Cleveland State University

Waskewicz College of Engineering

Department of Chemical & Biomedical Engineering

CHE 494/594 Chemical Process Safety: Fundamentals with Applications

Spring 2018

Catalog Description: CHE 494/594: Special Topics in Chemical Engineering (3-0-3). Chemical Process Safety: Fundamentals with Applications.

Textbook: Daniel A. Crowl & Joseph F. Louvar, "Chemical Process Safety: Fundamentals with Applications" Prentice Hall, Fourth Edition, 2016.

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Course Description:

All aspects of Chemical Process Safety and Loss Prevention are addressed in this course. Process safety is concerned primarily with the identification of potential hazards and hazardous conditions associated with the processes and equipment involved in the chemical process industries. It includes methods of predicting the possible severity of the associated hazards and preventing, controlling or mitigating them. The material is thus different from personnel safety or industrial hygiene.

As such, it is necessary to understand the operation of these processes and the equipment, and to apply sound engineering fundamentals to the analysis and prediction of performance under adverse circumstances. Thus, the course emphasizes quantitative engineering analysis. This is based on the application of mass and energy balances, fluid mechanics of liquid/gas/two-phase flow, heat transfer and the conservation of energy, mass transfer, reaction kinetics, process control, statistics, and diffusion & dispersion under highly variable conditions. Techniques for performing process hazard analysis, risk assessment, and accident investigations are covered, including the review of several significant incidents in the chemical processing industry. The course topics follow those in the text: A. Crowl and Joseph F. Louvar, **'Chemical Process Safety: Fundamentals with Applications'**, Prentice Hall (4^{th} edition), which will be supplemented with other pertinent materials. Homework assignments are taken primarily from the problems in the book with occasional supplements. The lectures and text are supplemented and extended with student projects, which culminate in a report and class presentation.

Prerequisites: Fundamentals of mass and energy balances, thermodynamics, fluid mechanics, heat and mass transfer operations.

Course Learning Outcomes:

1. Recognize professional and ethical elements of an outstanding safety program.
2. Evaluate ethical issues that may occur in professional engineering practice.
3. Recognize ethical standards and professional codes of conduct for engineers, e.g., NSPE Code of Ethics for Engineers.
4. Identify government agencies, regulatory bodies, codes, and standards that govern the global, societal, and environmental impact of plant design projects.
5. Be able to list examples of how unsound science or unethical behavior had a negative impact on society.
6. Identify and apply OSHA, PSM, and EPA RMP in the chemical process industries.
7. Describe and apply the principles and approach of inherently safer design to reduce and eliminate hazards and thereby lower the risk of new or currently operating chemical systems.
8. Describe the operation of chemical processes and equipment and apply engineering fundamentals to the analysis and prediction of performance under adverse circumstances.
9. Perform quantitative engineering analysis based upon the applications of mass and energy balances, fluid mechanics of liquid/gas/two-phase flow, heat transfer and the conservation of energy, mass transfer, reaction kinetics, process control, statistics, and diffusion & dispersion under highly variable conditions.
10. Perform PHA analyses of targeted chemical process industries and evaluate the safety performance.
11. Identify the potential hazards and hazardous conditions associated with the processes and equipment involved in the chemical process industries.
12. Work effectively in teams and develop / enhance problem solving skills. Prepare and present a professional project report.

Course Materials / **Lectures:** Weekly lectures will be posted on the Blackboard and will be available to students enrolled in the class.

Teams: Students will be grouped into teams of ~3, and work on the homework assignments and term project as a team. **Every team will submit homework assignments.** The purpose of working in teams is not to 'spread the work around' but to capture the synergies of teamwork, benefiting from each member's perspective. Team members will periodically evaluate each other in terms of their

contribution to homework and the team project, which will be reflected in grades.

Homework: Homework will generally be assigned each week. It is expected that **all team members** will participate in answering **all homework problems**. Late homework will **not** be accepted, except with *prior approval.* Homework solutions will be available for review. .

Attendance: Class attendance is important and class participation is encouraged. Material will be covered in class beyond the text, including several videos, and there will be unannounced quizzes.

Project: Each team will prepare a term project (selected from a list of topics provided), and the Graduate Student teams will make a formal class presentation on the project. Each team will submit a formal report on its project. Topics will be distributed early enough in the semester. Teams will select their top three topics within a week with the final topic confirmed by the Instructor. An abstract will be due in another week. A final report will be due in the last week of classes both an electronic version and a hard copy. **Presentations will be scheduled in the final week of classes.**

Grading of the project will be based on the abstract, written report, teammate evaluations, attendance and class participation. Graduate students will also be evaluated on their project presentation and response to Q&As. The former two are team grades, while all other areas are individual grades.

Exams: There will be two midterms and a final examination during the semester. All exams will be open-book in class. All three exams will be evenly spaced about 5 weeks apart. They will be announced at least 2 weeks before the exams are scheduled.

Class Policy: All quizzes are closed-book, while exams are open book. Missing a quiz/exam results in a zero unless arrangements are made with the instructor in advance. **No texting, Blackberry or cell phone use is permitted during lectures**.

Grading Criteria:	Homework	15%
	Project Report/Presentation	15%
	Quizzes	10%
	Exams	60%

Grades: 90-100 A: 80-89 B: 70-79 C: 60-69 D: <60 F

Support: TA – may or may not be available.
Instructor Office Hours: TTh 2:00 – 3:30.

Notices: The Americans with Disabilities Act (ADA) is a federal antidiscrimination statute that provides comprehensive civil rights protection for

persons with disabilities. Among other things, this legislation requires that all students with disabilities be guaranteed a learning environment that provides for reasonable accommodation of their disabilities. If you believe you have a disability requiring an accommodation, please contact the Office of Disability Services. No cheating, in any form, will be tolerated.

Lecture Outline	Hours	Chapter
I. **Introduction** - Process Safety Management Process vs. Personnel Safety & Metrics Safety Culture Hazard Identification, Assessment & Control Inherently Safer Design Ethics	3	11, 12
II. **Teamwork**	1	
III. **Source Models** Applications of Fluid Mechanics to Leakage of Liquid and Gas Through Holes, Pipes, and Fittings Evaporation, Flashing, and Boiling Two Phase Flow	3	4
V. **Toxic Release and Dispersion** Dispersion Models Pasquill-Gifford Plume and Puff Models	3	5
VI. **Fires and Explosions** Flammability of Liquids and Vapors Minimum Oxygen Concentration, Ignition Flammability Diagrams Explosions - Detonations and Deflagrations Blast Damage	3	6
VII. **Fire and Explosion Protection and Prevention** Inerting, Purging Static Electricity Explosion Proof Equipment Ventilation, Sprinklers	3	7
VIII. **Chemical Reactivity** Background Understanding Commitment, Awareness & Identification of Reactive Chemical Hazards Characterization of Reactive Hazards Using Calorimetry Controlling Reactive Hazards	1	8

IX.	**Reliefs** Location, Types Systems - Knockout Drums, Flares, Scrubbers & Condensers	2	9
X.	**Relief Sizing** Spring Operated, Rupture Discs Design for Liquid, Vapor, Two-Phase Flow Venting for Dust and Vapor Thermal Expansion	3	10
XI.	**Term Project Presentations**	Depends	
	Examinations Total Hours:	2	

ABET Credit Classification: Engineering Science – 50%, Engineering Design 50% hours

Important part of the course is what we as chemical engineers have learned from past experiences. Major chemical disasters will be listed. These events will be thoroughly analyzed, causes will be determined, circumstances leading to the disaster and the corresponding consequences and the actions taken will be described.

a. Flixborough, England, 06/01/1974 (28 fatalities)
b. Bhopal, India 12/3/1984 (3000 fatalities)
c. Phillips Pasadena Explosions, 10/23/1989 (23 fatalities)
d. Piper Alpha, North Sea, 165 fatalities
e. Texas City, Texas 1947, 576 fatalities
f. BP Refinery Explosions, Texas City, Texas 2005, 15 fatalities
g. Oppau (Germany) Ammonium Nitrate Explosion 9/21/1921, 500-600 fatalities,
h. Toulouse, France, Ammonium Nitrate explosion, 09/21/2001, 30 fatalities
i. Cubatao, Brazil, petrol tank explosion, 1984, 500 fatalities
j. PEMEX Mexico City, San Juanico, methane LPG blast, 300+ fatalities
k. Feyzin, France BLEVE 1966, 18 fatalities

The syllabus, as stipulated is too optimistic. Depending on the time available, I may reduce the extent to which the above-mentioned topics are covered in the

course. I will provide appropriate references, reading material assignments as we go along.

Important websites for the course:

http://www.csb.gov

http://www.sache.org

http://www.aiche.org/ccps

http://www.hse.gov.uk/comah/sragtech/casestudyind.htm Case Studies

Other Books:

T. Kletz, Learning from Accidents in Industry

T. Kletz, What went wrong? Case Histories of Process Plant Disasters

T. Kletz, Plant Design For Safety- a user friendly approach

Lee: Loss Prevention in Process Industries

https://www.youtube.com/watch?v=_PcDNRSsM24 – Piper Alpha 90 mins

https://www.youtube.com/watch?v=Nwbw5PHZnqk – Piper Alpha National Geographic Special – 45 minutes

https://www.youtube.com/watch?v=gtybqJ-jWvw BLEVE

https://www.youtube.com/watch?v=3V-1BL1Tr90&index=1&list=PL8ilW_a2YUUAWUjj-B7HPjr4MgbMSZWdZ PEPCON

https://www.youtube.com/watch?v=rJg19W8x_Ls Bhopal

https://www.youtube.com/watch?v=gOIFK0E1Pgs Bhopal

https://www.youtube.com/watch?v=HsuUQzhP2Ds Bhopal

https://www.youtube.com/watch?v=XuJtdQOU_Z4 BP Texas City Explosion 2005

https://www.youtube.com/watch?v=rSWOx1WH-_c BP Texas City 2005

https://www.youtube.com/watch?v=GPNmUnxB_Hs Feyzin, France