Given the dramatic benefits to the environment, you would think that you'd be given incentives to convert your vehicle to alcohol. Instead, the legal requirements for pollution control devices on alcohol-driven vehicles are still somewhat ambiguous. Air pollution control laws are actually designed to enforce the placement of smog devices on vehicles, regardless of lower emissions. What's more, most things you might add to the engine to enable clean running of alcohol would also be illegal. Any alteration is considered "tampering" by the government.

In the 1980s, court victories in California and other states challenged those laws, and, in those cases, vehicles that could document emissions within legal limits were allowed to dispense with emission control devices. Nowadays, most smog agencies on both state and federal levels ignore these court decisions and refuse to recognize the legitimacy of converting gasoline vehicles to alcohol *unless they are certified.* Flexible-fuel vehicles are certified, and thus are legal to use alcohol. In theory, you could have your conversion certified, but the process for being certified generally costs more than the purchase price of your car (see Chapter 26 for more on this subject).

Mileage

The myth that alcohol fuel gets only half or two-thirds the mileage of gasoline is often repeated, but no one ever cites any road tests. A properly designed alcohol engine will generate more miles per gallon than a gasoline engine. Alcohol burns at a much faster speed than gasoline, turning more of its energy into work faster, and more of its chemical energy into work rather than waste heat.

The mileage myth assumes a simple but spurious comparison of the two fuels' heating value (expressed as Btu/gallon) as the basis for low mileage figures for alcohol. The oft-cited David Pimentel, Ph.D., at Cornell University, has declared that "because of the relatively low energy content of ethanol, 1.5 gallon[s] of ethanol have the energy equivalent of one gallon of gasoline." Let's examine this erroneous assumption.

Heating value is the measure of the amount of Btu generated by the perfect combustion of the material with an ideal amount of oxygen, as in burning wood for a fire. The heating value of one and a quarter pounds of wood, a cup of gasoline, and four pounds of dynamite are about the same (7000 Btu).[11] But the work each of these materials generates is vastly different.

In an engine, what we care about is how well the fuel drives a piston. The issue is work, not heat. To measure the energy of work, the standard unit is the **joule**. That's about the amount of energy it takes to toss an apple vertically a foot. Simply defined, it's the force against the apple (or a piston) multiplied by the distance.

Power is the speed at which a joule takes place. When you generate one joule per second, that's a **watt**, a term you should be familiar with in rating the power of motors or power tools, which do work. Showing how irrelevant heating value is to work, the wood generates 30 kilowatts (thousands of watts), the gasoline, 3.2 gigawatts (billions of watts), and the dynamite, 2000 gigawatts.

In general, since there is a limited amount of time to complete the combustion of fuel in an engine, the speed at which the fuel burns in an engine determines both how efficiently the engine converts the fuel into power (watts). The gasoline in the example above will explode in about 2.5 milliseconds (thousandths of a second), while the wood takes several minutes to release its heat. The dynamite delivers its energy in four microseconds (millionths of a second).

Pundits will argue that it's not fair to use wood or dynamite in a comparison because they are not liquid fuels. So, let's compare liquid fuels.

The reason you don't use heating value to compare auto fuels is that it is not a valid way to compare the work of liquid fuels in an engine. Liquid fuels have other characteristics that are more important than heating value. If heating value were

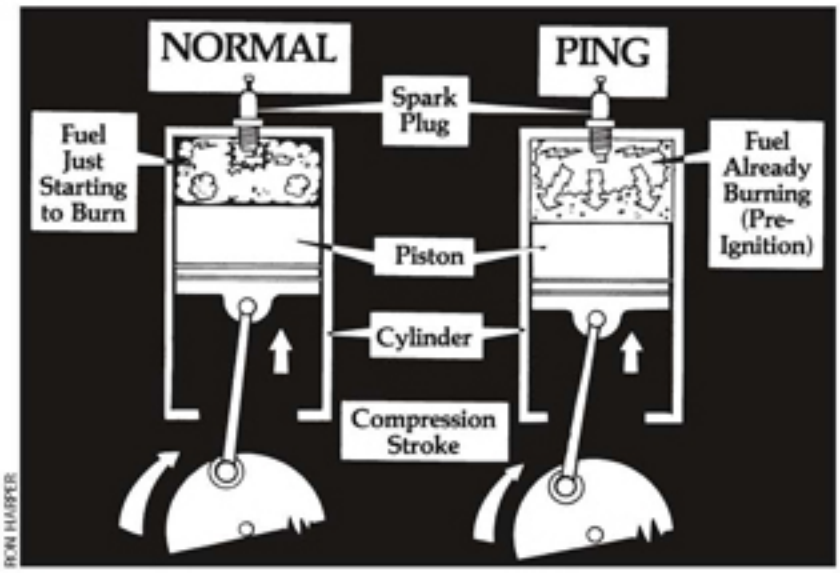


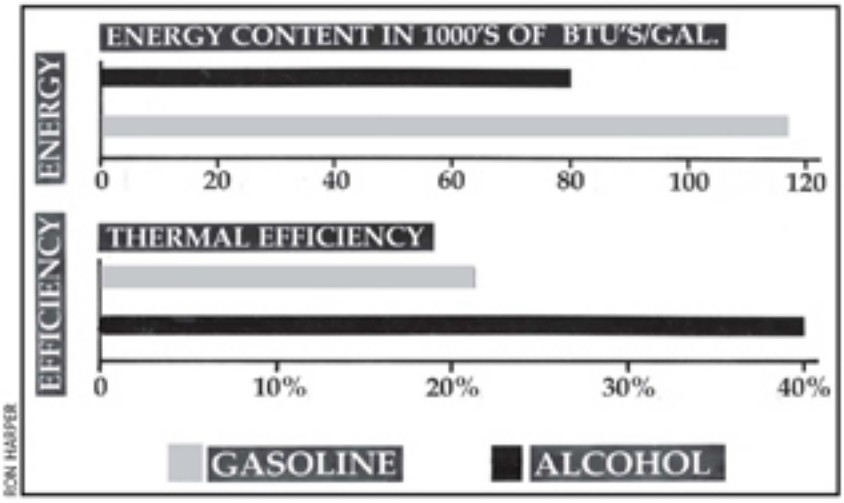
Fig. 14-8 Pinging. *In pinging, the fuel explodes due to auto-ignition when the temperature in the cylinder gets too high during compression. This is caused by low octane rating of fuel for the compression ratio of the engine. Pinging spikes temperature and causes engine-damaging stress due to mistiming of the combustion.*

the valid way to compare fuels, why wouldn't we run our gasoline engines on diesel fuel or melted candle wax (an excellent rocket fuel), which have far more heating value than gasoline? The answer is simple: Other characteristics are far more important. Octane, efficiency in combining oxygen with fuel, volume of the combustion products, and speed of the **flame front** are all more important than heating value.

A miles-per-gallon comparison between gasoline and alcohol, considering alcohol's higher efficiency, is much closer than the difference in heating values would seem to indicate. Field tests by my students and other independent studies commonly indicate reductions in mileage of 10 to 15% in low-compression conversions of engines designed for gasoline.[12] These are the largest reductions to be expected, except in very simple conversions.

Fig. 14-9 Energy content versus efficiency. *Alcohol starts off with a lower heating value but makes up for it with greater efficiency in producing work with its energy.*

Energy Content Versus Efficiency



Consumer Automotive Buying Preferences in Years 1980, 1981, 1983, 1985, 1987, 1996, 1998, 2000, 2001

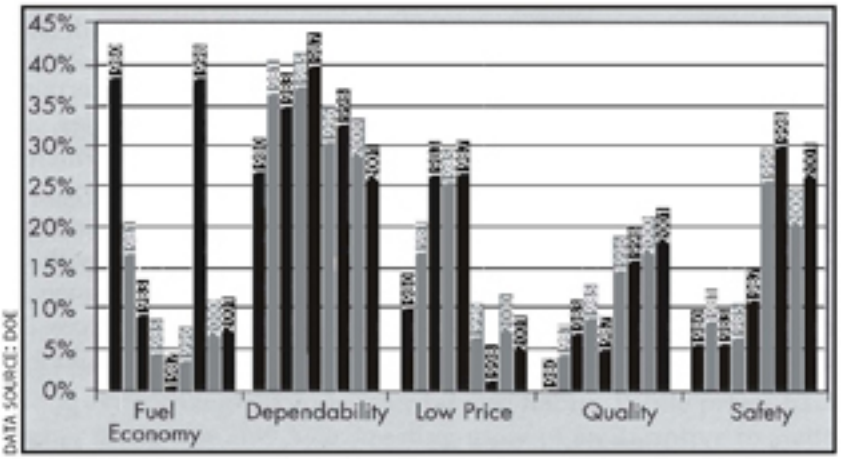


Fig. 14-10 Consumer automotive buying preferences. *Although we've been discussing mileage as if it is important, consumers care less about mileage than nearly any other characteristic about their vehicle. The exception in 1980 reflects the sharp spike in prices during the Arab oil embargo. But note the almost immediate reversal of concern about mileage after the embargo ended.*

In 1982, *Mother Earth News* performed some mileage studies on a 1970 Chevrolet 250-cubic-inch inline (carbureted) six-cylinder engine, with some very good results. The truck lost 5% mpg while unloaded, but, when loaded with 2200 pounds, the comparison swung in alcohol's favor—16% better than gasoline.[13] With a load, alcohol maintained its mileage, while gasoline's mileage dropped.

In doing its study, *Mother Earth News* altered the vehicle's carburetor to deliver more fuel to match the fixed amount of incoming air. The main jet determines the amount of fuel to be mixed with the incoming air. Assuming heating value was the proper measure for fuel mixing, their first tests used a carburetor metering jet drilled out 40% larger. But instead of losing 40% mpg, they showed a loss of only 12% mpg. With further experimentation, they found that the optimum increase of jet size was only 19%. Losses are often less, or nonexistent, in high-compression vehicles (which I'll discuss below) or in vehicles under load.

At that time, several inventors, some major auto companies (e.g., Mercedes), and NASA recorded mileages way above alcohol's heating-value-predicted mileage by completely vaporizing the fuel and using a propane-type gaseous fuel carburetion system. The highest scientifically verifiable figures for liquid fuel efficiency are more than double the amount of work per Btu compared to gasoline (see Chapter 13 on alcohol engines). But during the 1980s, I personally witnessed several vaporized alcohol engines getting almost double the mileage of gasoline.

In Brazil in the 1980s, government-licensed alcohol conversion shops were required by law to deliver mileages on alcohol no more than 25% lower than what the same car would get on gasoline. Over a hundred shops in Brazil's capital routinely exceeded government minimums, but all shops had to at least meet this standard. Even this modest standard should have been impossible, if heating value corresponded to mileage.

When comparing fuels, it's important to compare Btu per mile and the efficiency with which a fuel is converted to work. Although alcohol starts off with fewer heating value Btu, it burns with a much higher efficiency than gasoline, so that the miles