# SACHE News

CENTER FOR CHEMICAL PROCESS SAFETY
An AIChE Industry Technology Alliance

## Safety and Chemical Engineering Education - Spring 2004

## Status of SACHE

Dennis Hendershot, Chair
CCPS Undergraduate Education Committee

**SACHE Web Site**

All SACHE members should have received information on how to access the SACHE web site (www.sache.org). If you did not receive a password and login instructions, please contact Karen Person at the Center for Chemical Process Safety of AIChE. The web site currently has the following 2003 and 2004 products in electronic format:

- Safety Valves: Practical Design Practices for Relief Valve Sizing (2003, Eric N. Parvin and Arthur M. Sterling, Louisiana State University)
- Safety, Health, and Environmental Text for Textbooks (2003, S. Horsch and J. Louvar, Wayne State University, and M. Horsch, University of Michigan)
- Mini-Case Histories (2003, D. Dakshinamoorthy and J. Louvar, Wayne State University)
- Consequence Modeling Source Models I: Liquids and Gases (2004, Jan Wagner, Oklahoma State University)

We plan to put the rest of the 2004 products on the web site for electronic distribution as soon as they are available. As resources permit, we will also place previous year's products which already exist in electronic format on the web site.

**Conversion of Older Products to Electronic Format**

We would like to get feedback on which of the older SACHE products originally created in various "hard copy" formats (35 mm slides, overhead transparencies, etc.) are particularly useful and worth converting to electronic format. Rather than make our own assumptions, the SACHE Committee welcomes feedback from all product users. If you are using any of these older products and would like to have them converted to current electronic formats, please contact Joe Louvar (jlouvar@ameritech.net) or Dennis Hendershot (DHendershot@rohmhaas.com). As time and financial resources permit, we will work on converting some of the older products to current formats.

**Safety Related Web Sites**

We plan to add a "Safety Related Web Links" page to the SACHE web site. If you have any sites which you feel are valuable and worth sharing with your colleagues at other universities, please send the URL to Dennis Hendershot or Joe Louvar.

**SACHE Dues Reduced for Overseas Members**

SACHE dues have historically been $300 per year for US members, and $420 per year for overseas members. The difference was primarily because of the higher cost of shipping products to overseas universities. Since we will be distributing our products electronically over the Internet in the future, there is no longer any justification for this difference in dues, and, in the future, dues for overseas universities will be the same as for US universities. While $300 does not sound like a lot of money, it can be a real barrier in a developing country, and we hope that this reduction will make it easier for universities in these countries to join SACHE.

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SACHE, or Safety and Chemical Engineering Education, is a project under the auspices of AIChE's Center for Chemical Process Safety (CCPS). SACHE's charter is to enhance the presentation of process safety in undergraduate education.

*SACHE News* is published two times annually by the Undergraduate Education Committee of the AIChE Center for Chemical Process Safety. 

Articles related to any aspects of safety in the academic community are solicited from both the academic and industrial communities for publication in *SACHE News*. Material should be sent directly to the editor for consideration.

## Undergraduate Education Committee

## Chemical Process Safety and the FE Exam

James T. Cobb
Department of Chemical and Petroleum Engineering, University of Pittsburgh

Taking and passing the Fundamentals of Engineering (FE) examination, administered twice a year by the state engineering licensing boards across the United States, is the first step in obtaining a Professional Engineer (PE) license. Complete information about the FE exam can be found on the website of the National Council of Examiners for Engineering and Surveying, http://www.ncees.org/.

The eight-hour FE exam is divided into two segments. The first is a four-hour (morning) general engineering segment, consisting of 120 multiple-choice questions covering the non-discipline-specific material from the first two years of the engineering curriculum. The second segment is a four-hour (afternoon) discipline-specific session, consisting of 60 multiple-choice questions from the courses of the major field studied by the candidate. While taking the examination, the candidate can use only a supplied Reference Handbook for assistance in remembering the specific equations and methods needed for choosing a response to each question from the four responses suggested for that question.

The afternoon segment for chemical engineering includes questions on:

- Chemical Reaction Engineering
- Chemical Thermodynamics
- Computer and Numerical Methods
- Heat Transfer
- Mass Transfer
- Material / Energy Balances
- Pollution Prevention
- Process Control
- Process Design and Economics Evaluation
- Process Equipment Design
- Process Safety
- Transport Phenomena

The Sixth Edition of the Reference Manual, just issued, contains five pages of information on these topics. Included for the first time in the Sixth Edition is information on Process Safety, including material on:

- Threshold Limit Value
- Flammability
- Concentrations of Vaporized Liquids
- Concentration in the Atmosphere
- Sweep-through Concentration Change in a Vessel

It is the policy of the American Institute of Chemical Engineers to advise its members to become a licensed chemical engineer at the earliest practical time in their careers. Having a PE license provides an engineer with the greatest flexibility in seeking employment. Employees of consulting companies and individuals in private practice, both of whom work for the public in process design and environment control, must be licensed to advertise their services and to seal the documents they produce. Taking the FE exam while a student in the senior year of college, or shortly after graduation, maximizes the candidate's prospects to pass the exam without extensive review, while the material is still fresh in mind.

SACHE urges everyone to follow AIChE's advice and become licensed as soon as possible in their career.

## ioMosaic Extends SuperChems™ and ioXpress™ to SACHE Universities

ioMosaic President Dr. Georges A. Melhem announced on May 12, 2004, that ioMosaic will extend complimentary copies of its industry standard emergency relief system (ERS) design solutions, SuperChems and ioXpress, to all national universities under the *Safety and Chemical Engineering Education Program* (SACHE).

Details of this generous contribution to SACHE members can be obtained at http://archives1.iomosaic.com/press_releases/SuperChems_ioXpress_Universities/index.htm.

EDITOR'S NOTE: This is the second of two winning entries in the 2003 SACHE Student Essay contest. The first essay by Chandler Benton, Michigan Technological University, was published in the Fall, 2003, issue of *SACHE News*. Each student received a $500 award and a certificate at the AIChE Annual Meeting in San Francisco.

## Inherent Safety in Chemical Processes

Jeremy Pelt
Wayne State University

Safety in the chemical manufacturing industry is crucial to avoid unnecessary death and investment loss. When dealing with safety, researchers and scientists need to be aware of the safety, health, and environmental (SHE) consequences that their decisions have when manufacturing chemicals. Risk management strategies can be categorized into four main categories. The first category is inherent SHE, which is eliminating or reducing the hazards by using materials and processing conditions that are less or non-hazardous. The second category is passive SHE, which is minimizing the hazard by process or equipment design features that don't eliminate the hazard, but reduce the risk without the need for any device to actively function. The third category is active SHE, which is using controls, safety interlocks such as double-block and bleeds, and emergency shutdown systems to detect and correct any potential hazards before they become severe enough to result in an incident. The final category is procedural SHE, which involves operating procedures, administrative controls, emergency response, and other management controls to reduce the number of incidents or the severity of an incident. We will be discussing inherent SHE.

When developing reactive chemical processes the greatest opportunity to employ safety is in the earliest stages of the research and design process. The idea of inherent SHE is to design processes and plants to remove or avoid these hazards. Inherent SHE can be broken down into four main strategies: minimize, substitute, moderate, and simplify.

The minimization strategy of a reactive chemical process can inherently improve the safety of the plant by minimizing the quantity of hazardous material and energy involved in the process. This can happen in the earliest stages of the design process when a chemist proposes a chemical synthesis route. One way is to produce a product at high yield with few or no by-products that would have to be removed down the line. This will simplify the process and remove unnecessary chemicals that may pose a hazard. Another minimization strategy is to use a process that operates as closely to ambient temperature and pressure as possible. This reduces the potential energy from higher temperatures and pressures, which will reduce the possibility of equipment failure and can possibly reduce incidents such as BLEVEs and runaway reactions. To minimize the chance of a runaway reaction, reaction pathways should be used that don't employ highly exothermic reactions. This minimizes the need to cool the process and will help to alleviate the possibility of a runaway reaction.

An example of a minimization strategy is a process that continuously manufactured phosgene for supplying a batch process that required phosgene. This eliminated the storage of liquid phosgene, which is a highly toxic, irritating, corrosive material that is highly reactive and decomposes to toxic chemicals. The process engineers were able to interface a continuous process for making phosgene with a batch process that required phosgene. The engineers were able to do this by having an excellent understanding of the chemical reaction mechanism. They had to impose stringent requirements for rapid startup and steady state operation on the phosgene manufacturing plant.

Substitution is another inherent SHE strategy. The substitution strategy involves substituting a chemical synthesis route using less hazardous materials, intermediates, or less energetic reactions.

One example of a substitution synthesis route is the production of acrylic esters by the oxidation of propylene to produce acrylic acid. This is followed by the esterification of the acrylic acid to manufacture the various esters. This process is inherently safer than the Reppe process that uses acetylene, carbon monoxide, and nickel carbonyl, which is a highly reactive chemical, to manufacture the acrylic esters.

Another area where substitution is used in inherently safer processes is the substitution of less hazardous solvents in a process. Solvents themselves can moderate hazardous reactants, intermediates, and products. If the solvent itself is toxic or flammable it can be substituted with a less

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## Inherent Safety in Chemical Processes

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harmful solvent. For example, many cleaning and degreasing processes have eliminated the use of organic solvents, which are usually very flammable, with water based systems. This reduces the risk of an explosion or fire in the system, which can lead to a runaway reaction elsewhere.

Moderation is another inherent safety strategy. Moderation involves an understanding of process chemistry and what controls reaction pathways and reaction rates. Reaction catalysis is a way inherent SHE can be improved. Catalytic reactions allow reactors and associated equipment to be made smaller, they reduce the need for downstream purification units, they increase process yields in the reaction, and they allow reactions to be run at lower pressures and temperatures. These improvements greatly reduce the possibility of runaway reactions and can reduce the consequences of BLEVEs.

An example of a way a process has been moderated is in the production of ammonia. In the 1930s, ammonia plants operated at pressures as high as 600 bar. The improved understanding of the chemistry behind the ammonia synthesis allowed the process to be run at much lower pressures. In the 1980s, plants were being constructed that operated at a pressure range of 100 to 150 bar. These new designs were inherently safer due to the lower pressures in the equipment and the plants were cheaper and more efficient.

The final strategy involved in inherent SHE is to simplify. Understanding the basic chemistry and the hazards involved allows chemists and engineers to design simpler reaction systems and plants. "One pot" and "in-situ" processes allow the engineers to produce dangerous intermediates in the same reactor where they will be used. This eliminates storing or piping these hazardous intermediates throughout the plant, which involves more equipment and a higher probability of accident. The hazardous intermediates are used up as they are produced so the hazardous material will be limited to a single batch run.

Another example of simplification is the trade-off between a complex plant design with the complexity of one piece of equipment. For example, a new process was designed to produce methyl acetate that only required three reactive distillation columns. The old process required a reactor, an extractor, and eight other columns. The new process is inherently safer than the old process because it has less equipment, which equals fewer possibilities of equipment failure. Of course reactive distillation is much more complex than using a reactor and a series of columns, but the new process is safer, simpler, and more economical.

These are the main ideas behind inherent SHE in a reactive chemical process. The future of inherent SHE is to use non-hazardous raw materials and intermediates, operate processes at ambient temperature and pressure, produce no waste or undesirable by-products, have low capital investment and life cycle operating costs, and have a material efficiency of 100 percent in reactions. Unfortunately, these criteria aren't yet able to be reached. There is much research that is needed to come anywhere close to reaching these goals. Until then, we can only strive to make chemical process inherently safer.

References:

Hendershot, D.C. (1998). "Inherent Safety Strategies for Process Chemistry." *Chemical Health & Safety* *5*,4 (July/August).

D. A. Crowl and J. F. Louvar, Chemical Process Safety: Fundamentals with Applications 2nd, Prentice Hall, NJ (2002).

## Hazard View

Hazard View is a source of advice, comment and information for safety, environment, and risk professionals concerned with major accident hazards in the process industries. The site is managed and edited by Dr. Paul Davies who is a Partner with Environmental Resources Management's risk team, based in Manchester, UK.

The View Library provides a visual appreciation of hazards through a collection of photographic slideshows. For example, the collection features images of post-incident scenes, site views, equipment, fires, explosions and toxic clouds.

Registration is required to obtain a userid and password, but there is no charge for access to the View Library and many technical articles.

## New SACHE Module

This SACHE product is included in the 2004 SACHE educational resources distributed to member universities. Faculty and students should contact their SACHE representative for access to these and other SACHE products, including slide and PowerPoint presentations, videos, problem sets, NIOSH publications, and CCPS books. Recent SACHE deliverables are posted at http://www.aiche.org/sache/sachedel.htm.

## Consequence Modeling
## Source Models I: Liquids and Gases

Jan Wagner
Oklahoma State University

This module was developed to help introduce issues of safety and loss prevention in undergraduate engineering courses. Each of the five major sections can be used independently, depending on the student's background.

Section 1 is an introduction to the role of source models in the risk assessment process. Section 2 introduces the basic information required to select or develop an appropriate source model for a given release scenario. The fundamental concepts of the 1st Law of Thermodynamics, the mechanical energy balance, and friction losses in pipes and fittings are reviewed briefly in Section 3. Section 4 deals with flow of liquids in pipes and orifices. The example problems are intended to introduce loss prevention issues, and they can be used in any fluid mechanics class. Section 5 presents the flow of ideal gas in orifices and pipes. This material may be appropriate in fluid mechanics or thermodynamics classes. The derivations of equations for compressible flow are intended to show the relationships between physical phenomena and the mathematical model; the fundamental concepts apply to ideal and real gases.

A few student problems have been included. For some of these problems and example problems, Microsoft Excel™ spreadsheets have been developed to facilitate solutions. These spreadsheets do not contain macros or other programs that would tend to remove the details of the solution from the user. An instructor's manual is available, which includes solutions for all of the student problems.

## Process Safety Awards
## AIChE National Student Design Competion

SACHE and the Safety and Health Division sponsor a total of six awards for applications of chemical process safety principles in solutions to the National Student Design Competion.

**Sponsor:** SACHE

**Description:** Each year, chemical engineers from a designated company devise a student contest problem that typifies a real, working, chemical engineering design situation. The problem solution requires a wide range of skills in calculation and evaluation of both technical data and economic factors. The SACHE award is presented to team and individuals for designs that apply appropriate principles of chemical process safety.

**Award:** One team design award of $300 and one individual design award of $200 for the best applications of the principles of chemical process safety.

**Sponsor:** The Safety and Health Division

**Description:** There will be four awards ($500 each) for the appropriate application of inherent safety in the designs. The awards will be granted to the teams or individuals who apply one or more of the following concepts of inherent safety in their designs: a) Design the plant for easy and effective maintainability; b) Design the plant with less waste; c) Design the plant with special features that demonstrate inherent safety; d) Include design concepts regarding the entire life cycle. The school must have a student chapter of AIChE. The report will need a separate section titled "inherent safety" to describe the design features that represent inherent safety. The Safety and Health Division will evaluate all of the designs that are submitted for the AIChE National Student Design Competition using the inherent safety criteria mentioned above.

**Award:** The teams with the best application of inherent safety will receive $500 or the individuals with the best application of inherent safety will receive $500. Four $500 awards will be granted each year.

## Status of SACHE

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### SACHE Workshop

We are currently contacting potential hosts for the next SACHE workshop. We hope to have specific information in the next newsletter.

### SACHE Breakfast

We had a small, but enthusiastic, group of attendees at the SACHE breakfast at the AIChE National Meeting in November 2003 in San Francisco. We consider this breakfast an important opportunity to get feedback from many universities on current and future SACHE products. Please watch for information on the SACHE meeting at the 2004 AIChE National Meeting in Austin, Texas, and plan on attending.

One interesting topic of discussion at last year's breakfast was safety in the ChemE Car competition. Apparently there were incidents with cars from at least two schools. One of them presented a poster describing the incident investigation, the other was mentioned by some students watching the competition. Both were related to insufficient pressure rating and/or pressure relief in acid-sodium bicarbonate reactions to produce carbon dioxide to propel the car. If you are involved in the ChemE Car competition, please emphasize the importance of safety to the students, and make sure they have access to appropriate information and resources to ensure the safety of their cars.

### Student Awards

Participation in the student essay contest has been dropping off in recent years, and the committee has decided to drop this award in the future. We welcome feedback on what kind of an award might replace it as a way of generating student interest in safety.

SACHE and the Safety and Health Division of AIChE will once again present awards for the best use of principles of safety, and the best use of the principles of inherent safety for both team and individuals for the AIChE Student Design Contest problem. Detailed information is available on the AIChE web site (http://students.aiche.org/honors/#awards) and summarized on Page 6.

## Awareness and Preparedness for Emergencies at Local Level

Awareness and Preparedness for Emergencies at Local Level (APELL) is a program developed by United Nations Envrionment Program (UNEP) in conjuction with governments and industry to minimize the occurrence and harmful effects of technological accidents and environmental emergencies.

The APELL approach is identifies and creates awareness of risks in an industrialised community, initiates measures for risk reduction and mitigation, and develops co-ordinated preparedness between the industry, the local authorities and the local population. The APELL Program produces handbooks and technical reports including case studies of technical accidents and natural disasters. The Program also maintains a disasters database that can be searched by type of incident, industry, or activity. Most of the information is available at http://www.uneptie.org/pc/apell/home.html.

## Safety Report Assessment

Britain's Health and Safety Commission (HSC) and the Health and Safety Executive (HSE) are responsible for the regulation of almost all the risks to health and safety arising from work activity in Britain. One of the duties of HSE is the assessment of Safety Reports.

The Safety Report Assessment Guidance is available on-line at http://www.hse.gov.uk/comah/sragtech/index.htm and includes the assessment criteria with links to relevant technical measures, documents, and case studies. Technical Measures provides descriptions of control and mitigation measures for different failure modes of systems and unit operations. Documentation links provide the reader access to documentation that is relevant to the technical aspects of the COMAH Safety Reports. The last chapter Case Studies contains descriptions of major accidents and illustrates cases where technical measures were missing or no properly implemented. One document that may be useful to instructors introducing loss prevention in process safety or design courses is Table of Case Studies and Technical Measures, a cross-reference to technical measures that were found to be inadequate in each case study.