

ChemE 497, ME 495 and 499
Fuel Cell Technology

Overview: In this class, students work in small teams to research, design, and manufacture components and systems for proton exchange membrane fuel cell stacks. A stack and ancillary facilities are being built for use as an experiment in the Unit Operations Laboratory, ChemE 437.

Meeting Times: Whole group (Fridays @ 9:30 in Benson 109)
ChemE group meeting (Fridays @ 1:30 in Benson 109)
ME group meeting (Thursdays @ 1:30 in MEB 259)
EE group meeting (to be announced by EE instructor)

Class website: <http://depts.washington.edu/fuelcell>

Class email list: fuel_cell@u.washington.edu

Resources: Lab notebook, <http://education.janl.gov/resources/fuelcells/>

Expectations: All students are expected to contribute to the planning, research, and design activities of their group. There will be writing assignments and one group presentation. The grades will be founded on the group performance.

Assignments:

Proposal and Safety Report (10%)	Due 3:30 pm	1/16/02
Weekly Updates (15%)	Due weekly at whole-group meetings	
Midterm Design Report (15%)	Due 3:30 pm	2/11/02
Final Design Report (40%)	Due 3:30	3/15/02
Oral Presentation (20%)	Due 3:30	3/15/02

Grading Requirements: The grade for the quarter **will not** be based on the completion of your group's goals, but rather on your group's ability to develop and demonstrate the following:

- 1) Synthesis of background material to identify critical-path research and design issues soluble in the allowed time.
- 2) Engineering Approach: Application of engineering problem solving methods.
- 3) Group Approach: Setting and achieving intermediate goals, with all contributing.
- 4) Recommendations: Documenting the next logical steps to be taken.

Groups: The groups and their composition will be determined during the first meeting, January 11 at 9:30 in Benson 109.

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Project Descriptions

1) Test Stand

- Objective: Evaluate the engineering safety and operating characteristics of the test stand established in Benson Hall B10, including start-up characteristics and a steady state process model. For the **midterm report**, document the operation procedures that you follow to operate and analyze the performance of a stack. For the **final report**, ensure that stack is able to measure and record current, voltage, fluid flow, temperature, pressure, etc. and provide data as appropriate. Your final report should include a cover letter, an executive summary, introduction and objectives, methods, results, and recommendations for future work.

2) MEA Performance Engineering

- Objective: Using safe laboratory methods, develop improved MEA fabrication protocols that lead to better performing small single cells. For the **midterm report**, describe how you improved your membrane fabrication process and analyze reproducibility. For the **final report**, describe actions taken to improve performance and provide and analyze related data. Your final report should include a cover letter, an executive summary, introduction and objectives, methods, results, and recommendations for future work.

3) MEA Stack Integration

- Objective: Using safe laboratory methods, develop a stack-scale MEA fabrication protocol that is sufficiently flexible to accommodate new discoveries made by the small single cell group, and material and dimension specifications provided by the Stack Engineers. For the **midterm report**, describe how you are producing a set of membranes large enough for the existing stack. For the **final report**, provide and analyze operating data for the stack in conjunction with the test stand. Your final report should include a cover letter, an executive summary, introduction and objectives, methods, results, and recommendations for future work.

4) Flow Field Plate Redesign

- Objective: Redesign the existing undergraduate flow field plate design focusing on analytical analysis of flow patterns and characteristics. Provide and analyze a number of design concepts, select a superior concept, and provide modeling methods and results. Prepare **midterm and final design reports** as described below (Note: should a small number of students work on this project, the reporting requirements will be modified as dictated by the instructors).

5) FC Application to a Local Residence

- Objective: Design a hybrid system combining wind, solar, and fuel cell power for per the customer's specifications. Prepare **midterm and final design reports** as described below.

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Project Proposal and Safety Report Requirements
(10% of grade)

Use double spaced, 12 point font, with 1" margins, for the proposal. Your proposal should include the following Sections:

- **Statement of Design Problems** to be tackled this quarter (about 1 page).
- **Description of Proposed Work** including general (optimize membrane structure, etc.) and specific (compare dip coating to blade coating of membranes, etc.) tasks needing completion. Identify individuals who will be responsible for specific tasks, and try to establish what equipment will be necessary (and if it is available). Try to anticipate where the main challenges lie. (3 pages max)
- **Timetable** for the quarter (1 page)
- **Hazards Mitigation** that includes a brief specification of specify hazards and approach to mitigating them.

Design Report Requirements

Fuel Cell Technology

All student **Lab Books** and **Peer Evaluation Forms** are to be turned in at the same time as the **Design Reports**. The lab books will be reviewed to assess your individual work, results, and documentation of progress.

Design Report Requirements

Your team will work on this project throughout the quarter. There are two major objectives that you seek to satisfy through your team's design report:

- Demonstrate that the team fully understands and appreciates the design problem.
- Convince the reader that the team developed and executed a very good plan (including sound ideas) to solve the problem.

One report per group is all that is required. As described below, the **midterm design report** must include the "Introduction" portion of the *Design Project Description*. Also described below, the **final design report** must include a cover letter, cover page, executive summary, table of contents, and design project description (including the introduction incorporating the instructor's comments provided on the midterm design report).

Cover Letter

The cover letter should (a) be less than 1 page long, (b) summarize important points in the problem statement and (c) briefly describe the superior design concept. The cover letter should be addressed to the course instructors and any customer who helped with the project.

Title Page

The title page should be one page long and include the design project title and a list of team members including names and project roles.

Executive Summary

The executive summary should be one to two pages long. It should be a self-contained, specific description of the design project capturing the most important points in the proposal. It may contain graphics if appropriate.

Table of Contents

The table of contents, itself not paginated, should be placed immediately after the executive summary. It should direct the reader to the pages for all sections of the proposal, beginning with the *Design Project Description* on page 1.

Design Project Description

The *Design Project Description* should immediately follow the table of contents. The description should not exceed 15 pages of text, figures, and tables (not including appendices) on 8.5" x 11" paper on one side of each page with margins must be at least 1". There should be no page reductions.

Text should be 12-point and double-spaced with no more than 3 lines per inch. Text in tables and figures should not be smaller than 10-point. Figures and tables should be integrated within the text of the description unless they are clearly part of an appendix. Original quality illustrations (photographs, color prints, etc.) should be included in the original and all copies of the proposal.

The *Design Project Description* consists of 4 sections: (1) an introduction, (2) an engineering rationale, (3) a project management plan, and (4) citations. These sections are described below.

1. Introduction (include in midterm and final design reports)

This section provides a clear statement of the proposed design project and should be presented such that it is evident your team fully understands and appreciates the problem. You should begin with a brief discussion of what will be presented in the introduction, and then include the following sections:

- **Problem Statement.** Your problem statement should be a summary of the problem statement and important information provided above.
- **Customer and Stakeholder Requirements.** An introductory statement should be followed by a list of the customer and stakeholder requirements, a ranking of importance, and a description of how requirements were identified.
- **Product/ System Engineering Characteristics.** An introductory statement should be followed an analysis of the requirements and associated product/ system engineering characteristics (properties or metrics that facilitate the requirements) and an interpretation of the results. Remember that your objective is to convince the reader that you understand and appreciate the design problem.
- **Benchmarking.** An introductory statement should be followed by an analysis of existing designs and should include analysis of engineering characteristics. You should search patents and archival literature to identify existing designs.
- **Analysis of Product/System Function and Unit Operations.** An introductory statement should be followed an analysis of the product/ system function and sub functions and the unit process flows.
- **Design Concepts.** An introductory statement should be followed a description of at least 2 design concepts, an evaluation of the design concepts, and the selection and justification of a superior design concept(s).

2. Engineering Rationale

This section will present the rationale behind the proposed design decisions to demonstrate that the team has a very good plan to engineer a solution to the problem. You should begin with a brief discussion of what will be presented in the engineering rationale, and then include the following sections:

- **Product/ System Architecture.** An introductory statement should be followed by documentation of and comment on the product/ system architecture for the superior design concept(s). Include appropriate schematic and process flow diagrams, a geometric layout, and drawings as appropriate.
- **Product/ System Modeling and Simulation.** An introductory statement should be followed by a subsection describing the analysis performed on the superior design concept(s).

- **Reliability Analysis.** An introductory statement should be followed by an analysis of product/ system reliability and a discussion of the results.
- **Other Considerations.** An introductory statement should be followed by comment on manufacturing and assembly, robustness, quality, environmental issues, legal, and ethical issues that might be encountered for the superior design concept(s).
- **Extended Parts List.** An introductory statement should be followed by a list of parts for your superior design concept(s). Provide a description of each part including its function, what materials it will be made of, and how it will be made or where it might be purchased. Depict assemblies if appropriate.

3. Project Management Plan

This section will present the management plan describing how the product/ system will be produced. You should begin with a brief discussion of what will be presented in the management plan, and then include the following sections:

- **Cost Analysis.** An introductory statement should be followed by a cost analysis including the following:
 - Use currently available prices to estimate the cost of the product/ system components. Also, determine the amount of labor involved in manufacturing/ assembly. Use a value of \$30/hr for labor costs. Also include fuel costs.
 - Estimate the yearly total product cost (TPC) of the product/ system. These estimates were developed for chemical plants, but they can be applied to a single fuel cell system as follows:

$$\text{TPC} = 1.25 (\text{RM} + \text{U}) + 2.13 \text{ Labor}$$
 where RM is the raw materials cost, U is the utilities cost (for one year of operation), and Labor is the labor cost to make the product/ system. The value of 1.25 multiplying RM and U accounts for a 25% charge on supplies and other costs associated with fabrication of the system. The value of 2.13 multiplying the labor cost accounts for benefits, supervision, and overhead.
- **Plan and Schedule.** An introductory statement should be followed by a plan and schedule of the development and test of a prototype, the development of production capabilities, and production for the superior design concept(s). Include a list of tasks, an estimate of task durations, task predecessors, key deliverables, milestones, and a Gantt chart.

4. Recommendations for Future Work

Provide recommendations with enough detail so that groups working next quarter have a good jumping off point (this is almost a proposal for next quarter).

5. Citations

Each of the major sections of the *Design Project Description* must contain discussions of the relevant technical and academic literature. The literature must be formally cited. All citations should be complete as described at <http://wally.rit.edu/pubs/guides/apa.html>

Appendices

Include appendices as specified in the body of the proposal.