TO: The Engineering Faculty

FROM: The Faculty of the School of Mechanical Engineering

RE: New Course – ME 62000 Combustion of Energetic Materials

The Faculty of the School of Mechanical Engineering has approved the following new course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

ME 62000 Combustion of Energetic Materials, 3 credits
Prerequisites: Thermodynamics I & II, or equivalent. ME 525 or AAE 539 is suggested, but not required.
Attributes: Graduate Students

Course Description: The fundamentals of energetic materials (propellants, pyrotechnics, and explosives) from an engineering perspective are addressed in this course. An emphasis is placed on state-of-the-art creative research and hands-on experimental projects. The fundamentals of combustion applied to energetic materials is emphasized at every stage of the class and students will be encouraged to develop research skills, including performing experiments. There is a literature review and small-group project.

History: This course has previously been offered 8 times since 2007 as a ME 697 course titled "Combustion of Energetic Materials." The student enrollment in the course and student evaluations were as follows has ranged from 12 to 20 students.

Details of this course are outlined in the appended material below.

Eckhard A. Groll
Eckhard Groll, Head
William E. and Florence E. Perry Head of Mechanical Engineering,
and Reilly Professor of Mechanical Engineering

ME 62000
Combustion of Energetic Materials

Course Outcomes

After completing this course, students will be:

- Familiar with 1) the basic terminology, material science, physics & chemistry of energetic materials, 2) how to safely work with energetic materials, 3) how to experimentally or computationally approach research, and 4) how to approach literature reviews and form hypotheses for future research.
- Equipped with the knowledge and experience needed to *understand, model, develop, and experimentally characterize energetic materials, and well as numerous related fields.*

1. Introduction to EMs (1 week)

1. Define of Energetic Materials
2. Deflagration and detonation
3. Composite and homogeneous EMs
4. Historical context

Application: the role of EMs in applications

2. Classification of EMs (1 week)

1. Classification by application
2. Organic EMs, including basic organic chemistry
3. Substituent groups
4. Inorganic EMs
5. Oxygen balance

Application: Classification of EMs

3. Safety (1 week)

1. Importance of safety
2. Sensitivity testing and procedure
3. Methods to manage safety
4. Types of hazards specific to Ems
5. Combined hazards

Application: perform safety testing in lab

4. Homogeneous EMs (5 weeks)

1. Thermochemistry, kinetics, governing equations, low-Ma approximation, reactive Euler equations, Rankine-Hugoniot analysis, detonation, ignition, deflagration, convective combustion, deflagration-to-detonation, and hot-spot theory.
2. Experimental methods, modeling and simulation, and open issues

Application: experimental and simulation tools developed in homework and lab work

5. Heterogeneous EMs (3 weeks)

1. Fabrication of composites, ignition, deflagration experiments and models, metal combustion, thermites, intermetallics, combustion synthesis, green energetics

Application: toolsets applied composites developed in labs and homework

6. Advanced Energetics (2 weeks)

1. High nitrogen materials
2. Co-crystal materials
3. Engineered particles
4. Microscale applications
5. Additive manufacturing
6. Current concepts

Application: Literature project

7. Nanoenergetics (2 weeks)

1. Foundations of nanotechnology
2. Fabrication, formulation, unique challenges, propagation physics, experimental and modeling approaches, and current research gaps.

Application: Group research project

COURSE NUMBER: ME 62000

COURSE TITLE: Combustion of Energetic Materials (3 credits)

SHORT TITLE (max 30 char): Comb. of Energetic Materials

REQUIRED COURSE OR ELECTIVE COURSE: Elective

PROPOSED EFFECTIVE TERM: Fall 2021
TERMS OFFERED: Every other Fall Semester (once in two years)

JUSTIFICATION FOR THE COURSE: This course is needed to educate these students in this topic area, especially given the expansion of research in the area of energetic materials at Purdue. Dozens of faculty now work with energetic materials and more than 100 graduate students work in this area.

JUSTIFICATION OF THE NEED FOR THE COURSE: With the Purdue Energetic Research Center (PERC), including a current $8M/year collaborative agreement with the Army Research Laboratory, we have over 100 grad students working in energetics. New faculty in the energetic materials area may also be interested in teaching/developing this course.

JUSTIFICATION THAT THE COURSE WILL BE TAUGHT AT GRADUATE LEVEL: The course builds on prerequisite combustion and propulsion courses, also taught at the graduate level, so it is justified for the graduate level.

JUSTIFICATION FOR ONLINE/DISTANCE DELIVERY: There are many online students working at propulsion and aerospace companies that might be interested in this course. About a dozen currently take ME 525, and some may be interested in this also. In addition, this topic is of great interest to numerous national laboratories.

TEXTBOOK/REQUIRED MATERIAL:

- Lecture notes provided by the instructor
- Key papers & chapters
- Book is in preparation by Steven Son

PRE-REQUISITIES:

- Thermodynamics I & II, or equivalent
- ME 525 or AAE 539 is suggested, but not required

ATTRIBUTES: Upper Division (Junior status or above)
RESTRICTIONS: None
COURSE REPEATABLE? Yes

COORDINATING FACULTY: Steven Son

COURSE DESCRIPTION:
Students will learn the concepts of how to approach research in the area of Energetic Materials (EM) based on an understanding of the fundamental principles. Students will learn how energetic materials are fabricated, safety used, as well as understand life cycle issues, homogeneous & heterogenous combustion, and advanced energetic material concepts. Multiphase combustion phenomena will be introduced and emphasized. They will apply these concepts to a literature review and group research project, as well as that includes applying thermochemistry and chemical kinetic software. In addition, six hands-on labs are performed. This material will be covered in the context of real-world applications, with an emphasis on energetic materials, combustion, propulsion, explosives, pyrotechnics, and detonation phenomenon.

COURSE OUTCOMES:
After completing this course, students will be:

1. Familiar with 1) the basic terminology, material science, physics & chemistry of energetic materials, 2) how to safely work with energetic materials, 3) how to experimentally or computationally approach research, and 4) how to approach literature reviews and form hypotheses for future research.
2. Equipped with the knowledge and experience needed to *understand, model, develop, and experimentally characterize energetic materials, and well as numerous related fields.*

ASSESSMENTS TOOLS:

1. Homework
2. Hands-on labs
3. Individual literature project
4. Group research project

5. One mid-term examination
6. Final examination

• There are about seven homework problems to complement the lectures and required reading, and to access understanding.
• There are about six hands-on labs that provide students with insight into energetic materials laboratory methods and techniques. Short reports are required.
• The literature review project involves a written report, recorded (or live) presentation, and recorded (or live) elevator pitch.
• Group research project consists of identifying a current research direction and, as a team, begin work on the topic. A Powerpoint slide deck will be prepared to summarize the project.
• Exams access the students understanding of the presented material, homework, reading, and labs.

NATURE OF DESIGN CONTENT: N/A

PROFESSIONAL COMPONENT:

1. Engineering Topics: Engineering Science – 100%
   3 credits

COMPUTER USAGE: CHEMKIN, NASA CEA, MATLAB, EES

COURSE STRUCTURE/SCHEDULE:

Lecture - 3 days per week at 50 minutes per lecture, 16 weeks

RELATED ME PROGRAM OUTCOMES:
N/A

GRADE MODE (Regular; Pass/No Pass; Audit; Satisfactory/Unsatisfactory: Regular, P/NP, Audit

FINAL GRADING CRITERIA (%):

Exams & Quizzes: 30%

Papers & Projects: 40%

Homework: 10%

Laboratory Exercises: 20%

Class Preparation: 0%

	Other:
LIBRARY RESOURCES (describe any library resources that are currently available or the resources needed to support this proposed course. If none needed, explain how the students will complete their research for the course): Purdue online library database resources will be used.	**ADDITIONAL FEES: No** **EXPLANATION OF COURSE FEES (Coop, Lab, Rate Request): N/A**
ADDITIONAL COURSE INFORMATION:	
PREPARED BY: Steve Son	**REVISION DATE:** 04-29-21