# Thoughts About Meeting the ABET Safety Requirements For Chemical Engineering Programs

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## Abstract

Safety was first listed as a criterion for Chemical Engineering programs for the 2012-13 ABET accreditation cycle. In order to address this criterion, chemical engineering departments have been developing methods to incorporate safety into their program. The University of Iowa satisfies this criterion through a required junior-level chemical process safety course that was first offered during the Spring 1996 semester. A major laboratory component was added to this course in 1998 to provide students with numerous hands on experiences. While a dedicated chemical process safety course is the most straightforward method of addressing this ABET criterion, the criterion can also be addressed by incorporating safety into existing courses.

## Introduction

The ABET criterion regarding safety in the chemical engineering curriculum, which initially went into effect for the 2012-13 accreditation cycle, states the following[1]:

> The curriculum must provide a thorough grounding in the basic sciences including chemistry, physics, and/or biology, with some content at an advanced level, as appropriate to the objectives of the program. The curriculum must include the engineering application of these basic sciences to the design, analysis, and control of chemical, physical, and/or biological processes, **including the hazards associated with these processes**.

This criterion can be addressed by (i) a dedicated course and/or (ii) incorporating safety into other courses. In the Department of Chemical and Biochemical Engineering at the University of Iowa we have a dedicated three semester hour course and incorporate safety into other courses, particularly our 2-course Design sequence.

## Dedicated Safety Course

Since 1996, the University of Iowa has offered a required three semester hour Chemical Process Safety course that is taken by students during the Spring semester of their Junior year. Incorporating this course into the curriculum required only a slight modification of our curriculum, which is inconsistent with the common excuse ("cannot fit it into our curriculum") given for not having a dedicated Chemical Process Safety course. A dedicated laboratory component was introduced in the 1998 offering of the course as described previously[2]. The course lecture and laboratory have been modified over the years. The current details of the course and laboratory are summarized in Tables 1 and 2. This course utilizes the textbook written by Crowl and Louvar[3] and material from many websites, including Safety and Chemical Engineering Education (SAChE) [4-6], U.S. Chemical Safety Board[7], Chemical Reactivity Worksheet[8], and AIChE Design Competition[9]. The content of these websites and thoughts about incorporating the material into courses throughout the curriculum are discussed below.

**Incorporating Safety into the Chemical Engineering Curriculum**

The experiments denoted in Table 2 are generally not applicable for easy incorporation into other courses. An exception is the reactivity experiment. Many chemical engineering departments throughout the United States have purchased the Advanced Reactive System Screening Tool (ARRST)[10] from Fauske & Associates for use in their laboratory courses. This instrument can collect general kinetic data as well as data related to runaway reaction evaluation. The flash point component of the flammability experiment, which requires the purchase of a flash point tester (e.g., the Miniflash Automatic Flash Point Tester[11], which is a closed cup unit), is another experiment that could easily be incorporated into an existing laboratory course.

There is a wealth of information available to assist in teaching chemical process safety throughout the chemical engineering curriculum. The SAChE website[5] contains information (e.g., problems, case studies, lectures, etc.) relevant to specific courses, including material/energy balances, fluid flow, heat transfer, mass transfer, thermodynamics, chemical reaction engineering, process control, design and laboratory. This SAChE website[6] also contains all of the "Process Safety Beacons" that have appeared monthly in *Chemical Engineering Progress* since 2001. The Process Safety Beacons are developed by AIChE's Center for Chemical Process Safety (CCPS) with the intent of delivering process safety messages to plant operators and other manufacturing personnel. Finally, the SAChE website[4] contains the Student Safety Certificate Program that provides the opportunity for students to complete online courses and receive a certificate verifying their completion of a specific topic. Currently, there are 8 different safety certificates available: (i) Process Safety Lessons Taught From Experience, (ii) Process Safety 101, (iii) Dust Explosion Control, (iv) Inherently Safer Design, (v) Safety in the Process Industries, (vi) Risk Assessment, (vii) Runaway Reactions, and (viii) Chemical Reactivity Hazards.

The AIChE Student Design Competition website[9] contains all of the problem statements beginning with the 1932 problem. These can be used to introduce safety into the design courses. Since ~2001 safety has been a required component of the Student Design Competition solution. This involves a discussion of (i) general safety issues and (ii) incorporating inherently safer design (ISD) strategies to make the process safer. The discussion of safety issues can include such items as a complete HAZard and Operability (HAZOP) study, a summary of important properties (i.e., toxicity, flammability and reactivity) of all reactants, intermediates and products, and the location of relief valves. Furthermore, ISD strategies include minimize, substitute, moderate and simplify.

Finally, there are two particularly useful government websites that can be utilized to teach safety in a variety of courses. The U.S. Chemical Safety Board[7] website contains many interesting videos, including simulations of accidents that their staff have investigated. This website also contains reports of their accident investigations. The Chemical Reactivity Worksheet (CRW) website[8] is found within the National Oceanic & Atmospheric Administration (NOAA) website. This website contains CRW software that can be used to evaluate chemical reactivity and interactions between chemicals. Thus, if all of the chemicals within a process are included (water and air are also usually included since they are ubiquitous and can easily become available to react with the process chemicals), then this software can indicate potential reactions between these chemicals and the severity thereof (sometimes explosive!).

## Conclusions

It is recommended that Chemical Engineering Programs incorporate a dedicated chemical process safety course into their curriculum. This course will assist in preparing students for industrial employment and also greatly simplifies satisfying the new ABET safety criterion. It is also recommended that safety be incorporated into other courses throughout the curriculum, particularly the design course(s). The dedicated chemical process safety course at the University of Iowa has received numerous complements from our alumni and members of our professional advisory board. It is clear that industry appreciates students with a strong background in chemical process safety. Many of our former students received job offers as a direct result of their chemical process safety knowledge, including five current Fauske & Associates employees.

**Bibliography**


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**Table 1. Details of Chemical Process Safety Course at the University of Iowa**

Major Topics Covered in Lecture

| | |
|---|---|
| Government Regulation | Reactivity |
| Process Safety Management | Fires and Explosions |
| Toxicology | Fire and Explosion Prevention |
| Industrial Hygiene | Relief Design |
| Source Models | Hazard Identification |
| Dispersion Models | Risk Assessment/Reliability Engineering |
| Flammability | Case Studies |
| Electrostatics | Inherently Safety Design |

Homework

There are weekly homework assignments.

Quizzes

There are weekly quizzes (~15-20 min). These seem to improve the learning process and to discourage student procrastination.

Exams

There is one midterm exam and a final exam.

Topical Papers

In recent years students have written two topical papers ("opinion pieces") of 500 to 1000 words: (i) Chemical Regulation – What Is The Best Approach For The U.S.? and (ii) Chemical Plant Security: Should Inherently Design Be Required?

Laboratory Reports

There are laboratory reports for each of the four experiments given in Table 2. The reports for the flammability and electrostatics experiments are individual reports, while the other two reports are written by groups of 2 students.

Project/Presentation

There is a project involving previous AIChE Design Problems (a variety of problems are distributed among student in the class). Specifically, the report consists of (i) a literature review of the process, (ii) a process flow diagram (PFD), (iii) a discussion of safety issues, including a complete HAZard and OPerability study (HAZOP) and location of relief valves, and (iv) a discussion of how inherently safer design strategies (i.e., minimize, substitute, moderate, and simplify) can be used to make the process safer. These projects are conducted in groups of 2 or 3 students and also involve giving a PowerPoint presentation to the class.

**Table 2. Chemical Process Safety Laboratory at the University of Iowa**

| Laboratory Experiment | Equipment Used | Comments |
|---|---|---|
| Flammability | • *Minimum Ignition Energy (MIE) Apparatus<br>• *Flammability Chamber<br>• Miniflash Automatic Flash Point Tester (Closed Cup) | This laboratory involves determining (i) the MIE of a flammable gas, (ii) the LFL, UFL, and LOC of a flammable gas, and (iii) the flash point of pure flammable liquids and mixtures. Thermodynamics of ideal and nonideal mixtures are used to calculate the flash points of the mixtures and compared to actual measurements. |
| Reactivity | • Advanced Reactive System Screening Tool | This laboratory involves collecting data for four different reactions and analyzing the resulting data. Furthermore, the data are used to size relief valves for specified scenarios. |
| Electrostatics | • Liquid Conductivity Apparatus<br>• Powder Chargeabilty Apparatus<br>• Powder Volume Resistivity Apparatus<br>• Humidity Chamber<br>• Van de Graaf Generator<br>• Keithley Electrometers | This laboratory involves determining (i) liquid conductivity, (ii) powder chargeabilty resulting from transport through plastic, glass and metal tubes, and (iii) powder resisitivity. The laboratory also investigates (depending on the year) the chargeabilty of humans, charge accumulation due to mixing liquids, etc. The humidity chamber allows the humidity to be controlled in some of the experiments. |
| Explosions | • *Minimum Ignition Energy Apparatus<br>• Modified Hartmann Tube<br>• Hartmann Bomb | This laboratory involves characterizing gas phase and dust explosions. |

*Custom made by Fauske & Associates