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**A Low Energy Continuous Reactor Separator
for the Production of Ethanol
from Starch, Molasses and Cellulose**

**5th Quarterly Report to the
Energy Related Inventions Program**

March 16-June 15, 1995

Project DE-FG01-94CE15594

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Dr. Dale visited the Iowa pilot plant site on April 19th , taking a seed tank of flocculant yeast for the CSRS.

Dr. Dale has continued working with Tony Souda on designs for a whey permeate to ethanol plant for mid north central Wisconsin.

On May 8-12 Dr. Dale presented a paper on our work on biomass conversion to ethanol at the Biotechnology Symposium on Biomass Utilization sponsored by the National Renewable Energy Lab (NREL) in Vail Colo. Dr. Dale also gave a project summary to a NREL review board in Golden Co. about the joint Xylan/Purdue biomass to ethanol efforts. A copy of this paper is appended as Appendix 1.

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On May 10, Dr. Okos presented an overview of our DOE IWP project to an IWP program review in Chicago, IL. Bob Lehman and Carol Lehman were able to attend and to meet with Doug Gish about our project goals and prospects for further funding.

On May 17th, Dr. Dale gave a presentation about the CSRS/SAED system for dry mill corn/grain to a grain handling company in Anderson, IN. This company is actively considering the installation of a 1 to 5 million gal ethanol plant.

On May 25, Dr. Dale gave a presentation on our research objectives and current state of pilot scale efforts to the USDA ethanol fuels group headed by Rod Bothast at the NCAUR in Peoria, IL. It is hoped that we will cooperate with this group in the future.

On June 1 Dr. Dale completed a paper (Appendix 2) for the Biomass of America's Conf. on Aug 19-24 in Oregon. This paper entitled "A lab and pilot scale CSRS for Ethanol .." describes some of our work to date on raw starch fermentations.

On June 5 an article was printed in the Lafayette Journal and Courier about the project. This article is appended as Appendix 3.

On June 6, Dr. Dale took an ethanol receiver tank/pump to Iowa, and met with Mr. Lehman to discuss the installation details of the SAED system. Mr. Suda of EPS was also there and the controls system for the SAED system was described allowing EPS to design and bid a controls system.

On June 22, Dr. Dale took a new tank of flocculating yeast out to Hopkinton IA and the timeline for installation of the SAED system was discussed w/ the Lehman's.

50 Liter-Pilot Plant

During April, a solvent mix system was tested, first on a small lab scale, and then on the pilot scale. These tests indicated that the dehydration system should work well.

24,000 Liter Continuous Stirred Reactor-Separator (CSRS) Pilot Plant

During April, the shaft sealing system was totally redesigned and re-installed. A design discussed by Lehman and Dale was designed by Lehman, and installed by Lamont Fabricating company. First, the floors to the tank vessels were leveled though welding in angle iron support beams of 304 SS. This will ensure that there is a perpendicular angle between the shaft seal and the floor of the tank. Secondly, a roller bearing support shaft seal was placed below the floor of each stage, with a lip seal used above the floor. This will prevent shaft wobbling which was primarily responsible for wear on the seals. These modifications were completed by April 19th.

A feed sterilizer/cooler was added to the system. This will allow a heating/holding time/ and cooling step to be added before the feed is taken to the reactors.

Duct work and installation of the regenerative blower were installed by Lamont Fabrication Co. They finished these tasks on April 27th. This completes construction and installation of the complete absorber/CSRS system. We will now begin installation of the SAED system for production of anhydrous ethanol.

Operation

The CSRS was operated continuously from May 18th through June 22. The seals in all the tanks held well except for vessel 2. The fermentation performance was quite good over this time period with near complete utilization of a 20% dextrin feed noted. Cell density was good, but the cells did not go into the flocculent mode.

Construction of SAED

The structured packing for the absorber was ordered in early May and received in late May. The use of a 20 ft, 24" ID column for vacuum stripping of the anhydrous ethanol is planned. This column has been purchased, but needs to be stiffened to prevent collapse when a vacuum is pulled. Mr. Lehman discussed the column specifications with Roger Hinner of Merrill Iron and Steel. M I&S designed a spiral bracing of the column. Mr. Lehman plans to have this bracing applied to the column in late June. Dale and Lehman discussed and planned the siting of the three basic components of the SAED system, a regenerative HX, a dehydration column, and a vacuum stripper column.

Current time lines plan for installation of the columns during July, installation of piping and electrical lines in late July to early August, and testing of the system beginning by August 15th.

50 Liter-Pilot Plant

During May and June, the SAED system was piloted with a solvent mix system. Different temperatures and gas/liquid flow rates were tested to narrow in on the optimal operating conditions. Mark Moelman also completed a performance comparison between a ceramic random saddle packing and a structured packing.

Laboratory Studies

a) Flocculent yeast for permeate fermentation. Dr. Lei operated continuous stirred fermenter for the production of ethanol from whey permeate during April. A strain of *K. marxianus* which flocculate under some conditions was introduced, with different conditions tested to induce flocculation.

b) SSF of starch granules. The fermentation of raw starch in a stirred reactor was tested during March and April, with the effect on starch granules on the formation of yeast floccs examined. Mr. Zhou ran this reactor continuously during April.

c) Biomass conversion to ethanol in some SSF experiments were performed by Mr. Zhao, and a report on this work completed by Dale for Xylan and NREL who asked our lab to test the Xylan cellulose pretreatment system.

d) Modeling of the SAED system. Mr. Zhou and Dr. Dale worked on an Aspen II model of the SAED system during April. Performance of this model indicates the SAED system should work largely as expected as hand calculations suggested.

e) Flocculent yeast for permeate fermentation- A reactor with a flocculating agent was run during May and June , while a reactor without the floc agent was operated during May by Dr. Lei. The reactor w/o floc performed quite well, and we hope that the reactor with the floc will eventually prove to perform even better.

f) Alpha cellulose conversion to ethanol in some SSF experiments were performed by Mr. Zhao to complete our work for Xylan/NREL, and a report on this work completed by Dale for Xylan and NREL .

g) Modeling of the SAED system. Mr. Zhou has continued working on an Aspen II model of the SAED system during May and June. Performance of this model indicates the SAED system should work largely as expected as hand calculations suggested.

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Appendix 3

Monday, June 5, 1995

Researcher toils to drive down cost of ethanol

By ANGELA TOWNSEND

Journal and Courier

Explaining the technology that Clark Dale, a senior research engineer at Purdue University, has been working on for the past 10 years is as intricate a task as the machines he has developed to make fuel out of waste.

But the bottom line people can easily understand, especially those involved in agriculture, is: money — and more of it.

Dale has developed an improved fermentation technique that turns whey

permeate, a waste byproduct of cheese-making, into ethanol alcohol. The ethanol, in turn, can be used as a source of fuel to replace more expensive gasoline.

This new technology got its beginnings as part of Dale's doctorate work in agricultural engineering, which he completed at Purdue in 1984. Purdue re-

leased the rights of the technology back to Dale, which allowed him to pursue the patent for the technique, and to develop into an agricultural entrepreneur.

Dale is currently testing the effectiveness of two types of fermenting machines.

"The first technique is to use an immobilized cell system," he said. "One large unit is built, which can do the fermentation very quickly because of the high density of yeast."

The second technology is the reactor. It's not quite as fast as fermentation, but it is more resistant to infection that may be present in the yeast, he said.

Whey's high sugar content makes it difficult to convert it to a usable product.

Both types of machinery are being tested at a small alcohol plant.

See ETHANOL

By Frank Oliver/Journal and Courier

Senior research engineer Clark Dale displays a flask of ethanol similar to the type fermented from cheese byproducts.

Ethanol

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Dale has received interest from companies in Marshfield, Wis., and Anderson, Ind., to have the machinery installed there as well.

While this technology does not come cheap — the unit in Iowa has a unit capacity of making 500,000 gallons of ethanol per year at a cost of just under \$1 per gallon — Dale hopes it will allow smaller-scale alcohol products to be used at small dairies or cheese-making operations.

The desired result would be a savings in labor, time and money.

Mark Moelhman, an engineering technician who has worked with Dale for the past five years, said the ultimate goal of this work is to scale down the machine to size so that it is even more accessible to farmers.

"If we're successful, we'll be able to produce ethanol at a cheaper price from any waste product (with sugar content)," he said. "With ethanol being used more, technology is especially important to the farm belt states. It adds value to products, and increases profit margins."

The project is receiving partial funding from the Office of Industrial Technologies, part of the U.S. Department of Energy.