

**As the U.S. looks to decrease its dependence on foreign oil and curb environmental degradation, cleaner-burning gasoline alternatives are getting attention. This article covers some common alternative fuel options and what they mean for engine builders.**



# Alternative and Flexible Fuels

## Liquified Petroleum Gas (LPG) and Compressed Natural Gas (CNG)

BY **DAVE HAGEN, STEVE FOX AND MIKE CARUSO** WITH **ROB MUNRO AND JAY RYAN**

A great effort has been made to clean up exhaust emissions. Those efforts and the increased need for alternative fuels have resulted in renewed interest for use of LPG (Liquefied Petroleum Gas) or CNG (Compressed Natural Gas) as an engine fuel. AERA has learned that if a car/truck is manufactured as a Flex Fuel vehicle, they are built using hard valve seats and higher temperature material for intake valves. Increased heat production from LPG and CNG necessitate that intake valves be made of harder than normal material. Generally, this material is found in stock gasoline exhaust valves. Exhaust valves require more durable material than standard so Inconel or other OEM/aftermarket material indicated for LPG or CNG use is advised.

LPG and CNG have about the same BTU/H.P. value but CNG operates using a very high pressure fuel tank. Whereas LPG operates at a much lower pressure fuel tank, making it safer to refill. In Europe, LPG is known as Autogas or GPL (no lead or carbon deposits). LPG is

extremely popular in the Netherlands, Serbia, Italy, Poland, Australia, Korea and Hong Kong. Armenia might be the greatest user of Autogas.

The use of LPG as a fuel for automotive use has diminished over the last ten years as the price of LPG has metered closer to that of the gasoline fuel. However, many fleets and governmental facilities continue to use LPG. There are fewer conversions being made now, simply because the cost is greater with the use of multi port injected engines. It used to be easier to convert as you could use the existing intake manifold and just swap out the carburetor for a fuel mixer. The modern day electronics play big into conversions as well.

Another word of note is late model OEM Flex Fuel engines that are set up to burn gasoline or E85 may also use LPG and CNG without modification to basic internal engine components. As OEMs constantly advance engine design, more and more engines will be produced to use a variety of alternative fuels.

### Seats, Valves, Rings and Materials

More vehicles are being offered by the OEMs called Flex Fuel that are already converted to run on E85 fuel. Other vehicles are set up from the OEMs to be run as a dual fuel gasoline and LPG fuel. What does this mean for cylinder head engine builders today? There are great

opportunities out there for the shop that does the work right the first time. Let's look at this fuel and what its use means to the engine builder.

Gaseous fuels burn with an almost complete absence of ashy deposits. These deposits in gasoline engines protect the valve and seat faces from wear. Their absence gives rise to the name "Cold, Dry Fuel" commonly used to describe LPG and CNG fuels. The lack of these deposits allows direct contact between the valve and seat mating surfaces in the combustion chamber. This direct contact causes micro welding to occur with metal from the valve seat or valve face surface transferring (micro welding) to the other.

During the next open-close cycle, the deposits heat up and oxidize. These oxides are both corrosive and abrasive and explain why some non-OEM converted engines suffer severe and rapid valve and seat wear. Another cause of rapid seat wear is that valve heads flex under combustion pressures. In some applications this can accelerate a wear problem and lead to early failure. To combat this wear, various techniques should be used. The first plan of attack is to widen the seat contact point to around 0.100". Remember that a full 76% of the heat transferred out of the valve goes out through the valve face to seat contact point. Widening the valve seat contact area allows more heat transfer and spreads the compressive load over a larger

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area. This helps prevent the welding process. Also you do not have to worry about carbon being trapped between the valve face and valve seat. These fuels burn very clean due to the lack of carbon content.

The next concern is to ensure ample contact between valve and seat faces. It is not recommended to machine an interference angle between these faces and is particularly important for LPG heads. It is also good practice to “blue” the contact area and hand lap if necessary. Valve rotators should be replaced with standard type retainers. Some shops have welded rotators solid to prevent excessive face wear.

The most immediate action is to upgrade valve and seat materials. Exhaust material is used to make both intake and exhaust valves for LPG and CNG engines which are specifically designed to withstand the extra wear experienced with the use of LPG and CNG fuels.

Valve faces need added heat protection as do the seat contact surfaces. In the case of valves, addition of hard facing materials, usually Stellite is considered essential in preventing valve failures. In some cases the valve head can be made from Cobalt based super alloy such as Inconel. This alloy flexes less than regular exhaust material thus preventing wear due to valve head bending. In some cases, 454 GM for example, both Stellite seats and Inconel exhaust valves are required to provide acceptable service life. The valve can also be internally cooled with sodium if required and available.

Valve seats also need attention. If the head was not designed to run on LPG or CNG, hard corrosion resistant valve seats need to be inserted with a material specifically designed for gaseous fuel use. These seats are very hard and are indicated for high heat operating conditions. These seats are made from special materials with high Nickel, and / or Stellite content to withstand corrosive and abrasive actions present in LPG and CNG fueled engines. Ever wonder why we use black instead of common grey pipe in our homes when using Natural Gas to fuel our heating systems? Corrosion resistance is right at the top of the list.

The valve guides of choice are Manganese-Bronze with special bronze alloys which utilize hard filament shaped wear particles that are evenly distributed throughout the material and aligned along

the length of the finished valve guide. This combination of materials provides good thermal transfer of heat from the valve stem into the valve guide.

Manganese-Bronze alloy has the highest heat transfer rate of any bronze valve guide alloy.

- More than 200% of nickel-aluminum bronze guides.
- More than 200% of aluminum-silicon bronze guides.
- Exceeds phosphor bronze alloys with 88% copper.

Ring packs are pretty standard for LPG and CNG engines. Much like turbocharged engines that must also contend with heat issues, LPG and CNG fueled engines use Moly rings with great result. If additional protection is deemed necessary, it may be well worth time spent calling your favorite ring manufacturer and see what other ring application they may recommend.

Gaskets for these engines are no different than their gasoline counterparts unless there is coolant or exhaust contained within the intake manifold. In those older engines, you may want to consider blocking off coolant or exhaust flow within the intake manifold. This can be accomplished in various ways such as a block off plate within the intake gasket or physically sealing the opening with a metal pipe plug. Consider doing this only after careful thought as some engines may not respond favorably to this modification.

## Related Areas of Concern

Often, after the sale service can make a big difference to ensure engine survival. When an engine has been converted to LPG or CNG use and the cylinder head has been built specifically for the fuel, it can still fail without attention to both the ignition system and the fuel mixture. The distributor must be re-curved to provide total advance of 36° at 1000 RPM (15” of vacuum) and total advance of no more than 42° at 3000 RPM. Initial timing can be advanced about 10% but if this is done, an equal amount must be removed from the total advance curve. The fuel delivery system is also important. Most LPG systems require a 2% oxygen exhaust content to ensure adequate cooling in the combustion chamber.

When it comes to arriving at a reliable compression ratio, the best results have

been achieved with ratios from 9.5:1 up to 10.0:1. For some performance applications they will go a little above the 10.1:1. But for any heavy duty application it is best to stay below that figure.

As mentioned earlier, propane is a “cold” fuel and it is best to keep it that way by eliminating any intake manifold preheating done either through an exhaust crossover or engine coolant. Many engine builders also use a lower temperature engine coolant thermostat, somewhere around 180°F if available. It is not recommended to use LPG on V-10 style engines unless a dual feed intake manifold is comprised. A single feed mixer has the tendency to lean out the cylinders on the ends under heavy loads.

Unlike gasoline engines, a rich LPG mixture overheats the valves and seats causing seat recession. Failures witnessed in engines that have been in service a long time are generally from inadequate maintenance of the fuel mixer or ignition system. LPG engines do not like lean or rich mixtures of fuel and offer no tell tale signs of over fueling like gasoline with black smoke coming out the tail pipe. As a general tuning practice, keeping total ignition advance to 30° BTDC seems to keep them together while providing appropriate power. The only way to ensure correct fuel mixture is to use an exhaust gas analyzer. There are many sources for these tools but one is Honeywell Analytics in Lincolnshire, IL (1-800-538-0363). Another method would be to use a Wide Band O2 (LM1 or similar) sensor which is available from Innovate Technology, Inc. Irvine, California (949-502-8400) among others.

## Summary of Parts Required to Retro Fit for LPG and CNG use

1. High temperature intake valves are made from exhaust valve material.
2. Exhaust valves made from high temp materials such as Inconel.
3. Sodium filled valves for extra protection.
4. Harder valve seats installed into cylinder heads reducing erosion.
5. High lubricity valve guides.
6. Special valve stem seals if made for your engine.
7. Eliminate valve rotators; some people weld while others replace retainers.
8. Moly ring packs are recommended.

## Advantages of LPG and CNG over Gasoline

These fuels offer abundant local supplies with vast reserves without relying on imported crude oil. LPG and CNG are less expensive than the cost of gasoline and diesel fuels. They are readily available with an excellent infrastructure. They continue to expand from remote areas into the city.

LPG is stored as a liquid under pressure in safe extremely strong storage tanks or vessels. LPG is a liquid and turns into a gaseous fuel which disperses and diffuses quickly when released from its pressured tank. LPG has an auto-ignition temperature point of 878°F (470°C). When that temperature is compared to gasoline's auto-ignition temperature points of 572-752°F (300 – 400°C) LPG seems safer to store and handle. The cleaner burning LPG fuel produces less harmful CO (carbon monoxide) gasses and less HC (hydrocarbon) and NOX (oxides of nitrogen) emissions than gasoline.

- Does not produce fine particulates dangerous to people with respiratory problems.
- Have lower emissions during cold starts because no choke enrichment required.
- Produces less Greenhouse Gas (GHG) emissions carbon dioxide.
- Helps prevent detonation; stops the pinging or knocking noises.
- Offers longer spark-plug life vital for emergency service vehicles. (No fouling)
- Offers longer engine life producing no abrasives in oil or oil dilution by fuel.
- Does not get trapped in piston ring grooves to form hydrocarbons.
- Gaseous fuel does not wash lubricating oil off cylinder bores that normally cause excessive bore wear.
- Does not form smoke even if the mixture is very rich air/fuel ratios.
- No fuel line freeze-up in cold weather; no water in fuel system.
- Mixes evenly and quickly with the induction air in very even air/fuel ratios.
- More tolerant to very lean mixtures.
- Simple fuel system reliable and very easy to diagnose and service.
- Engines which are Normally Aspirated (N/A) are perfect to run a higher Dynamic Compression Ratio making more power for the same amount of fuel flow.

These fuels when used in a Turbo or Supercharged engine can make more power by addition of ignition advance. Even more power can be obtained by raising the slope of the boost curve and adjusting the maximum boost level higher without any internal engine modifications. *(continued on the next page)*

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## ALTERNATIVE AND FLEXIBLE FUELS

BY DAVE HAGEN, STEVE FOX AND MIKE CARUSO

### E-85: Fuel for the ages or more trouble than it's worth?

BY MARTY BROWN

E-85 seems to stay front and center in the news. Often blamed for the run up of corn and grain prices thereby driving up the price of virtually every grocery item worldwide, it has its share of supporters and detractors.

Leaving politics and the environmental elitists out of the equation for the moment, it would appear that at least for the next several years the E-85 fuel program is going to continue to receive subsidies from Federal and State Governments to expand the production of this alternative fuel. That means more production and, at least for now, a lower price per gallon contrary to the cost of the raw materials.

Boiled down to the simplest elements, E-85 describes the fuel content 85%

Ethanol, 15% Gasoline. A common misconception however is that is the normal ratio. E-85 indicates the maximum Ethanol percentage at 85. It can be lower, in some cases such a much lower percentage than the stated 85%. The percent of gasoline can increase for any number of reasons most often cited is better starting during cold weather but there does seem to be quite a bit of variation in blend percentages (as monitored at retail pump locations) and that would suggest at least for now there are likely some transportation and distribution issues keeping the mix ratio between the Ethanol and gasoline in the correct relationship.

Shortly several companies will have inexpensive monitoring systems that will enable an individual to determine what the Ethanol/Gasoline ratio actually is to take some of the potential guess work out of using this fuel full time for a specific application.

When everything is correct, E-85 simply using conventional unleaded pump gas has an octane rating of 105. That's

music to any performance enthusiast's ears. It's been a long, long time since you could drive into a gas station and actually pump a product that contains 105 octane directly into your tank. I would guess the last hold out was probably Sunoco 260 which vanished around 1975. So now that we have this new high octane fuel available what can we do with it?

For specialty applications that require more compression like pre-73 muscle cars, street performance cars with modified engines or local racing classes it looks inviting. E-85 is a low cost alternative to increasingly more expensive racing fuel or at the very least a host of additives necessary to keep the octane level high enough to keep the engine parts happy. As any engine builder knows, compression is the way to make horsepower. While it is possible to make very impressive horsepower numbers with low compression that is compatible with today's pump gas, it is usually far more cost effective to increase the compression ratio that a high octane fuel allows.

As with any alcohol fuels there are some issues to deal with. First, the engine will consume approximately 30% more fuel than with gasoline. This requires that all the components in the fuel delivery system must be equal to the higher fuel volume demand. Second all the internal fuel passages within the carburetor must be larger not to mention some things you might not usually think about like large needle and seats with a stainless steel needle tip as the normal Viton® won't hold up with prolonged exposure to E-85. Likewise, the Nitrophyll (black cellular construction) floats will eventually absorb fuel, then sink resulting in flooding. Any of the accelerator pump diaphragms should be exchanged discharging the black rubber diaphragms in favor of the green G.F.L.T. diaphragm material that holds up far better to alcohol based fuels. Finally, never use a paper filter in the fuel system — the Ethanol will destroy it in short order, plugging up the whole system.

At Quick Fuel Technology we offer a variety of options to address the carburetor part of the equation. We have a couple conversion kits (one specifically designed for race only carburetors) and we also offer a pair of metering blocks that can be used as the foundation for converting existing gasoline carburetors if an individual is so inclined. We offer the other required parts to complete the  
*(continued on page 20)*

**If your car's catalytic converter isn't operating efficiently, it's "red-lighting" your engine's power output.**

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Even when brand new, most original equipment converters are restrictive enough to put a serious dent in an engine's horsepower curve. And if the fuel or ignition calibration isn't right, it doesn't take long for a converter to deteriorate, causing even more restriction and horsepower loss.

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# Aeromotive adapts to changes in fuels and fuel additives

BY KYLE FICKLER

As a fuel system manufacturer, Aeromotive is constantly challenged with changes in fuels and fuel additives for both street and racing applications, so the introduction of E85 could best be described as just a single step in a long journey. However, to the performance enthusiast, the introduction of E85 was unique. Performance enthusiasts are usually faced with declining fuel quality, so a fuel such as E85 that offers increased performance potential was noteworthy, particularly given that it was intended to be not only affordable, but also widely available.

Aeromotive's primary concern was how E85 would affect internal soft parts and coatings or processes on hard parts. Our experience with Methanol and other alcohols indicated that soft parts such as regulator diaphragms, fabric filter elements, gaskets and o-rings are the most affected by alcohol based fuels and fuel additives. Our early E85 soak tests and durability testing showed that no changes to the Aeromotive product line were needed, but obviously we do not recommend the use of a fabric or paper fuel filter element which holds true with methanol as well. If the customer already has an Aeromotive filter assembly with a fabric element, the 10 micron fabric element can be replaced with a 100 micron stainless steel, or in some instances, a 40 micron stainless steel element for E85 service.

Aeromotive also has an extensive line of AN style and specialty adapter fittings that are CNC machined from 6061 T6 aircraft grade aluminum and Type II bright dip anodized for corrosion resistance, and are E85 compatible. Many websites and other information sources recommend Teflon lined hose or stainless steel hardline for E85 applications, and Aeromotive will defer to the hose manufacturers for their E85 recommendations.

The second area we addressed was the capacity of the fuel system itself. As a general rule, E85 requires about 30-35% more volume than gasoline to make the same horsepower. As such, the engine builder and performance enthusiast need to think of it in these terms: If they intend to make 500HP on E85, they need the equivalent of a fuel



system capable of supporting at least 675 HP on gasoline. Keep in mind that most fuel systems are rated in either gallons per hour (GPH) or pounds per hour (lbs/hr). A gallon of gasoline weighs approximately 6.2 lbs per gallon, whereas a gallon of E85 weighs approximately 6.6 lbs per gallon.

Of course, the capacity of the fuel system is determined by the fuel pump. Aeromotive offers the widest selection of fuel pumps in the performance aftermarket, with more than 25 fuel pumps that are E85 compatible. Dave Slatten Racing Engines, one of the early adopters of E85 and other ethanol/gasoline mixes for racing purposes, developed both carbureted and EFI engine packages for E85 using Aeromotive fuel systems and his on-track results confirmed our engineers test results. Dave has used both belt-driven mechanical systems and electric in-line pumps such as the Aeromotive Eliminator and Pro Series for his engine packages, most of which develop well in excess of 1000 horsepower. Fuel pressure regulator choice is dictated by the fuel pump and intended application, but is the same for gasoline or E85. Aeromotive offers a Power Planner in its catalog and on its website to coordinate pump and regulator selection.

As a manufacturer that built its reputation on performance, we have enjoyed the influx of calls to our tech lines regarding E85. Aeromotive has engineered fuel systems for continuous duty or race applications ranging from 5 to 5000 horsepower. If you have any questions, please call us at 913-647-7300, or visit our website, [www.aeromotiveinc.com](http://www.aeromotiveinc.com). ■



For more information, please contact Kyle Fickler at Aeromotive Inc., 7805 Barton Street, Lenexa, KS 66214. Call 913-647-7300 or visit their website: [www.aeromotiveinc.com](http://www.aeromotiveinc.com).

# ALTERNATIVE AND FLEXIBLE FUELS

BY DAVE HAGEN, STEVE FOX AND MIKE CARUSO



conversion. In addition, we offer a range of carburetor sizes to suit most applications although the majority have a race bred calibration. We do offer a 650 CFM street version that would work extremely well on most low compression run of the mill small block engine found in a large percent of “drivers”. As the horsepower increases so too does the expectations of the carburetor. Our Q-Series carburetors are certainly capable of meeting the requirements of engine packages approaching 900 Horsepower.

Obviously it is difficult to cover both the fuel and the parts needed to take advantage but clearly there is a great deal of information available on E-85 and the flow of new information seems endless. With a little research and some practical experience with this new fuel it shouldn't take too long for you to become the resident expert. If we can be of any assistance on the carburetor or fuel delivery system certainly feel free to call us we would be more than happy to try to assist you where ever we can.

E-85 offers the win-win situation, we can increase the power of our engines and get an environment thumbs up for doing so. I can't think of any scenario better than that for our industry!

## FAST™ offers many options for E85 users

BY JAY ROHRBACK

We at FAST™ have done extensive testing with alternative fuels, especially E85. Anyone doing business with customers in the Midwest should certainly be looking at how they can help their customers utilize the benefits of this fuel if they haven't already. As I sit here writing this I'm listening to a local southern Michigan radio station report on several new manufacturing facilities for this fuel being built in the Michigan/Ohio/Indiana area. It's here and it does offer benefits to the performance enthusiast.

In our dyno and in-vehicle testing we've found that the higher octane rating does (in most cases) allow for a few more degrees of timing to be applied over standard gasoline, as well as an obvious increase in compression ratio. This is also very good news to the muscle car owner that has an original, higher compression V8. He now has more options than just knocking the compression down in the next rebuild, or dropping the timing back to get away from detonation, or dumping

a bottle of octane boost in the tank with every fill-up. How would it be to pull up to the pump in a Mustang, Cuda, Camaro, GTO, or 442 like the old days out on Woodward Ave. here in Detroit or the local cruise in your area. That's actually becoming possible again with the availability of E85.

We've been known in the past as an EFI company, but with the addition of our Wide-Band Air Fuel Meters a few years ago that can easily be used for both carbureted or EFI applications, we've really transformed FAST into an electronic tuning company. That's really what our stand alone XFI™ system is, a tuning tool. It allows the user to easily tune an engine in many ways he couldn't possibly do before with a carburetor.

In the testing I mentioned before we've worked diligently to come up with easy to use electronic tuning tools to help you take advantage of E85. For the carbureted user and those that are re-tuning factory EFI engines, we've added E85/E98/Methanol capable Wide Band Air Fuel Meters in both single (part# 170590) and dual (part# 170608) sensor versions. These, along with just released free software called FASTView™ allow the user to not only tune, but download, save, view, and compare air/fuel data logs to get that engine exactly where you need it to be. It's our most inexpensive tuning tool and a must have for any tuner, novice to professional. We've also come up with a unique feature to utilize E85 with our XFI™ EFI system (part# 30-1000). The Fuel Energy Constant feature allows the user to input a numeric value that corresponds to the type of fuel being used. For example, gasoline is a 1.00 constant, where E85 is a .680 constant. All fuel type constants can be found in a handy chart in our software (a sample of this chart is shown on page 21).

What the XFI™ does with this constant is modify the Target Air/Fuel Ratio table so that fueling is adjusted properly for the fuel type you're using. In other words, it allows you to tune an engine on gasoline, and then just by changing one simple number in the software you can switch to using E85 without needing to re-tune the engine. The XFI™ also has our Qwik Tune™ Technology, which allows the user to save 4 separate tune-ups in memory of the XFI™, and with the use of a simple 4 position switch choose any of the 4 tune-ups without having to plug in a laptop. That way you can have

## FUEL ENERGY CONSTANTS (FEC) FOR COMMON FUELS

Fuel Type	FEC	Stoichiometric A/F
Compressed Natural Gas (CNG)	1.17	17.2:1
Liquid Propane (LP)	1.07	15.7:1
Gasoline	1.00	14.7:1
Methyl Tertiary Butyl Ether (MTBE)	.796	11.7:1
85% Ethanol/Gasoline Mix (E85)	.680	10.0:1
Ethanol (ETOH)	.612	9.0:1
Methanol (MEOH)	.439	6.45:1

one tune-up for gasoline and one tune-up for E85. Or, with the price of gasoline going up as much as it has lately you could have an economy tune-up for each and a performance tune-up for each with the simple flick of a switch. If you want to take it even further, with the addition of a Flex Fuel Sensor available at your local GM dealer parts counter, it can very easily be wired into the XFI™ so that the constant can be controlled by the Flex

Fuel Sensor automatically. When the sensor senses a different type of fuel, it sends a signal to the XFI™ and the XFI™ will switch the Target Air/Fuel Ratio table to match that fuel type without the user doing anything but driving.

We've been hard at work adding things that can help you utilize alternative fuels. For more information, go online to [www.fuelairspark.com](http://www.fuelairspark.com) or call 877-334-8355.■

The AERA Tech Team – **Dave Hagen**, Senior Technician, has over 36 years of experience in our industry. An ASE-certified Master Machinist, Dave specialized in cylinder head work and complete engine assembly for the first 17 years of his career. **Steve Fox** has over 20 years experience in the engine building industry with eight of those years spent working in the machine shop. Steve is an ASE-certified Master Machinist, as well as a longtime member of the drag racing circuit. **Mike Caruso** brings over 42 years of rebuilding and high-performance experience to AERA. An ASE-certified Master Machinist, Mike came to us from FEL-PRO's high-performance R&D and tech line, where he worked for 11 years.

**Rob Munro** is President of Valley Speed Machine Shop in Kamloops, British Columbia, Canada. Rob is a former AERA Chairman. He also served as first and second chairman, treasurer, as well as a board director for three years.

**Jay Ryan** is with S.B. International in Nashville, TN. Call 800-843-7348 or go online, [www.sbintl.com](http://www.sbintl.com).

**Marty Brown** is with Quick Fuel Technologies in Bowling Green, KY 42101. Call 270-793-0900 or go online, [www.fuelairspark.com](http://www.fuelairspark.com).

**Jay Rohrback** is with Comp Performance Group. Call 734-341-6307 or go online, [www.compperformancegroup.com](http://www.compperformancegroup.com).

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