

## **2.7 Company memory (management of information)**

8. Each company/business/facility shall ensure:

- a) There is a system to document knowledge and information gained from plant experience that is likely to be important for future safety of the facility; and
- b) Information is sufficiently catalogued and detailed so that it is not overlooked or forgotten as personnel or the organization change.

## **B. RECOMMENDED GUIDELINES**

1. There should be a storage mechanism that allows easy retrieval of the process safety risks and supports evaluation of the adequacy of the safeguards associated with the process.

## **ELEMENT 3 - CAPITAL PROJECT REVIEW AND DESIGN PROCEDURES**

### **A. INTRODUCTION**

Capital projects are used to establish new facilities and make modifications to existing facilities. Projects are the source of the greatest changes that will occur at a site and must be managed appropriately to avoid introducing new or unknown hazards into the facility. Capital projects must be controlled through adequate procedures and must be subjected to design and hazard reviews at each stage of the project.

### **B. REQUIRED ELEMENTS**

#### **3.1 Appropriation request procedures**

1. Each company/business/facility shall ensure:
  - a) The request for approval for capital projects requires the requestor to identify potential risks associated with the project and to identify the capital and other resources necessary to manage those risks; and
  - b) The approval system requires process safety reviews to have been satisfactorily completed at appropriate stages in the design, construction and start-up of the project in order for the project to proceed to the next stage.

#### **3.2 Hazard reviews**

2. Each business/facility shall ensure:
  - a) Process hazard reviews are completed to ensure risks associated with hazardous material and energy have been identified and the residual risk is acceptable;
  - b) Adequate capital and other resources are made available to minimize exposure of workers, the public and the environment to the effects of hazardous materials and energy associated with the process;
  - c) The scale of the review is adjusted dependent upon the potential hazards of the proposed process and the stage of the project; and
  - d) More intensive review techniques are carried out as the design proceeds and additional information becomes available.

#### **3.3 Siting**

3. Each business/facility shall ensure the siting of a proposed expansion or new plant considers:
  - a) Buffer zones between the plant and the public;
  - b) **Worst credible scenarios** for release of toxic chemicals, explosion or fire and the effect(s) on exposed groups;
  - c) The exposure hazard to and from other plants or facilities in the area;
  - d) Possible exposures due to natural events such as earthquake, flood, tornado, hurricane, subsidence, etc.;
  - e) Effects of transportation of hazardous material feedstocks or products through local communities; and
  - f) Miscellaneous location information such as altitude, distance from the sea or ocean, land topography and meteorological conditions (e.g. direction and velocity of prevailing winds).

#### **3.4 Plot plan**

4. Each business/facility shall ensure the plot plan review of a proposed expansion or new plant specifically considers:
  - a) Congestion (e.g. overlapping hazard zones, difficult access, possible confinement of a vapour release, etc.);
  - b) Location of control rooms, offices and other permanent and temporary buildings;

- c) Location of storage areas (e.g. tank farms, warehousing);
- d) Location of loading and unloading areas;
- e) Layout of drainage and location of containment areas;
- f) Proximity to hazards from other process areas;
- g) Proximity to public receptors beyond the site boundary;
- h) Insurance requirements;
- i) Federal, provincial and local regulations; and
- j) Company/industry spacing guidelines.

### **3.5 Process design and review procedures**

5. Each business/facility shall ensure the design process includes a system for review and approval, with appropriate sign off, at each stage of the design process, including:

- a) Conceptual design;
- b) Process design;
- c) Detailed engineering design;
- d) Construction; and
- e) Commissioning.

6. Each business/facility shall ensure the depth of each review is dependent upon the complexity and degree of hazard of the process.

### **3.6 Project management procedures and controls**

7. Each business/facility shall have controls in place to ensure fabrication and installation of equipment corresponds to design intentions and specifications.

8. Each business/facility shall ensure a pre-startup safety review is completed before new or modified facilities are put into service.

9. The pre-startup safety review shall:

- a) Confirm that construction meets design specifications;
- b) Ensure safety, operating, maintenance, and emergency procedures are in place and adequate;
- c) Confirm that a process hazard analysis has been done and that recommendations have been resolved or implemented prior to start up;
- d) Confirm that modified facilities meet the management of change requirements;
- e) Ensure worker training has been completed; and
- f) Ensure critical equipment has been identified and incorporated into a preventative maintenance program.

10. Each business/facility shall ensure project management controls are documented and form part of the project file.

### **C. RECOMMENDED GUIDELINES**

There are no recommended guidelines for this element.

## **ELEMENT 4 - PROCESS RISK MANAGEMENT**

### **A. INTRODUCTION**

Every operating facility contains situations that present risk to workers, the public and the environment. To ensure safe operation of the facility, the hazards that give rise to these risks must be identified and mitigated, as necessary. These reviews must be ongoing since a facility is continuously changing as it operates. A process risk management program is an effective way to address these changes and manage the residual risks.

### **B. REQUIRED ELEMENTS**

#### **4.1 Hazard identification**

1. Each business/facility shall have:
  - a) A practice in place to identify hazards associated with operation and maintenance of the facility;
  - b) Access to practitioners who are trained in hazard identification methods such as **What If, Checklist, HAZOP, LOPA, Bow-Tie Analysis, FMEA or Fault Tree Analysis**; and
  - c) A system in place to ensure hazards that have been identified are addressed by emergency response plans.

#### **4.2 Risk analysis of operations**

2. Each business/facility shall have an established system to estimate the risks once hazards have been identified.

#### **4.3 Reduction of risk**

3. Each business/facility shall have a system in place to reduce those risks that are deemed unacceptable.

#### **4.4 Residual risk management**

4. Each business/facility shall have a documented emergency response plan to manage residual risks and mitigate the effects should an incident occur.
5. The emergency response plan shall identify an emergency control centre sited in a safe location.
6. The emergency response plan shall contain:
  - a) Emergency reporting procedures;
  - b) A list of designated assembly areas with alternatives, if needed;
  - c) Emergency escape routes and evacuation procedures;
  - d) Procedures to account for people following an evacuation (headcount);
  - e) Emergency response procedures (fire suppression, spill control, etc.);
  - f) Rescue and medical duties;
  - g) Organizational responsibilities during an emergency;
  - h) Provisions for visitors, contractors and handicapped persons;
  - i) Information regarding coordination with the local community, the fire department and other response personnel;
  - j) Procedures for workers who are required to operate critical systems;
  - k) Requirements for internal and external communications;
  - l) Required response equipment/location; and
  - m) Notification of affected public.

7. Each facility shall have a site-wide alarm and/or communication system that:
  - a) Has distinctive alarms to indicate **Alert, Evacuate** and **All Clear**;
  - b) Has an easily remembered means of activation (e.g. a special telephone number); and
  - c) Is regularly tested and maintained.
8. Company employees shall be trained in the application of the emergency response plan.
9. Regular drills shall be carried out to test the effectiveness of the emergency response plan.
10. Copies of the emergency response plan shall be readily available to all workers.

#### **4.5 Process management during emergencies**

11. Each facility shall have written emergency operating procedures to cover both the process where the emergency occurs and other processes that interact with or are near that process.

#### **4.6 Encouraging client and supplier companies to adopt similar risk management practices**

12. Each business/facility shall have a system in place to encourage client and supplier companies to adopt risk management practices that will address the risk of incidents at upstream and downstream facilities and while materials are being transported between sites.

#### **4.7 Selection of businesses with acceptable risk**

13. The company shall have a system in place to assess and deal with risks for new businesses or acquisitions.

### **C. RECOMMENDED GUIDELINES**

#### **Hazard identification**

1. Each business/facility should have access to practitioners who are trained in application of the **Dow Fire and Explosion Index**, the **Dow Chemical Exposure Index**, or other appropriate hazard identification and prioritization methodologies.

#### **Risk analysis of operations**

2. Each business/facility should:
  - a) Estimate risk based on the combination of potential consequences and the likelihood of occurrence, using qualitative and/or quantitative methods such as Fault Tree Analysis, **Event Tree Analysis, Risk Indices**, etc.; and
  - b) Evaluate the total risk by comparing against established risk acceptability criteria.

#### **Reduction of risk**

3. Each business/facility should employ a range of risk reduction methodologies. These include protective equipment, improved training and procedures as well as **Inherently Safe Design** principles, such as inventory reduction, alternative processes and alternative materials.

#### **Residual risk management**

4. Each business/facility should consult with those who may face risks resulting from process operations (e.g. workers, community).
5. Each business/facility should post critical portions of the emergency response plan in conspicuous locations throughout the facility along with a diagram detailing emergency evacuation routes.
6. The emergency response plan should:
  - a) Comply with any applicable regulations under Section 200 of the Canadian Environmental Protection Act (CEPA);
  - b) Contain possible mutual aid arrangements, where necessary; and
  - c) Include contingency and recovery plans.

## **ELEMENT 5 - MANAGEMENT OF CHANGE**

### **A. INTRODUCTION**

Process safety is achieved by effectively managing changes in people, equipment and technology. These changes are often well understood and planned, especially when the change involves alterations to the pressure envelope of a facility or the systems that affect the pressure-containing components, such as storage, utilities and distribution facilities. The best way to manage these planned changes is through a Management of Change system that identifies the specific items that must be in place when making changes that can affect process safety and implementing the procedures associated with the system every time a change is made. By following a Management of Change system, the integrity of the process can be maintained at the same level as when the facility and its organization were established.

### **B. REQUIRED ELEMENTS**

1. Each business/facility shall have a system in place to manage all hardware and software changes to the facility, except replacement in kind.
2. The Management of Change system shall clearly define what constitutes a change.
3. Management of Change documentation shall include:
  - a) A description of the change that is being proposed (scope of application);
  - b) The technical basis for the proposed change;
  - c) The risks to and potential impacts on health, safety and environment arising from the proposed change;
  - d) Authorization or approval to make the change;
  - e) The training requirements for employees or contractors due to the change; and
  - f) Updating of documentation including drawings, process safety information, operating procedures, maintenance procedures, alarm and interlock settings and fire protection systems.

#### **Change of Process Technology**

4. Each facility shall ensure:
  - a) Critical operating parameters or safe operating limits are readily available to operations personnel; and
  - b) Operation outside defined operating limits is subject to prior review and approval by qualified personnel.
5. The Management of Change system shall address the means to contact personnel if authorization of a change in process technology is needed on short notice.

#### **Change of facility**

6. The Management of Change system shall:
  - a) Define facility changes that are not replacement in kind;
  - b) Address major equipment changes through the **Capital Project Review and Design** system;
  - c) Address smaller changes and minor changes, such as cross connections or instrumentation changes;
  - d) Require an assessment of hazards and risks associated with the change;
  - e) Require approval by qualified personnel; and
  - f) Address contingencies for “emergency” changes.

### **Organizational changes**

7. Each company/business/facility shall have a process in place to assess and deal with risks associated with changes to the organization and the organizational structure.
8. The Management of Organizational Change system shall:
  - a) Address the transition period as well as the way the new organization is to work;
  - b) Address change in reporting relationships even where no staff losses occur;
  - c) Address the need for transfer and retention of knowledge and skills due to departure of staff, and especially elimination of organizational units (e.g. through downsizing);
  - d) Ensure accountability and safe control of operations continues despite the loss of key knowledge and skills; and
  - e) Ensure the workload consequent to any staff reductions does not result in unacceptable short or long term increases in risk.

### **Variance procedures**

9. The facility shall have a system in place to ensure exceptions to procedures are managed promptly and the situation remains under control.
10. Variance procedures shall require review and approval by qualified personnel.
11. The system for control of variance shall ensure all involved understand the basis for the approval and the new limits established for the variance.

### **Permanent changes**

12. The facility shall ensure permanent changes are subjected to the usual steps of planning, organizing, implementation and control in conjunction with other programs such as the systems for work orders, purchase orders, Capital Project Review and Design, etc.
13. The facility shall ensure risk management is included as part of the system for dealing with permanent changes.

### **Temporary changes**

14. The facility shall subject temporary changes to reviews that are similar to those that apply to permanent changes.
15. The Management of Change system shall require:
  - a) That the time limit for a temporary change to be clearly defined;
  - b) A system for review and approval if an extension of the time limit is required; and
  - c) A plan to ensure all equipment is returned safely to normal conditions at the end of the temporary change.

## **C. RECOMMENDED GUIDELINES**

### **Variance procedures**

1. Variance procedures should be easy to use and include the appropriate levels of approval.

## **ELEMENT 6 - PROCESS AND EQUIPMENT INTEGRITY**

### **A. INTRODUCTION**

During the life of a facility, equipment is subjected to wear to varying degrees. In some cases, this equipment is necessary to ensure the safe and reliable operation of the facility. To reduce the chance of premature failure, the state of equipment must be monitored and, if necessary, corrected, or the equipment replaced. This is accomplished through a predictive and preventative maintenance program that is well designed and properly implemented.

### **B. REQUIRED ELEMENTS**

1. Each facility shall have written procedures to maintain the ongoing integrity of process equipment including:
  - a) Pressure vessels and storage tanks;
  - b) Piping, instrument and electrical systems;
  - c) Process control software;
  - d) Relief and vent systems and devices;
  - e) Emergency and fire protection systems;
  - f) Controls including monitoring devices, sensors, alarms and interlocks;
  - g) Power transformers, elevating devices, cranes (including overhead type gantry units); and
  - h) Rotating and hydraulic equipment.
2. A file shall be maintained for each piece of equipment.

#### **Reliability engineering**

3. Each facility shall:
  - a) Identify equipment that is critical for process safety; and
  - b) Establish predictive maintenance schedules for monitoring, inspection and performance testing of equipment critical to process safety to enable cost effective correction of problems before they develop to the critical stage.

#### **Materials of construction**

4. Each business/facility shall:
  - a) Establish, where appropriate, systems such as design standards for piping and pressure vessels to supplement industry standards; and
  - b) Identify critical items that may need special tracking to verify materials used are as specified.

#### **Fabrication and inspection procedures**

5. Each business/facility shall establish a quality assurance program, which includes a materials control system that ensures installed equipment:
  - a) Meets the requirements of the design specifications;
  - b) Is traceable to its manufacturer;
  - c) Has met all required testing, with test results available for review if needed; and
  - d) Is labelled so it is clearly identifiable to those doing the installation.

#### **Installation procedures**

6. Each business/facility shall ensure:
  - a) Critical steps in the installation of equipment are identified during the planning stage of a change to the facility; and
  - b) Field inspection is used to verify that installation corresponds to design.



## **Preventative maintenance**

7. Each facility shall establish a preventative maintenance (PM) program that includes:
  - a) A method of identifying critical equipment;
  - b) A method to establish PM frequencies for critical equipment;
  - c) A mechanism to ensure PM is completed at the specified frequency; and
  - d) A record of the previous items.

## **Process, hardware and systems inspection and testing**

8. Each facility shall ensure a pre-startup safety review is conducted before starting up a new or modified process.
9. The pre-startup safety review shall cover both equipment and operating procedures to ensure all elements are in place and functional.
10. Each facility shall ensure inspection and testing of process equipment is:
  - a) According to good engineering practices; and
  - b) At a frequency determined by applicable codes and standards, or more frequently if operating experience suggests it is necessary.
11. Inspection and testing of process equipment shall incorporate:
  - a) A system to ensure corrective action is taken when results fall outside acceptable limits;
  - b) Documentation that includes:
    - i. Date of inspection;
    - ii. Name of inspector;
    - iii. Serial number or other equipment identifier;
    - iv. Description of the tests done;
    - v. Results of the inspection or test; and
    - vi. Recommended action(s).

## **Maintenance procedures**

12. Each facility shall have safe work practices, which apply to both employees and contractors, for proper control of maintenance, construction and related activities.
13. As a minimum, safe work practices shall cover:
  - a) Permits to work and their application (hot work, confined space entry, lock out/tag out, excavation, master tag, etc.);
  - b) Opening of process lines and equipment; and
  - c) Control of access to the facility by maintenance, contractor, laboratory and other personnel, and vehicles.
14. Each facility shall ensure:
  - a) Maintenance procedures are in place and readily accessible to workers;
  - b) There is a system for regularly verifying that procedures are current and accurate; and
  - c) There is a system for updating procedures to incorporate changes in maintenance practice.

## **Alarm and instrument management**

15. Each facility shall have safe work practices for proper alarm and instrument management that includes not only equipment hardware but also computer components and software instructions for process control.
16. As a minimum, alarm and instrument management programs shall cover:
  - a) Identification and prioritization of critical alarms and interlocks;

- b) A procedure to control changes to alarm set points and interlock systems; and
- c) A system of regular testing of interlock systems and pressure safety valves.

**Decommissioning and demolition procedures**

17. Each facility shall have procedures in place to address safe removal of equipment from service, dismantling, decontamination and related disposal of waste.

**C. RECOMMENDED GUIDELINES**

- 1. Each facility should ensure a pre-start-up safety review is conducted before starting up replacement equipment or recommissioning mothballed equipment.
- 2. Each facility should establish baseline conditions for equipment and piping.

## **ELEMENT 7 - HUMAN FACTORS**

### **A. INTRODUCTION**

Human beings play a major role in all aspects of design, construction, operation and maintenance of a facility. During each of these phases human errors will occur and must be addressed. “Human factors” is the term given to a wide range of human activity; however, the ultimate goal of human factors studies is to manage human error so the risk to people, property and the environment remains acceptable.

### **B. REQUIRED ELEMENTS**

#### **Operator-process/equipment interface**

1. Each company/business/facility shall have a system in place to address human factors at the design, construction and operational phases of a project.
2. Each business/facility shall assess human interactions with the facility as part of the design process.
3. Human factors assessment shall address computerized control systems that can confront operators with unmanageable amounts of information during an upset condition (alarm management).
4. The human factors assessment system shall examine the following interfaces for potential problems:
  - a) Alarm display;
  - b) Information display; and
  - c) Ergonomics.
5. Each facility shall conduct task analyses to determine what can go wrong during a task, how it can be reversed through human recovery and, failing that, how the potential problem areas can be controlled.

#### **Administrative control versus engineering control**

6. Each business/facility shall have a strategy with respect to the use of administrative versus engineering controls.

#### **Human error assessment**

7. Each facility shall assess the potential for human errors throughout the facility lifecycle including design, construction, commissioning, operation and maintenance.
8. Each business/facility shall have access to competent resources for human error assessment.
9. Human factor reviews shall consider approaches to reducing human error that include:
  - a) Written guidelines and procedures;
  - b) Human factor audits;
  - c) Written communications; and
  - d) Design of operator-process/equipment interface.

### **C. RECOMMENDED GUIDELINES**

#### **Operator-process/equipment interface**

1. Human factors assessment should address confusing equipment, positioning of dials, colour coding, different directions for on/off, cultural norms, labelling, etc.

### **Administrative control versus engineering control**

2. When administrative controls are implemented in preference to engineering controls, the facility should have a system to review the effectiveness of the administrative controls at a future date to ensure they remain effective.

### **Human error assessment**

3. Human error reviews shall include factors such as understanding, judgment, motivation, education, training, stress, fatigue and cognition.

## **ELEMENT 8 - TRAINING & PERFORMANCE**

### **A. INTRODUCTION**

Personnel at a facility must possess the necessary qualifications and skills to perform their functions and tasks effectively. Qualifications begin with the hiring system and continue through orientation, job-specific training and on-going education. Prior to being entrusted to take on an independent role, the employee must prove to be competent to perform the job functions associated with the role. In this way, the facility will ensure the risk associated with operation and maintenance of the facility will be adequately managed.

### **B. REQUIRED ELEMENTS**

1. Each company/business/facility shall have a system in place to ensure employees receive the necessary education and training to develop the understanding and skills required to do the job.
2. The training program shall include ongoing retraining to maintain these skills.

#### **Definition of skills and knowledge**

3. Each company/business/facility shall:
  - a) Identify key functions and document their required skills, knowledge and abilities; and
  - b) Provide training to ensure those doing the jobs are competent.

#### **Design of operating and maintenance procedures**

4. Each facility shall:
  - a) Have a standard system or procedure for developing job procedures, including job descriptions and job safety analysis; and
  - b) Use operating and maintenance procedures as the basis for developing training programs.

#### **Initial qualifications assessment**

5. Each business/facility shall specify qualification, testing and evaluation requirements to ensure prospective employees have the aptitude and base knowledge/skills which, with appropriate training, will enable them to do the job.

#### **Selection and development of training programs**

6. Each business/facility shall require that employees and contractors be trained to understand and use site safety systems. In particular, the following items shall be included:
  - a) General safety rules;
  - b) Permit to work procedures;
  - c) Use of personal protective equipment;
  - d) Emergency procedures;
  - e) Specific hazards of the area in which they will be working; and
  - f) Specific hazards of the materials which they may encounter.
7. An evaluation of competency shall be administered to employees and contractors to ensure the information given has been understood.

#### **Measuring performance and effectiveness**

8. Each business/facility shall utilize a method of evaluation or other verification to ensure the training is understood to a level consistent with doing a job safely.

### **Instructor program**

9. Each business/facility shall identify, as part of the training program:
  - a) Specific criteria to be used for instructor selection; and
  - b) Instructor training to ensure instructors have sufficient teaching/communications skills as well as the necessary technical knowledge.

### **Records management**

10. Each business/facility shall maintain a record of training received by each person in each task.
11. Training records shall include the name of the trainer, the date of the training and the results of the competency verification.
12. Training documents shall be used to track training received and to schedule retraining.

### **Ongoing performance and refresher training**

13. Each business/facility shall include refresher training in the training program to ensure skills/personnel remain current and at a level consistent with the safe operation of facilities.

### **C. RECOMMENDED GUIDELINES**

There are no recommended guidelines for this element.

## **ELEMENT 9 - INCIDENT INVESTIGATION**

### **A. INTRODUCTION**

The goal of PSM is to effectively manage changes in people, equipment and technology. On occasion, the systems that are put in place are insufficient to prevent an incident from occurring. In situations such as these, it is important that the incident be thoroughly investigated so that a recurrence can be prevented. By sharing the lessons of the incident with other facilities, it may be possible to assist those facilities from experiencing a similar incident.

### **B. REQUIRED ELEMENTS**

1. Each company/business/facility shall have a program in place to investigate incidents and near misses/abnormal events.

#### **Major incidents**

2. The incident investigation system shall include:
  - a) A clear definition of what is meant by “major incident”;
  - b) Investigation of every actual or potential process-related incident;
  - c) Procedures for completing an investigation;
  - d) Prompt investigation by a competent person having the knowledge, skill and experience to effectively lead and/or conduct the investigation and at least one person knowledgeable in the process where the incident occurred; and
  - e) A report to management following the investigation stating:
    - i. Incident date;
    - ii. Incident description;
    - iii. Factors which contributed to the incident; and
    - iv. Recommendations to prevent recurrence.

#### **Third party participation**

3. The incident investigation system shall identify when personnel external to the organization need to be included in the investigation.

#### **Follow-up and resolution**

4. The incident investigation system shall include a follow-up system to address the recommendations made in the report and ensure timely implementation of corrective actions.

#### **Communication**

5. Key results of investigations shall be shared with other parts of the facility, the organization, the process industry and other industries where the lessons learned could usefully be applied.

#### **Incident recording, reporting and analysis**

6. The company shall maintain a system to analyze incident reports to identify opportunities for elimination of commonly recurring or systemic causes.

#### **Near-miss reporting**

7. Near-misses and abnormal events shall be recorded and analyzed as part of the incident investigation system.

## **C. RECOMMENDED GUIDELINES**

### **Major incidents**

1. For all but small facilities the investigation shall be by a team.
2. At least one person in any team conducting an incident investigation shall be trained in incident investigation, with emphasis on root cause analysis. This may be waived where the investigation is conducted by a qualified/subject matter expert third party.



## **ELEMENT 10 - COMPANY STANDARDS, CODES AND REGULATIONS**

### **A. INTRODUCTION**

Company standards and external codes and regulations are generally developed as a result of safety-related incidents that have occurred within the industry. For example, pressure vessel design codes were developed to prevent vessels rupturing prematurely due to improper design, construction or maintenance. Complying with such guidance reduces the likelihood of similar incidents in future. However, to make the best use of these references they must be current and readily accessible to those who are expected to consult them.

### **B. REQUIRED ELEMENTS**

1. Each company/business/facility shall have a management system in place to ensure the various internal standards and guidelines and external standards, codes and regulations are current, disseminated to appropriate people and departments, and applied throughout the organization.

#### **External codes/regulations**

2. Each company/business/facility shall have a system in place to monitor and respond to changes in the applicable legislative and regulatory framework including:
  - a) Environmental regulations;
  - b) Occupational health and safety regulations;
  - c) Planning and zoning regulations;
  - d) Boiler and pressure vessel codes;
  - e) Electrical and building codes; and
  - f) Fire codes.
3. Each company/business/facility shall have a system in place to monitor and respond to changes in external standards including:
  - a) Industry-wide standards such as those published by the Canadian Standards Association (CSA), the American Petroleum Institute (API), the American Society of Mechanical Engineers (ASME), the American Society for Testing and Materials (ASTM) and the American National Standards Institute (ANSI);
  - b) Professional technical bodies such as the Center for Chemical Process Safety (CCPS), the American Institute of Chemical Engineers (AIChE), design groups (e.g. Design Institute for Emergency Relief Systems), Canadian Society for Chemical Engineering (CSChE), and the Chlorine Institute; and
  - c) National and international codes, such as those published by the National Fire Protection Association (NFPA), and the International Labour Organization (ILO).

#### **Internal standards**

4. Each company/business/facility shall have a system in place to monitor and respond to changes in internal standards and guidelines including:
  - a) General standards (e.g. maintenance practices, hot work or inspections);
  - b) Reporting procedures (e.g. incident reporting and equipment monitoring data);
  - c) Behaviour in facilities (e.g. smoking and driving);
  - d) Specific process standards (e.g. chemistry, process design principles and metallurgy); and
  - e) Mechanical, electrical, civil and instrumentation design standards.

### **C. RECOMMENDED GUIDELINES**

There are no recommended guidelines for this element.

## **ELEMENT: 11. AUDITS AND CORRECTIVE ACTIONS**

### **A. INTRODUCTION**

Management systems are the key to ensuring process safety programs are properly designed, implemented and maintained. Over time, it is possible for management systems to degrade or even fall into disuse. A management system audit program that includes regular follow-up on outstanding action items will ensure process safety continues to be managed effectively.

### **B. REQUIRED ELEMENTS**

1. Each company/business/facility shall have an audit program in place to assess the status and effectiveness of PSM efforts and the progress toward achieving identified goals.

#### **PSM systems audits**

2. Management systems audits shall:
  - a) Verify that the systems are effective in assuring business/facility policies, standards and procedures are being implemented; and
  - b) Identify opportunities where systems may be strengthened.

#### **Process safety audits**

3. Each company/business/facility shall have a system in place to conduct process safety audits to provide increased assurance that facilities are being operated and maintained in a way that properly protects the safety and health of workers, the environment, the surrounding community, plant assets and continuity of operations.

#### **Compliance reviews**

4. Each company/business/facility shall have a system in place to conduct compliance reviews to verify adherence to regulations and to business/facility standards and procedures.

#### **Internal/external auditors**

5. Audits shall be conducted by trained personnel and partially staffed with expertise from outside the department or facility to provide objectivity and different approaches.

#### **Corrective actions**

6. Facilities shall develop an action plan with assigned responsibilities and timelines to resolve recommendations from audits.
7. Facilities shall maintain a follow-up system to verify completion and track/report outstanding recommendations from audits.

### **C. RECOMMENDED GUIDELINES**

There are no recommended guidelines for this element.

## **ELEMENT 12 - ENHANCEMENT OF PROCESS SAFETY KNOWLEDGE**

### **A. INTRODUCTION**

The state of the art of PSM is continually advancing as knowledge and experience are gained in a wide range of industries, countries and cultures. An effective management system for process safety must therefore provide access to this developing body of knowledge so that policy decisions on its application are made on the basis of informed knowledge and relevant aspects can be adapted and incorporated into a company's existing system rather than allowing it to become static.

### **B. REQUIRED ELEMENTS**

1. Each company/business/facility shall have a program in place to encourage continuous improvement that builds on the experiences and knowledge within the company and incorporates the technological advances that are constantly emerging throughout the industry.
2. The company shall utilize the knowledge it gains through incident reports, maintenance records, case histories, and trend analysis of upset conditions to provide basic information and changes that can help prevent catastrophic events.
3. The company shall maintain a process safety resource system that contains:
  - a) Material relevant to the design technology and operation of the process;
  - b) Incident reports;
  - c) Plant equipment design data;
  - d) Plant equipment inspection/testing data;
  - e) Design practices and specifications;
  - f) Appropriate laws and regulations;
  - g) Trade association information;
  - h) Physical and chemical properties, including reaction kinetics and safe handling information;
  - i) Technical papers;
  - j) Case histories concerning incidents which illustrate PSM principles;
  - k) A search facility available locally or through arrangement with another organization (e.g. a large reference library); and
  - l) Appropriate reference books.

#### **Quality control programs and process safety**

4. The business/facility shall have an integrated approach to PSM that applies the concepts contained in quality management programs (Plan, Do, Check, Act).

#### **Professional and trade association programs**

5. The company/business/facility shall encourage participation in professional and trade associations as a means to enhance process safety knowledge.

#### **Technical association programs**

6. The company/business/facility shall encourage participation in technical associations like the Canadian Society for Chemical Engineering (CSChE) PSM Division, American Petroleum Institute (API) and the Center for Chemical Process Safety (CCPS) as a means to enhance company and staff process safety knowledge and advance the state of the science.

#### **Research, development, documentation and implementation**

7. Research and Development programs shall include process safety inputs from departments such as safety, environment, operations, engineering, and maintenance.
8. Data supplied from research projects shall be documented, available to those who need to know, and communicated to plant operations to ensure new knowledge is incorporated into the enhancement of process safety.

#### **Improved predictive systems**

9. Information contained in incident reports, equipment failures and maintenance records shall be catalogued and analyzed for opportunities for continuous improvement in process safety.

#### **Process safety resource centre and reference library**

10. The company/business/facility shall maintain a reference library that contains a process safety section.
11. The company/business/facility process safety section shall include:
  - a) Reference books;
  - b) Technology-specific references; and
  - c) Journals and proceedings of conferences to provide topical interest.
12. The necessary resources and accountability for the library and contents shall be formally established.
13. There shall be a system to ensure the information in the library is kept current and disseminated throughout the plant to those who need to know.

#### **C. RECOMMENDED GUIDELINES**

There are no recommended guidelines for this element.

## GLOSSARY AND DEFINITIONS

**Alert, Evacuate and All Clear:** Standard alarms that are used to inform personnel regarding an emergency condition in a facility.

**API, ASME, etc:** These acronyms refer to industry standards setting, testing and certifying bodies. Examples include:

- American National Standards Institute (ANSI)
- American Petroleum Institute (API)
- American Society of Mechanical Engineers (ASME)
- Canadian Standards Association (CSA)
- Chlorine Institute (CI)
- Design Institute for Emergency Relief Systems (DIERS)
- International Labour Organization (ILO)
- International Organization for Standardization (ISO)
- National Fire Protection Association (NFPA)

**Bow-Tie Analysis:** A simple and effective tool for communicating risk assessment results, combining simplified fault and event trees in one diagram to clearly show the links between the potential causes, preventative and mitigative controls and consequences of a major incident. Bow-tie diagrams may be used to display the results of various types of risk assessments and are useful training aids. They may also be integrated with semi-quantitative analysis techniques such as **LOPA**, depending on the level of complexity required.

**Buffer Zone:** Refers to a controlled area separating the public and other facilities from the consequences of a **process-related incident**.

**Capital Project Review and Design;** A process that ensures changes to equipment are subject to scrutiny with respect to design concepts and the hazards that may be created in making the change.

**Critical:** An adjective describing actions, conditions, systems, procedures, or equipment which are indispensable to the safe and environmentally responsible operation of a facility.

**Critical interlocks:** Systems that either prevent or mitigate incidents;

**Dow Chemical Exposure Index:** A method of rating the relative potential of acute health hazard to people from possible chemical release incidents.

**Dow Fire and Explosion Index:** A step-by-step quantitative evaluation of the realistic fire, explosion and reactivity potential of process equipment and its contents.

**Fault Tree Analysis:** A deductive technique that focuses on one particular incident scenario or main system failure, and provides a method for determining causes of that event.

**FMEA:** Failure Modes and Effects Analysis: A systematic, tabular method for evaluating and documenting the causes and effects of known types of component failures.

**Good Engineering Practices:** Those practices generally accepted in the industry as necessary to ensure the safe operation of a facility.

**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, corrosive, explosive, etc.).

**HAZOP:** Hazard and Operability Study: A systematic method by which process hazards and potential operating problems are identified using a series of guidewords to investigate process deviations.

**Inherently Safe Design;** An inherently safe process with a low level of danger even if things go wrong. It is used in contrast to safe systems where a high degree of hazard is controlled by protective systems.

**LOPA:** Layer of Protection Analysis: a semi-quantitative method of risk assessment which lies between qualitative techniques such as HAZOP or PHA and full quantitative risk analysis. Used to determine safety integrity levels under standards such as IEC 61511.

**Key performance indicators:** A set of quantifiable measures that a company or industry uses to gauge or compare performance in terms of meeting their strategic and operational goals.

**Management System:** A system intended to achieve specific objectives. Components of a management system include:

- Clearly stated objectives;
- Clearly defined responsibilities for achieving the objectives;
- Tools, resources, procedures and schedules necessary to achieve the objectives;
- A means of measuring progress; and
- A feedback and control mechanism to correct deviations.

**Master Tag:** A permit which lists all tags, lockouts, etc., placed on equipment for a given job as part of a temporary change, maintenance work order, etc. The master tag enables subsequent return of all equipment settings (such as valve positions) to the original status even if done by a different team from those who took the equipment out of service.

**Material Safety Data Sheets:** An information resource that includes information on materials, such as physical properties; storage and disposal requirements; health effects and toxicity; and first aid response. MSDS do not have a standard format, but there is certain information that each MSDS must contain.

**Near Miss:** An event that generates no actual adverse consequences, but could easily have done so with a slight change in circumstances.

**Pressure-containing Components:** Items that form the pressure-containing envelope of the piping system.

**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 corrosivity.

**Process Hazard Analysis:** 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 Related Incident:** Incidents of the following type which result from the failure of process equipment:

- Explosion or implosion;
- Fire;
- Exposure to hazardous material(s); and/or
- Chemical release.

**Process Safety Management:** Management of the changes that can occur in the process, the equipment, and the people.

**Risk:** A measure of the likelihood and consequence of a specified, undesired event occurring within a specified period or in specified circumstances.

**Root Cause Analysis:** A method of examining incidents which looks beyond the immediate causes to identify the systemic underlying factors which allow a hazardous situation to occur.

**Traditional Occupational Health and Safety:** The protection of people from hazards not caused by process-related incidents.

**Worst Credible Scenario:** While it is not possible to define this precisely, the following suggestions may help:

- Incidents which have already happened somewhere in the industry;
- A scenario with a predicted frequency of 1 in 10,000 years or less;
- Incidents involving less than three simultaneous and independent failures;
- Release of 100% of hazardous material in the system over a period of 30 minutes; and/or
- Complete failure of equipment as a result of known causes such as metal embrittlement.