A BIODIESEL DEMONSTRATION PLANT:
PHASE II

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16. Abstract
The objective of this research was to develop a biodiesel demonstration plant to duplicate commercial practices and to assist with process development and research on new feedstocks for biodiesel production. This plant was to be constructed with the same processes and equipment that would be used in an actual commercial plant – although the size would be smaller to limit cost and space requirements. This facility will be used to educate students, potential producers and consumers, and the general public who are interested in biodiesel. It will also be used to assist and validate process development and research on new feedstocks, thus facilitating technology transfer to potential biodiesel producers and will serve as a vehicle for further process optimization and research.

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Introduction

Over 170 biodiesel plants have been constructed across the United States with annual production exceeding 450 million gallons in 2007. These plants use widely varying production technology with most built following unique designs that are intended to provide a competitive advantage to the operator or to utilize a specific feedstock.

The University of Idaho has had a significant biodiesel production capacity for over 20 years. However, the facilities at the UI do not model the processes used in commercial plants. The current UI facility can produce quality fuel but it generates byproducts that are not utilized, recovers no excess feedstocks that are reusable, and operates at a higher cost than would be acceptable for commercial production. It also does not provide the opportunity to insert specific plant components into the process to evaluate their effect on the overall system.

The objective of this research was to develop a biodiesel demonstration plant to duplicate commercial practices and to assist with process development and research on new feedstocks for biodiesel production. This plant was to be constructed with the same processes and equipment that would be used in an actual commercial plant – although the size would be smaller to limit cost and space requirements. This facility will be used to educate students, potential producers and consumers, and the general public who are interested in biodiesel. It will also be used to assist and validate process development and research on new feedstocks, thus facilitating technology transfer to potential biodiesel producers and will serve as a vehicle for further process optimization and research.

The upgrades to the biodiesel plant cannot be accomplished in a single project. It is expected to take several years. The tasks accomplished as part of the current project involved design and fabrication of an alcohol recovery system. This included flash stripping processes for the biodiesel and glycerin streams to remove the alcohol and other volatiles and then a distillation column to separate water from the alcohol streams so that the alcohol can be reused in the reaction and the water can be used for washing the biodiesel.
This part of the biodiesel production process has been one of the most problematic for small biodiesel producers and this is why we made it our first priority. Many small biodiesel producers have not had the technical expertise to design a satisfactory alcohol recovery system and are simply wasting 50 percent of the alcohol added to the reaction by sending it to the local sewage treatment plant. In some cases, to reduce the amount of waste, they are reducing the amount of alcohol added to the reaction, which tends to lower the quality of their final product.

The system was designed so that it could produce alcohol that is of acceptable quality for reuse in the plant’s production process. The system will operate with either methanol or ethanol. However, because of the azeotrope that is formed between ethanol and water, it will be necessary in a later project to add a small molecular sieve to the system to remove the last 5 percent of the water.

Originally, we were in contact with the Kim-Hotstart Company in Spokane about collaborating on this project. As a producer of fuel and engine heating systems, the indicated an interest in seeing their equipment used for biodiesel production. At an early stage of the project, they declared that they had decided against entering the biodiesel industry and dropped out of the project. We altered our design to include a small steam boiler as a heat source instead of the electric heaters produced by Kim-Hotstart.

As described earlier, because of the cost and complexity of the plant, we intend to make the upgrades in phases, as described in Table 1. The overall flow diagram of the plant is provided in Figure 1 and the sections of the plant that are planned to be added or changed in each phase are identified.

Phase 1 represents the original state of the plant before any changes. Phase 2 consists of the implementation of the alcohol stripper and distillation column for the biodiesel and biodiesel streams completed as part of the current project.
### Table 1. Phase descriptions for the biodiesel demonstration plant.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Basic oilseed crushing capability with settling to remove particles; Batch transesterification reactors with gravity separation of glycerin.</td>
</tr>
<tr>
<td>2</td>
<td>Ethanol stripping from biodiesel and glycerin streams with a model distillation column to separate alcohol and water.</td>
</tr>
<tr>
<td>3</td>
<td>Sulfuric acid pretreatment for high free fatty acid feedstocks; Acidulation of glycerin to split soap and separate free fatty acids; Continuous water washing system.</td>
</tr>
<tr>
<td>4</td>
<td>pH adjustment of the biodiesel and glycerin; Absorbent purification of biodiesel (Magnesol). Acidulation and free fatty acid recovery of glycerin.</td>
</tr>
<tr>
<td>5</td>
<td>Oil refining to include degumming, caustic refining, silica filtration, and oil drying; Automation for computer control of plant.</td>
</tr>
</tbody>
</table>

The biodiesel demonstration plant will ultimately include the full spectrum of processes that are actually in-use by commercial producers. By doing so, we expect that the capability of biodiesel fuel production and utilization research at UI will be greatly enhanced, and UI’s leading position in this area will be further strengthened. It is our expectation that the plant will ultimately be able to:

1) Demonstrate biodiesel production technology to people considering using the fuel or investing in the industry so they can more easily understand the technology.

2) Serve as a teaching tool to educate students about biodiesel plant operations, including undergraduate students at the University of Idaho and individuals from the biodiesel industry who could use the facility for training in plant operations.

3) Provide a system for development of new technologies and evaluation of existing and proposed technologies.
Figure 1. Flow diagram of Biodiesel Pilot Demonstration Plant
Project Objectives

The objectives of this proposed research were to:

1. Develop a biodiesel demonstration plant to duplicate commercial practices and to assist with process development and research on new feedstocks. This plant will be constructed to duplicate the processes and equipment that would be used in an actual commercial plant – although the size will be smaller to limit cost and space requirements. This facility will be used to educate potential producers and consumers of biodiesel. It will also be used to assist with process development and research on new feedstocks, thus facilitating technology transfer to potential biodiesel producers and will serve as a vehicle for further process optimization and research.

2. Develop techniques for biodiesel production using ethanol to produce biodiesel that is totally bio-based as opposed to most existing producers that use fossil-based methanol. The University of Idaho has considerable laboratory-based experience using ethanol to produce biodiesel. Because of the higher cost of ethanol, the biodiesel industry has not embraced ethanol-based biodiesel production. However, current high natural gas prices have raised the price of methanol and oversupply has lowered the cost of ethanol to the point where it is comparably priced to methanol. There is now renewed interest in using ethanol to produce biodiesel and there is a need to demonstrate the technology at the pilot plant scale.

One of the key aspects of the technology development is the use of ethanol to make the biodiesel. Recent price increases in methanol have made ethanol more cost effective for biodiesel producers. However, most do not have the technical capability to manage a transition to this new alcohol in their plants. Our ability to demonstrate the use of ethanol in biodiesel production provides us with a unique capability in the U.S. and provides the opportunity to have a significant impact on the profitability of the industry. The stripper and distillation column that were fabricated for this project can be used for both ethanol and methanol.
Task Descriptions

This project consisted of three specific tasks.

1. Design and fabrication of biodiesel flash system for volatile removal.
2. Design and fabrication of glycerin flash system.
3. Design and fabrication of alcohol/water distillation system.

Early in the project, it was determined that it would be much more efficient to combine the biodiesel flash system and glycerin flash system into a single assembly since the basic components for the two systems are the same. The same device can serve both purposes although at different times and with adjustments made to temperature and flow settings. A schematic diagram of the methanol stripping system and the distillation column is shown in Figure 2.

![Figure 2. Schematic of alcohol stripping system.](image-url)
A photograph of the methanol stripping system is shown in Figure 3. The system is complete, although we intend to add a process controller to automate its operation.

Figure 4 shows a schematic diagram of the distillation column assembly. This system will allow the alcohol-water mixture that is removed by the stripping system to be purified. Very pure alcohol will emerge from the top of the distillation column which can be reused in the process. This column portion of this system can be broken into 4 separate parts so that the column height can be varied in experiments. We can also vary the column feed temperature, the heat input to the reboiler and the reflux rate. This will allow us to optimize the column for the specific fluid being evaluated (methanol or ethanol in water).
Figure 4. Distillation column

Figure 5. Distillation column
Figure 5 shows the distillation column as it was built. In this photograph, the column was partially disassembled to allow the supports for the column to be painted.

**Student Involvement in Alcohol Recovery System**

Four undergraduate students were involved in the design and fabrication of the alcohol recovery system. Tony Pastrama, a BAE sophomore, a non-traditional student experience in private industry, did all of the plumbing on the flash unit. Scott Burn has completed his junior year and is also a non-traditional student who came to the BAE department after seven years in the Navy and another year in the biodiesel industry. He was instrumental in fabricating the frame and contributed ideas for the design. Luke McCall is finishing up his BS in Agricultural System Management. He has worked for BAE in the work study program and as an IH student for four years. He was involved in the electrical side of the project, running conduit and mounting components for the main power controls. Brice Starr is an ASM freshman and was awarded a Work and Learn Scholarship in 2008. He did some fabrication on the superstructure for the distillation column.

**Relationship to the NIATT Strategic Plan and to Other Research Projects**

This project is closely related to the education goal of the NIATT strategic plan to enhance graduate and undergraduate students’ learning process by integrating course work to problem solving activities, gaining hands-on research experiences, and preparing skilled professionals for the biodiesel and renewable/clean energy industry. The project is also closely related to NIATT’s research and technology transfer goals. Availability of the results advances the knowledge of clean energy from renewable resources and would be readily implemented by biodiesel industry.

**Potential Benefits of the Project**

The primary benefit of this project will be a system design that can be adopted by small biodiesel producers across the country. This will greatly improve the safety and cost-effectiveness of their operations while reducing their environmental impact. It will also provide the University of Idaho with a demonstration facility to assist in commercializing biodiesel production and
utilization technology. We will use this facility for research, workshops, tours, and a wide variety of other activities. The University of Idaho is currently recognized as the leading public source of information on biodiesel production in the U.S. and this system will ensure we maintain that leadership into the future. In addition to the direct impact of the demonstration plant, we provided biofuels educational opportunities for one four undergraduate students.