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Process Safety Management

In 1985, the American Institute of Chemical Engineers formed the Center for Chemical Process Safety (CCPS) to promote the improvement of process safety among those who transport, use, process, and store hazardous materials. The first projects supported by CCPS were highly technical in nature. CCPS recognized, however, that major accidents could not be prevented by technology alone. The evolution of process safety from a purely technical issue to one that demanded management approaches was essential to continued process safety improvement.

An overview brochure, A Challenge to Commitment, introduced the concept of Process Safety Management (PSM) in terms of twelve management responsibilities or activities:

Accountability
Process Knowledge and Documentation
Capital Project Hazard Review
Process Risk Management
Management of Change
Process Equipment Integrity
Human Factors
Training and Performance
Incident Investigation
Standards, Codes and Regulations
Audits and Corrective Action
Enhancement of Process Safety Knowledge

These activities play interactive roles in process safety management, provide overlapping layers of assurance to achieve safe operations, and must be considered when making decisions regarding manufacturing and transportation of raw materials, products, and waste. Particular attention must be paid during organizational transitions, such as downsizing, mergers, acquisitions, or divestitures.

Management systems consist of explicit sets of arrangements for planning, organizing, implementing, and controlling work within complex organizations. They are established by managers to assist in achieving an organization's goals and objectives. The planning function includes the need for policy development by senior management. It also involves establishing company goals and objectives, developing strategies for their achievement, and allocating resources to carry out those strategies. The organizing function provides the structure and delineates the roles, responsibilities, authority, and accountability for accomplishing the work. Organizing creates the basis for effectively directing and coordinating company resources. The implementing function provides the initiating mechanisms and executes the work. Implementing determines the company's results. The controlling function provides the framework for measuring, evaluating, and correcting implementation performance. Controlling keeps a company on track.

Management systems perform these functions on at least three planes within an organization. At the highest level, management systems are primarily concerned with strategic issues: establishing or revising the goals of the company and identifying the strategies for achieving them. In the middle ranks, the systems exist to provide tactical information and direction for allocation of resources: time and money. At the task-oriented levels, management systems seek to assure that specific work assignments are carried out efficiently and effectively.

Chemical process safety requires management systems to provide sound facility design, construction, operation, and maintenance. These management systems serve to assure that appropriate resources are made available and are used productively and efficiently. Of paramount importance is the integration of process safety management with business management. The twelve CCPS process safety management activities, or elements, are briefly defined in the following paragraphs.

Accountability: Objectives and Goals
A system for accountability institutionalizes every employee's obligation to explain and answer for one's actions that are related to company expectations, objectives, and goals. Because it is associated with positive and negative rewards for actions taken, accountability gives "teeth" to the roles and responsibilities assigned through the management system. Accordingly, it is a powerful element of an effective PSM system, and it should be built into each component of a PSM system. Most existing PSM structures do not include accountability as an explicit element; however, some address it with overall PSM policy statements.

Process Knowledge and Documentation
This is a system for process knowledge and documentation maintains up-to-date documentation for the life of a process. The information may be kept and protected in hard copy form or in electronic form, but it must be accessible to employees who need it in performing their safety-related duties within a plant's PSM system. This information represents the plant's institutional memory concerning the hazards, technology, equipment, processes, and decisions that are made to manage the risk of plant operations.

Capital Project Hazard Reviews
This is a system for performing qualitative hazard reviews from process concept inception until process deployment. This system interacts with a company's project management system to communicate identified hazards and suggested improvements to process development/design teams. Plans are developed for hazard reviews at appropriate times throughout the development/design phase of the process until process deployment. This helps ensure that adequate physical and/or administrative controls are in place.

Process Risk Management
This is a system for evaluating the risk of operating processes using qualitative or quantitative risk analysis techniques. This system interacts with the management of change system and project management system to communicate identified hazards and suggested improvements to facility management. Plans are developed for risk evaluations at appropriate times through the operating lifetime of the process until decommissioning. This helps ensure that adequate physical and/or administrative controls are in place to manage risk.

Training and Performance
This is a system to develop procedures and to train plant personnel on the operation, maintenance, and emergency actions associated with plant processes. The system should provide for initial and refresher training at appropriate intervals; training documentation should be developed and maintained. This system also addresses the training of plant personnel on how to participate in the operation of the plant's PSM system.

Human Factors
This is a system to ensure that human factors issues have been addressed in all relevant PSM activities. This system ensures that human factors reviews of process design/operations are conducted at appropriate times during the lifetime of the process. Most existing PSM structures do not include human factors as an explicit element; however, an increasing number address it within the relevant work activities of other PSM elements or in PSM policy statements.

Management of Change
This is a system for preventing the introduction of new hazards or an unknown increase in the risk associated with existing hazards resulting from modifications to plant operations. It establishes a formal, documented authorization process for all changes that are not replacements-in-kind.

Process and Equipment Integrity
This is a system to ensure that equipment, systems, structures, and components are maintained in a fit-for-duty manner that does not increase the risk associated with process operation. It includes procedures to schedule, perform, and document preventive maintenance, inspections, and tests on critical equipment, and to resolve equipment deficiencies as soon as possible in a way that minimizes risk.

Company Standards, Codes, and Laws
This is a system to develop, acquire, evaluate, disseminate, and maintain an archive of standards, codes, and laws. It creates and maintains company standards, keeps this information up-to-date, and makes it accessible to potential users.

Incident Investigation
This is a system for scheduling, staffing, performing, and documenting investigations of process safety incidents and near misses. It manages the resolution of findings and corrective actions generated by the investigations.

Audits and Corrective Actions
This is a system for scheduling, staffing, performing, and documenting audits of process safety management systems and operating processes. It manages the resolution of findings and corrective actions generated by the audits.

Enhancement of Process Safety Knowledge
This is a system to proactively seek out new process knowledge and documentation from internal and external sources. Most existing PSM structures do not include increasing process safety knowledge as an explicit element, although some address it with overall PSM policy statements.

ProSmart
Historically, measurement of process safety performance by industry and government regulatory agencies is based on the experience gained over many years of compilation of personnel injury data. Collection of injury statistics through a rigorous compilation of recordable, lost time, and fatal injury statistics has provided a useful tool to drive improvement. The comparable effort to drive process safety improvement by collecting statistical data on process safety incidents has been much less successful. The frequency of significant incidents is very low for a single location or even for a single company. On a national basis a statistically significant number of incidents occurs, but this data does not provide direction for improvement at a single site or in a single company.

The successful total quality management improvement effort faced a similar dilemma. No quality defect was acceptable to the customer, and detecting flaws after manufacture at the end of the pipe was both ineffective and expensive. The answer was total quality management or control of the upstream process to eliminate the root cause of quality defects. Quality control of the upstream process replaced counting a small, but unacceptable, number of defects.

With the total quality concept as a guide, the Center for Chemical Process Safety began a project in 1993 to measure the effectiveness of process safety management systems. The ultimate objective was to provide management with the tools for assessing the health of PSM systems on a real-time basis. By frequently measuring the performance of the elements in a PSM system, flaws can be detected and corrected promptly before an accident occurs. Because the nature of safety in facilities means that accidents rarely happen, these indicators must be able to measure the "quality" of the PSM process taking

place at a facility, not simply waiting to measure the results (i.e., accidents, incidents, near misses) that occur. Since the features of a PSM system must be matched to the hazards, complexity, and culture of facilities, the indicators must compare performance, not on an absolute scale for all of industry, but against the appropriate design expectations established for the facility's PSM system. Then, a plant can decide either to make cost-effective incremental improvements to their PSM system, or to change the design capacity of their PSM system in order to meet their increased expectations.

In partnership with Concord Associates of Knoxville, Tennessee, CCPS has created a software program utilizing key, measurable variables of performance to develop an index of performance. The final product, ProSmart, utilizes readings of measurable variables for PSM performance, updated on a schedule keyed to their change characteristics. This contrasts with an audit evaluation, which captures a snapshot of the PSM performance at a particular instant of time. ProSmart defines the data to be collected, provides the computer interface, and calculates a numerical value, or index, of PSM system performance.
The measure structure can be thought of as a tree or outline. The top-level structure of the measure for each of the twelve elements is identical to the following outline:

Element
- Written Program
  - A. Planning
  - B. Organizing
  - C. Implementing
  - D. Controlling

Implementation
- Program Implementation Indicators
  - A. Planning
  - B. Organizing
  - C. Implementing
  - D. Controlling
- Product Evaluations

The planning/organizing/implementing/controlling structure is from Appendix A of Reference 1. Your PSM program elements do not have to follow this structure to use this measure, but they must address the general topics included as sub-elements under these four elements for you to have a high PSM rating.

The CCPS PSM performance measure evaluates performance by considering two main categories: written program and program implementation. Program implementation is divided into implementation indicators and product evaluations. The following sections describe each of these areas.

Written Program
A management system is a formal set of controls, procedures or tasks that an organization wants implemented on a reliable, ongoing basis. A management system has several important features: a written program, designated activities, anticipated inputs and outputs, selected targets or schedules, specified roles and responsibilities, and allocated resources.

A written program is a written description of the management system's important features including whatever level of detail is necessary and appropriate for sustained organizational growth. A "management system" that has not been codified by a written program is merely an informal set of practices or activities, however well organized, intentioned, and accepted. These practices will likely not be sustainable over the life of the organization because of a lack of a solid institutional memory that can serve as a common basis for employee understanding of the desired management intentions - particularly as people come and go in the organization. Thus, the desired management intentions must be written down in plain language and be accessible to all who are expected to participate in the functioning of the system.

Program Implementation - Program Implementation Indicators
Maintaining good PSM performance requires having comprehensive written programs and diligently implementing the written program requirements. Therefore, the performance measure for each element has a series of questions about the quality of the written program and one or more corresponding questions about the implementation of the written program. The implementation questions that can be answered directly are included in this part of the measure. However, many of the implementation questions are difficult or impossible to answer directly without reviewing a sample of the products of the program. Therefore, the measure includes product evaluation worksheet(s) that ask questions about the quality of the products produced by the element as described below.

Program Implementation - Product Evaluations
Every management system has anticipated outputs or work products. One important way to measure the performance of a management system in efficiently meeting its stated goals is to carefully look at the products it creates. Sampling PSM element products to determine their quality provides an important indication of how well the systems are working.

One issue with evaluating management system performance is to determine whether the products of work activity were created at all; the next issue is to determine how well the work products meet the intentions of the system. Thus, the quality of the work product is evaluated to determine whether it includes all of the necessary attributes to make it useful to the management system. Furthermore, the quality of the work process used to generate the product is evaluated to determine whether the underlying work to create the product was appropriate. For example, the worksheets have questions regarding the composition of the teams performing the work; did the teams have the right participants/expertise.

The CCPS PSM performance measurement system uses Product Evaluation Worksheets (PEWSs) to aid in the evaluation of the quality of the system's generated work products. These worksheets are checklists of essential features of each particular product type. The measure calculates a moving average score for each product evaluated and uses this average score as an indicator of program performance. For example, the PEWS for MOC requires the user to sample a change that went through the MOC process and answer questions about the review team composition, the quality of the results, etc. One change should be evaluated each month. After a few months, a meaningful (and probably stable) average will be reached. Ideally, the performance will improve over time so the average will go up. By doing a moving average (e.g., including the last 10 changes sampled), the average will go up even faster for an improving plant. The user has complete control over which completed PEWSs are included in the moving average.

Some management systems create products frequently (e.g., process equipment integrity creates equipment maintenance records indicative of quality preventive maintenance work performed); other systems create products as needed or infrequently. In the one case, many recent products are available for review. On the other hand, recent work products may be few. The frequency at which the various PSM product evaluations should be conducted will vary from plant to plant based on factors that include the size and complexity of the plant, the frequency at which products are produced, and trends in the results of previous product evaluations.

Initial frequencies have been built into the measure, but individual users should adjust the frequencies (more or less frequent) to suit their conditions. The guidance/intent statements associated with each individual product evaluation worksheet include a discussion of the sampling frequency for that worksheet. Note that the program provides alerts if indicators and worksheets are not updated frequently enough. To avoid these alerts in cases where you sample less frequently, you must "reset the clock." This is accomplished by selecting the element and choosing Update With Same Rating Value from the Element menu.

The following sections address some general issues and uses of ProSmart.

Other PSM Structures
Plants that have PSM structures different from the CCPS, twelve-element, structure will still benefit significantly from using this measure. The differences are primarily in the organization, not the content. The Help files in the software provide guidance for mapping to the OSHA PSM structure.
You may elect to collect data on only those elements that map directly into elements of your PSM program.

Non-Applicable Items
There are cases where some elements or factors in the PSM measure do not apply to a plant. For example, a stable, mature plant, that has had no capital projects for years and anticipates no future capital projects, does not need a Capital Project Hazard Review program. In such cases, the rating for the non-applicable item should be over-ridden and

set to either its favorable (highest) value or set to a value near the overall PSM measure score. Setting the value to the overall PSM measure score may require one or more iterations. In this manner a non-applicable item does not penalize the overall PSM rating as it would if the rating were left at its unfavorable value.

What-If Analysis
ProSmart is useful for performing a variety of what-if and sensitivity analyses. For example, an exercise was conducted to develop ratings for the incident investigation element for a relatively good plant. The rating was approximately 80. Then the ProSmart development team analyzed a hypothetical case of a reduction of 20 percent of this plant's technical staff. We re-evaluated the ratings with this hypothetical scenario in mind, and the result was a rating of 65 for incident investigation. This type of what-if analysis could be useful in a company considering reducing staff by realistically showing the effect such downsizing could have on process safety performance.

The sensitivity graphs and reports in ProSmart can be used to develop scenarios to guide PSM resource allocation. ProSmart identifies the areas where improvement can be most effective. Cost/benefit data can then be developed.

Benchmarking
A plant's initial PSM performance rating provides a benchmark against which to gauge future performance. The purpose of ProSmart is to aid continuous improvement in PSM performance by helping users make maximum use of PSM resources. ProSmart is not intended as a tool for comparing different plants. There are too many sources of variability (including user subjectivity) to make comparisons among plants even in the same company very meaningful.

Reports and Graphs
ProSmart creates a variety of reports and graphs (graphs may be printed for inclusion in reports) useful for documenting current and historical performance and for helping in PSM resource allocation planning. All reports are produced as Microsoft Word documents so users can combine reports, graphs, and other user-developed documentation into custom reports.

Summary
The purpose of ProSmart is to help companies identify and use qualitative and quantitative indicators of the performance of PSM Systems to aid in continuous improvement. Continuous improvement is the hallmark of any quality program and should be a goal for companies interested in managing the risk of hazardous chemical operations. Continuous improvement for PSM systems is used to mean (1) the incremental increase in the performance of the PSM system with no significant increase in resources, or (2) the incremental increase in the cost-effectiveness of existing PSM activities resulting in equivalent or better PSM performance. The following are some of the benefits for companies that utilize ProSmart for continuous improvement of PSM:

- Reduce risk of catastrophic accidents.

- Improve cost-effectiveness of PSM activities.
- Benchmark against PSM performance expectations.
- Justify that PSM resources have been well spent.
- Help establish priorities for PSM improvements.

Lord Kelvin, the 19th- century English physicist who discovered the vital pillar of science known as the second law of thermodynamics, put it this way:
"When you can measure what you are speaking about and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind."

The following books are referenced in ProSmart software documentation and/or Help files. All provide valuable supplemental information. References 1 and 2 are particularly recommended as companions to the PSM measure.

1. *Guidelines for Technical Management of Chemical Process Safety*, Center for Chemical Process Safety/American Institute of Chemical Engineers, New York, NY, 1989.
2. *Plant Guidelines for Technical Management of Chemical Process Safety*, Center for Chemical Process Safety/American Institute of Chemical Engineers, New York, NY, 1992.
3. *Guidelines for Hazard Evaluation Procedures, Second Edition with Worked Examples*, Center for Chemical Process Safety/American Institute of Chemical Engineers, New York, NY, 1992.
4. *Guidelines for Investigating Chemical Process Incidents*, Center for Chemical Process Safety/American Institute of Chemical Engineers, New York, NY, 1992.
5. *Handbook of Human Factors*, Salvendy, Gabriel, Ed., John Wiley & Sons, New York, NY, 1987.
6. Military Standard, *Human Engineering Design Criteria for Military Systems, Equipment, and Facilities*, MIL-STD-1472F Department of Defense, 1996.
7. *Human-System Interface Design Review Guidelines, Vol. 1: Process and Guidelines*, NUREG-0700, Rev. 1, US Nuclear Regulatory Commission, 1996.