MASTER

ETHANOL PRODUCTION BY VAPOR COMPRESSION
DISTILLATION

INTERIM REPORT

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Grant Number DE-FG02-80R510240

Covers period from August 26, 1980 to February 1, 1981.

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INTRODUCTION

The production of fuel ethanol by those with a suitable bio-mass available could significantly reduce our national dependence on fossil fuels.

A common criticism of fuel ethanol is that the amount of energy consumed during its production is roughly equal to the energy contained in the finished product. This assessment, however, includes the use of a conventional distillation process. The energy required for distillation, the most energy intensive portion of the process, can be reduced by at least 75% with the implementation of the vapor compression distillation technique.

It is the goal of this project to develop and demonstrate a one gallon per hour vapor compression distillation unit for fuel ethanol production that can be profitably manufactured and economically operated by individual family units.

SUMMARY

Vapor compression distillation is already an industrially accepted process and this project's goal is to demonstrate that it can be done economically on a small scale.

Theoretically, the process is independent of absolute pressure. It is only necessary that the condenser be at higher pressure than the evaporator. By reducing the entire process to a pressure of approximately 0.1 atmosphere, the evaporation and condensation can occur at near ambient temperature. Even though this approach requires a vacuum pump, and thus will not represent the final cost effective design, it does not require preheaters, high temperature materials, or as much insulation as if it were to operate at near ambient pressure. Therefore, the operation of the ambient temperature unit constitutes the first phase of this project.

Presently, the ambient temperature unit is fully assembled and has begun testing. So far it has successfully separated ethanol from a nine to one diluted input solution. However the production rate has been very low.

FABRICATION

Shown in figure (1) is a photograph of the ambient temperature vapor compression distillation unit completely assembled, and Table (1) is a list of the major components which comprise the unit. The compressor can be seen mounted on top of the table, while the vacuum pump and two channel peristaltic pump are located on the base of the unit.

Since the essence of the process is that the condenser must reside at a higher pressure than the evaporator, it is important to understand the distillation vessel assembly. The distillation vessel is constructed by clamping the separator plate between the two halves of the enclosure.

Following is a description of the fabrication and utilization of each of the components.

Ambient Temperature Distillation Unit

Figure (1)

TABLE (1) LIST OF COMPONENTS

<u>DESCRIPTION</u>	<u>SOURCE</u>
Distillation Vessel Enclosure	Fabricated from a fiberglass water tank
Distillation Vessel Chamber Separator Plate	Fabricated from a PVC plate
Condenser Coil	Fabricated from 3/8" copper tube
Spray Nozzle Model 1/8 T 11001	Spraying Systems Inc.
Rotary Lobe Compressor Model 1702	Roots
Compressor Drive Motor	1/4 HP General Electric
Vacuum Pump	Adapted from a salvaged refrigeration compressor
Vacuum Pump Drive Motor	3/4 HP General Electric
Two Channel Peristaltic Pump	Designed and built by G. Ellis
Support Structure	Adapted from a metal frame owned by G. Ellis

Vessel Enclosure:

Each of the halves of the enclosure is like a bell jar, (shown in figure 2). A fourteen inch diameter fiberglass water tank, made by Structural Fibers, Inc. of Chardon, Ohio, was sawn in half and sealing flanges were molded onto each piece. To do this a formica and plexiglass mold was made such that the tank half, fiberglass cloth and polyester resin could be placed to form the flange. The flanges are wide enough to accomodate both the clearance holes for the clamping bolts and a smooth region to mate with the seal.

Separator Plate:

As a matter of theory, this plate merely serves to permit the condenser to be maintained at a higher pressure than the evaporator. In fact, for simplicity of assembly, this plate, (shown in figure 3) also supports the condensing coil and evaporator nozzle, contains a groove on each side for the o-ring seals and provides the porting necessary to flow circulating beer through the condensing coil and removing the condensate.

The separator was machined from a one inch thick plate of PVC to the specifications defined on the sketch (shown in figure 4).

Two Channel Peristaltic Pump:

One channel of this pump, (shown in figure 5), serves to circulate the beer from the evaporator reservoir through the condensing coil and nozzle, and then back to the evaporator. The other channel is used to raise the pressure of the condensate from the 0.1 atmospheric pressure at which it is collected to ambient pressure for delivery.

The peristaltic pump is well suited for this application because it is both positive displacement and zero clearance volume. Therefore, the demanding 10:1 pressure ratio presents no problem. Also, it's a noncontaminating type of design.

This pump uses 3/16" I.D. tubing on a 2.4" diameter and is driven by a 90rpm motor, so it displaces about five gallons per hour.

Compressor:

The compressor is a Roots Model 1702 rotary lobe type, chosen because it is of appropriate delivery volume and pressure, rugged in design and requires a relatively low power input to drive it. Originally, a rotary vane compressor, (shown in figure 6), was tried because it was inexpensive, it had been salvaged from some discarded industrial equipment. It was heavy, low in delivery volume and had inadequate seals on the shafts. That is, the system would not hold a vacuum because air leaked in the compressor shafts. It was only after much effort to fabricate seal inserts for that unit that it was abandoned for the Roots blower.

Condenser Portion of Vessel
Figure (2)

Separator Plate
Figure (3)

Separator Plate

G. Ellis

Figure 4

Two Channel Peristaltic Pump

Figure (5)

Rotary Vane Compressor

Figure (6)

Vacuum Pump:

The vacuum pump is a single cylinder refrigeration compressor purchased at a yard sale.

TESTING

Results:

The ambient temperature unit is working. However, its production rate is a mere few cc's per hours.

Although, that the unit does perform the distillation process is to be appreciated. Compressor problems, with the rotary vane unit, halted the original attempts at a steady state run. Installation of the Roots rotary lobe compressor solved those problems and permitted long term operation. At first, production was not evident and the homemade nozzle was felt to be the problem. It emitted a coherent stream rather than a mist, and thus no surface area for evaporation was created. Nozzles were purchased from Spraying Systems to permit the desired atomization. The first nozzle installed created a nice cone shaped pattern, but was very susceptible to clogging. Another, flat pattern with a built in filter, has worked very well.

Finally, after much wrestling with vacuum leaks a 3.5 hour successful verification of distillation was achieved.

Since the original achievement of distillation, a number of others have been performed after minor modifications to both the evaporator and the condenser. Each hoping to up the rate of production, and none doing so. It is this series of tests which has lead me to believe that the problem lies in the "thermal leak" created by having the compressor located outside the condenser chamber.

Conclusions:

1. Locating the compressor external to the distillation vessel was not a good idea.
2. Without adequate temperature and pressure monitoring equipment, problem analysis is very difficult.
3. Designing around the need for a small orifice nozzle would enhance the ease of operation.

Discussion:

The compressor was mounted external to the distillation vessel because it was felt to be one of the least reliable components in the system, and this location would facilitate easy access for maintenance. The Roots blower has proven to be a trustworthy assembly and the thermal separation created by the external mounting is now felt to be the major reason for the low production rate. Primarily, the

evaporate passes through two feet of pipe, onto which it can prematurely condense and yield its latent energy. Also, the heat generated by the inefficiency of the compressor is lost directly to the surroundings instead of to the condenser, where it could serve to make up for the losses from the condenser to the environment.

Presently the only instrumentation on the unit is one 2.5 inch diameter vacuum gage, used to monitor the condenser pressure. It would be helpful to also have a differential pressure measurement between the condenser and evaporator and temperature measurements of each chamber.

This program has used diluted grain alcohol as its input solution and has had nozzle blockage due to fiberglass dust from within the still. In practise that could be avoided, but the unit will have to be able to operate with yeast particles without requiring frequent cleanings.

PLANS FOR UPCOMING ACTIVITIES

Continue Ambient Temperatures Unit Testing:

It is imperative that the production rate of the present unit be improved before ambient pressure operation is attempted. The major improvement to be incorporated is going to be the relocation of the compressor into the condenser chamber. This will require, as a minimum, the design, fabrication and installation of a sealed shaft feed through.

Some temperature and pressure measuring equipment will be purchased to aid in the analysis of system operation.

Design Ambient Pressure Unit:

An attempt will be made to use as much of the present hardware as possible, yet a few new components have still to be selected. Also, details of the new assembly need to be sketched.

Order Components For Ambient Pressure Unit:

Even though it should be possible to make the ambient pressure distillation vessel by modifying the present one, other supplies do need to be purchased. For example, insulation, a heater and a relief valve.

SCHEDULE AND BUDGET

At this time, it is expected that this project will be completed on time and within the budget.