Adding Equipment to make E-85 in the UO laboratory

Extended Abstract

Laboratory and design courses bring students closer to real world projects than in any other part of the engineering curriculum. However, most of our departments laboratory courses use well defined systems that have mathematically predictable outcomes, whereas, most of the industrial systems are much more complex. Graduates of our program sometimes had problems extending their education to these much more complex systems. Furthermore, while the experiments serve to reinforce classroom topics, none of our past Unit Operations Laboratory experiments connected students with the outside world or leant themselves to economic analysis. To address these concerns, the McKetta Department of Chemical & Bioprocess Engineering modified its existing methanol / water distillation experiment to produce E-85 grade fuel from grain. Additional equipment was purchased to enzymatically convert the starches to sugar (mash), ferment the sugar into alcohol, and dry the distilled ethanol. These enhancements cost well under $5000 and can produce over 1 gallon of E-85 per batch. The benefits include an increase in student's interest, the inclusion of a much more complex system into our laboratory mix and a direct connection to trends in modern society. In addition, this laboratory may help performance on outcomes associated with the departments learning objective on both "Social Awareness and Responsibility" and "Problem Solving Ability".

Introduction

Students in the Chemical Engineering degree program at Trine University are exposed to several different unit operations laboratory experiments. These experiments serve several functions including reinforcing concepts that the students have studied in class, introduction to real life technical problems and reinforcement of both written and verbal communication. However, a few weaknesses have been uncovered as part of the assessment system in regards to the laboratory curriculum.

- All of the experiments involved relatively simple well defined systems. While these simple systems are valuable in reinforcing concepts studied in class, they are not typical of our recent graduates work experiences. Typically the systems that the students must face upon graduation do not lend themselves to such well defined analysis. Feedback from employers and members of the Industrial Advisory Board indicated that recent graduates had difficulties at applying analytical reasoning to these more complex and less well defined systems. Furthermore these former students, when faced with complex systems frequently relied on custom and hear say and ignored applying any analytic or statistical principles.

- None of the experiments in the core curriculum involved fuels or were of concern to popular society. Because Trine University is located in the Corn Belt and students are certainly familiar with the push to "grow" more of our fuel. With the rising cost of energy, it seemed timely and appropriate to add a fuels component to the laboratory.

- With the exception of water, the previous experiments do not involve substances that the students are already familiar with. For instance, one of our experiments involves the extraction of propionic acid out of kerosene. While this is a nice demonstration of countercurrent multistage liquid - liquid extraction, students don't know why they would want to extract propionic acid out of kerosene. On the other hand, they know exactly why they would want to make ethanol. Having some familiarity with the products from the experiments helps the students make the connection to the "outside world".

- None of the laboratories involved a usable product and therefore the products from the laboratories were discarded. While these "products" are non-hazardous, this is certainly not the goals of "green engineering" and differs from the typical industrial situation. The ethanol product can be used for powering the basic utility vehicle that the Mechanical Engineering students work on. The spent grain from the mashing step of the process can be used for supplemental livestock feed. Yeast from the primary fermentation step can be used as the starter culture for subsequent fermentations. Molecular sieves can be regenerated using heat and vacuum.

- There was little emphasis in the laboratories on society and the source of raw materials or products. The raw materials for ethanol production are common commodities from well publicized international markets and are directly tied to the state of the world economy. This further ties the experiment to the real world. It is an opportunity to talk about such diverse topics as grain and future markets and the societal impact of using a food source for a fuel feed stock. The cost and efficiency of gathering the grain compared to other fluid sources of fuel andthe possibility of making ethanol from other sources such as cellulosic sources.

- Most of the laboratories dealt with substances that cannot be easily communicated with non-technical individuals. Prospective students and their parents typically did not relate to the previous experiment such as separating methanol from water or pipe friction. This same group becomes very interested when you bring up making fuel from grain sources.

- Most of the experiments were not concerned with economics and completing both the material and energy balances. By making a usable product like E-85, it is possible to calculate the analyze both the cost to make a gallon of the fuel but also how much energy it takes to get a unit energy of liquid fuel. Students can further analyze where they are using the most energy and suggest ways to reduce the energy usage and increase the efficiency of the conversion. Recovery for each of the processes can also be analyzed.

- While more biology has been added to both the required and elective curriculum, there was no biochemical engineering component to any of the unit operations laboratories. By adding, the mashing and fermentation steps to the UO lab we have added both enzymatic conversion and yeast fermentation.

- All of the previous unit operations were continuous in nature. No transient state or batch processes were studied. However many of the processes that are graduates faced were either transient of batch wise. The nature of the mashing, fermentation and adsorption is batch. In addition, the distillation column operation was switched from steady state operation to a batch process.

World class ethanol production facilities are currently under construction in the region so plant trips to these facilities enhance and re-enforce the conversion and separation processes. Students get to see how concepts and principles used in the laboratory are applied in world scale plants. Furthermore the plant trip becomes more meaningful.

Equipment:

Ethanol production can be divided into several discrete steps or unit operations. These steps include:

- Mashing - Conversion of starch into fermentable sugars
- Fermentation - Converting the fermentable sugars into ethyl alcohol
- Separation by distillation and drying of the ethanol using adsorption on molecular sieves.

The department purchased a 20 gallon mashing system. Since this equipment is typically purchased for private beer making the system is relatively inexpensive. The total cost for a largely automated and instrumented stainless steel system was just over $3000.

Fermentation was conducted in 5 gallon water jugs. These are very inexpensive and are easy to relocate and clean.

The department had a six stage, 6 inch diameter distillation column. This was run in continuous mode to separate methanol and water. As was mentioned previously, this column was utilized in batch mode to make the water ethanol separation. The composition of the distillate off the top of the column was close to the azeotropic composition.

The department purchased molecular sieves to dry the ethanol from the distillate composition to near 100% ethanol. The molecular sieves are re-generated by using a vacuum oven that the department had in storage.

Feedback from students indicated that a dramatic increase in student interest in the laboratory. Examination data indicate an increase in statistics and statistical reasoning. However these results need to be monitored to see if a long term shift has occurred. Plans are being made to assess if the ability of students to analyze complex systems and problem solving has been improved. Longer term measurements from employers and the Industrial advisory board have not been obtain but are planned.

In conclusion, with a relatively small expenditure we believe we have dramatically improved our Unit Operations laboratory experience. The current E-85 manufacturing takes raw grain and turns them into a liquid fuel. A dramatic increase in student interest in this laboratory has been observed.