ENGINEERING FACULTY DOCUMENT NO. 47-03

MARCH 27, 2004

TO: ENGINEERING FACULTY

FROM: FACULTY OF THE SCHOOL OF NUCLEAR ENGINEERING

DATE: MARCH 27, 2004

SUBJECT: NEW UNDERGRADUTE COURSE

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

NUCL 470 Fuel Cell Engineering
Sem. 1, Class 3, cr. 3.
Prerequisite: Junior standing in science, engineering or technology or consent of instructor.

The principles of electrochemical energy conversion for a single fuel cell and fuel cell stack. Process engineering in fuel and oxidizer supply systems. Principles, components, operation and performance for alkaline, phosphoric acid, solid polymer, molten carbonate and solid oxide fuel cells. Provides broad insight into science, technology, system design, and safety concerns in design and operation of fuel cells.

REASON: The fuel cell technology is fundamental to the hydrogen economy. This course provides education and training in the science of fuel cell with emphasis on engineering and application. Currently there is no formal course in the schools of engineering, science or technology on fuel cell. This course has been offered twice on trial basis with 22 students in Fall 2003 and now in Spring 2004 with 13 students from schools of engineering, science and technology. This course can be taken as technical elective course.

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Lefteri H. Tsoukalas
Head, School of Nuclear Engineering

NUCL 470
Fuel Cell Engineering

1. **Course Title for Official Student Ledger**: FUEL CELL ENGG

2. **Justification**: Provides basic education and training in fuel cell, engineering and technology. No similar course is taught at the University.

3. **Course Level:** Undergraduate Engineering Course

4. **Pre-requisite:** Junior standing in science, engineering or technology or consent of instructor

5. **Course Instructor**: Nuclear engineering faculty will teach the course.

6. **Course Outline:**

   Course Objectives:

   - To provide fundamental understanding of theory, analysis, performance, design and operation principles of various fuel cell components and systems and fuel processing.

   - To understand the current state of technology of stationary and automotive fuel cell systems and components, and the challenges the industry faces today.

   Text:

   (1) Fuel Cell Handbook, J. H. Hirschenhofer, D.B. Stauffer, R.R. Engleman and M.G. Klett, U.S. Department of Commerce, 1999. (free of cost –download)
   http://www.fuelcells.org/fchandbook.pdf
   (2) Fuel Cells – Green Power, Thomas & Zalbowitz; Los Alamos National Laboratory. (free of cost –download)
   http://education.lanl.gov/resources/fuelcells/fuelcells.pdf
   Class Notes
   Additional material will be handed out in class.

OUTLINE OF THE CLASS LECTURE

1. Introduction To Fuel Cells
    - 1.1. Introduction/History of Fuel Cells
    - 1.2. Basic Electrochemical Concepts and Definitions
    - 1.3 Principles of Electrochemical Energy Conversion
    - 1.4 Fuel Cell Types
    - 1.5 Bipolar Plates And Cell Stacks
    - 1.5 Fuel Cell Characteristics
    - 1.6 Advantages and Disadvantages
    - 1.7 Applications

2. Fuel Cell Performance
    - 2.1 EMF of the Hydrogen Fuel Cell
    - 2.2 Efficiency and Fuel Cell Voltage
        - A. Cell Efficiency
        - B. Gibbs Free Energy and Ideal Performance
    - 2.3 Cell Energy Balance
    - 2.4 Effect of Pressure and Gas Concentration
        - A. The Nernst Equation
        - B. System Pressure and Hydrogen Partial Pressure
    - 2.5 Fuel Cell Irreversibilities
    - 2.6 Activation Losses, Tafel equation
    - 2.7 Fuel Crossover
    - 2.8 Ohmic Losses
    - 2.9 The Charge Double Layer
    - 2.10 Fuel Cell Equations

3. Alkaline Electrolyte Fuel Cell (AFC)
    - 3.1 Types
    - 3.2 Cell Components
    - 3.3 Operation and Performance
    - 3.4 Application

4. Proton Exchange Membrane Fuel Cell (PEMC)
    - 4.1 Polymer Electrolyte, electrode structure
    - 4.2 Water Management
    - 4.3 Cell Cooling and Air Supply Methods
    - 4.4 Component Developments
    - 4.5 Direct Methanol Fuel Cell (DMFC)
    - 4.5 Cell Performance

5. Medium and High Temperature Fuel Cells
    - 5.1 Common Features - Fuel Reforming, Fuel Utilization
    - 5.1 Phosphoric Acid Fuel Cell (PAFC)
        - 5.1.1 PAFC-Components
        - 5.1.2 PAFC-Thermodynamics

5.1.3 PAFC- Performance
5.1.4 PAFC-Recent Development

5.2 Molten Carbonate Fuel Cell (MCFC)
5.2.1 MCFC-Components
5.2.2 MCFC-Thermodynamics
5.2.3 MCFC- Performance
5.2.4 MCFC-Recent Development

5.3 Solid Oxide Fuel Cells (SOFC)
5.3.1 SOFC-Components
5.3.2 SOFC-Thermodynamics
5.3.3 SOFC- Performance
5.3.4 SOFC-Recent Development

6. Fuel Cell Systems

6.1 Fueling Fuel Cell
6.2 Basic of Fuel Processing
6.3 The Hydrogen Economy; Hydrogen Storage
6.4 System Processes
6.5 Systems Engineering Considerations (Balance of Plant)
6.6 Fuel Cell safety
7.7 Codes and Standards for Fuel Cell Systems

Topic Coverage

Topic	Weeks
Introduction To Fuel Cells	1
Fuel Cell Performance	3
Alkaline Electrolyte Fuel Cell (AFC)	1
Proton Exchange Membrane Fuel Cell (PEMC)	3
Medium and High Temperature Fuel Cells	5
Fuel Cell Systems	2