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Building a Farm-Scale Fuel Ethanol Plant

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University of Minnesota farm-scale fuel ethanol plant, West Central Experiment Station, Morris, Minnesota.

Building a Farm-Scale Fuel Ethanol Plant

Introduction

The 1980 session of the Minnesota Legislature appropriated funds for the University of Minnesota to construct a farm-scale fuel ethanol plant at the West Central Experiment Station, Morris, and to do research on the use of the by-products of ethanol production as animal feeds. This publication describes the construction and operation of the University of Minnesota plant and tells how to obtain more detailed plans for it from the University of Minnesota Agricultural Extension Service.

At the time the University of Minnesota plant was to be constructed, there were few reliable suppliers of equipment, and those who could supply plants were hesitant to allow the University of Minnesota Agricultural Extension Service to publish plans and specifications of their equipment. The set of

equipment finally assembled was designed from publicly available information to meet the following criteria:

1. Capable of fermenting as many as 10,000 bushels of grain per year.
2. Capable of distilling 100 gallons of 95-percent (by volume) ethanol daily.
3. Routine operation that required about four hours' skilled labor per day.
4. Capable of being easily scaled up.

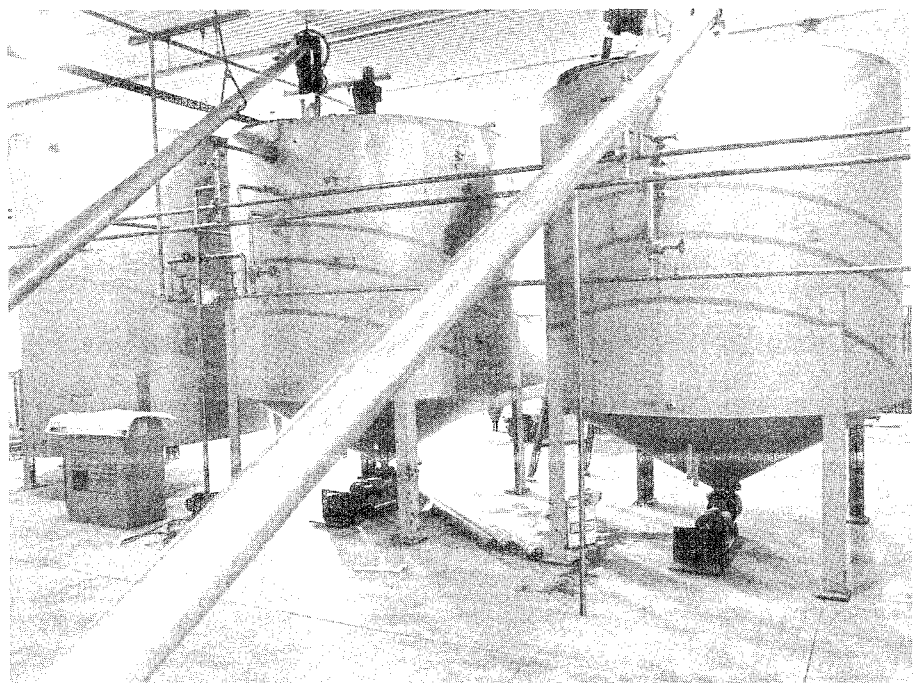
Smaller- and larger-capacity, farm-scale fuel ethanol plants have since been built and details of their operation are publicly available. (See publications 4 and 5 on the Literature List at the end of this publication.)

Planning for Fuel Ethanol Production

The decision to build or buy a fuel ethanol plant should be made only after much study and planning. The first three publications on the Literature List deal with farm-scale fuel ethanol production and use, and must be consulted to gain an understanding of the chemistry and engineering involved. Only then will equipment plans be of any use.

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Ground grain augers and process tanks during construction.



The planning process should identify the following items:

1. markets for the ethanol, and its value in those markets;
2. buyers for by-products from ethanol production, and the by-products' value to these buyers;
3. acceptable disposal methods for unmarketable or unusable by-products;
4. sources and prices of feedstocks;
5. ethanol and by-product yields based on actual experience;
6. equipment and production costs;
7. availability of water, heat, and power;
8. labor skilled enough to operate the plant; and
9. permits required. (A list of these is available from the Minnesota Energy Agency, 150 E. Kellogg Blvd., St. Paul, MN 55101.)

This publication, and the plans described in it, is for the reader who has consulted publications similar to those in the Literature List and is familiar with the terminology of fuel ethanol production.

Process Description

The final process selected for the University of Minnesota ethanol plant is shown schematically in Figure 1. It is an atmospheric-pressure, batch mash preparation and fermentation process with solids separation prior to distillation. The distillation system is semicontinuous and also takes place at atmospheric pressure.

Mash Preparation and Fermentation

The preparation of the mash and its fermentation to ethanol is now a relatively straightforward procedure, with predictable results when commercially pre-

pared enzymes and yeasts are used. The details of grinding, dissolving, and converting grain starches to sugar, and the fermentation of the sugars to ethanol are described in detail in Publication 6 of the Literature List. A partial list of suppliers of yeast, chemicals, and monitoring equipment is also included in that publication.

In the University of Minnesota ethanol plant, the mash is prepared and fermented in the same tank. Three cooker-fermenters are available, so three batches may be under way at any one time. Heat for cooking is provided by direct injection of steam into the mash. Cooling is provided by the addition of cold water to the mash. The mash is agitated by a tank-top-mounted propellor agitator.

Solids Separation

It was found that if the fermented mash (the "beer") containing the product ethanol was pumped to the distillation columns, considerable plugging of the columns occurred due to the undissolved solids remaining in the beer. To avoid this problem, the solids are separated from the liquid portion of the mash with a screw press before distillation. This reduces the recovered ethanol yield because some of the ethanol is on the wet solid particles that are removed in this step, but distillation of the filtrate is simplified greatly.

Distillation

Packed distillation columns were selected because of their ease of construction, installation, and maintenance. The filtered beer is pumped from storage to a point about two-thirds up the stripping column. The ethanol is stripped from the beer by steam injected at the bottom of the column. The dealcoholized, filtered beer (thin stillage) is removed from the

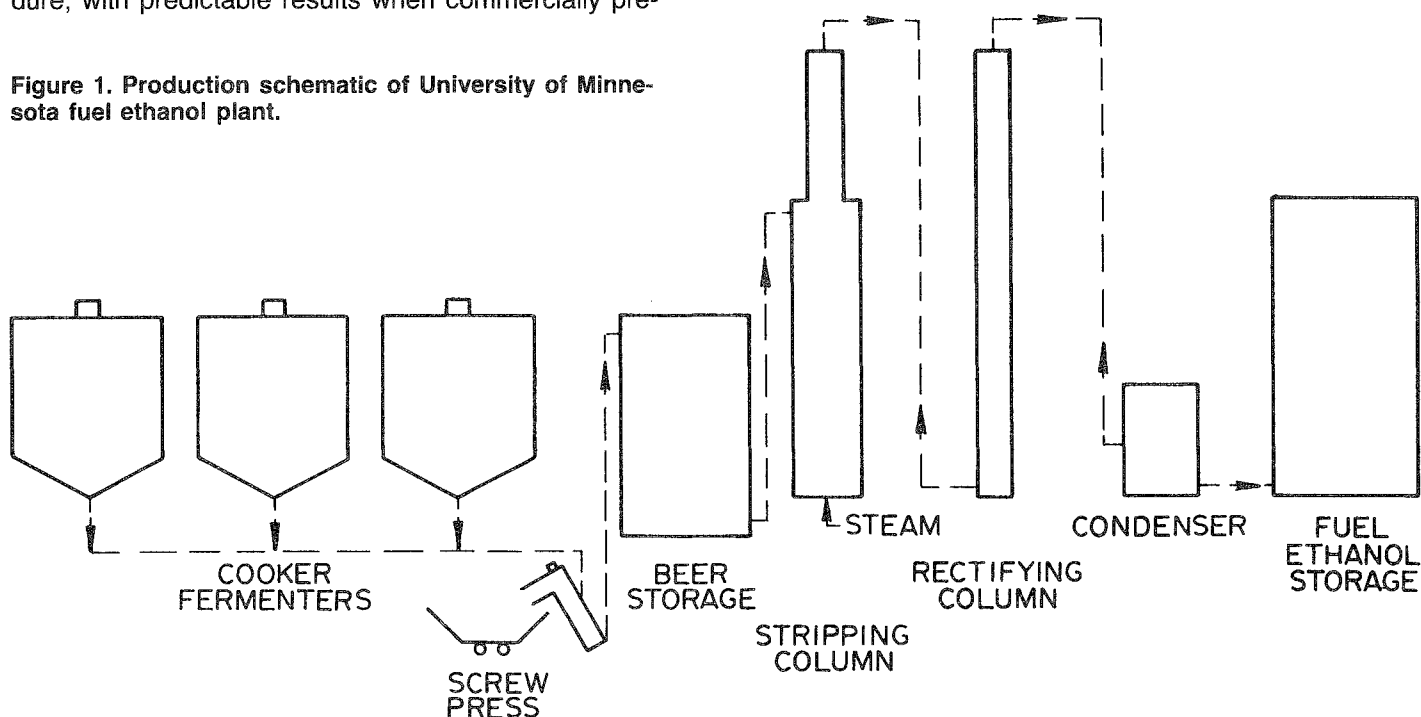


Figure 1. Production schematic of University of Minnesota fuel ethanol plant.

bottom of this column. Ethanol-rich vapors are carried over to the rectifying column, where they are purified and collected in a water-cooled condenser. Some of the condensed product from the condenser is returned to the rectifying column as a reflux. All of the liquid at the bottom of the rectifying column is returned to the stripping column as a reflux. The product ethanol is pumped to an outside storage tank.

Auxiliary Equipment

In addition to the main process equipment described above, considerable support equipment and services are needed. These include a boiler of suitable size, with feed water treatment; a grain mill; ground grain storage; augers; mash pumps; ethanol pumps; heat exchangers; stillage storage; a water supply; electrical service; plumbing; and controls. The equipment and systems required will in many cases depend on factors that are specific to each location and project. Some recommendations for these items are included in the detailed plans.

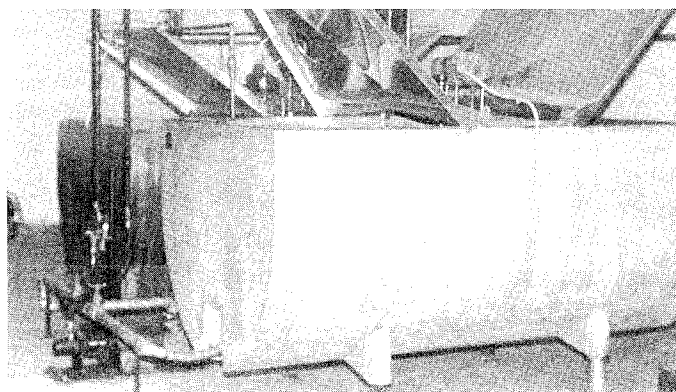
Availability of Detailed Plans

Plans for the University of Minnesota fuel ethanol plant are available and include:

1. a process flow sheet,
2. specifications for process tanks,
3. specifications for distillation columns,
4. a partial piping diagram and suggested equipment layout,
5. pump specifications,
6. recommendations for monitoring equipment, and
7. utility requirements.

Residents of the State of Minnesota may obtain one free copy of these plans by sending a written request to Extension Agricultural Engineering, 1390 Eckles Ave., University of Minnesota, St. Paul, MN 55108. Additional sets of plans are available for \$7.50 from the same address.

Final plumbing system for cooker-fermenters.



Storage for beer prior to solid separation and thin stillage.

Literature List

1. *Economic considerations: Should I get involved in fuel alcohol production?* North Central Regional Extension Publication No. 154. Available from Extension Agricultural Engineering, 1390 Eckles Ave., University of Minnesota, St. Paul, MN 55108.
2. *Fuel from Farms—A Guide to Small Scale Ethanol Production.* This publication is on file at each county Extension office in Minnesota. It is also available from the Superintendent of Government Documents, U.S. Government Printing Office, Washington, DC 20402. Stock No. 061-000-00372-0. Price: \$4.50.
3. *Ethanol Fuel Use, Production and Economics.* 353 pages. Available from the National Technical Information Service, 5285 Port Royal Rd., Springfield, VA 22161. Price: \$27.00. Publication No. SERI/SP-751-1018.
4. *Construction Plans for the MAVTI Vacuum Distillation Alcohol Fuel Plant.* Available from Mankato Area Vocational Technical Institute, 1920 Lee Blvd., North Mankato, MN 56001. Cost: \$4.00.
5. *Design Report—Small-Scale Fuel Alcohol Plant.* This three-volume set is available from the National Technical Information Service, 5285 Port Royal Rd., Springfield, VA 22161.
Volume 1: General Plant and Process Description. Stock No. IDO-10088V1. Price: \$13.50.
Volume 2: Detailed Construction Information. Stock No. IDO-10088V2. Price: \$24.00.
Volume 3: Drawings. Stock No. IDO-10088V3. Price: \$15.00.
6. *Fermentation Guide for Common Grains: A Step-by-Step Procedure for Small-Scale Ethanol Fuel Production.* Available from the Superintendent of Government Documents, U.S. Government Printing Office, Washington, DC 20402. Stock No. 061-000-00553-6. Price: \$3.00.

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