The Role of Process Safety Management in the Manufacturing Engineering Curriculum

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ABSTRACT

Process safety management (PSM) is fast becoming a necessary constituent of a manufacturing engineering student's education. The impact of government regulations relating to environmental and safety concerns in the manufacturing arena requires students entering the workforce to be trained in the basics of PSM. No longer is it acceptable, either ethically or financially, to produce a product without regard to the impact that the product has on the environment or the people who produce it. Government regulations maintain boundaries for the manufacturing industry to adhere to, and will undoubtedly become increasingly more stringent as we learn more about the consequences of present day manufacturing techniques.

Process Safety Management utilizes a collection of fourteen "tools" that together form a comprehensive approach to maintaining a safe work environment while providing the flexibility to transition with the ever changing manufacturing industry. These tools provide the basis for a long-term look at the different products manufacturing enterprise produce and the potential consequences associated with these products during their life cycles. The key to the successful implementation of PSM throughout industry is to provide the manufacturing engineering student an education that views PSM as an extension to the more conventional design and process technology curriculum. As PSM becomes more universally accepted by the manufacturing industry, engineering students with even a basic exposure to the established practices of PSM will be sought after to fill newly established positions within an organization. It is therefore, the responsibility of the engineering and technology programs to incorporate PSM into the established Manufacturing Engineering curriculum to broaden the student's overall educational experience while shedding some light on an often overlooked element of the manufacturing process.

We propose a course that gives a cursory treatment of the fourteen tools of PSM and uses the capstone design course as a case study to provide practical application and better comprehension. Excellent clarity is achieved, because the students in the capstone course actually manufacture some equipment or device. Those tools that are heavily involved in the equipment/device manufacture can be covered in greater detail.

Introduction

In 1985, the American Institute of Chemical Engineers (AIChE) formed the Center for Chemical Process Safety (CCPS) to promote the improvement of process safety among those who handle, use, and store hazardous materials [5]. This action was in direct response to the unacceptably high number of catastrophic industrial accidents plaguing the chemical processing industries at the time. At first, the CCPS chose a technical approach to deal with reducing the number and severity of industrial incidents and accidents. Although effective, it soon became clear that technology oriented solutions alone could not prevent major accidents. The CCPS identified that a systematically managed approach to process safety would be more effective in preventing accidents. The evolution of process safety from a purely technical issue to one that demanded management approaches was essential to continued process safety improvement [5]. Process safety management (PSM) is the end result of the dedicated involvement of the CCPS to prevent catastrophic accidents in the chemical processing industry.

The Nature and Importance of PSM

PSM, as intended by the CCPS, introduces twelve (12) elements, that when implemented systematically, provide a comprehensive approach to process safety management. The twelve elements are listed in Table I. As the name implies, the responsibility for a successful PSM program lies internal to the management structure of a corporation. The success of PSM within an organization can be measured by the commitment of the management.

Table I **Twelve Elements of Process Safety Management**

- Accountability: Objectives and Goals
- Process Knowledge and Documentation
- Capital Project Review and Design Procedures
- Process Risk Management
- Management of Change
- Process and Equipment Integrity
- Incident Investigation
- Training and Performance
- Human Factors
- Standards, Codes and Laws
- Audits and Corrective Action
- Enhancement of Process Safety Knowledge

PSM is a fairly new approach that directly addresses the operation of a manufacturing facility. The Occupational Safety and Health Administration (OSHA) has been tasked with maintaining compliance. Title 29 CFR OSHA 1910.119: Compliance guidelines and recommendations for process safety management [6], was generated to provide guidelines to industry in order to maintain compliance. In this regard, OSHA has generated an expanded list of fourteen (14) PSM elements. Many elements duplicate the intent of the twelve CCPS elements. The fourteen elements are listed in Table II. Arguably, due to the similarity of the elements and the regulatory responsibility of OSHA, the fourteen elements listed in Table II have been embraced by industry as the standard.

Title 29 CFR OSHA 1910.119
Table II — Fourteen Elements of Process Safety Management

(I)	employee participation	(VIII)	mechanical integrity
(II)	process safety information	(IX)	hot work permit
(III)	process hazard analysis	(X)	management of change
(IV)	operating procedures	(XI)	incident investigation
(V)	training (both initial and refresher)	(XII)	emergency planning
(VI)	contractors	(XIII)	compliance audits
(VII)	pre-start up safety review	(XIV)	trade secret protection

Process safety management (PSM) is the application of management systems to identify, understand, and control process hazards in order to prevent process related injuries and incidents. PSM was developed by and for the chemical industry to prevent catastrophic accidents relating to hazardous chemical processing. However, it is clear that many of the elements can be incorporated into the management philosophy of other less hazardous industries. For instance, the non-chemical manufacturing industry is beginning to embrace PSM as an effective means of managing their operations to reduce process safety concerns, as well as provide a structured approach to increase process uptime. These benefits equate directly to reduced operating costs and correspondingly higher profits. Although some elements deal exclusively with chemically hazardous conditions, the majority can be implemented into a management structure regardless of the industry.

No business, including manufacturing enterprises, can afford to ignore safety issues, because bottom line profits would suffer. Law suits, insurance premiums, public perception as bad corporate citizen, fines, and threat of criminal prosecution could drive an enterprise guilty of such neglect to bankruptcy. It is, therefore, imperative that industrial safety education must begin prior to entering the workforce. Logically, PSM should be incorporated into the manufacturing engineering/technology curriculum. We should realize that there is no better approach to industrial safety than the fourteen PSM tools proposed by OSHA. These tools are comprehensive and systematic. Incorporating some or all of these tools in capstone courses offer an excellent venue for teaching PSM to manufacturing engineering and technology students.

PSM and its fourteen tools

Process safety management according to [1] may be defined as a list of fourteen comprehensive tools for addressing the identification, evaluation, mitigation, and or prevention of hazards that could occur as a result of failures in manufacturing process, procedures, or equipment in the industrial setting. The fourteen tools are numerated as follows: (i) employee participation, (ii) process safety information, (iii) process hazardous analysis, (iv) operating procedures, (v) training (both initial and refresher), (vi) contractors, (vii) pre-start up safety review, (viii) mechanical integrity, (ix) hot work permit, (x) management of change, (xi) incident investigation, (xii) emergency planning, (xiii) compliance audits, and (xiv) trade secret protection. Though these tools had their origin in the chemical industry, they are still useful in manufacturing industries that are non-chemical in nature. Some tools by their nature may only apply to the chemical industry. Capstone courses offer a venue for a detailed discussion of certain tools that are very pertinent to a particular capstone project, while still providing a cursory treatment of the rest of the tools.

Each discipline will adapt the tools to its capstone courses. Incorporation of PSM into a manufacturing curriculum may be better illustrated by using students' capstone projects in the manufacturing department of Arizona State University East. This program involves metal working and mechanical manufacturing. The following seven tools: (a) employee participation, (b) process safety information, (c) process hazard analysis (PHA), (d) operating procedures, (e) pre-start up safety review, (f) mechanical integrity, (g) management of change, would be appropriate for in-depth coverage in our capstone project. For example, early this year (march 1999) the students designed and built a retrofit kit for converting a propane powered forklift engine used by Boeing Company to a hydrogen powered engine where the battery and the lifting power is provided by hydrogen power. This project won a first place and a grand prize award among engineering manufacturing departments of the southwest at the WESTECH competition in Los Angeles, California.

Incorporating the seven pertinent tools into our capstone forklift project

Process hazard analysis (PHA): Probably, the most coverage would be devoted to this tool. In addition to identifying hazards at the design stage, hazards and corresponding risks would have to be identified in the process using Failure Modes, Effects and Criticality Analysis (FMECA), Hazards and Operability analysis (HAZOP), and implementation of any recommendations made to prevent or mitigate the hazards. Hydrogen containment issues would have to be addressed. The explosive and flammable nature of hydrogen would offer ample illustration of PSM tools implementation, including any safeguards and controls that can be placed on the hydrogen tank itself. Engineering principles, calculations, and analysis are often employed in process hazard analysis.

Process safety information: Material safety data sheet (MSDS) and all pertinent safety information regarding material, equipment, process conditions, and procedure should be available and communicated to all personnel who need to know or those involved with the forklift manufacture. State and federal guidelines regarding the use of alternative fuels must be considered. It should address safety information regarding the material, equipment, and process utilized in the Capstone hydrogen powered forklift project.

Operating procedure: This tool is used for training personnel and for proper running of a manufacturing process. Conventional manufacturing operations and materials must be studied and modified for the use of high-pressure hydrogen. Procedures must be thoroughly communicated because mistakes arising from improper communication can result in accidents.

Employee participation: It should be communicated to the capstone project personnel that safety is everyone's responsibility. The students should learn that safety cuts across disciplinary boundaries and must be approached with multifunctional teams. It should be stressed to the students that every step of the manufacturing process, from documentation to engine timing adjustment, is crucial to project safety and success.

Pre-start up safety review: This tool is sometimes referred to as "operational readiness inspection" (ORI). It involves both pre-operational inspection and actual operational testing. It should be communicated to the capstone project personnel that not only could failure result in an accident and consequent loss of life, but also the loss in capital equipment and other process materials including an entire manufacturing facility could occur. Students would develop an operator safety checklist, where the operator must consider the hydrogen tank and line integrity, as well as the surrounding environment. It should be communicated to the students that this tool utilizes real plant hardware and associated documentation. Capstone project experience can be augmented with lessons learned from case studies involving companies that had near misses as well as actual incidents. Videos of these near misses and actual incidents can be shown for more vivid illustration of what can happen when a proper pre-start up review is not conducted and a failure occurs.

Management of change:
Every change must be documented. Technical basis for proposed change, impact of change on safety and health, modifications to operating procedures, necessary time period for the change, authorization requirements for the proposed change, and training of personnel involved in process operation must be addressed and documented. Loss of key personnel and new suppliers should be documented as changes and managed accordingly.

Mechanical integrity:
This tool is required to identify deficiencies in the process equipment and ensure that the equipment is appropriate for the design intent. Preventive maintenance is central to maintaining mechanical integrity. Preventive maintenance is performed to assure that there is no high likelihood that a catastrophic failure will result when a demand is placed on the system. Such catastrophic failure may result in toxic releases, personal injury from thermally induced fatigue, explosions, and fires. Technical training and documentation is carried out in support of the process equipment. The intent is to maintain logs detailing the documented maintenance, testing and inspection programs currently in use.

Conclusion

The implementation of safety can be directed, but should not be dictated by management. Ultimately, it should be stressed to the students that everyone in an organization has a share of responsibility regarding safety, and that management should normally provide a closed loop system of open communication. The students should learn that PSM tools provide a better alternative to production-at -any- cost philosophy, and that all manufacturing enterprises can tailor some PSM tools to their operations in order to (i) prevent accidents, (ii) reduce likelihood of accidents, (iii) reduce consequences of accidents, and (iv) mitigate the consequences. Different capstone projects might utilize different combinations of PSM tools.

It should be emphasized to the capstone student personnel that the order of protection are safety of people (workers), then environment, next equipment, and lastly profits.

In the words of McKelvey [4], McCright and Bergmiller [2], and Dorland and Baria [3], it should be stressed to the capstone student personnel that the intent of every PSM should be to achieve continual and cost-effective improvement of the reliability of the process, equipment, the accuracy of the procedures, the capabilities of the personnel, and the effectiveness of the program to minimize risk and maximize preparedness.

Capstone courses offer a viable medium to teach PSM.

References

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