



Process Safety Management

Third Edition



Canadian Society for Chemical Engineering

This document was prepared by the process safety working group of the former Major Industrial Accidents Council of Canada (MIACC) in conjunction with the process safety management committee of the Canadian Chemical Producers' Association (CCPA). Rights to the document were transferred to the Canadian Society for Chemical Engineering (CSChE) on the dissolution of MIACC in 1999. It is sincerely hoped that the information in this document, which provides introductory guidelines for users to consider and not standards or procedures that must be followed, will lead to an even better safety record for the process industries of Canada.

The CSChE Process Safety Management Division gratefully acknowledges the financial assistance of Health Canada in printing this guide.

For more information on process safety management or on publications available on this and related subjects, please contact:

Canadian Society for Chemical Engineering
550-130 Slater Street
Ottawa, Ontario K1P 6E2
Tel: (613) 232-6252; Fax: (613) 232-5862
E-mail: info@cheminst.ca
URL: <http://www.chemeng.ca>

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 CSChE, CCPA nor the organizations nor persons involved in producing this publication warrant or 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. It remains the responsibility of the user of the publication to determine its suitability for the particular application intended, to use the information provided in the publication in a manner appropriate to that application, and to consult with qualified professionals as necessary.

Notwithstanding the above, or any other provisions in this publication or any applicable statutory provisions, the Canadian Society for Chemical Engineering, the Canadian Chemical Producers' Association, the organizations, or the persons involved in producing this publication shall not be liable to the user for special or consequential damages arising directly or indirectly from the application of this publication.

PROCESS SAFETY MANAGEMENT

Expressions appearing in bold face in the text are explained in the Glossary

Introduction

The purpose of this guide is to provide an overview of process safety management (PSM) for facilities handling hazardous materials. The guide shows the scope of PSM, and explains briefly the meaning of its elements and components.

The approach is based on that developed by the Center for Chemical Process Safety (CCPS) of the American Institute of Chemical Engineers. This approach was selected after reviewing several of the alternatives currently available, and was chosen because it is comprehensive, well supported by reference materials, tools and an organizational infrastructure, and is 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 (e.g. API RP750) do not necessarily need to switch to the approach given here. They should however be aware of any items here which may not be addressed under their present PSM scope (e.g. human factors). They should also be able to demonstrate that they have alternative measures in place for proper control of those items.

It is obviously not possible in a document of this length to provide all the necessary information even on the items described. 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, and are available from the **CCPS**.

Definition

Process Safety Management (PSM) is the application of management principles and systems to the identification, understanding and control of **process hazards** to prevent process-related injuries and accidents.

Scope

This guide describes the application of these PSM principles to prevent accidents at facilities that manufacture, store, handle or use hazardous materials. The process safety **management system** suggested by the Center for Chemical Process Safety consists of 12 elements. These elements are shown in Table ¹

The elements listed in Table 1 are described in this guide. These elements are intended to work in conjunction with **traditional health and safety** programs and applicable federal/provincial legislation. Some elements or components of PSM may be less applicable to some facilities, depending on the nature and degree of potential hazards involved. However, each item should be considered before assuming that it is not applicable. Nonetheless, a complete framework of PSM elements is recommended for each facility.

1 ACCOUNTABILITY: OBJECTIVES AND GOALS

Management commitment at all levels is necessary for PSM to be effective. The objectives for establishing accountability are to demonstrate the status of process safety compared to other business objectives (e.g. production and cost), to set objectives for safe process operation and to set specific process safety goals. These objectives should be internally consistent, i.e., supported by appropriate resources. Key components of accountability are:

1.1 Continuity of operations

Management is responsible for resolving the conflicts between meeting production/cost targets and shutting down or reducing output for planned or unplanned maintenance or modifications. To avoid compromising process safety, continuity of operations is best addressed at the planning stage by features such as spare and redundant equipment, multi-train rather than single stream operations, independent capability to shut down small sections of the plant, etc.

1.2 Continuity of systems

Accountability for process systems extends beyond the process units in question, to include adequate resourcing of supporting job functions or units for each phase of the life cycle of the process. Resourcing should be driven by the process hazards rather than by the economic viability of the process.

1.3 Continuity of organization

Changes in organizational structure can have a severe impact on process safety. Accountability should be flexible enough to accommodate such changes while ensuring that process safety tasks are properly assigned and performed throughout the change.

¹ The CCPS process safety management system described here is taken from References A1 and A2. This material is copyright 1989 by the American Institute of Chemical Engineers and is reproduced by permission of the Center for Chemical Process Safety of AIChE.

1.4 Quality process

Accountability for process safety has much in common with accountability for quality. Process safety problems can be seen as non-conformance with specifications, and many of the techniques used to establish systems for quality can be applied to control process safety performance.

1.5 Control of exceptions

Flexibility is important in management systems since it is often not practical to attempt to specify in advance exactly how each situation should be handled. Variance procedures should allow exceptions to be managed with appropriate controls by assigning accountability to qualified personnel.

1.6 Alternative methods

Accountability is more difficult with performance standards, which identify only desired results, than with specification standards identifying also the means to be used. Where guideline methods are suggested, e.g. for process hazard reviews, those using alternatives should be accountable for ensuring that the method selected is at least as effective as the guideline method for the intended purpose.

1.7 Management accessibility

Successful PSM makes senior managers accountable for being accessible to their staff for support and guidance on process safety decisions, and for resolving conflicting views among safety, engineering, production and business managers.

1.8 Communications

Senior managers should communicate their understanding of process safety accountability for their unit and individuals within it. This accountability should also include communication and coordination of overlapping responsibilities between individuals/units to ensure that no gaps occur.

1.9 Company expectations

Broad process safety goals should be established by management and should include philosophical issues as well as detailed targets. These must be consistent with other aspects of the organizational vision or master plan, i.e. they must match any other constraints and the availability of resources.

2 PROCESS KNOWLEDGE AND DOCUMENTATION

Information necessary for the safe design, operation and maintenance of any facility should be written, reliable, current and easily accessible by people who need to use it. Process safety information is needed in the following areas:

2.1 Chemical and occupational health hazards

This normally takes the form of Material Safety Data Sheets (MSDS) for every chemical used, stored or produced at a site, plus information on reactivity, chemical and physical properties for use by those involved in process development and design.

2.2 Process definition/design criteria

This is information needed to operate a facility within its design range and to enable potential changes to be properly reviewed for their impact on the facility's safety and reliability. Minimum information required is:

- ◆ **process flow diagram;**
- ◆ safe upper and lower limits for temperatures, pressures, flows, compositions and levels;
- ◆ evaluation of the effects, including those on health, safety and the environment, of operating outside of these safe limits;
- ◆ process chemistry, including chemistry of side reactions, by-products and contaminants;
- ◆ maximum intended inventory; and
- ◆ material and energy balances.

2.3 Process and equipment design

This covers the data needed to ensure and maintain the mechanical and process integrity of the equipment at a facility. Minimum information requirements are:

- ◆ materials of construction;
- ◆ piping and instrument diagrams (P&IDs);
- ◆ process control systems, including software integrity;
- ◆ electrical classification drawings;
- ◆ relief system design and design basis;
- ◆ design codes and standards employed; and
- ◆ ventilation system design.

2.4 Protective systems

These are data on systems which either prevent or mitigate accidents. Examples include:

- ◆ **critical** alarms;
- ◆ **critical** interlocks;
- ◆ pressure relief and venting systems;
- ◆ fire detection and protection equipment; and
- ◆ emergency isolation valves;

2.5 Normal and upset conditions (operating procedures)

Operating procedures should be readily accessible to employees who work with or maintain the process. There should be a system for updating procedures to ensure they reflect current operating practice (including changes of process chemistry, technology, equipment, facilities or organization) and regular certification that procedures are current and accurate. Procedures should address:

- ◆ steps for each operating phase, including:
 - initial start up of a new facility;
 - normal and temporary operations;
 - emergency shutdown, including identification of conditions which require shutdown;
 - normal shutdown; and
 - start-up following an emergency or normal shutdown;
- ◆ plant operating limits:
 - consequences of deviating from established operating limits; and
 - steps required to correct or avoid a deviation from operating limits; and
- ◆ safety systems and their functions.

2.6 Process risk management decisions

Risk management decisions should be documented, showing the decisions made and the basis on which they were made. This is a sensitive area because of implications for liability and due diligence, and should be carefully coordinated with the company's legal department.

2.7 Company memory (management of information)

Knowledge and information gained from plant experience which is likely to be important for future safety of the facility should be documented in a system so that it is not overlooked or forgotten as personnel or the organization change.

3 CAPITAL PROJECT REVIEW AND DESIGN PROCEDURES

3.1 Appropriation request procedures

The approval process for new capital projects should ensure that the request has identified risks, together with capital and other resources necessary to manage those risks. Process safety reviews must be satisfactorily completed at appropriate stages for the project to proceed.

3.2 Hazard reviews

Hazard reviews ensure that **risks** associated with hazardous chemicals have been identified and that adequate capital and other resources are made available to minimize exposures to employees, the public and the environment. The scale of review required will depend upon the hazards of the proposed process and also with the stage of the project, since the more intensive review techniques require information which becomes available only as the design proceeds.

3.3 Siting

Siting of a proposed expansion or new plant should consider the following factors:

- ◆ **buffer zones** between the plant and the public;
- ◆ **worst credible scenarios** for release of a toxic chemical, explosion or fire, and effect(s) on exposed groups;
- ◆ exposure hazard to and from adjacent plants or facilities;
- ◆ possible exposures due to natural events such as earthquake, flood, tornado, etc.; and
- ◆ effects of transportation of hazardous material feedstocks or products through local communities.

3.4 Plot plan

Here the proximity of equipment and storage of hazardous materials are evaluated. A plot plan review should include:

- ◆ congestion, e.g. overlapping hazard zones, difficult access, possible confinement of vapour release, etc.;
- ◆ location of control rooms, offices and other buildings;
- ◆ storage areas;
- ◆ loading and unloading areas;
- ◆ drainage and containment;
- ◆ other process areas;
- ◆ insurance requirements;
- ◆ federal, provincial and local regulations; and
- ◆ company/industry spacing guidelines.

3.5 Process design & review procedures

The design process should include a system for review and approval, with appropriate sign off, at each stage of the design process. Normal stages are: conceptual design, process design, detailed engineering design, construction and commissioning. The depth of each review will depend upon the complexity and degree of hazard of the process.

3.6 Project management procedures and controls

These controls ensure that fabrication and installation of equipment corresponds to design intentions. A key control is the pre-startup safety review required before new or modified facilities are put into service. Minimum requirements for this review are:

- ◆ confirm that construction meets design specifications;
- ◆ ensure that safety, operating, maintenance, and emergency procedures are in place and adequate;
- ◆ confirm that a **process hazard analysis** has been done and that recommendations have been resolved or implemented prior to start up;
- ◆ confirm that modified facilities meet the management of change requirements;
- ◆ ensure that employee training has been completed; and
- ◆ ensure that critical equipment has been identified and incorporated into a preventive maintenance program.

Project management controls should be documented and form part of the project file.

4 PROCESS RISK MANAGEMENT

4.1 Hazard identification

The most important step in process risk management is hazard identification. *If hazards are not identified, they cannot be considered in implementing a risk reduction program, nor addressed by emergency response plans.*

For examples of this and the following steps, see Reference C1. There are several methods for hazard identification such as What If, Checklist, **HAZOP**, **FMEA**, **Fault Tree Analysis**, etc., (see Reference C2). The **Dow Fire and Explosion Index** and **Dow Chemical Exposure Index** (References B1, B2) are recommended as useful tools for assessing the degree of hazard.

4.2 Risk analysis of operations

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.

4.3 Reduction of risk

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, etc..

4.4 Residual risk management

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 accident 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 employees required to operate critical systems;
- ◆ procedures to account for people following an evacuation (headcount);
- ◆ rescue and medical duties;
- ◆ emergency reporting procedures;
- ◆ emergency response procedures (fire suppression, spill control, etc.); and
- ◆ organizational responsibilities during an emergency.

Each site should have a site wide alarm 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; and
- ◆ is regularly tested and maintained.

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:

- ◆ co-ordination with local community fire department and/or other response personnel;
- ◆ provisions for visitors, contractors and handicapped employees;
- ◆ designated assembly areas with alternatives if needed;
- ◆ establishment of an emergency control centre sited in a safe area; and
- ◆ internal and external communications.

See also Reference C7 for more information on emergency planning.

4.5 Process management during emergencies

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.

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

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, assure continuity of production and avoid litigation.

4.7 Selection of businesses with acceptable risk

Sometimes risks cannot easily be reduced to an acceptable level, or the cost of doing so is prohibitive, in which case it may be necessary to exit a business. For new businesses or acquisitions, this situation can be avoided through the Capital Project Review process (see Section 3).

5 MANAGEMENT OF CHANGE

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 following the change;
- ◆ updating of documentation including; process safety information, operating procedures, maintenance procedures, alarm and interlock settings, fire protection systems, etc.; and
- ◆ contingencies for "emergency" changes.

5.1 Change of process technology

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 that 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.

5.2 Change of facility

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. Major equipment changes should be covered by the Capital Project Review (see Section 3). Procedures should also be used for smaller changes, since major hazards can be introduced by minor changes, e.g. a cross connection or instrumentation change. The procedure should be simple, but require approval by qualified personnel.

5.3 Organizational changes that may have an impact on process safety

Changes in organization must address the transition period as well as the way the new organization is to work. Even where no staff losses occur the change in reporting relationships can lead to problems. Departure of staff, and especially elimination of organizational units, e.g. through downsizing, pose special challenges since accountability and safe control of operations must continue despite the often sudden loss of key knowledge and skills.

5.4 Variance procedures

Exceptions can be expected for all procedures, and there should be systems to enable exceptions to be managed promptly and under control. Variance procedures should be easy to use yet call for review and approval by qualified personnel. The system should ensure that all involved understand the basis for the approval and the new limits established for the variance.

5.5 Permanent changes

Permanent changes should be subject to the usual steps of planning, organizing, implementation and control, and should be handled in conjunction with other plant programs such as the systems for work order, purchase order, capital project review, etc. Appropriate risk management should be a part of this process.

5.6 Temporary changes

Temporary changes should be subject to conditions similar to those that apply to permanent changes, and the time limit for the change should be clearly defined. Steps must also be taken to ensure that all equipment, etc. is returned safely to normal conditions at the end of the change.

6 PROCESS AND EQUIPMENT INTEGRITY

Procedures for fabricating, inspecting and maintaining equipment are vital to process safety. Written procedures should be used to maintain ongoing integrity of process equipment such as:

- ◆ pressure vessels and storage tanks;
- ◆ piping, instrument and electrical systems;
- ◆ process control software;
- ◆ relief and vent systems and devices;
- ◆ emergency and fire protection systems;
- ◆ controls including monitoring devices and sensors, alarms and interlocks; and
- ◆ rotating equipment.

A documented file should be maintained for each piece of equipment.

6.1 Reliability engineering

Equipment critical for process safety should be identified so that schedules can be established for monitoring and inspection to enable cost effective correction of problems before they develop to the critical stage.

6.2 Materials of construction

Systems should be established where necessary to supplement industry standards such as piping and pressure vessel codes. Critical items may need special tracking to verify materials used are as specified.

6.3 Fabrication and inspection 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 the people doing installation.

6.4 Installation procedures

Critical steps in installation should be identified during planning, and field inspection used to verify that installation corresponds to design.

6.5 Preventative maintenance

The preventative maintenance (PM) system should include:

- ◆ a method of identifying critical equipment
- ◆ a method to establish PM frequencies for critical equipment
- ◆ a mechanism to ensure that PM is done at the required frequency; and
- ◆ a record of the above

6.6 Process, hardware and systems inspection and testing (pre-startup safety review)

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 assure that all elements are in place and functional.

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 which includes:
 - date of inspection;
 - name of inspector;
 - serial number or other equipment identifier;
 - description of the tests done; and
 - results of the inspection or test.

6.7 Maintenance procedures

Proper control of maintenance should include safe work practices which apply to both employees and contractors, such as:

- ◆ permits to work and their application (hot work, confined space entry, lock out/tag out, excavation, **master tag**, etc.);
- ◆ opening of process equipment; and
- ◆ control of access to the facility by maintenance, contractor, laboratory and other personnel.

6.8 Alarm and instrument management

Proper alarm and instrument management includes not only equipment hardware but also computer components and software instructions for process control. Systems should include:

- ◆ identification of critical alarms and interlocks;
- ◆ a procedure to control changes to alarm set points and interlock systems; and
- ◆ a system of regular testing of interlock systems and pressure safety valves (PSVs.)

6.9 Decommissioning and demolition procedures

Procedures should address safe removal from service, dismantling, decontamination and related disposal of waste.

7 HUMAN FACTORS

Human factors are a significant contributor to many process accidents. Three key areas are operator – process/equipment interface, administrative controls and human error assessment.

7.1 Operator – process/equipment interface

Design of equipment may increase the potential for error. Examples are confusing equipment, positioning of dials, colour coding, different directions for on/off etc.. Computerized control systems can confront operators with unmanageable amounts of information during an upset condition. Interfaces which should be examined for potential problems are:

- ◆ alarm display;
- ◆ information display; and
- ◆ ergonomics.

A task analysis (a step-by-step approach to examine how a job will be done) can be used to determine what can go wrong during the task and how these potential problem areas can be controlled.

7.2 Administrative control versus hardware control

Hazards may be controlled by the use of procedures or by the addition of protective equipment. This balance is often a matter of company culture and economics.

If procedures are well understood, kept current and are used then they are likely to be effective. Similarly protective systems need regular testing and maintenance to be effective. The problem of administrative versus hardware controls should be considered and a balance selected by conscious choice rather than allowing it to happen by default.

7.3 Human error assessment

Human error is a fact of life. Individuals and organizations do not perform like machines, but behave in ways which are strongly influenced by such factors as understanding, judgement and motivation. Actions may vary depending upon the individual or the situation.

Effective process safety management demands an understanding of human error so that systems can be devised to prevent its occurrence or mitigate its effects. This applies to all aspects of process safety management including design, construction, maintenance and operation. See Reference E2 for an explanation of this subject.

Table 1: Elements and Components of Process Safety Management*

<p>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</p>	<p>5. Management of Change Change of process technology Change of facility Organizational changes Variance procedures Permanent changes Temporary changes</p>	<p>9. Incident Investigation Major incidents Third party participation Follow-up and resolution Communication Incident recording, reporting and analysis Near-miss reporting</p>
<p>2. Process Knowledge and Documentation Chemical and occupational health hazards Process definition/design criteria Process and equipment design Protective systems Normal and upset conditions (operating procedures) Process risk management decisions Company memory (management of information)</p>	<p>6. Process and Equipment Integrity Reliability engineering Materials of construction Fabrication and inspection procedures Installation procedures Preventative maintenance Process, hardware and systems inspection and testing Maintenance procedures Alarm and instrument management Decommissioning and demolition procedures</p>	<p>10. Company Standards, Codes and Regulations External codes/regulations Internal standards</p>

- 3. Capital Project Review and Design**
- 7. Human Factors**
Operator - process/equipment interface
Administrative control versus hardware
Human error assessment
- 11. Audits & Corrective Actions**
Process safety management systems audits
Process safety audits
Compliance reviews
Internal/external auditors
- 3. Process Risk Management**
Appropriation request procedures
Hazard reviews
Siting
Plot plan
Process design & review procedures
Project management procedures and controls
- 8. Training & Performance**
Definition of skills and knowledge
Design of operating and maintenance procedures
Initial qualifications assessment
Selection and development of training programs
Measuring performance and effectiveness
Instructor program
Records management
Ongoing performance and refresher training
- 4. Process Risk Management**
Hazard identification
Risk analysis of operations
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
- 12. Enhancement of Process Safety Knowledge**
Quality control programs and process safety
Professional and trade association programs
CCPS program
Research, development, documentation and implementation
Improved predictive system
Process safety resource centre and reference library

* As defined by the Center for Chemical Process Safety. The version shown here is compiled from the tables of contents of References A1 and A2. The sub-headings under each element may vary slightly from that used by the CCPS due to slight inconsistencies in format in the various CCPS publications. Key information from the list given above is explained in this guide, though only highlights can be covered in this brief document. Please consult References A1-A2 for more information.

Some approaches to reducing human error include:

- ◆ written guidelines and procedures;
- ◆ human factor audits;
- ◆ written communications; and
- ◆ design of operator – process/equipment interface.

8 TRAINING AND PERFORMANCE

People need to be trained in the right skills and to have ongoing retraining to maintain these skills. The following sections describe the steps in achieving this.

8.1 Definition of skills and knowledge

Key jobs should be identified and their required skills, knowledge and abilities documented. Training is then given to ensure that people doing these jobs are capable of doing them properly.

8.2 Design of operating and maintenance procedures

The job procedures, together with job descriptions and job safety analysis, provide the building blocks for development of training programs.

8.3 Initial qualifications assessment

Specification, testing and evaluation can be used to ensure that prospective employees have the aptitude and base knowledge/skills which, with appropriate training, will enable them to do the job.

8.4 Selection and development of training programs

Both employees and contractors must be trained to understand and use site safety systems. 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.

A competency test should be administered to employees and contractors to ensure that the information given has been understood. It is especially important that people supervising contractors understand the training given.

8.5 Measuring performance and effectiveness

A method of testing or verification should be used to ensure that the training is understood to a level consistent with doing a job safely.

8.6 Instructor program

Specific criteria should be used for instructor selection and training to ensure that instructors have sufficient teaching/communications skills as well as the necessary technical knowledge.

8.7 Records management

Records of training received by each person in each task are needed. These should include: the name of the trainer, the date of the training and the results of the competency verification. This document is then used to track training received and to schedule retraining.

8.8 Ongoing performance and refresher training

Refresher training is needed to ensure skills/personnel remain at a level consistent with the safe operation of facilities. This is especially true where procedures are changed and/or new equipment is added.

9 INCIDENT INVESTIGATION

9.1 Major incidents

Investigation of accidents and incidents (near misses) is a vital part of PSM. Minimum requirements for incident investigation include:

- ◆ a clear definition of what is meant by incident and accident;
- ◆ investigation of every actual or potential **process related accident**;
- ◆ investigation done promptly by a team with at least one person knowledgeable in the process (see Reference F1).
- ◆ a report to management following the investigation stating:
 - incident date;
 - incident description;
 - factors which contributed to the incident or accident; and
 - recommendations to prevent recurrence.

In addition to these minimum requirements, a good system should include:

- ◆ procedures for doing an investigation; and
- ◆ training of people involved in investigation, with emphasis on **root cause analysis**.

9.2 Third party participation

The presence of external team members encourages objectivity, fresh perspectives, specialist skills and freedom from bias, and adds to the credibility of the investigation.

9.3 Follow-up and resolution

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.

9.4 Communication

Key results of the investigation should be shared, as appropriate, with other parts of the plant, the organization, and the chemical industry and other industries where the lessons learned could usefully be applied.

9.5 Incident recording, reporting and analysis

Recording of incidents enables a system of analysis of incident reports to identify opportunities for elimination of commonly recurring causes.

9.6 Near-miss reporting

Lessons from near-misses are often as important as from actual incidents. Significant near-misses should be recorded and analyzed as part of the incident investigation system.

10 COMPANY STANDARDS, CODES AND REGULATIONS

A **management system** is needed to ensure that the various internal and external published guidelines, standards and regulations are current, disseminated to appropriate people and departments, and applied throughout the plant.

10.1 External codes/regulations

Legislated items include, for example:

- ◆ environmental regulations;
- ◆ occupational health and safety regulations;
- ◆ planning and zoning regulations;
- ◆ boiler and pressure vessel codes;
- ◆ electrical and building codes; and
- ◆ fire codes.

External standards include such items as:

- ◆ industry wide standards such as those published by **API**, **ASME** and **ANSI**;
- ◆ professional technical bodies such as Center for Chemical Process Safety (CCPS), AIChE design groups (e.g. **DIERS**), CCPA, Chlorine Institute; and
- ◆ national/international codes, such as those published by **CSA**, **NFPA**, **ILO**, etc.

10.2 Internal standards

These take many forms depending upon the nature of the operation. Typical examples include:

- ◆ general standards, e.g. maintenance practices (hot work, inspection, etc);
- ◆ reporting procedures (accident reporting, equipment data etc.) and behaviour in plant areas (smoking, driving, etc.);
- ◆ specific process standards, e.g. chemistry, process design principles, metallurgy, etc.; and
- ◆ mechanical, electrical, civil, and instrument design standards.

11 AUDITS AND CORRECTIVE ACTIONS

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. Types of audits include:

11.1 Process safety management systems audits

Management systems audits verify that the systems are effective in assuring company/plant policies and procedures are being implemented. They also identify opportunities where systems may be strengthened.

11.2 Process safety audits

Process safety audits provide increased assurance that facilities are being operated and maintained in a way which properly protects the safety and health of employees, the environment, the surrounding community, plant assets and continuity of operations.

11.3 Compliance reviews

Compliance reviews verify adherence to regulations and to company/plant standards and procedures.

11.4 Internal/external auditors

Audits should be conducted by teams of plant personnel and partially staffed with expertise from outside the plant to provide objectivity and fresh ideas.

11.5 Corrective actions

The most important result of an audit is corrective action to reduce risks. An action plan to resolve recommendations with assigned responsibilities is needed. There must be a follow-up system to verify completion and track/report outstanding recommendations.

12 ENHANCEMENT OF PROCESS SAFETY KNOWLEDGE

A management system for process safety should be designed for continuous improvement. Safety requirements are becoming more stringent, while knowledge of systems and technology is growing, e.g. consequence modelling techniques. Safe operation of a process plant calls for personnel to stay abreast of current developments, and for safety information to be readily accessible.

A minimum requirement is a process safety resource system, which may be quite simple for a small organization but should nevertheless contain:

- ◆ material relevant to the design technology and operation of the process; and
- ◆ a search facility available locally or through arrangement with another organization, e.g. a large local reference library.

Examples of material contained in such a system might include:

- ◆ accident/incident reports;
- ◆ plant equipment design data;
- ◆ design practices and specifications;
- ◆ appropriate laws and regulations;
- ◆ trade association information;
- ◆ chemical data, including reaction kinetics and safe handling information;
- ◆ technical papers;
- ◆ case histories concerning incidents which illustrate PSM principles; and
- ◆ appropriate reference books.

GLOSSARY AND DEFINITIONS

<i>API, ASME, ...etc:</i>	<p>These acronyms refer to industry standards setting, testing and certifying bodies. Examples include:</p> <ul style="list-style-type: none">◆ American National Standards Institute (ANSI)◆ American Petroleum Institute (API)◆ American Society of Mechanical Engineers (ASME)◆ Canadian Standards Association (CSA)◆ Chlorine Institute◆ Design Institute for Emergency Relief Systems (DIERS)◆ International Labour Office (ILO)◆ National Fire Protection Association (NFPA)
<i>Buffer Zone:</i>	<p>Refers to a controlled area separating the public and other facilities from the consequences of a process related accident. (Contact CSChE for more information on buffer zones)</p>
<i>Critical:</i>	<p>An adjective describing actions, conditions, systems, procedures, or equipment which are indispensable to the safe and environmentally responsible operation of a facility.</p>
<i>DOW Chemical Exposure Index:</i>	<p>A method of rating the relative potential of acute health hazard to people from possible chemical release incidents. See Reference B2.</p>
<i>DOW Fire and Explosion Index:</i>	<p>A step-by-step quantitative evaluation of the realistic fire, explosion and reactivity potential of process equipment and its contents. See Reference B1.</p>
<i>Fault Tree Analysis:</i>	<p>A deductive technique that focuses on one particular accident or main system failure, and provides a method for determining causes of that event. See Reference C2.</p>
<i>FMEA:</i>	<p>Failure Modes and Effects Analysis: A systematic, tabular method for evaluating and documenting the causes and effects of known types of component failures. See Reference C2.</p>
<i>Good Engineering Practices:</i>	<p>Those practices generally accepted in the industry as necessary to assure the safe operation of a facility.</p>
<i>Hazardous Material:</i>	<p>A substance (gas, liquid or solid) capable of creating harm to people, property or the environment, e.g. materials which are flammable, toxic, etc.</p>
<i>HAZOP:</i>	<p>Hazard and Operability Study: A systematic method in which process hazards and potential operating problems are identified using a series of guidewords to investigate process deviations. See References C2, C3, C4.</p>

Management System:	<p>A system intended to achieve (a) specific objective(s). Components of a management system include:</p> <ul style="list-style-type: none"> ◆ clearly stated objective(s); ◆ clearly defined responsibilities for achieving this (these) objective(s); ◆ tools, resources, procedures and schedules necessary to achieve this (these) objective(s); ◆ a means of measuring progress; and ◆ a feedback and control mechanism to correct deviations.
Master Tag:	<p>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.</p>
Process Flow Diagram:	<p>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.</p>
Process Hazard:	<p>A physical situation with a potential for human injury, damage to property or damage to the environment through the release of chemical energy in the form of fire, explosion, toxicity or corrosivity.</p>
Process Hazard Analysis:	<p>The action of identifying undesired events which could lead to the materialisation of a hazard and the estimation of the magnitude and likelihood of any harmful effects resulting from this materialisation.</p>
Process Related Accident:	<p>Accidents of the following type which result from the failure of process equipment:</p> <ul style="list-style-type: none"> ◆ explosion or implosion; ◆ fire; ◆ exposure to hazardous material(s); and/or ◆ chemical release.
Risk:	<p>A measure of the likelihood and consequence of a specified undesired event occurring within a specified period or in specified circumstances.</p>
Root Cause Analysis:	<p>A method of examining incidents which looks beyond the immediate causes to identify the systemic underlying factors which allow a hazardous situation to occur. See Reference F1.</p>
Traditional Occupational Health and Safety:	<p>The protection of people from hazards not caused by process related accidents.</p>

*Worst
Credible
Scenario:*

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

- ◆ accidents which have already happened somewhere in the industry;
- ◆ a scenario with a predicted frequency of 1 in 10000 years or less;
- ◆ accidents involving less than three simultaneous and independent failures;
- ◆ release of 100% of hazardous material in the system over a period of 30 minutes; and
- ◆ complete failure of equipment as a result of known causes such as metal embrittlement.

REFERENCES

In case of difficulty in locating items shown below, contact the CSChE office.

A. General References

1. CCPS, "Guidelines for Technical Management of Chemical Process Safety", 1989, ISBN No. 0-8169-0423-5.
2. CCPS, "Plant Guidelines for Technical Management of Chemical Process Safety", 1992, ISBN No. 0-8169-0499-5.
3. American Petroleum Institute, Recommended Practice 750 "Management of Process Hazards", 1990, reaffirmed 1995. Available via the API at www.api.org
4. U.S. Occupational Safety and Health Administration, 29-CFR-1910.119, "Process Safety Management of Highly Hazardous Chemicals".
5. Canadian Chemical Producers' Association (CCPA), Responsible Care® codes of practice. Available on the CCPA website www.ccpa.ca

B. Capital Projects Review and Design

1. American Institute of Chemical Engineers, "Dow's Fire and Explosion Index Hazard Classification Guide", latest edition, ISBN No. 0-8169-0623-8.
2. American Institute of Chemical Engineers, "Dow's Chemical Exposure Index", latest edition, ISBN No. 0-8169-0647-5.

C. Process Risk Management

1. Canadian Chemical Producers' Association, "Manufacturing Code of Practice - Site Acute Risk Assessment Implementation Aid", November 1992. Available via the CCPA at www.ccpa.ca.
2. CCPS, "Guidelines for Hazard Evaluation Procedures. Second Edition with Worked Examples", 1992, ISBN No. 0-8169-0491-X.
3. Knowlton, R. Ellis, "A Manual of Hazard and Operability Studies - the Creative Identification of Deviations and Disturbances", 1992, ISBN No. 0-9684016-3-5. Available Kvaerner-Chemetics, www.chemetics.kvaerner.com.
4. Kletz, T.A., "Hazop and Hazan: Identifying and Assessing Process Industry Hazards", London: The Institution of Chemical Engineers, Third Edition 1999, ISBN No. 1-5603-2858-4.
5. Greenberg, Harris R., and Cramer, Joseph J., "Risk Assessment and Risk Management for the Chemical Process Industry", John Wiley & Sons, 1991, ISBN No. 0-4712-8882-9.

6. Canadian Standards Association, "Risk Management: Guideline for Decision Makers", CAN/CSA-Q850-97.
7. Canadian Standards Association, "Emergency Planning for Industry", CAN/CSA-Z731-95.

D. Management of Change

1. Sanders, Roy E. "Management of Change in Chemical Plants: Learning from Case Histories", Butterworth-Heinemann Ltd. 1993, ISBN No. 0-7506-1135-9.

E. Human Factors

1. Kletz, T. A., "An Engineer's View of Human Error", London: The Institution of Chemical Engineers, third edition 2001, ISBN No. 1-5603-2910-6 (available from CCPS).
2. CCPS, "Guidelines for Preventing Human Error in Process Safety", 1994, ISBN No. 0-8169-0461-8.
3. Health and Safety Executive (UK), "Human Factors in Industrial Safety", HS(G)48, London HMSO, 1989, ISBN No. 0-11-885486-0.

F. Incident Investigation

1. CCPS, "Guidelines for Investigating Chemical Process Incidents", 1992, ISBN No. 0-8169-0555-X.

G. Compliance Verification

1. CCPS, "Guidelines for Auditing Process Safety Management Systems", 1993, ISBN No. 0-8169-0556-8.

This guide 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 Canadian Society for Chemical Engineering (CSChE), and a new subject division formed for this purpose. For more information on this division and its activities, please contact the CSChE as shown on the inside cover of this document.

The material in this 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.

**Canadian Society for Chemical Engineering
Société canadienne de génie chimique**

Suite 550, 130 Slater Street

Ottawa, ON K1P 6E2

Tel./Tél. : (613) 232-6252

Fax/Télec. : (613) 232-5862

E-mail/Courriel : info@cheminst.ca

Website/Site Web : www.chemeng.ca