Jilin fuel ethanol plant

By **Josef Modl**

Vogelbusch GmbH, A-1050 Wien, Blechturmgasse 11, Austria
Tel: +43 1 54661-210 Fax: +43 1 5452979 Email: office@vienna.vogelbusch.com

Abstract

This paper briefly describes the largest ethanol production plant in the Jilin Province, China opened in November 03. The plant has the capacity to process 2.3 million litres/day fuel ethanol. The process technology supplied by Vogelbusch is described and discussed.

Introduction

A grand opening ceremony was held in the city of Jilin in November 2003 to celebrate the production start-up of the first of two lines of a fuel ethanol project implemented by Jilin Fuel Ethanol Co. Ltd. With a final capacity of 600,000 tons per year, that is 2.3 million litres per day, the plant will be the world's largest bioethanol production facility (see Figure 1).

Jilin Fuel Ethanol Co. Ltd is one of the largest corn processing developer and newly risen energy supplier. It is also the first large-sized fuel ethanol production unit, which is approved by the Chinese Government. Three partners, China National Petroleum Corp., Jilin Food Stuff (Group) and China Resources Corp., established Jilin Fuel Ethanol Co. Ltd. with a registered capital of RMB 1.2 billion (USD 145 million) with 55 %, 25 % and 20 % of the capital, respectively. Jilin Fuel Ethanol Co., established on September 19, 2001, is located in the Northeastern part of China – Jilin City. It is located in the centre of the Jilin Economic Technology Development Zone and the country's primary corn production region. The Jilin fuel ethanol production is listed as one of the state key projects in the Tenth Five Year Plan and is a showcase project in China to promote the application of bioethanol. The operation of the plant takes place under ISO-9000 quality system, ISO-14000 environmental system and OHSAS-18000 plant operation system.

Figure 1. Overall view of the fuel ethanol plant

Time frame

Following an international tender in February 2001 contracts were signed in September 2001 and the work on construction started in November 2001. During the winter, temperatures fall to – 25 °C necessitating a break from construction for four to five months. Nonetheless, the building schedule went as planned with plant testing undertaken in August 2003 and ethanol production commencing in October 2003.

Process design

As a major global supplier of advanced alcohol technology since 1921 and technology supplier for the biggest Bioethanol project until Jilin Fuel Ethanol, namely Aventine Renewable Energy / Pekin USA, Vogelbusch was selected to provide the process design for the plant. Basic engineering included

raw material preparation, continuous fermentation, distillation and mole sieve dehydration along with supervision services for detail design and start-up assistance. The detail design was carried out by Shanghai Design Institute and partially by the Design Institute of the Petroleum Industry. Vogelbusch also delivered the column trays for all columns in the distillation section as proprietary equipment.

A special request of Jilin Fuel Ethanol was the incorporation in the design to use not only traditional milling processes, but also a newly developed Chinese wet milling technology.

Basic Process

• *Liquefaction*

Corn slurry is metered into the process and preheated dilution water, which is a combination of evaporator condensate and fresh utility water, is added into a static mixer. A portion of alpha amylase is added to the corn slurry and acts as a catalyst in the hydrolysis of the high molecular weight starch molecules.

The starch in the grain slurry is simultaneously gelatinized by high temperatures and thinned by alpha amylase under optimum pH-conditions suitable for the enzyme. The pre-liquefied slurry is pumped through the mash hydroheater where the slurry is mixed with steam to a controlled temperature of approximately 110 °C. The cooker provides enough residence time in order to ensure complete gelatinisation of the starch and pasteurisation of bacteria, which might enter the process with the raw material. The hot mash is then flashed into a vacuum in the expansion vessel, lowering the temperature to approximately 89 °C and the major portion of alpha amylase is added for the complete liquefaction of the starch.

• *Pre- Saccharification*

From the liquefaction tanks, the mash is pH-adjusted for optimum AMG enzyme activity. The pre-saccharification tank provides residence time for the second enzyme, amyloglucosidase (AMG), to facilitate further conversion (saccharification) of dextrins to glucose. AMG enables water to cleave individual glucose molecules from both the linear and non-linear sections of the dextrin molecules.

From the pre-saccharification tank, the mash is cooled and pumped to the fermentation section. The mash is not yet fully saccharified at this point, however, the AMG enzyme will continue to produce glucose throughout the subsequent fermentation, albeit at a slower rate due to the lower fermentation temperatures.

• *Fermentation*

The design uses continuous fermentation technology pioneered by Vogelbusch since mid 1970's. The result of such a configuration is a less labour intensive operation, a reduction in the amount of tank cleaning (resulting in less chemical and wastewater costs), an increased fermentation capacity of approximately 130% of batch systems, and increased ethanol yield (due to reduced yeast growth and reduced infection levels) and simultaneously a complete reliable operation proven in numerous plants worldwide.

• *Prefermentation*

The prefermenter is used to continuously grow the majority of the yeast required for fermentation. For an initial start-up with new yeast, active dry yeast is hydrated in warm water in special yeast cream vessel. After the initial growth of yeast the prefermenter is filled with mash. It operates continuously under steady state conditions. The flow rate of mash and prefermenter level are adjusted to provide a residence time such that a constant concentration of about 4.3 to 5.0% w/w alcohol and a constant yeast population are maintained. Nitrogen and /or phosphate in the form of nutrients like urea, diammoniumphosphate and vitamins are added to supplement any nutrient deficiencies that may occur in the mash. This is very dependent on the used raw material.

Figure 2. VB Multicont continuous fermentation with 7 fermenters in series

• *Main Fermentation*

The Fermentation unit consists of a cascade of several fermenters in series (depending on total capacity of the plant). In the case of Jilin Fuel Ethanol plant, seven fermenters each comprise of 3400 m^3 (see Figure 2). Each fermenter has an agitator to keep yeast and solids in suspension.

The continuous overflow from the prefermenter is pumped into the first stage fermenter and a controlled flow of

mash from the pre-saccharification tank is added. The flow rate of mash and first stage fermenter level are adjusted to provide a residence time such, that a constant concentration of about 5.5 to 6.5% w/w alcohol and a constant yeast population are maintained. To obtain some additional yeast growth in the first stage fermenter, a controlled flow of air is added. If a need arises where the first fermenter has to be emptied due to maintenance or CIP, the second stage fermenter can also be aerated.

From the first stage fermenter, mash is pumped from stage to stage by overflow. At the end of fermentation, the enzymatic conversion of the residual sugars is the limiting factor. When all dextrins have been converted to sugar by AMG and all sugars converted to alcohol by the yeast, the finished alcoholic mash is pumped into an intermediate mash tank. Final alcohol concentration depends on the starch content of the raw material.

The alcohol levels are relatively high throughout the fermentation area, which inhibits the growth of naturally occurring microorganisms, such as bacteria and other yeasts. In the Vogelbusch continuous process, serious contamination by bacteria will be checked when CIP schedule is kept. The fermentation by yeast of sugars into alcohol and carbon dioxide is exothermic. If left alone, the temperature of the mash would rise and the yeast would die. The heat of fermentation is removed by circulating the mash in the fermenters through external heat exchangers. The temperature of the fermenting mash is maintained at 31 °C-33 °C, which is slightly higher than in the prefermenter where it is maintained at 30-31 °C. This is due to the different conditions favouring yeast growth and alcohol production.

Figure 3. VB Multipressure distillation system

• *CO_2 Scrubber and Mash tank*

Carbon dioxide produced during is collected in a header and routed to CO_2 scrubbers. In these scrubbers, alcohol contained in the CO_2 is washed with fresh process water and the liquid is routed to intermediate mash tanks. The scrubbed CO_2 gas, which contains only traces of alcohol, is discharged from the top of the scrubber to the CO_2 plant or to the atmosphere.

Distillation and Dehydration

The plant consists of a VOGELBUSCH Multipressure Distillation system, making more economic use of heat energy and thus reducing steam consumption compared with traditional distillation systems (see Figure 3).

The following columns are part of the distillation:

05 C 0011	Distillation column I with degassing part	MC 1
05 C 0031	Distillation column II	MC 2
05 C 0051	Aldehyde column	AC
05 C 0061	Rectification column I	RC 1
05 C 0071	Rectification column II	RC 2

General Heat flow through the column system

The columns operate at different pressure levels so that one column can be heated with the overhead vapours of another. The rectification column RC 1 is indirectly heated by life steam across the thermosyphon reboiler. The overhead vapours of RC 1 are partially condensed in a reboiler to heat the distillation column MC 2 respectively the rectification column RC 2 (concentrating part of MC 2). Main crude alcohol vapours from the top of RC 2 are used to heat the distillation column MC 1 (reboiler 05H0111) which operates under a vacuum. The distillation column MC 2 operates under low pressure.

Process steps from alcoholic mash to concentrated alcohol (as vapour)

The alcoholic mash is preheated by the condensers of AC and MC 1 and the dehydrated alcohol condenser of dehydration plant. This preheated mash is fed to the top of the distillation column MC 1 (the top trays are acting as degassing section to strip off CO2 and aldehydes). The degassed mash partly flows to the bottom of MC 1 and leaves it as thin stillage. Partly the degassed mash is preheated (by thin stillage of MC 2) and fed to the top of the distillation column MC 2, flows to the bottom of the column and leaves it as thin stillage.

The thin stillage (bottoms) from both distillation columns are pumped to the decanters for removal of solids. The raw alcohol vapours from MC 2 are used to heat RC 2 directly. The degassing vapours from top of MC 1 are used to heat AC 1 directly where the aldehydes are concentrated on the top and, if desired, removed for improved product quality.

The rectification is split in two columns for more economic use of heat. The raw alcohol is purified and concentrated up to about 94 vol%. The top product of RC 1 is fed to top of RC 2 from where the

alcohol vapours are fed to a molecular sieve unit of dehydration plant. The bottoms of RC 2 are preheated with the above-mentioned top product of RC 1.

For product qualities allowing less fusel oil, a fusel oil decanter is installed in connection with RC 1. The separated fusel oil is fed to the dehydrated alcohol product.

The water content of raw alcohol leaves the bottom of rectification column RC 1 as singlings (lutter), which is used as sealing water for various pumps.

• *Molsieve Dehydration*

The alcohol vapour feed coming from the distillation plant goes to a steam driven superheater, where the temperature is increased to approximately 115 °C. From there the superheated crude alcohol vapour is fed to one of the molecular sieve beds A and B.

In the mole sieve bed the water within the alcohol/water vapour is adsorbed by the 3A-Zeolite material. Thus, the outlet vapour of the bed contains only very small amounts of water. This dehydrated alcohol vapour is condensed and pumped to the product storage after cooling.

As soon as the bed A is saturated with water and breakthrough is about to occur, the automatic control switches the valves for the feed stream to the regenerated bed B. The loaded bed A is switched to the regeneration mode. In this mode the top of the bed A is connected to the vacuum system, which reduces the pressure in the bed to app. 0.14 bar absolute. At this low pressure, the water starts to be desorbed again. The cycle time for adsorption and regeneration mode is approximately 5 to 7 minutes each.

Regeneration of the beds is done by feeding a small amount of the product vapour stream from A to the bottom of B (or vice versa). This vapour stream takes up the desorbed water and carries it to the purge condenser. The purge condensate is pumped back to the distillation section.

In addition, an evaporation section for stillage, Decantation & DDGS Drying (see Figure 4), auxiliaries comprising a CIP station and a station for preparation of different chemicals and nutrient are incorporated in the design.

Figure 4 Steam tube drying units