

AN APPROACH TO HELP DEPARTMENTS MEET THE NEW ABET PROCESS SAFETY REQUIREMENTS

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This paper has two sections: the first provides a brief history of the new ABET process safety requirements; the second describes a SChE Product that has been prepared to help departments meet and document these process safety requirements through their senior capstone design project. The paper concludes with a summary of how departments can combine SChE products and the SChE Safety Certificate Program to effectively teach fundamental process safety awareness to undergraduates.

A BRIEF HISTORY

For the last two decades, industrial and academic process safety experts have been creating products describing many of the fundamental process safety risk-reduction concepts. These products are free to chemical engineering department students and instructors through AIChE's "Safety and Chemical Engineering Education (SChE)" Program. SChE was formed in 1992 as AIChE's link between industrial process safety experts in the Center for Chemical Process Safety (CCPS) and universities. The SChE website contains more than 100 process safety-related products to assist instructors.^[1] In addition, SChE program members also organize faculty workshops that help share best industrial practices with academic instructors.^[2]

In 2007, the fatal explosion at the T2 Laboratories, Inc., triggered an investigation by the U.S. Chemical Safety Board (CSB) and resulted in several findings.^[3] One of these findings included the following statement:

Chemical engineer (part owner) killed because of lack of proper understanding of reactive chemistry hazards and process safety and risk reduction design.

As a result of their investigation, the CSB recommended to the AIChE:

"Work with the Accreditation Board for Engineering and Technology, Inc., (ABET) to add reactive hazard awareness to baccalaureate chemical engineering curricula requirements."

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TABLE 1 AIChE/SACHe Guidelines for Teaching Safety and Design	
1	The graduate must understand the importance of process safety and the resources and commitment required. This should include the important incidents that define process safety, and how these incidents affected the practice of chemical engineering.
2	The graduate must be able to characterize the hazards associated with chemicals and other agents. This must include toxic, flammable, and reactive hazards.
3	The graduate must understand and be able to apply concepts of inherently safer design.
4	The graduate must understand how to control and mitigate hazards to prevent accidents. This should include generally accepted management systems, plant procedures, and designs to prevent accidents.
5	The graduate should be familiar with the major regulations that impact the safety of chemical plants.
6	The graduate should understand the consequences of chemical plant incidents due to acute and chronic chemical releases and exposures.
7	The graduate should be reasonably proficient with at least one hazard-identification procedure.
8	The graduate should have an introduction to the process for hazard evaluations and risk.

Since the report, AIChE has developed and proposed guidelines to ABET for teaching safety to undergraduates. These guidelines are shown in Table 1.

This paper presents the basic concepts for a SACHe Product that provides guidance to engineering design teams to help them meet the combined process safety guidelines of both academia and industry.^[4,5] A department can “prove” its process safety awareness efforts for an ABET auditor by documenting its efforts in the senior capstone design report. This approach, described in this product, will help ensure that students graduate with, at minimum, an awareness of the different hazards analysis techniques that must be used when they design their risk-reduction controls, preventing irreversible life-changing process-related incidents from affecting them or their coworkers.

Please recognize the distinction between “process safety” and “personal safety.” Process safety requires a thorough hazards evaluation that identifies and controls all potential risks associated with a chemical process. The consequences of these process hazards, such as runaway reactions, toxic releases, fires or explosions, must be understood and reduced as much as is practical through adequate process design—this is known as the “first line of defense.” On the other hand, personal health and safety may require students in a unit operations laboratory to wear personal protective equipment (PPE), such as safety glasses, hard hats, and gloves. PPE is required to address any residual risks associated with the chemical process—the PPE is the “last line of defense.”

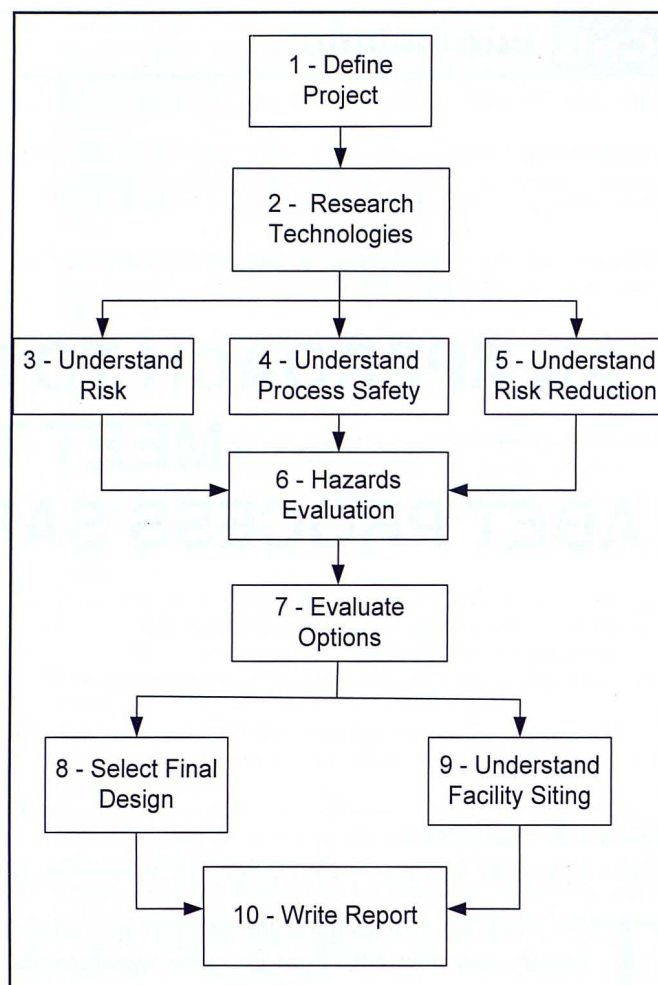


Figure 1. *The Design Project Road Map.*

THE SACHe PRODUCT

The SACHe product, “Safety Guidance for Design Projects,” combines the steps in a senior design project (the basis) with the AIChE Process Safety Guidelines and the principles of Process Safety Management (PSM). As is shown in the “Road Map” in Figure 1, the design team’s project has 10 basic steps:

1. *Define Project*
2. *Research Technologies*
3. *Understand Risk*
4. *Understand Process Safety*
5. *Understand Risk Reduction Strategies*
6. *Hazards Evaluation*
7. *Evaluate Options*
8. *Select Final Design*
9. *Understand Facility Siting*
10. *Write Final Report*

The flow of the blocks noted in Figure 1 helps the design team organize their efforts to meet their academic and industrial process safety requirements, including references to the industry's basic principles of Process Safety Management (PSM).

The connections between the process safety Guidelines listed in Table 1 and the Road Map in Figure 1 are shown in Table 2. The steps shown in Figure 1 that are focused on safety include steps 3, 4, 5, 6, and 9. These process safety-related steps are described in more detail below.

The SChE Product provides guidance for engineering design teams to help them meet the combined process safety

requirements of education and industry.^[4] It can be used by professors, industrial trainers, and students who are working on a process design project, as well.

The Product includes:

1. *An Overview document written to assist the instructor on how to use the module,*
2. *A PowerPoint presentation (the module), and*
3. *Handouts that are used with the PowerPoint presentation.*

The presentation begins with a brief description of the T2 accident that was the genesis of the CSB recommendation

TABLE 2
The Design Project Steps Linked to the AIChE/SChE/ABET Guidelines

Design Project Steps		Description of Project Steps (with referenced AIChE/SChE/ABET guidelines—see Table 1.
1	Define Project	Project Proposal - must have clear understanding of objectives and business case (what is the benefit of making this product?) Will it make a profit? Must be clearly written and understood by all Team members.
2	Research Technologies	Research and locate potential technology options that will meet project goals. (Literature review) Establish high-cut types of Process Safety Information (see step 4 below)
3	Understand Risk	The graduate should have an introduction to the process for hazard evaluations and risk assessments [Guideline 8].
4	Understand Process Safety	<p>a. The graduate must be able to characterize the hazards associated with chemicals and other agents. This must include toxic, flammable, and reactive hazards [Guideline 2]. Understand Process Safety Information (PSI) required to manufacture product. Includes basic description of Hazards of Materials, Process Design Technology and Equipment Design Technology [part of Guideline 2].</p> <p>b. The graduate should understand the consequences of chemical plant incidents due to acute and chronic chemical releases and exposures [Guideline 6].</p> <p>c. The graduate must understand the importance of process safety and the resources and commitment required. This should include the important incidents that define process safety, and how these incidents affected the practice of chemical engineering [Guideline 1].</p> <p>d. The graduate should be familiar with the major regulations that impact the safety of chemical plants [Guideline 5].</p>
5	Understand Risk Reduction Strategies a. Understand Engineering and Administrative Controls b. Understand Inherently Safer Design c. Understand Human Factors	<p>a. The graduate must understand how to control and mitigate hazards to prevent accidents. This should include generally accepted management systems, plant procedures and designs to prevent accidents [Guideline 4].</p> <p>b. Reduce the Frequency as much as is practical. Note for US - Design Project Steps (Road Map) Description of Project Steps [with referenced AIChE/SChE/ABET Guidelines – see Table 1] Required for OSHA PSM [parts of Guidelines 4 and 5].</p> <p>c. The graduate must understand and be able to apply concepts of inherently safer design [Guideline 3].</p> <p>d. Improve the “Human Factors” term in the risk equation (“Operating Discipline,” “Conduct of Operations,” etc.) - improvement in human factors will reduce risk. Note for US - Required for OSHA PSM [part of Guideline 5].</p>
6	Hazards Evaluation	The graduate should be reasonably proficient with at least one hazard identification procedure [Guideline 7].
7	Evaluate Options	Evaluate overall risk associated with chosen technologies (effect of safety, health, environmental and business) to select final design project. Perform a risk gap analysis.
8	Select Final Design	Must define final Process Safety Information (PSI) required to manufacture product. Includes Hazards of Materials, Process Design Technology and Equipment Design Technology. Analyze Cost / Benefit for Final Design.
9	Understand Facility Siting	Must understand impact on personnel and communities. The difficulty for a design project is that design concepts do not have a site layout. An option for Design Team could be to identify a part of their hazardous process (if any), propose a site layout and then define their worst case scenario using a facility siting hazards analysis checklist. Note for US - This analysis is required for OSHA's PSM standard (29 CFR 1910.119) and is essential for the EPA's Risk Management Plan (RMP) [Guideline 5].
10	Write Final Report	Use a report template. Note that a chapter could be included to address findings discovered later that could affect the final choice (such as “Directions for Future Efforts” - an important chapter when deadlines approach)

to AIChE and ABET. The design project “Road Map” is presented next, helping the design team visualize how the elements of Process Safety Management (PSM) used in industry are incorporated into their project.

The handouts include four tables. Table 1 describes the AIChE/SACHe/ABET proposed process safety guidelines; Table 2 compares the steps in a design project that meet part of the process safety guidelines. Note that the team’s final written design report helps departments document that their students meet the AIChE/SACHe process safety guidelines. Specific SACHe products and SACHe Safety Certificates are referenced in Tables 3 and 4 to point the student to additional resources for learning and understanding how to develop a safe design.

The product helps describe the process safety-related steps shown Figure 1:

Step 3: Understanding Risk. The module starts with a definition of risk and includes an example of a risk matrix. The matrix consists of a frequency term and a consequence term. The term “unacceptable risk,” with its high frequency

and high consequence is compared to the term “acceptable risk,” with its correspondingly low frequency and low consequence. Each team must establish its own risk tolerance levels before proceeding with its analysis – just like any business must do before allocating resources to reduce its process safety-related risks.

Step 4: Understanding Process Safety. The types of process safety hazards are: fires, explosions, runaway reactions, and toxic releases. A simplified PSM definition is included in the SACHe PowerPoint charts. PSM’s goals are to reduce the process safety risk to people, the environment, and the business.

Step 5: Risk-Reduction Strategy. The risk-reduction strategies include lowering the expected frequency with engineering or administrative controls and/or lowering the consequence with inherently safer designs. Engineering design considerations include alarms and interlocks (safety instrumented systems, or SIS). Administrative controls include written operating procedures. Inherently safer design considerations (especially crucial at this point!) include, for example, less hazardous materials or reduced processing temperature or pressure extremes. Consequence

TABLE 3
SACHe Products Linked to Design Project Steps (Online via sache.org)

Design Project Step	SACHe Product (Development year via sache.org)
1. Define Project	The Product described in this paper: a. Safety Guidance in Design Projects (2011) These Products help with Steps 3, 4, 5, 6 and 9 below: b. A Process Safety Management Overview (2012) c. Conservation of Life: Application of Process Safety Management (2012)
2. Research Technologies	
3. Understand Risk	a. Risk Assessment (2008) b. Green Engineering Tutorial (2004) c. Project Risk Analysis (2009) d. Understanding Atmospheric Dispersions of Accidental Releases - CCPS book (2010) e. Dow Fire and Explosion Index (F&EI) and Chemical Exposure Index (CEI) Software (2011)
4. Understand Process Safety	a. Chemical Process Safety (2006) b. Seminar on Fires (2009) c. Explosions (2009) d. Dust Explosion Control (2006) e. Chemical Reactivity Hazards (2005) f. Properties of Materials (2007) g. Fire Protection Concepts (2010) h. Introduction to Biosafety (2005)
5. Understand Risk Reduction Strategies	a. Runaway Reactions – Experimental Characterizations (2005) b. Design for Overpressure and Underpressure Protection (2006) c. Safety Valves: Practical Design Practices for Relief Valve Sizing (2003) d. Compressible and Two-Phase Flow with Applications Including Relief System Sizing (2011) e. Inherent Safety (2006) f. Fundamentals of Chemical Transportation with Case Histories (2012)
6. Hazards Evaluation	a. Layers of Protection Analysis (2011) b. Static Electricity as an Ignition Source (2008) c. Process Hazard Analysis (2009)
7. Evaluate Options	Inherently Safer Design Conflicts and Decisions (2008)
8. Select Final Design – Risk Based	
9. Understand Facility Siting	
10. Write Final Report	Improving Communication Skills (2004) Includes Oral Presentations

reduction strategies could include quick detection of the potential event and a quick emergency response, such as smoke detectors, sprinklers, and then immediate action by an emergency response team.

NOTE: The important operational discipline (OD) concepts must be considered when applying risk evaluations in industry. For example: If people do not follow the process safety “rules” (i.e., operating procedures, equipment codes or standards, or maintenance and reliability programs, etc.), then their risk is larger since their OD is less than 1 (where 1 equals perfect compliance to OD). This is shown in a “perceived risk” vs. “actual risk” chart when there is poor OD.

Step 6: The Hazards Evaluation. The elements of Process Safety Management (PSM) are briefly discussed in the module, with particular focus on reinforcing the importance of the Process Safety Information (PSI) and Process Hazards Analysis (PHA) elements and their considerations in the design process.

Step 9: Facility Siting. Please refer to more details of Facility Siting, which is industrially significant, in the notes written in Table 2, Step 9.

The Product concludes by reminding the students of the process safety-related steps in the design team’s project Road Map chart. The final two charts were influenced by the Deepwater Horizon disaster in early 2010 (the time when this Product was being prepared). Hopefully the students will understand: Although we have made progress in process safety, we still have work to do.

SUMMARY

Fatalities, such as those that occurred at the T2 Laboratory in 2007, could have been avoided with better understanding and implementation of the elements of Process Safety Management (PSM). Significant advances in industry have helped engineers reduce process safety risks with better design-related tools for understanding, analyzing, designing, and controlling hazardous processes. The SChE Product described in this paper helps bridge a gap between universities and industry in process safety-related awareness and education. The SChE product provides a Road Map (a framework) for organizing the existing SChE products, combining the requirements of the design project with the

PSM principles. The product can be used to improve the awareness of the PSM-related resources and techniques, with particular emphasis on locating the SChE products that have been designed to be integrated within the chemical engineering curriculum. Using this Product will help ensure that students graduate with, at minimum, an awareness of different hazards analysis techniques that must be used when they design their risk-reduction controls.

A brief note on future efforts: These process safety-related education/design efforts described in this paper focus on the traditional studies of material and energy balances—conserving mass and energy. Industrial application of process safety requires two more concepts, however:

“Operational Discipline” and the “conservation of life.”^[6-8] These additional concepts help us achieve AIChE’s first principle in our “Code of Ethics” [underlined below,⁹]:

“Members of the American Institute of Chemical Engineers shall uphold and advance the integrity, honor and dignity of the engineering profession by:

Being honest and impartial and serving with fidelity their employers, their clients, and the public;

Striving to increase the competence and prestige of the engineering profession;

Using their knowledge and skill for the enhancement of human welfare.

To achieve these goals, members shall:

Hold paramount the safety, health and welfare of the public and protect the environment in performance of their professional duties.”

Expect to read more about how we will continue to meet this principle in the future.

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TABLE 4
SChE Safety Certificates Linked to the Design Project Steps (Online via sache.org)

Design Project Step	SChE Product (Year via sache.org)
3. Understand Risk	Risk Assessment (2008)
4. Understand Process Safety	a. Safety in the Process Industries (2008) b. Chemical Reactivity Hazards (2008) c. Runaway Reactions (2008) d. Dust Explosion Control (2010) e. Process Safety 101 (2010)
5. Understand Risk Reduction Strategies	Inherently Safer Design (2009)

Design Inherently Safer Process Plants”

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