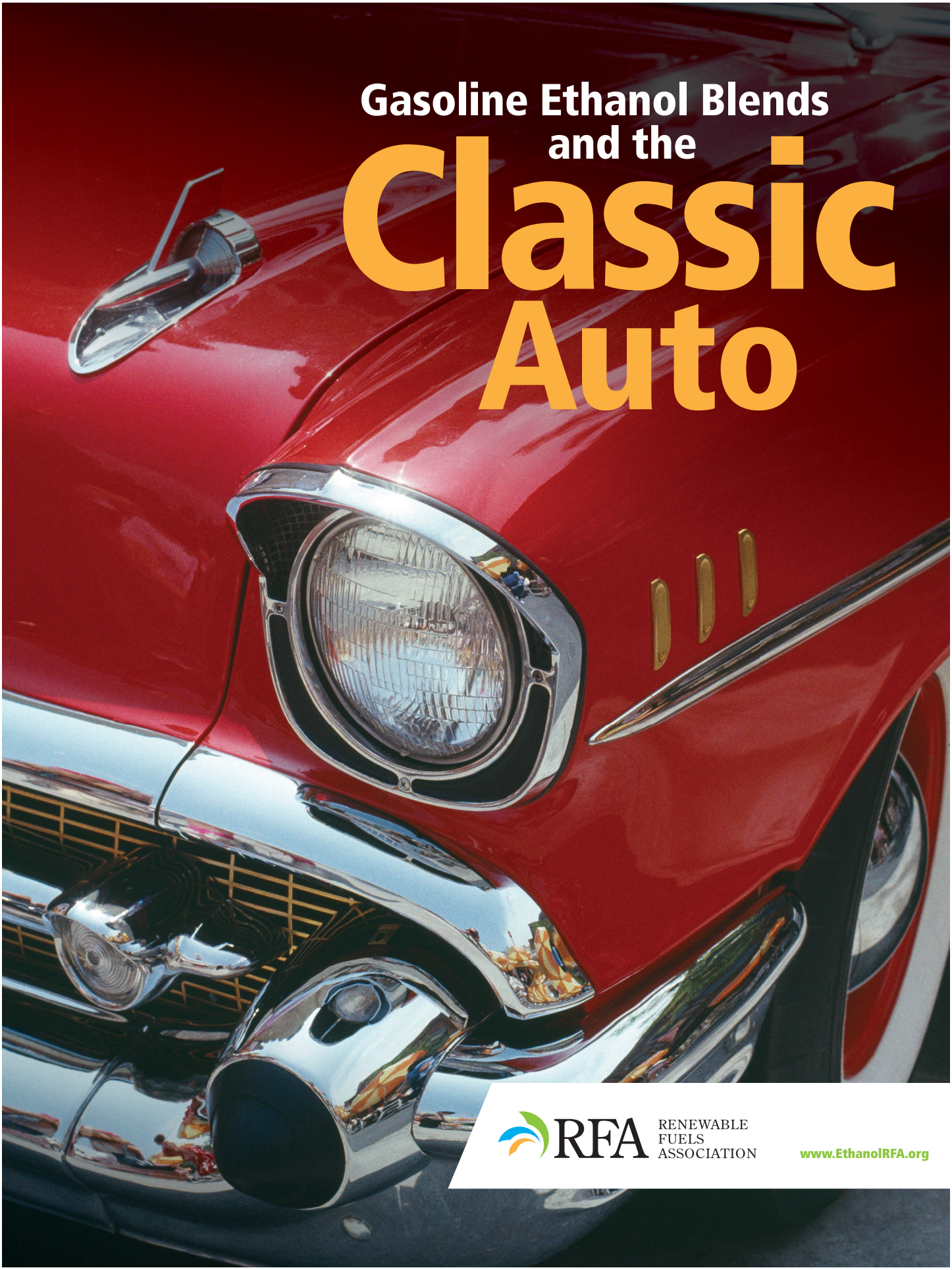
Gasoline Ethanol Blends and the Classic Auto



RFA RENEWABLE FUELS ASSOCIATION

www.EthanolRFA.org

Copyright © 2011 Renewable Fuels Association. All Rights Reserved.

In 2011, the U.S. EPA approved the use of 15v% ethanol (E15) in 2001 and newer automobiles. However, this approval to use E15 does not apply to automobiles manufactured before 2001. Consequently, the information in this document pertains strictly to E10 and use in classic automobiles.

June 2011

This document was prepared by the Renewable Fuels Association (RFA). The information, though believed to be accurate at the time of publication, should not be considered as legal advice or as a substitute for developing specific company operating guidelines. The RFA does not make any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or applicability of the information presented in this document.

Copyright © 2011 Renewable Fuels Association. All Rights Reserved.

Gasoline Ethanol Blends and the Classic Auto

Introduction

The ongoing effort to alter gasoline to minimize its impact on the environment and reduce U.S. dependence on foreign crude oil has refocused attention on fuel quality issues. The increased use of ethanol, now in well over 90 percent of the nation's gasoline, has prompted questions and sometimes raised concerns with the antique auto community. For the owner of a classic automobile that question is whether today's fuels will work in yesterday's automobiles.

Owners of classic vehicles have unique considerations: the vehicle's fuel system may differ significantly from that of modern cars; the vehicle usually is not driven often and is stored for long periods; and the vehicle probably operates rich at specified air/fuel settings compared to modern cars. In the case of "muscle cars," the compression ratio may dictate the use of very high octane gasoline and, if the valve seats are not hardened, the effect of unleaded gasoline with, or without ethanol, on exhaust valve seats may be an issue.

Unfortunately, limited information has been written in a manner that addresses these concerns from the perspective of the classic car owner. This paper is meant to address fuel related questions and concerns for these unique car owners.

Owners of classic vehicles have unique considerations…

Background

Gasoline is constantly changed and reformulated based on a variety of factors including the type of crude oil used, the mix of finished products produced, federal laws and regulations, and advancements in process technology. More recently, changes have been driven by environmental concerns and issues of energy independence. The seventies saw the introduction of unleaded gasoline. The eighties and nineties saw the reduction in use of lead in automotive gasoline. Fuel volatility was reduced in 1989 and again in 1992 by requiring fuels with lower vapor pressure. The next round of environmental changes was driven by the 1990 Clean Air Act Amendments. This legislation ushered in the age of oxygenated fuels in carbon monoxide non-attainment areas in 1992 and the introduction of reformulated gasoline (RFG) in 1995. This legislation also required certain controls on so-called "conventional gasoline" and required the complete elimination of lead use in automotive gasoline by the end of 1995. Finally, the legislation required that all gasoline sold after January 1, 1995 contains a detergent effective in controlling carburetor, fuel injector, and intake valve deposits.

Copyright © 2011 Renewable Fuels Association. All Rights Reserved.

E10

In 2005, the U.S. Energy Policy Act adopted the nation's first Renewable Fuels Standard. This law required an increasing amount of renewable fuels to be used to replace gasoline. Initially, this requirement was met by the use of ethanol in gasoline at the 10 volume% (v%) level, commonly referred to as E10. A small amount of biodiesel was also blended into a portion of the diesel in use.

U.S. EPA approval to use E15 does not apply to automobiles manufactured before 2001.

In late 2007, the Energy Independence and Security Act was passed by Congress and signed by the President. This law dramatically raised the amount of required renewable fuel used and specified certain types of renewable fuels. Thus far these requirements have been met by expanding the use of E10, and in early 2011 over 90 percent of the nation's gasoline was E10.

It should be noted that the traditional ethanol blend in the marketplace has contained 10v% ethanol and is referred to as E10. In 2011, the U.S. EPA approved the use of 15v% ethanol (E15) in 2001 and newer automobiles. However, this approval to use E15 does not apply to automobiles manufactured before 2001. Consequently, the information in this document pertains strictly to E10 and use in classic automobiles.

It is important to note that the above requirements are driven by concerns about the environment and reducing imported energy. At the same time, gasoline must also continue to meet certain performance standards and industry guidelines as established by ASTM International, regardless of ethanol content. Indeed some oil companies have requirements that exceed those of ASTM. The standard specification for gasoline and gasoline ethanol blends includes requirements and guidelines for such important fuel properties as octane, volatility, corrosivity, and stability. ASTM standards do not generally dictate what components should be in gasoline but rather how the gasoline should perform.

The following provides an overview of the various areas of special interest to the classic auto owner.

Fuel Oxygenates

Fuel oxygenates are comprised of hydrogen, carbon, and oxygen and therefore add oxygen to the fuel. Oxygenates include various alcohols and ethers and at one point Methyl Tertiary Butyl Ether (MTBE) was widely used up to 15% by volume blended with gasoline. However MTBE has since been banned in many states due to concerns about groundwater contamination. Today ethanol is the only widely used oxygenate in the United States. Ethanol is the same alcohol used in beverage alcohol. For fuel use it is nearly 200 proof and denatured to make it unfit for drinking. There is an ASTM standard for the quality of the ethanol that is to be blended into gasoline. The oxygen content of an E10 blend is approximately 3.5%.

Copyright © 2011 Renewable Fuels Association. All Rights Reserved.

Octane

Octane is nothing more than a measure of a fuel's ability to resist engine knock. When octane is too low for a given engine, the fuel will spontaneously ignite. This causes an explosion that collides with the flame front initiated from the spark plug, resulting in engine knock or ping.

Octane is rated in single cylinder laboratory engines using specified reference fuels. There are two test methods: the Research Method yields a Research Octane Number (RON) and a Motor Method yields a Motor Octane Number (MON). The number posted on the gasoline pump is an average of those two numbers, (R+M)/2.

All gasolines must meet the octane number posted on the pump. Today, gasoline octane ranges from 85 to 94 (R+M)/2, with the typical grades being regular unleaded at 87, midgrade at 89, and premium at 91 to 93. Prior to the eighties, gasoline octane was often posted based solely on the RON, which allowed postings as high as 100 octane. Premium gasolines sold today often have a RON of 100 or higher but must post the (R+M)/2 value. For instance, a 93 octane premium will likely have a motor octane of 85 and a research octane of 101 (101 + 85) /2 = 93.

Some classic vehicles fall into the "muscle car" category and for these higher compression ratio engines sufficient octane may be an issue. Most higher octane premium fuels (91-93 octane) can satisfy the octane requirements of these vehicles. However, if engine ping is experienced on the highest octane gasoline available it may be necessary to take other actions. One course is to retard the timing, although this reduces performance. Other mechanical steps could include richening the air/fuel mixture, although this would increase exhaust emissions.

Octane is nothing more than a measure of a fuel's ability to resist engine knock.

Since maximum octane requirement occurs at an air/fuel ratio of 14.7:1, going rich from that point will lower the octane requirement of the engine. Other mechanical causes should also be checked out. A marginal cooling system that results in higher operating temperatures can increase the octane requirement of a vehicle as can excessive combustion chamber deposits. Eliminating such problems is obviously preferable to adjustments that would have a negative effect on performance.

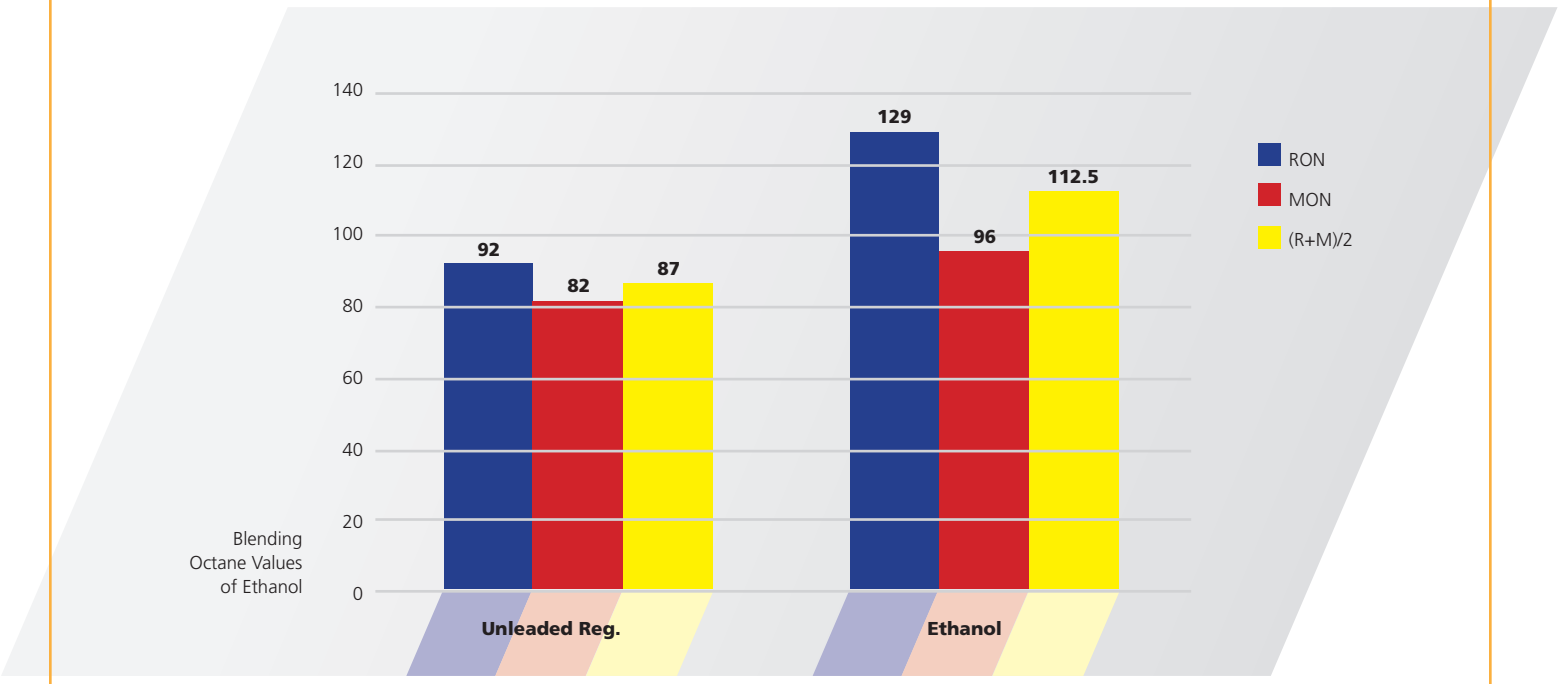
There are also "over-the-counter" octane enhancers, although most of these provide an increase of only a fraction of an octane number. Another approach is to blend a portion of unleaded racing fuel with the premium grade available to achieve the desired octane level. Racing fuels are preferred to aviation gasoline (AV-gas) because AV-gas does not have the necessary scavengers and additive

Copyright © 2011 Renewable Fuels Association. All Rights Reserved.

packages for automotive use. However, most racing gasolines sold at race tracks and aviation gasolines are no longer legal for street use because they do not meet EPA's requirements for that use.

Ethanol is an octane enhancer and raises the octane level of the gasoline to which it is added by approximately 2.5 numbers (see Figure 1). Ethanol enleans the air/fuel charge by up to a half number. This equates to about 1 carburetor jet size. This is equivalent to the increased oxygen content of the atmosphere for a 30°F to 40°F temperature drop. If your vehicle is set leaner than factory specifications this added oxygen may necessitate richening the air/fuel ratio to compensate for the extra oxygen.

Figure 1: Octane value of ethanol compared to regular unleaded gasoline



Source: RFA.

NOTE: In some areas later model classic cars are subject to Inspection and Maintenance Programs. In this case you must ensure that any adjustments do not result in the vehicle exceeding specified exhaust emissions levels.

Lead Phase Out and Exhaust Valve Seat Recession

Lead had been blended with gasoline since the 1920s primarily to cheaply boost octane levels. However, the Clean Air Act banned the sale of leaded fuel for use in on-road vehicles in 1995 due to lead's serious adverse health effects. From a technical standpoint, lead resulted in a buildup of lead oxide deposits on exhaust valve seats. These lead oxides prevented metal to metal contact between the exhaust valve and exhaust valve seat, thereby preventing exhaust valve seat recession (EVSR) in engines without hardened valve seats.

Copyright © 2011 Renewable Fuels Association. All Rights Reserved.

Operating without lead over a period of time exposes the engine to possible EVSR. Most tests have shown that engines are not at great risk unless they are operated at high revolutions per minute (rpm) or under heavy loads (such as pulling a trailer). The mechanical fix is to install hardened valve seats. However, there are also chemical fixes in the form of lead replacement additives, often called "lead substitutes," which can be added to gasoline. The active ingredient in these additives is usually sodium or phosphorous, both of which prevent the exhaust valve from recessing into its valve seat. Care should be taken to limit additives to the recommended treat rates since too much of a lead substitute could increase engine deposits. Be sure to purchase and use only legal and proven fuel additives. Ethanol has not been shown to be a significant factor in EVSR.

Fuel Volatility

Volatility is a measure of a fuel's ability to vaporize and is an important characteristic of gasoline. Fuel must be volatile enough to provide good cold start and warm up performance. However it must not be made excessively volatile or it can contribute to hot restart problems, vapor lock/fuel foaming, and poor fuel economy. Refiners adjust gasoline based on the prevailing climate in the area in which the fuel is sold. More volatile gasolines are sold in the winter, less volatile in the summer. While the gasoline volatility of winter fuels has not changed much in recent years, the volatility of the summer grade has been reduced. These less volatile fuels may not provide cold start and warm up performance comparable to gasolines of the late eighties. However, they will be less likely to contribute to vapor lock and similar problems.

Volatility is a measure of a fuel's ability to vaporize and is an important characteristic of gasoline.

One key measure of gasoline volatility is its vapor pressure. Adding 10% ethanol to gasoline will increase the vapor pressure of the fuel blend by about 1 pound per square inch (psi). However, this is not of great concern since the maximum volatility of all summer grades is regulated by the EPA and is at much lower levels than gasoline sold in the late eighties. This has eliminated any hot restart/vapor lock problems in all but the most sensitive vehicles.

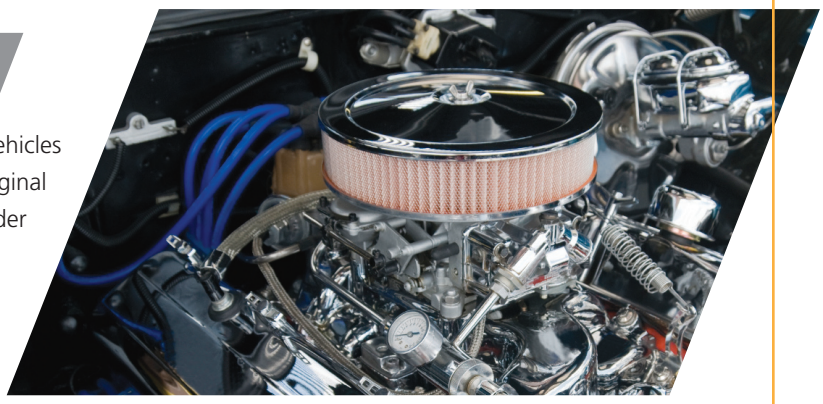
Copyright © 2011 Renewable Fuels Association. All Rights Reserved.

Enleanment

Oxygenated fuels enlean the air/fuel ratio due to the additional oxygen contained in the fuel. An E10 blend contains about 3.5% oxygen. To put this into perspective, this is the same effect that would be experienced for the denser air resulting from a 30°F temperature drop or a decrease of 1,500 feet in altitude. All regular street driven vehicles experience such changes in normal operations and do not require any special modifications. Unless an engine is tuned to the absolute limit (very few non-race engines are) the additional oxygen presents no problem.

On a race car that is tuned to a specific air/fuel ratio, the enleanment from the oxygen can be offset by increasing fuel flow by a percentage comparable to the oxygen content of the fuel. This is normally accomplished by changing the carburetor jets to the next largest size since each jet usually represents a 3% to 4% increase in fuel delivery.

Materials Compatibility



The fuel system materials used in late model vehicles are dramatically improved compared to the original equipment used in vintage/classic vehicles. Older fuel systems could contain natural or synthetic rubber – much less compatible with today's fuels than the Viton® and fluoroelastomers used in modern fuel systems. However, older cars usually have had most fuel system components replaced. Aftermarket components provided since the early eighties are usually compatible with today's fuels formulations.

Most questions on materials compatibility usually pertain to ethanol use, although it is not the only gasoline ingredient to consider. As refiners decreased the use of lead, something else had to be increased or added to maintain octane quality. This is often done by increasing the aromatic level of gasoline. On an octane equivalent basis, some of the aromatics are more aggressive to elastomers than ethanol. Whether octane is achieved by ethanol addition or increased aromatics, today's gasolines are generally more aggressive to elastomers than those of the sixties and seventies.

It should be kept in mind that extended storage periods without proper treatment of gasoline can also increase elastomer deterioration. Overuse (beyond recommended treat rate or excessive frequency) of certain over-the-counter additives may also contribute to accelerated deterioration of fuel system components.

If it becomes necessary to replace fuel lines and other fuel system components, preferred materials are Viton® and fluoroelastomers such as Fluorel™.

Copyright © 2011 Renewable Fuels Association. All Rights Reserved.

There should be no major concern about ethanol and metals corrosion. While all gasoline is potentially corrosive, the ASTM specifications include guidelines for corrosivity. Fuel marketers routinely add corrosion inhibitors to provide a level of corrosion protection comparable to that of other gasolines.

There is a lack of materials compatibility test information on the use of E10 in classic autos because most companies do not conduct research on autos that are no longer made and that represent a fraction of the vehicle population. Moreover, ethanol was not in use when pre-1980 model year vehicle fuel systems were designed. However, in 2007 Hagerty Insurance – one of the largest insurers of vintage vehicles and publisher of Hagerty Magazine – tested ethanol use in classic cars.

The Hagerty Ethanol Study

Hagerty Insurance partnered with Kettering University's Advanced Engine Research Laboratory to develop test procedures that closely replicated a collector vehicle's use cycle to determine the effect of long-term exposure to ethanol. Six sample fuel systems were used to represent fuel pump and carburetor combinations for a large portion of collector vehicles:

- 1948 Flathead Ford
- 1958 Volkswagen Beetle
- 1962 MGA
- 1963 Ford Falcon
- 1969 Chevrolet Bel Air
- 1970 Chrysler New Yorker

Durability test periods were 1,500-3,000 hours.

While not all testing was complete, Hagerty's Magazine concluded, "The results from the tests with the [Skinners Union] carburetors and fuel pumps suggest that E10 can be used in older vehicles, although the owner is likely to be faced with additional costs associated with sealing fuel tanks and cleaning and rebuilding fuel systems more frequently than in the past."

Furthermore, Hagerty's Magazine summarized that "…after 1,500 hours of testing (nearly twice the industry standard for such a test) fuel lines didn't leak, carburetors didn't disintegrate and fuel pumps did not fail. Although the study showed minor build up and corrosion in the carburetors and fuel pumps while using E10 as opposed to E0, the general consensus is that with minor updates and proper maintenance E10 will not prevent the ability to enjoy your collector car."

Hagerty's Magazine warned "…it's best to be cautious about reading into these preliminary results until the tests of the five other fuel systems are complete. Until then, it's safe to assume that you can continue to drive your collector vehicle using E10; it may cost you more in the long run." Additional results on the other vehicles will be reported in future issues of Hagerty's Magazine.

"…after 1,500 hours of testing fuel lines didn't leak, carburetors didn't disintegrate and fuel pumps did not fail."

Copyright © 2011 Renewable Fuels Association. All Rights Reserved.

Fuel Economy

There is a great deal of misinformation about the fuel economy (miles per gallon, or mpg) of various gasolines, especially those containing ethanol. Various fuel programs that require oxygenates, such as ethanol, have traditionally been implemented in the winter when gasolines are made more volatile for good cold start and warm up performance. These "lighter" winter gasolines contain less energy. Furthermore a number of driving conditions that occur in the winter reduce fuel economy.

Besides fuel related factors, there are a number of vehicle and climate related issues to consider. Vehicle technology, state of tune, ambient temperatures, head winds, road grade, tire pressure, use of air conditioners, and numerous other factors have an impact on fuel economy. Even the pitch of the car when refueled can distort fuel economy readings by several percentage points. Some of the factors that have been documented in testing are covered in Table 1.

Table 1. Factors That Influence Fuel Economy of Individual Vehicles

Factor	Fuel Economy Impact	
	Average	Maximum
Ambient temperature drop from 77°F to 20°F	-5.3%	-13.0%
20 mph head wind	-2.3%	-6.0%
7% road grade	-1.9%	-25.0%
27 mph vs. 20 mph stop and go driving pattern	-10.6%	-15.0%
Aggressive versus easy acceleration	-11.8%	-20.0%
Tire pressure of 15 psi versus 26 psi	-3.3%	-6.0%

Source: Renewable Fuels Foundation.

It is easy to see from the table why an individual using one or perhaps a few vehicles cannot make an accurate determination of the fuel economy impact of various gasolines. There are simply too many variables.

Through the course of a year, gasoline energy content can range from 108,500 British thermal units per gallon (btu/gal) to 116,000 btu/gal (see Table 2). Winter grades are made more volatile (less dense) to aid in cold start and warm up performance and typically contain 108,500 btu/gal to 114,000 btu/gal. Summer grades are of much lower volatility to minimize evaporative emissions and hot start/hot driveability problems. Summer grades will typically contain 113,000 btu/gal to 116,000 btu/gal. So the energy content, and therefore the fuel economy, can vary 2.7% to 5.0% based on the energy content of the fuel alone. Furthermore comparing the highest energy content summer fuel to lowest energy content winter fuel demonstrates that the variation in energy content is up to 6.9%. The lower energy content of winter fuels and the other wintertime influences on fuel economy can easily lead to reductions of 10% to 20% in mpg during the coldest winter months.

Copyright © 2011 Renewable Fuels Association. All Rights Reserved.

Table 2. Conventional Gasoline Energy Content

	Summer Grade	Winter Grade
Maximum btu/gal	116,000	114,000
Minimum btu/gal	113,000	108,500
Fuel Economy Variation	2.7%	5.0%
Difference between summer maximum and winter minimum	**6.9%**	

Source: Renewable Fuels Foundation.

Oxygenated fuel programs, being wintertime only programs, have therefore resulted in incorrectly blaming ethanol for massive fuel economy losses when in fact numerous other variables also contribute to fuel economy losses during winter months. Of course winter gasoline is usually not a factor for a collector car since it is usually stored during inclement weather.

The reduction in btu/gal from the addition of ethanol is generally around 3.4% although fuel economy may not be that much lower. As an example, ethanol contains 76,100 btu/gal; therefore, a 10v% ethanol blend would contain about 3.4% less energy per gallon. However, in controlled tests the fuel economy loss has been far less than would be indicated by the 3.4% lower energy content.

Older vehicles typically have an energy correlation factor of 0.6, meaning that 60% of any increase or drop in btu/gal will be reflected in fuel economy. More simply put, a 3.4% reduction in energy content translates to about a 2% drop in mpg in older vehicles. This factor represents other drains on energy efficiency such as friction (transmission/ drive train, rolling resistance, etc.). In some tests, older vehicles have shown improved mpg on oxygenated fuels. This is thought to occur because the enleaning effect of ethanol results in more complete combustion, thereby improving fuel economy.

Lubrication

This is perhaps the area of most inaccurate myths. There are no special lubricant requirements for using E10. Some automotive writers have reported that ethanol might wash lubricants from the cylinder walls. However, they were basing their reports on vehicles that operate on pure alcohol such as those in Brazil. When the fuel has a high percentage of ethanol (i.e., over 50%) a special motor oil is sometimes required. However, tests have shown no such special needs for lower levels of ethanol such as E10.

Copyright © 2011 Renewable Fuels Association. All Rights Reserved.

Over-Blends

Some service shops have expressed concern about the effects of over-blends – fuels containing higher than the permitted levels of ethanol. Everyone seems to have a favorite story of a 20% or higher blend, although those tales usually date to the late seventies or early eighties. Today, the blending process is very sophisticated and usually employs computerized injection blending equipment or, at a minimum, preset metering devices.

Fuel System Cleanliness and Detergents

Since January 1, 1995, the U.S. EPA has required that all gasolines contain a detergent/deposit control additive that is effective at controlling carburetor, fuel injector, and intake valve deposits. These standards also apply to E10 and are performance specifications based on established test procedures. Therefore, regardless of the brand or grade of gasoline you purchase you will be getting a detergent-treated gasoline. There is no need to add over-the-counter detergents unless excessive deposits already exist. In fact, using detergents too frequently or at higher dose rates than recommended can cause elastomer degradation (fuel lines, fuel pump diaphragms) and also oil thickening, which could contribute to insufficient lubrication.

Regardless of the brand or grade of gasoline you purchase you will be getting a detergent-treated gasoline. There is no need to add over-the-counter detergents unless excessive deposits already exist.

Off-Season Storage

Most owners of classic/vintage autos store their vehicles for extended periods of time at some point. Gasoline and E10 can deteriorate, weather (i.e., lose the more volatile components that aid in cold start), and take on moisture during storage. Storage considerations are therefore very important.

Fuels stored for extended periods will "oxidize," resulting in the formation of gums, which contribute to fuel system and engine deposits. Gasoline is typically stable for a period of at least 90 days but may be 30 days old when you purchase it. Therefore if you are storing your vehicle for a period in excess of 60 days you should add a fuel stabilizer. These stabilizers are "anti-oxidants" that extend the storage life of gasoline. One example would be Gold Eagle's STA-BIL®. Some refiner's gasolines remain stable well in excess of 90 days but it is difficult to identify such gasolines unless they are so advertised.

Copyright © 2011 Renewable Fuels Association. All Rights Reserved.

Gasoline and E10 will weather in storage. Some of the gasoline evaporates, leaving a less volatile mixture. The remaining less volatile fuel may not provide cold start and warm up performance comparable to when the fuel was first purchased.

Since the gasoline volatility is adjusted seasonably, it is also possible that when the vehicle is taken out of storage it may not have the proper volatility grade for the season. For instance, a car containing a summer or fall grade of gasoline that is pulled out of storage during mid-winter may experience longer cranking times and poor warm up performance because the gasoline is not volatile enough.

Finally, moisture levels and phase separation should be considered. Different types of gasoline will hold various levels of water before the gasoline phase separates and the water falls to the bottom of the tank. A gallon of conventional gasoline containing no ethanol can dissolve and suspend only about 0.15 teaspoon of water (at 60°F) per gallon. A gasoline/ethanol blend containing 10v% ethanol can suspend nearly 4 teaspoons of water per gallon.

When an all-hydrocarbon gasoline reaches the 0.15 teaspoon level, excess water will phase separate and form a corrosive water phase on the bottom of the tank whereas ethanol blends would require about four teaspoons of water before phase separating. It should be noted that in the case of ethanol blends, when the water begins to phase separate the ethanol will begin to separate with the water and form a corrosive ethanol/water layer on the bottom of the tank. Since water increases corrosion, you should always take precautions to eliminate any introduction of moisture into the fuel system. The tank should be kept reasonably full during storage to minimize condensation on the tank walls.

Contrary to popular belief it is difficult, if not nearly impossible, to absorb enough water from the atmosphere to induce phase separation. At 70°F and a 70% relative humidity, it would take over several months to saturate a gallon of an all-hydrocarbon gasoline and much longer than that to saturate an E10 blend.

So if you have taken steps to eliminate accidental introduction of water and tank wall condensation, phase separation should not be of great concern.

A gasoline/ethanol blend containing 10v% ethanol can suspend nearly 4 teaspoons of water per gallon.

Copyright © 2011 Renewable Fuels Association. All Rights Reserved.

Additives

As is the case for engine oil treatments, there are a number of gasoline additives available over the counter. The use of some additives may prove beneficial while others may not. Overuse of some additives cause more harm than good. Examples of beneficial additives include "lead replacement" or "lead supplement" additives and fuel stabilizers as covered earlier. Beyond these, gasoline generally contains the appropriate detergent/deposit control additive, corrosion inhibitors, and anti-oxidants for normal everyday use. Using additives too frequently or at too high a dose rate may lead to such problems as elastomer deterioration, oil thickening (reduced lubrication), and excessive combustion chamber deposits. Use additives with care, follow the recommended treat rates, and use them only when it is necessary to address a specific problem or condition.

Use additives with care, follow the recommended treat rates, and use them only when it is necessary to address a specific problem or condition.

Conclusion

The gasolines made today, including E10, differ somewhat from those available when vintage/classic cars were produced. However, the principles of combustion remain the same in all vehicles and today's gasolines continue to meet the ASTM performance guidelines.

The classic auto owner can run yesterday's car on today's fuel by exercising the same degree of care typically provided to the exterior and engine of the vehicle – especially regarding extended fuel storage and fuel system maintenance.

Copyright © 2011 Renewable Fuels Association. All Rights Reserved.

References

Downstream Alternatives Inc. *Changes in Gasoline & The Classic Auto.* Informational Document no. 960501. May 1996.

"Hagerty Announces Findings of Ethanol Study." *Hagerty Insurance – Fueling the Collector Car Hobby through Insuring and Supporting the Classics*. Hagerty, 30 Sept. 2009. Web. 20 June 2011. <http://www.hagerty.com/Hagerty-corporate/Press/Press-releases/2009/09/30/ETHANOL-STUDY>

Renewable Fuels Association. *Fuel Ethanol Industry Guidelines, Specifications and Procedures.* December 2010.

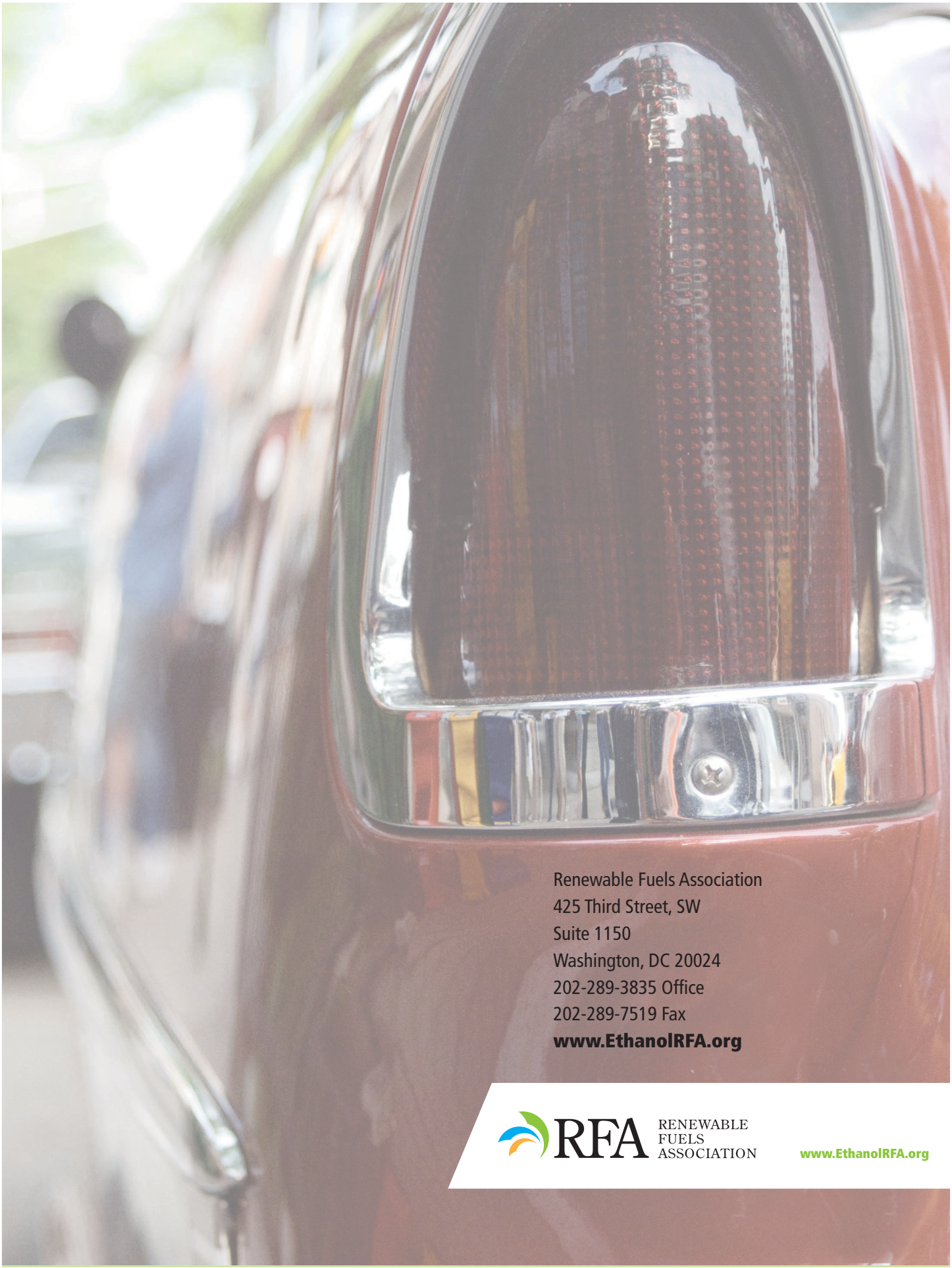
Renewable Fuels Foundation. *Changes in Gasoline IV: The Auto Technician's Guide to Spark Ignition Engine Fuel Quality.* June 2009.

Stein, Jonathan A., and Craig Hoff, PhD. "Ethanol: Demonic or Devine? – Hagerty Lifestyle." *Hagerty Insurance – Fueling the Collector Car Hobby through Insurance and Supporting the Classics.* Hagerty, 13 Aug. 2009. Web. 20 June 2011. <http://www.hagerty.com/lifestyle/hobby_article.aspx?id=55960>.

Stein, Jonathan A., and Craig Hoff, PhD. "The Ethanol Myth, Is E10 an Enemy of Your Collector Car Fuel System? A Study by Kettering University Attempts to Find Out." *Hagerty's Magazine 4.1* (Spring 2009): 36-37. Web. 20 June 2011. <http://www.hagerty.com/uploadedFiles/Resources/hagertys/v4i1.pdf>

Valve Seat Recession Working Group of the Partnership for Clean Fuels and Vehicles, United Nations Environmental Program. *Eliminating Lead from Gasoline: Report on Valve Seat Recession.* May 2004.

Copyright © 2011 Renewable Fuels Association. All Rights Reserved.



Renewable Fuels Association
425 Third Street, SW
Suite 1150
Washington, DC 20024
202-289-3835 Office
202-289-7519 Fax
www.EthanolRFA.org

RFA RENEWABLE FUELS ASSOCIATION

www.EthanolRFA.org

Copyright © 2011 Renewable Fuels Association. All Rights Reserved.