PETROJAM ETHANOL LIMITED

WHAT IS ETHANOL?

Ethanol is a renewable fuel currently made from abundant agricultural and biomass feedstocks. It is an alcohol-based alternative fuel produced by fermenting and distilling starch crops that have been converted into simple sugars. The feedstock (hydrous alcohol or wet ethanol) for this fuel contains a larger proportion of water and is produced from a range of agricultural products including sugar cane, corn and grapes. Ethanol can also be produced from "cellulosic biomass" such as trees and grasses and is called bioethanol.

The fuel grade ethanol (Anhydrous Alcohol or dry ethanol) contains no more than 0.5% water. It is used as an octane enhancer for motor gasoline.

PROPERTIES OF ETHANOL

Ethanol (ethyl alcohol, grain alcohol) is a clear, colorless liquid with a characteristic, agreeable odor. In dilute aqueous solution, it has a somewhat sweet flavor, but in more concentrated solutions it has a burning taste. Ethanol, CH_3CH_2OH, is an alcohol, a group of chemical compounds whose molecules contain a hydroxyl group, –OH, bonded to a carbon atom. The word *alcohol* derives from Arabic *al-kuhul*, which denotes a fine powder of antimony produced by distilling antimony and used as an eye makeup. *Alcohol* originally referred to any fine powder, but medieval alchemists later applied the term to the refined products of distillation, and this led to the current usage.

Ethanol melts at –114.1°C, boils at 78.5°C, and has a density of 0.789 g/mL at 20°C. Its low freezing point has made it useful as the fluid in thermometers for temperatures below –40°C, the freezing point of mercury, and for other low-temperature purposes, such as for antifreeze in automobile radiators.

Ethanol has been made since ancient times by the fermentation of sugars. All beverage ethanol and more than half of industrial ethanol is still made by this process. Simple sugars are the raw material. Zymase, an enzyme from yeast, changes the simple sugars into ethanol and carbon dioxide. The fermentation reaction, represented by the simple equation

$$C_6H_{12}O_6 \longrightarrow 2\ CH_3CH_2OH + 2\ CO_2$$

is actually very complex, and impure cultures of yeast produce varying amounts of other substances, including glycerin and various organic acids. In the production of beverages, such as whiskey and brandy, the impurities supply the flavor. Starches from potatoes, corn, wheat, and other plants can also be used in the production of ethanol by fermentation. However, the starches must first be broken down into simple sugars. An enzyme released by germinating barley, diastase, converts starches into sugars. Thus, the germination of barley, called malting, is the first step in brewing beer from starchy plants, such as corn and wheat.

The ethanol produced by fermentation ranges in concentration from a few percent up to about 14 percent. Above about 14 percent, ethanol destroys the zymase enzyme and fermentation stops.

Ethanol is normally concentrated by distillation of aqueous solutions, but the composition of the vapor from aqueous ethanol is 96 percent ethanol and 4 percent water. Therefore, pure ethanol cannot be obtained by distillation. Commercial ethanol contains 95 percent by volume of ethanol and 5 percent of water. Dehydrating agents can be used to remove the remaining water and produce absolute ethanol.

USES OF ETHANOL

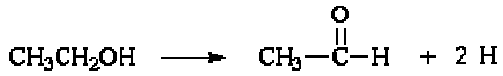
Much ethanol not intended for drinking is now made synthetically, either from acetaldehyde made from acetylene, or from ethylene made from petroleum. Ethanol can be oxidized to form first acetaldehyde and then acetic acid. It can be dehydrated to form ether. Butadiene, used in making synthetic rubber, may be made from ethanol, as can chloroform and many other organic chemicals. Ethanol is used as an automotive fuel by itself and can be mixed with gasoline to form gasohol. Ethanol is miscible (mixable) in all proportions with water and with most organic solvents. It is useful as a solvent for many substances and in making perfumes, paints, lacquer, and explosives. Alcoholic solutions of nonvolatile substances are called tinctures; if the solute is volatile, the solution is called a spirit.

Most industrial ethanol is denatured to prevent its use as a beverage. Denatured ethanol contains small amounts, 1 or 2 percent each, of several different unpleasant or poisonous substances. The removal of all these substances would involve a series of treatments. These denaturants render ethanol unfit for some industrial uses. In such industries undenatured ethanol is used under close centralized supervision.

ETHANOL AND HUMAN CONSUMPTION

When an alcoholic beverage is swallowed, it passes through the stomach into the small intestine, where the ethanol is rapidly absorbed and distributed throughout the body. The ethanol enters body tissues in proportion to their water content. Therefore, more ethanol is found in the blood and the brain than in muscle or fat tissue. The ethanol is greatly diluted by body fluids. For example, a 1-ounce shot of 100-proof whiskey, which contains 0.5 fluid ounces of ethanol (about 15 mL), is diluted 5000-fold in a 150-pound human, producing a 0.02% blood alcohol concentration.

Ethanol is toxic, and the body begins to dispose of it immediately upon its consumption. Over 90% of it is processed by the liver. In the liver, the alcohol dehydrogenase enzyme converts ethanol into acetaldehyde, which is itself toxic.

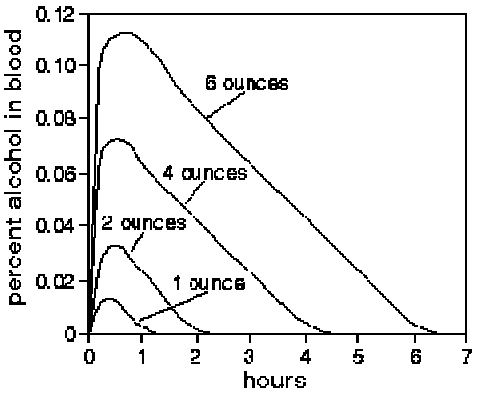


This is destroyed almost immediately by the aldehyde dehydrogenase enzyme, which converts it to acetate ions.

The hydrogen atoms represented by these equations are not unattached, but are picked up by another biologically important compound, nicotinamide-adenine dinucleotide (NAD), whose function is to carry hydrogen atoms. NAD is involved in both of the above processes, being converted to NADH.

NAD + H ⟶ NADH

Figure. Blood alcohol content versus time after consumption of 1, 2, 4, and 6 ounces of ethanol. figure shows how the blood alcohol level varies with time for various doses of ethanol.



NADH must be recycled to NAD for the disposal of ethanol to continue. If the amount of ethanol consumed is not great, the recycling can keep up with the disposal of ethanol. The ethanol disposal rate in a 150-pound human is about 0.5 ounce of ethanol per hour, which corresponds to 12 ounces of beer, 4 ounces of wine, or 1 ounce of hard liquor. The figure shows how the blood alcohol level varies with time for various doses of ethanol.

Ethanol acts as a drug affecting the central nervous system. Its behavioral effects stem from its effects on the brain and not on the muscles or senses themselves. It is a depressant, and depending on dose, can be a mild tranquilizer or a general anesthetic. It suppresses certain brain functions. At very low doses, it can appear to be a stimulant by suppressing certain inhibitory brain functions. However, as concentration increases, further suppression of brain functions produce the classic symptoms of intoxication: slurred speech, unsteady walk, disturbed sensory perceptions, and inability to react quickly. At very high concentrations, ethanol produces general anesthesia; a highly intoxicated person will be asleep and very difficult to wake, and if awakened, unable to move voluntarily.

Alcohol levels in the brain are difficult to measure, and so blood alcohol levels are used to assess degree of intoxication. Most people begin to show measurable mental impairment at around 0.05 percent blood alcohol. At around 0.10 percent, mental impairment will show obvious physical signs, such as an unsteady walk. Slurred speech shows up at around 0.15 percent. Unconsciousness results by 0.4 percent. Above 0.5 percent, the breathing center of the brain or the beating action of the heart can be anesthetized, resulting in death. Reaching this level of blood alcohol by ingestion is unlikely, however. In a 150-pound human, it would require rapid consumption of a fifth gallon of a 100-proof spirit.

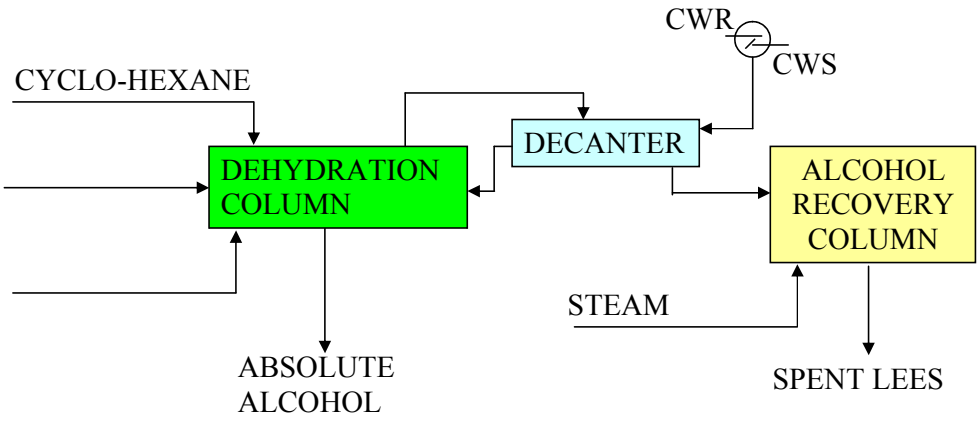
TECHNOLOGIES USED FOR DEHYDRATION

Molasses or cane-juice is first fermented using yeast to produce mash containing 7-10% by volume ethanol. This mash is then distilled using steam to produce rectified spirit (hydrous ethanol) having about 5% by volume water in it .This rectified spirit is further dehydrated by one of the following technologies:

1. Azeotropic Distillation
2. Extractive Distillation
3. Membrane Separation
4. Pressure Swing Adsorption (Molecular Sieve Dehydration)

Azeotropic Distillation Technology:

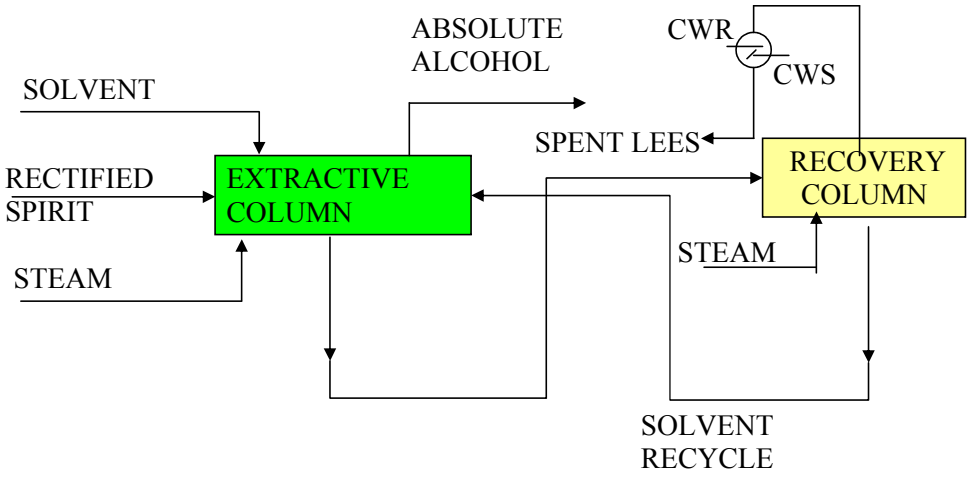
Azeotropic technology is the old dehydration solution as shown in the process block diagram below:



This process is less used today because of all or one of the following reasons:

- Uses carcinogens (benzene or cyclohexane) as dehydration agent
- High energy usage
- Traces of entrainer in product
- Complex installation and operation

Extractive Distillation Technology



This process is uses chemicals compounds like glycol to extract moisture. It requires high pressure steam and the operating cost is less than the Azeotropic technology but more than the molecular sieve technology described in the next section.

Pressure Swing Adsorption (Molecular Sieve Technology):

Ethanol dehydration improved with the emergence of molecular sieves that use micro porous particles. Molecular sieve dehydration technology utilizes micro-porous particles such as alumino-silicates, processing a very precise pore size. The pores make it possible to separate small molecules form large ones through selective adsorption. For example, ethanol dehydration is accomplished with molecular sieves which have a diameter of 3Å, which entraps water molecules which have a diameter of 2.5Å. Ethanol molecules which have a diameter of 4Å cannot enter and therefore flow around the material. See illustration diagram below.

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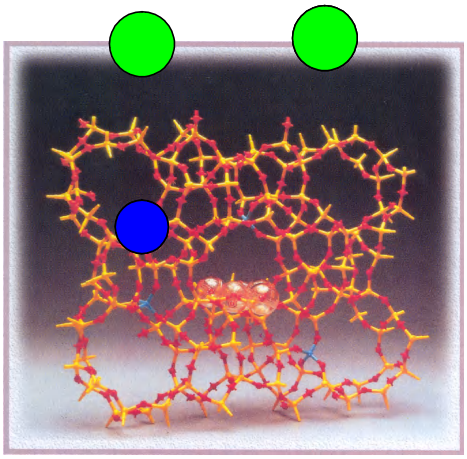
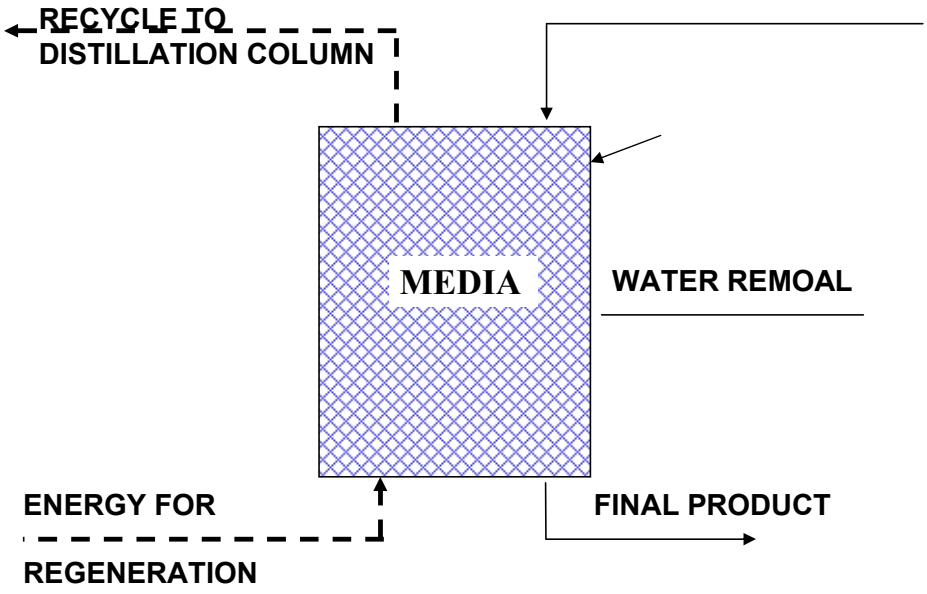


How they work?

- Separate molecules by size and polarity
- Very strong affinity for water
- Dehydrate under pressure, Regenerate under vacuum



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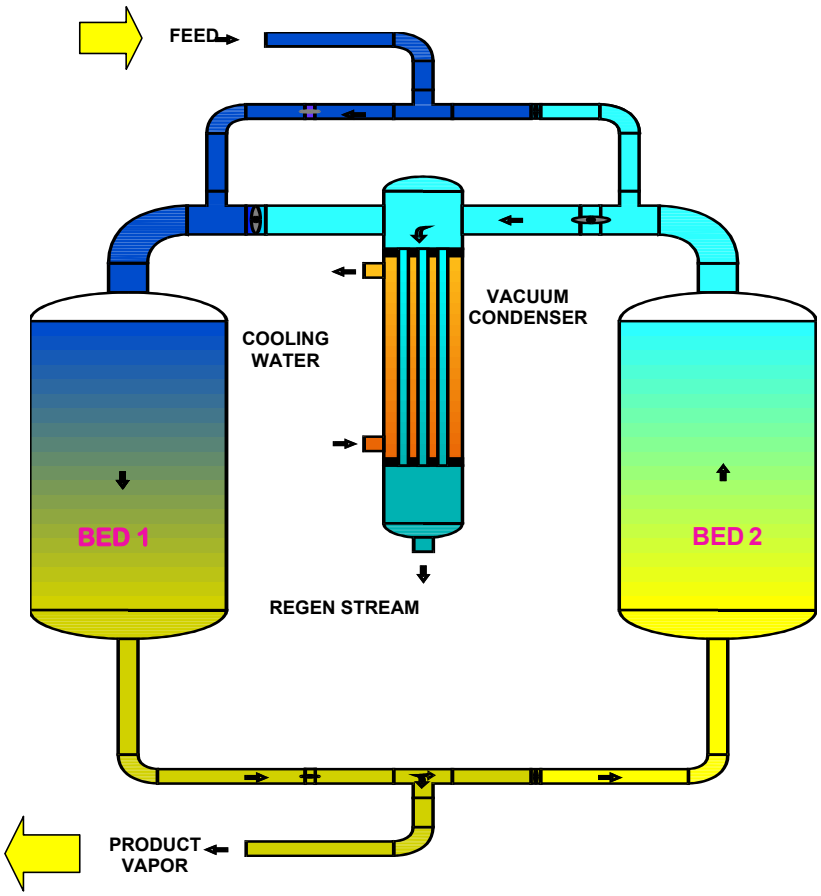
THE PROCESS



The technological advancements have resulted in the following process improvements:

- Lower operating cost
- No external chemical required making the product suitable for:
  - *Pharmaceutical Grade*
  - *Perfumery Grade Alcohol*
- Highly automated plant
- High alcohol recovery

THE BENEFITS OF ETHANOL AS A FUEL

Ethanol is a much cleaner fuel than petrol (gasoline):

- It is a renewable fuel made from plants
- It is not a fossil-fuel: manufacturing it and burning it does not increase the greenhouse effect
- It provides high octane at low cost as an alternative to harmful fuel additives
- Ethanol blends can be used in all petrol engines without modifications
- Ethanol is biodegradable without harmful effects on the environment
- It significantly reduces harmful exhaust emissions
- Ethanol's high oxygen content reduces carbon monoxide levels more than any other oxygenate: by 25-30%, according to the US EPA
- Ethanol blends dramatically reduce emissions of hydrocarbons, a major contributor to the depletion of the ozone layer
- High-level ethanol blends reduce nitrogen oxide emissions by up to 20%
- Ethanol can reduce net carbon dioxide emissions by up to 100% on a full life-cycle basis
- High-level ethanol blends can reduce emissions of Volatile Organic Compounds (VOCs) by 30% or more (VOCs are major sources of ground-level ozone formation)
- As an octane enhancer, ethanol can cut emissions of cancer-causing benzene and butadiene by more than 50%
- Sulphur dioxide and Particulate Matter (PM) emissions are significantly decreased with ethanol.

ETHANOL AS A HIGH PERFORMANCE FUEL

Ethanol is most commonly used to increase **octane**[†] and improve the emissions quality of gasoline. In some areas of the United States, ethanol is blended with gasoline to form an E10 blend (10% ethanol and 90% gasoline), but it can be used in higher concentrations such as E85 or E95. Original equipment manufacturers produce flexible-fuel vehicles that can run on E85 or any other combination of ethanol and gasoline.

Ethanol's high octane content helps your car run more smoothly. Ethanol keeps a car's fuel system clean for optimal performance.

- Gasoline blended with up to 10% ethanol is approved under the warranties of all auto manufacturers marketing vehicles in the U.S. Many even recommended ethanol because of its clean air benefits. Approval of ethanol blends is found in the owners' manuals under references to refueling or gasoline.

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[†] Octane ratings measure a gasoline's ability to resist engine knock, a rattling or pinging sound that results from premature ignition of the compressed fuel-air mixture in one or more cylinders. Most gas stations offer three octane grades: regular (usually 87 octane), mid-grade (usually 89 octane) and premium (usually 92 or 93). The ratings must be posted on bright yellow stickers on each gasoline pump.

- Ethanol-blended fuels can also be used in your yard care equipment, motorcycles and boats.

AIR QUALITY AND ETHANOL IN GASOLINE

Ethanol is one of the best tools we have to fight air pollution from vehicles. Ethanol contains oxygen, which improves fuel combustion and reduces exhaust emissions.

- Ethanol reduces carbon monoxide, volatile organic compounds, toxics and fine-particulate emission that pose a health threat, particularly to children and seniors.
- Adding ethanol to gasoline displaces toxic gasoline components.
- Ethanol is quickly biodegradable in surface water, groundwater and soil.
- As a renewable fuel ethanol helps reduce emissions of greenhouse gases that contribute to global warming.
- Ethanol helps to reduce pollution from "gross polluters," which are responsible for more than half of all vehicle emissions while making up only 10% of the vehicle fleet.

Ethanol has gained popularity in recent years as the preferred octane booster for gasoline blending in North America and several other regions of the world. This has followed a phase-out of lead as an additive due to its polluting effects in areas of high population and motor car density, particularly in the United States of America.

In Jamaica, several pre-conditions exist to encourage the introduction of ethanol. Sugar cane, one of the crops from which ethanol can be produced, is widely grown in Jamaica and other Caribbean territories. The technology and skilled manpower are available.

ETHANOL AS A REPLACEMENT FOR MTBE

Importance of MTBE & its Role in Gasoline - The principal use of Methyl-Tertiary-Butyl-Ether (MTBE) is as an additive to automotive fuels and is still the most widely used additive around the world. When blended into gasoline, MTBE enhances octane ratings and improves fuel combustion, thus reducing harmful exhaust emissions. MTBE's unique properties of high octane, low boiling temperature and moderate vapour pressure make it a very versatile gasoline blending component that is used to solve many of the refiner's gasoline quality and production problems. It has been used by refiners to replace the octane supplied by the toxic lead compounds in gasoline without the need to make large capital investments. MTBE also allows petroleum companies to adjust to changing gasoline markets by using it to expand gasoline production, upgrade regular gasoline production to higher premium grade gasoline (increasing the octane number) and meet new environmental specifications.

These unique blending properties coupled with MTBE's 18.2 wt. % oxygen, allow petroleum companies to produce cleaner burning reformulated gasoline that reduces vehicle emissions that are precursors to ozone and particulate matter in the atmosphere. In some facilities, blending MTBE also replaces some aromatic compounds in gasoline, which largely contribute to toxic emissions from vehicles.

MTBE was embraced because of its benign impact on local air quality; its adverse impact on water quality was never addressed. As a result, several countries are now phasing out MTBE. The focus is now on the alternative clean air additives that should substitute for MTBE. ***If MTBE is phased out, the only oxygenate available in large quantities is plant matter-derived ethanol.***

Ethanol Benefits - Ethanol can reduce our dependence on foreign oil because it can be produced domestically. Today, ethanol reduces the demand for gasoline and methyl tertiary-butyl ether (MTBE) imports around the world. The replacement of imported MTBE with locally produced ethanol would represent a significant reduction to our annual trade deficit. In addition, since the petroleum refining industry is running at near capacity, the development of an ethanol industry will help to extend our petroleum supply, thereby reducing fuel costs to consumers.