

Ethanol

Introduction

Henry Ford designed the famed Model T Ford to run on alcohol – he said it was “the fuel of the future.” On average, the world consumes some 86 million barrels of oil per day. According to the International Energy Agency (IEA), that number is slated to rise to 116 million barrels by 2030.

The fuel for the future is called E85, a blend of 85% ethanol and 15% gasoline. It is used by vehicles specifically designed to run on either gasoline or E85, so-called Flexible Fueled Vehicles (FFVs).

In 2007, the Indianapolis 500 and the entire Indy Racing League used 100 percent ethanol to power cars around the track in excess of 200 miles per hour.

2008 WORLD FUEL ETHANOL PRODUCTION (In Millions of Gallons)

U.S.A.	9,000.0
Brazil	6,472.2
European Union	733.6
China	501.9
Canada	237.7
Other	128.4
Thailand	89.8
Colombia	79.2
India	66.0
Australia	26.4
Total	17,335.2

Market Segment

Alternative fuels

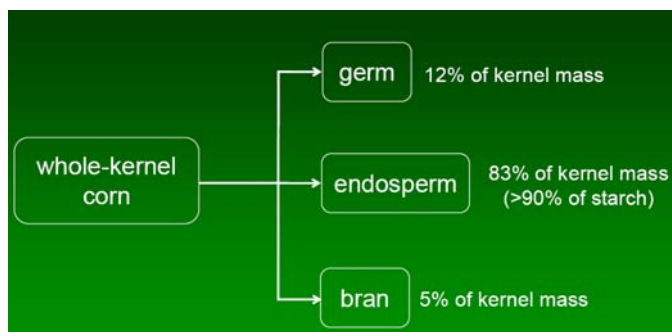
Description of the Challenge

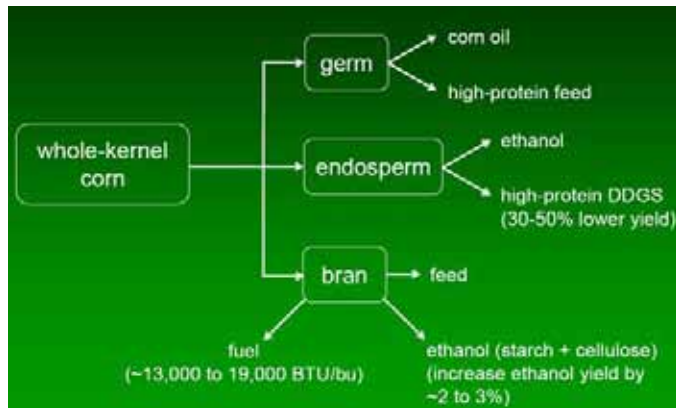
Typical gases to be monitored at a Ethanol plant are: combustible gases (primarily Ethanol, C₂H₅OH), Ammonia (NH₃), Oxygen (O₂), Chlorine (Cl₂), Carbon Dioxide (CO₂) and Sulfur Dioxide (SO₂).

Ethanol Yield

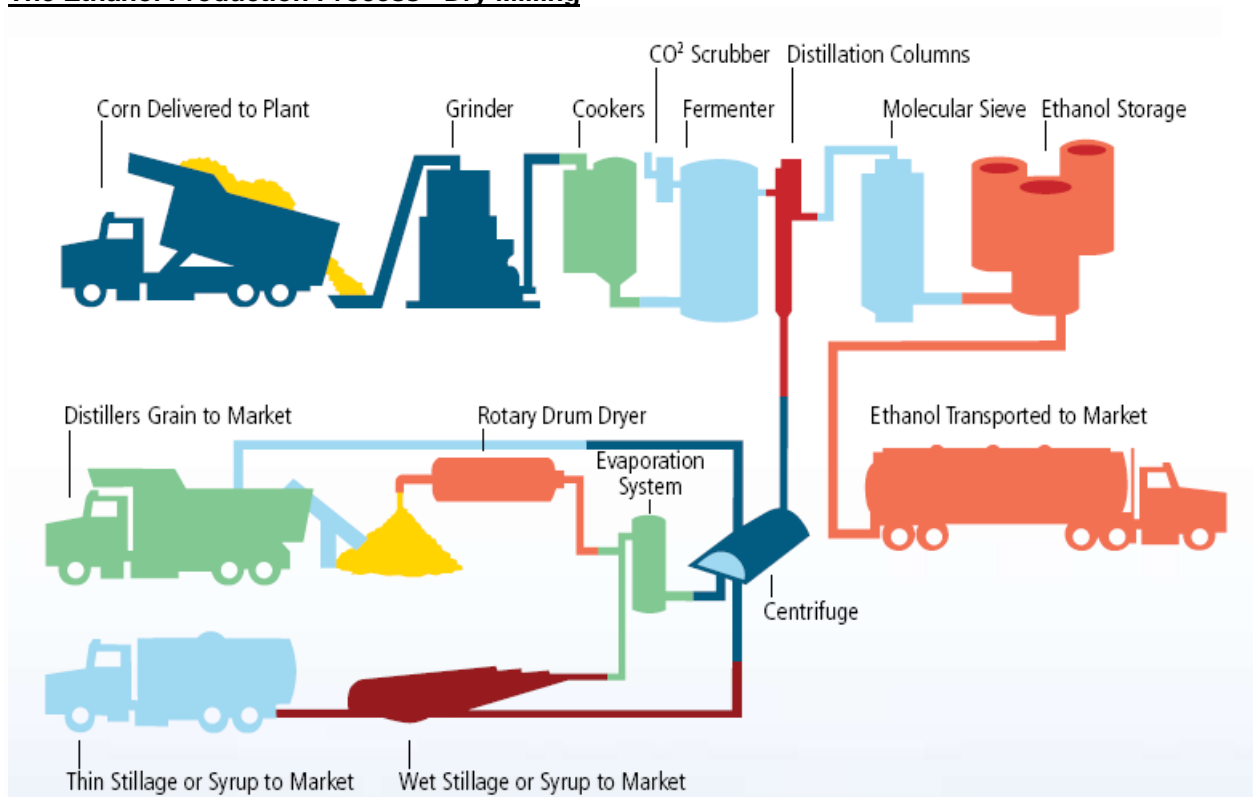
National Corn-to-Ethanol Research Center (NCERC):

1 bushel of corn (56 lbs.) + yeast + amylase enzymes + 92,600 Btu + 12 gal water
= 2.7 gallons (18 lbs.) ethanol + 18 lbs. CO₂ + 18 lbs. DDGS





The Ethanol Production Process - Dry Milling



In dry milling, the entire corn kernel or other starchy grain is first ground into flour, which is referred to in the industry as "meal" and processed without separating out the various component parts of the grain. The meal is slurried with water to form a "mash." Enzymes are added to the mash to convert the starch to dextrose, a simple sugar. **Ammonia** is added for pH control and as a nutrient to the yeast.

The mash is processed in a high-temperature cooker to reduce bacteria levels ahead of fermentation. The mash is cooled and transferred to fermenters where yeast is added and the conversion of sugar to **Ethanol** and **Carbon Dioxide** (CO_2) begins.

The fermentation process generally takes about 40 to 50 hours. During this part of the process, the mash is agitated and kept cool to facilitate the activity of the yeast. After fermentation, the resulting "beer" is transferred to distillation columns where the ethanol is separated from the remaining "stillage." The ethanol is concentrated to 190 proof using conventional distillation and then is dehydrated to

approximately 200 proof in a molecular sieve system.

The anhydrous ethanol is then blended with about 5% denaturant (such as natural **Gasoline**) to render it undrinkable and thus not subject to beverage alcohol tax. It is then ready for shipment to gasoline terminals or retailers.

The stillage is sent through a centrifuge that separates the coarse grain from the solubles. The solubles are then concentrated to about 30% solids by evaporation, resulting in Condensed Distillers Solubles (CDS) or "syrup." The coarse grain and the syrup are then dried together to produce dried distillers grains with solubles (DDGS), a high quality, nutritious livestock feed. The CO₂ released during fermentation is captured and sold for use in carbonating soft drinks and beverages and the manufacture of dry ice.

Dry mill process

Delivery/Storage

Grain is delivered by truck or rail to the ethanol plant where it's loaded in storage bins designed to hold enough grain to supply the plant for 7–10 days.

Milling

The grain is screened to remove debris and ground into course flour.

Cooking (Hot Slurry, Primary Liquefaction, and Secondary Liquefaction)

During the cook process, the starch in the flour is physically and chemically prepared for fermentation.

Hot Slurry

The milled grain is mixed with process water, the pH is adjusted to about 5.8, and an alpha-amylase enzyme is added. The slurry is heated to 180–190°F for 30–45 minutes to reduce viscosity.

Primary Liquefaction

The slurry is then pumped through a pressurized jet cooker at 221°F and held for 5 minutes. The mixture is then cooled by an atmospheric or vacuum flash condenser.

Secondary Liquefaction

After the flash condensation cooling, the mixture is held for 1–2 hours at 180–190°F to give the alpha-amylase enzyme time to break down the starch into short chain dextrins.

After pH and temperature adjustment, a second enzyme, glucoamylase, is added as the mixture is pumped into the fermentation tanks.

Simultaneous Saccharification Fermentation

Once inside the fermentation tanks, the mixture is referred to as mash. The glucoamylase enzyme breaks down the dextrins to form simple sugars. Yeast is added to convert the sugar to ethanol and carbon dioxide. The mash is then allowed to ferment for 50–60 hours, resulting in a mixture that contains about 15% ethanol as well as the solids from the grain and added yeast.

Distillation

The fermented mash is pumped into a multi-column distillation system where additional heat is added. The columns utilize the differences in the boiling points of ethanol and water to boil off and separate the ethanol. By the time the product stream is ready to leave the distillation columns, it contains about 95% ethanol by volume (190-proof). The residue from this process, called stillage, contains non-fermentable solids and water and is pumped out from the bottom of the columns into the centrifuges.

Dehydration

The 190-proof ethanol still contains about 5% water. It's passed through a molecular sieve to physically separate the remaining water from the ethanol based on the different sizes of the molecules. This step produces 200-proof anhydrous (waterless) ethanol.

Ethanol Storage

Before the ethanol is sent to storage tanks, a small amount of denaturant is added, making it unfit for human consumption. Most ethanol plants' storage tanks are sized to allow storage of 7–10 days' production capacity.

Co-Product Processing

During the ethanol production process, two valuable co-products are created: carbon dioxide and distillers grains.

As yeast ferment the sugar, they release large amounts of carbon dioxide gas. It can be released into the atmosphere, but it's commonly captured and purified with a scrubber so it can be marketed to the food processing industry for use in carbonated beverages and flash-freezing applications.

The stillage from the bottom of the distillation tanks contains solids from the grain and added yeast as well as liquid from the water added during the process. It's sent to centrifuges for separation into thin stillage (a liquid with 5–10% solids) and wet distillers grain.

Some of the thin stillage is routed back to the cook/slurry tanks as makeup water, reducing the amount of fresh water required by the cook process. The rest is sent through a multiple-effect evaporation system where it is concentrated into syrup containing 25–50% solids. This syrup, which is high in protein and fat content, is then mixed back in with the wet distillers grain (WDG).

With the added syrup, the WDG still contains most of the nutritive value of the original feedstock plus the added yeast, so it makes an excellent cattle ration for local feedlots and dairies. After the addition of the syrup, it's conveyed to a wet cake pad, where it is loaded for transport.

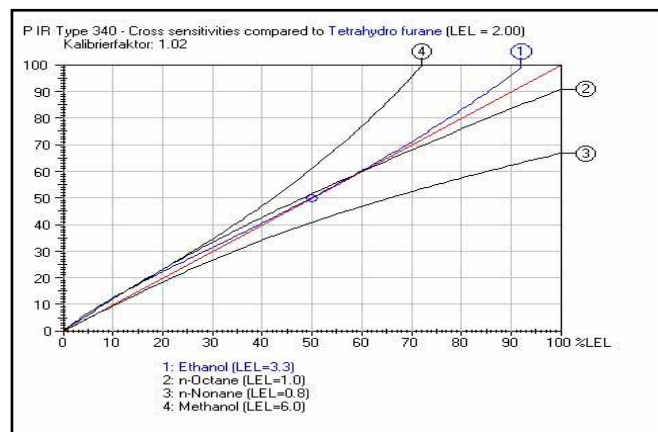
Many ethanol facilities do not have enough nearby cattle to utilize all of the WDG. It must be used soon after it's produced because it spoils easily. So, it's often sent through a drying system to remove moisture and extend its shelf life. This dried distillers grain (DDG) is commonly used as a high-protein ingredient in cattle, swine, poultry, and fish diets. It's also being researched for human consumption.

Solutions from Draeger

1. Detection of Ethanol

- Load/Out, Tank Farms, Pump Wells, distillation towers

Draeger PIR 7000 (340), Polytron IR 340 robust gas detector with SS 316 stainless steel housing, sophisticated double compensated optics which ensures less than 1 %LEL signal drift over 12 month, wide temperature range covering all climates (- 40 to + 65°C) and beam block warning before failure to schedule maintenance because of build-up of deposits on the optics.



- Tank Farms, Process Pump Headers

Polytron Pulsar Mid Range best used where the detector will be subjected to exposure to the elements, vibration, sunlight (and other bright light sources) and longer beam distances.

2. Detection of toxic gases

- NH₃ PH Control
- O₂ Nitrogen Blankets
- Cl₂ Waste treatment
- SO₂ Wet Grain Milling

Polytron 7000, Polytron 2 XP Tox a universal transmitter which accepts any DrägerSensor, downloads sensor-specific information from the embedded sensor EEPROM. The sensor has an embedded temperature element which allows to compensate the sensor signal in the range of - 40 to + 65 °C.

- CO₂- Fermentation

Draeger PIR 7200 robust gas detector with SS 316 stainless steel housing, sophisticated double compensated optics which ensures less than 0.03 Vol% signal drift over 12 month, wide temperature range covering all climates (- 40 to + 65°C) and beam block warning before failure to schedule maintenance because of build-up of deposits on the optics.

3. Detection of Fire

- Process Areas/ Storage, Rail Car Load Out

Draeger Flame 5000 explosion proof color imaging based flame detector. Each detector operates standalone and incorporates, within a single unit, an integrated CCTV system; digital signal processing and software algorithms to process live video image and interpret the characteristics of a flame.

Advantages of the Dräger Solution

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|----------------------|---|
| IR detectors: | - lower measuring ranges along with higher sensitivities result in larger monitoring areas
- constant sensitivity over lifetime of the instrument
- can be submersed without damage (IP 66 & IP 67) |
| Open Path: | - monitoring of large areas
- low cost of ownership
- fast response time |
| DrägerSensor: | - bigger sensor means bigger electrodes and more electrolyte, hence faster response, higher accuracy, more stability and longer life
- embedded micro-chip and temperature element
- sensor recognition, numerous self-test functions, remote calibration and signal compensation over the whole temperature range of typically - 40 to + 65 °C |

References

<http://www.ethanolmarket.com/index.html>

<http://www.ethanol.org>

<http://ethanolproducer.com/>



NEW ENGLAND
ETA PROCESS INSTRUMENTATION
 since 1971
 www.etapii.com
 sales@etapii.com
 tel: 978.532.1330



UPSTATE NEW YORK
MARTECH CONTROLS
 since 1997
 www.martechcontrols.com
 sales@martechcontrols.com
 tel: 315.876.9120