BIOFUELS – PART 1: ETHANOL BASICS

by
Bryan Crouch, Engineer

This article is the first of a series that will present an overview of the facts and issues regarding the manufacture and use of ethanol and biodiesel as alternative motor vehicle fuels. Ethanol and biodiesel are biofuels that provide alternatives to gasoline and diesel, respectively. Biofuels can be defined as fuels that are derived from recently-living biological resources. The "recently-living" part of the definition is what differentiates biofuels from traditional fuels, that is – fossil fuels. Traditional fuels, such as gasoline and diesel, are derived from very old biological resources – crude oil. Biofuels are generally more environmentally benign than traditional fuels and are further defined as being renewable, meaning that the feedstock used to make a particular biofuel can be replenished at a rate equal to or faster than the rate at which the biofuel is consumed.

What Is Ethanol?

Ethanol, also known as grain alcohol and ethyl alcohol (CH_3CH_2OH), is a flammable, colorless liquid. It is in widespread use as a fuel, a solvent, an intermediate for many other chemicals, and a beverage. It is toxic, but less so than other alcohols. In the context of a motor vehicle fuel, ethanol can be used neat (straight) or mixed with gasoline in any ratio; however, gasoline engines and fuel systems have to be modified to use blends of more than 10% ethanol.

How Is Ethanol Made?

Ethanol can be produced by synthesis from the chemical compound ethylene, which is derived from crude oil or natural gas, or by the fermentation of carbohydrates. In the U.S., virtually all fuel ethanol is produced by fermentation. Fermentation is the process whereby sugar is broken down into alcohol and carbon dioxide by the action of a microorganism. It has been utilized by humans for thousands of years. Any substance that contains a substantial amount of sugar, or can be converted into sugar, can be utilized to produce ethanol. When considering fuel ethanol, three categories of substances are of interest: sugar, starch, and cellulose.

The direct fermentation of sugar can utilize substances such as molasses, sugar cane juice, and sugar beet juice. After fermentation, a multiple step distillation process separates and collects the alcohol. The alcohol is then denatured to render it undrinkable and thereby not subject to beverage alcohol taxes.

Starches such as corn, barley, sorghum, and wheat must be converted into sugar before fermentation can take place. This is accomplished by the action of enzymes on the starch and is called hydrolysis. There are two main processes that are encompassed in the production of ethanol from starches, dry milling and wet milling. The difference is primarily in the treatment of the grain before it is converted to sugar. In the dry milling process, the grain is ground up and mixed with water. In the wet milling process, the grain is soaked in water and acid to facilitate the mechanical separation into its components. At this point in either process, the starch is hydrolyzed into sugar and then fermented and distilled in the same manner as described above.

Cellulose is a structural component in biomass (material derived from plants). Like starch, it can be

hydrolyzed into sugar (but not as easily) and then fermented into ethanol. There is also gasification technology that oxidizes the carbon contained in cellulose into carbon monoxide. There is also a new technology being developed that gasifies cellulose into carbon monoxide, carbon dioxide, and hydrogen, and then employs a special microorganism that ferments the carbon monoxide, carbon dioxide, and hydrogen into ethanol and water. When ethanol is made from biomass it is commonly referred to as bioethanol.

How Does Ethanol Compare To Gasoline?

Before ethanol can be compared to gasoline, it must first be understood how ethanol is used as an alternative motor vehicle fuel. As stated earlier, ethanol can be used neat or mixed with gasoline in any ratio, but in order to meet the definition of an alternative fuel, the percentage of ethanol in an ethanol/gasoline mixture must be 85% (referred to as E85) or greater. Due to poor cold weather starting and performance, ethanol content is practically limited to 85%; therefore, the comparison should be between gasoline and E85. Three important points of comparison are emissions, fuel economy, and octane quality.

Ethanol contains 35% oxygen by weight; gasoline contains none. Oxygen promotes more complete combustion which results in fewer tailpipe emissions. Compared to the combustion of gasoline, the combustion of ethanol substantially reduces the emission of carbon monoxide, volatile organic compounds, particulate matter and green house gasses. The caveat is that the only vehicles that are currently available and able to use ethanol in high concentrations are flex fuel vehicles (FFVs). FFVs are vehicles that can operate on any mixture of gasoline and ethanol (up to E85), and as a result, are not optimized to run on ethanol. In reality, FFVs have nearly equal EPA air pollution ratings when operating on either 100% gasoline or E85. FFVs reduce greenhouse gas emissions by approximately 20% when operating on E85.

A gallon of ethanol contains about 32% less energy than a gallon of gasoline. Less energy per gallon translates into fewer miles per gallon, a standard measure of fuel economy. E85 contains about 27% less energy than gasoline. The actual loss in fuel economy when using E85 depends on the particular vehicle/engine design, and driving conditions, but ranges from 10% to the full 27%.

One of the best qualities of ethanol is its octane rating. Octane rating is a measure of a fuel's ability to resist engine knock, a potentially destructive phenomenon. Unleaded gasoline octane ratings range from 85 to 95; E85 has an octane rating of 105. A higher octane rating allows certain engine design parameters, such as compression ratio, and valve timing, to be altered in such ways that fuel economy and power are increased.

Ethanol is one of the simplest to implement alternatives to gasoline (although when utilized as E85, it should be kept in mind that it does not completely displace gasoline); however, there are issues that must be considered. Some of these issues will be the focus of the next article in this series.

Sources

"Ethanol," *Kirk-Othmer Encyclopedia of Chemical Technology,* 5th ed.
Owen, Keith and Coley, Trevor, *Automotive Fuels Reference Book,* 2nd ed.
U.S. Dept. of Energy and Environmental Protection Agency's fuel economy website (URL: http://www.fueleconomy.gov).
Renewable Fuels Association website (URL: http://www.ethanolrfaorg).