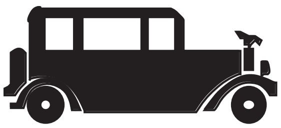

Changes in Gasoline & The Classic Auto

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Downstream Alternatives, Inc.

Introduction

The ongoing effort to alter gasoline to minimize its impact on the environment has refocused attention on fuel quality issues. The reformulation of gasoline and the addition of oxygenates such as ethanol, MTBE (methyl tertiary butyl ether) and other ethers have prompted questions and sometimes raised concerns. For the owner of a classic automobile that question is usually-Will today's fuels work in yesterday's automobiles?

Owners of classic vehicles have unique considerations. Their vehicle's fuel system may differ significantly from those of modern vehicles. The car is usually not driven often and is stored for long periods. It probably operates rich at specified air/fuel settings compared to modern vehicles. 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 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. That is what this information paper does, address the fuel related questions and concerns of the classic auto owner.

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 provided, and advancements in process technology. More recently, changes have been driven by environmental concerns. 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 were 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 January 1995. This legislation also requires certain controls of so called "conventional gasoline" and required the complete elimination of lead use in automotive gasoline as of December 31, 1995. Finally, the legislation required that all gasoline sold after January 1, 1995 contain a detergent effective in controlling carburetor, fuel injector and intake valve deposits.

These various legislative and regulatory requirements necessitated more alterations to gasoline formulations. It is important to note that the above requirements are environmentally driven. At the same time, gasoline must continue to meet certain performance standards and industry guidelines.

Gasoline performance standards are established by the American Society for Testing and Materials (ASTM). The standard specification for gasoline includes requirements and guidelines for such important fuel properties as octane, volatility, corrosivity, and stability.

Whether a gasoline is reformulated, oxygenated, or conventional it should still meet the ASTM performance guidelines. In addition some oil companies have requirements that exceed those of ASTM.

It is important to note that the ASTM standards do not generally dictate what 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. The oxygenates include various alcohols and ethers but only a few are used today. The only alcohol being used is ethanol. The most common ether is MTBE with some use of TAME (tertiary amyl methyl ether) and ETBE (ethyl tertiary butyl ether).

These oxygenates are used in reformulated and oxygenated gasolines to comply with environmental standards and in conventional gasoline to raise octane quality.

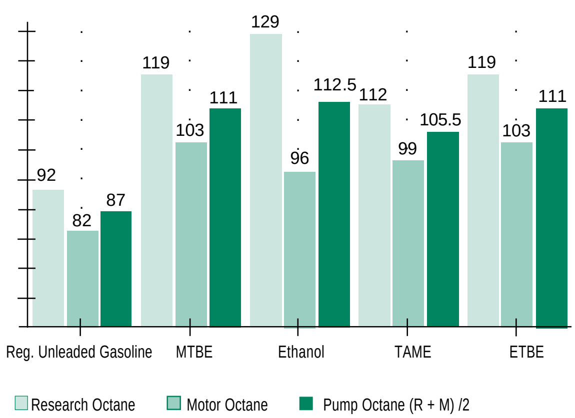
Ethanol is the same alcohol used in beverage alcohol. For fuel use it is 200 proof and denatured to make it unfit for drinking. There is an ASTM standard for the quality of ethanol blended to gasoline. Ethanol has been used in gasoline since the late seventies and about 12% of all gasoline sold in the U.S. contains ethanol. The most common level used in gasoline is the 10% maximum allowed under federal law, although some companies blend at the 5.7% or 7.7% levels for environmental program compliance. Therefore the oxygen content of a gasoline/ethanol blend generally ranges from 2.0% to 3.5%. Ethanol is also an octane enhancer and raises the octane level of the gasoline to which it is added by approximately 2.5 numbers.

MTBE and the other ethers are manufactured by reacting refinery petrochemicals with an alcohol. The ethers are blended in ranges up to about 17% depending on the ether used. MTBE, the most common ether used is generally blended at 11% in reformulated gasoline and 15% in winter time oxygenated fuels. This equates to an oxygen level of 2.0% to 2.7%. MTBE is used in 25% to 30% of all gasoline sold in the U.S. It also is an octane enhancer raising octane levels by around 2.5 numbers when blended at maximum permitted levels.

Figure 1 shows the octane values of common oxygenates compared to regular unleaded gasoline. Figure 2 shows the oxygen content of typical oxygenate blend levels.

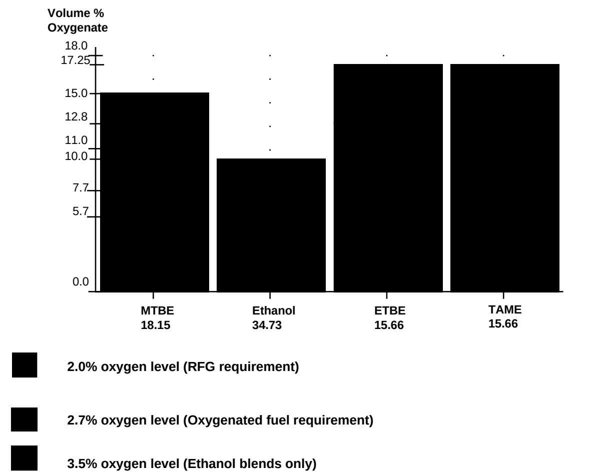
Probably no fuel components have generated as mush controversy and misinformation as the fuel oxygenates. Various myths have gained almost folk lore status and are therefore addressed in the appropriate sections of this paper.

Figure 1
Octane Value of Common Oxygenates



Exact octane values will vary based on octane and composition of gasoline to which the oxygenate is added

Figure 2
Volume Oxygenate Requirement for Regulatory Oxygen Levels



Octane

Octane is nothing more than a measure of a fuels ability to resist engine knock. When octane is too low for a given engine, the fuel will spontaneously ignite resulting in 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 which yields a Research Octane Number (RON) and a Motor Method which yields a Motor Octane Number (MON). The number posted on the gasoline pump is an average of those two numbers, (R+M)/2.

Today, gasoline octanes range for 85 to 94 (R+M)/2 with the typical grades being regular unleaded at 87, midgrade at 89, and premium at 91 to 94. Prior to the eighties, gasoline octane was often posted based solely on the Research Octane Number which allowed postings as high as 100 octane. Premium gasolines sold today often have a research octane number 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 premiums 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.

Since maximum octane requirement occurs at an air/fuel ratio of 14.7:1 going rich from that point will lower octane requirement. 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 only a fraction of an octane number. Another approach is to blend a portion of 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 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.

As mentioned, the oxygenates are octane enhancers. Furthermore all gasolines must meet the octane number posted on the pump. The oxygenates will enlean the air/fuel charge by up to a half number. This is equivalent to the increased oxygen content of the atmosphere for a 30˚ to 40˚ 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.

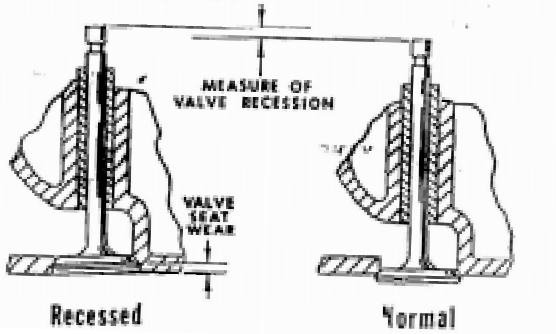
NOTE: In some areas later model classic cars are subject to Inspection and Maintenance Programs. In this case you must ensure that any adjustments do not result in the vehicle exceeding specified exhaust emissions levels.

Lead Phase Out and Exhaust Valve Seat Recession

In addition to providing cheap, albeit unhealthy, octane, lead also 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.

Figure 3

VALVE SEAT RECESSION



Over a period of time operating without lead these oxides diminish exposing the engine to possible EVSR (see Figure 3). Most tests have shown that engines are not at great risk unless they are operated at high rpms or under heavy loads (such as pulling a trailer). The mechanical fix is, of course, to install hardened valve seats. However there are also chemical fixes. There are lead replacement additives, sometimes 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. These products are generally sold over the counter under such names as ValveGuard, ValvePro, Valve Tect, Instead O Lead, etc.

These additives should not be added at higher than the recommended dose rates since to do so could increase engine deposits.

Fuel oxygenates have not been shown to be a significant factor in EVSR. All gasolines, whether oxygenated or not, are unleaded and it is really an issue of whether or not to use a lead replacement.

Fuel Volatility

Volatility is a measure of a fuels 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 to be 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 especially for reformulated gasoline. 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.

The effect of oxygenates on volatility varies but is not of great concern since the maximum volatility of all summer grades is now regulated by the U.S. Environmental Protection Agency (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.

Enleanment

Oxygenates do enlean the air/fuel ratio. An oxygenated fuel usually contains between 2.0% and 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 1500 feet in altitude. All regular street driven vehicles experience these changes in circumstances and do not require any special modifications. Unless an engine is tuned to the absolute limit (very few non-race engines are) 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 size usually represents a 3 to 4% increase in fuel delivery.

Materials Compatibility

Obviously 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 rubber or synthetic rubber much less compatible with today's fuels than the Viton® and fluoroelastomers used in modern fuel systems. Usually, however, older cars have already had most fuel system components replaced. Components provided by the aftermarket since the early eighties are compatible with today's fuel formulations.

Most questions on materials compatibility usually pertain to the oxygenates. However that 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 the oxygenates. Whether octane is achieved by oxygenate addition or increases in aromatics, today's gasolines are generally more aggressive to elastomers than those of the sixties and seventies. Where can one obtain a gasoline comparable to those sold in bygone years? You can't unless you have mastered time travel.

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 3M Fluorel®.

There should be no major concern about metals corrosion. While all gasoline is potentially corrosive, the ASTM specifications include guidelines for corrosivity. Petroleum companies routinely add corrosion inhibitors to their gasoline. Oxygenated fuels are treated with corrosion inhibitors to provide a level of corrosion protection comparable to that of other gasolines.

Fuel Economy

There is a great deal of misinformation about the fuel economy (miles per gallon) of various gasolines, especially those containing oxygenates. Various fuel programs that require oxygenates 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. Some of those that have been documented in testing are covered in Table 1. Even whether or not the car is level each time you fill it can distort fuel economy readings by several percentage points.

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%

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 (btu) per gallon to 117,000 btu/gal. Winter grades are made more volatile (less dense) to aid in cold start and warm up performance and typically contain 108,500 to 114,000 btu/gallon. Summer grades are of much lower volatility to minimize evaporative emissions and hot start/hot driveability problems. Summer grades will typically contain 113,000 to 117,000 btus/gallon. So the energy content, and therefore the fuel economy, can vary 3.4% to 5.0% just based on the energy content of the fuel. Furthermore comparing the highest energy content summer fuels to lowest energy content winter fuels demonstrates that the variation in energy content is up to 7.26% (see Table 2).

Table 2 Gasoline Energy Content
Conventional Gasoline - btu Content

	Summer grade btu	Winter grade btu
Maximum	117,000	114,000
Minimum	113,000	108,500
%	3.4	5.0

Difference between summer maximum and winter minimum-7.26%

The lower energy content of winter fuels and the other wintertime influences on fuel economy can easily lead to reductions of 10-20% in miles per gallon during the coldest winter months.

Oxygenated fuel programs, being wintertime only programs, have therefore been incorrectly blamed for massive fuel economy losses when in fact numerous other variables also contribute to fuel economy losses during winter months.

The reduction in btu/gallon from the addition of oxygenates is generally in the 2% to 2.5% range although fuel economy may not be that much lower. As an example, ethanol contains 76,100 btu per gallon. A 10 volume percent 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.

Table 3 lists the btu/gallon (energy content) of each of the four oxygenates currently in use and also the energy content of resulting fuels when those oxygenates are blended into a 114,000 btu gallon base fuel. The 2.0% oxygen level column is typical of reformulated gasoline while a 2.7% oxygen level is representative of gasoline sold in oxygenated fuel program areas.

Table 3 Energy Content of Oxygenate Blends
(when blended with 114,000 btu/gallon base fuel)

Oxygenate	Energy content (btu/gal)	Finished blend 2.0 wt.% oxygen btu/gallon	Finished blend 2.7 wt.% oxygen btu/gallon
Ethanol	76,100	111,836	111,082
MTBE	93,500	111,745	110,925
ETBE	96,900	111,811	111,059
TAME	100,600	112,215	111,688

Comparing each of the blends in Table 3, you can see that a blend containing 2.0 wt. % oxygen averages just under 2.0% lower energy content. A blend containing 2.7 wt. % oxygen will average about 2.5% lower energy content.

Older vehicles typically have a energy correlation factor of .6 meaning that 60% of any increase or drop in btus per gallon will be reflected in fuel economy. More simply put, a 2.5% reduction in energy content translates to about a 1.5% drop in miles per gallon in older vehicles.

Actually in some tests, older vehicles have shown improved miles per gallons on oxygenated fuels. This is thought to be because the enleaning effect of the oxygenates 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 oxygenated fuels. Some automotive writers have reported that oxygenates, particularly ethanol, might wash lubricants from cylinder walls. However, they were basing their reports on vehicles that operate on pure alcohol such as those in Brazil. When the fuel is a high percentage of ethanol or methanol (i.e. over 50%) a special motor oil is required However tests have shown no such special needs for lower levels of ethanol such as those used in oxygenated and reformulated gasolines.

Over-Blends

Some service shops have expressed concerns about the effects of overblends, fuels containing higher than the permitted levels of ethanol or MTBE. 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, whether blended at the terminal or refinery, the blending process is very sophisticated and usually employs computerized injection blending equipment or at a minimum preset metering devices. Both ethanol and MTBE cost much more than gasoline so no refiner or blender would intentionally add them in excess since it would raise costs. The price differential and modern blending equipment eliminates any need to worry about overblends.

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 oxygenated and reformulated gasolines 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.

Off Season Storage

Most owners of classic/vintage autos store their vehicles for extended periods of time at some point. Gasoline can deteriorate, weather, and take on moisture during storage. Storage considerations are therefore very important.

Gasoline 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. Those stabilizers are "anti-oxidants" that extend the storage life of gasoline. Examples include Gold Eagles "STA-BIL" and NAPA's "Store It-Start It". Some refiners' gasolines remain stable well in excess of 90 days but it is difficult to identify such gasolines unless they are so advertised.

Gasoline will also 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 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 result in longer cranking time 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 it phase separates and the water falls to the bottom of the tank.

A gallon of conventional gasoline containing no oxygenates can dissolve and suspend only about 0.15 teaspoon of water (at 60˚F) per gallon. A gasoline/ MTBE blend can suspend about a half teaspoon of water per gallon while a gasoline/ethanol blend containing 10% ethanol can suspend nearly 4 teaspoons of water per gallon.

When a non-oxygenated gasoline reaches the 0.15 teaspoon level mentioned, excess water will phase separate and form a water phase on the bottom of the tank. MTBE blends would require a half teaspoon of water before water separation occurs. 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 an 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 two years to saturate a gallon of non-oxygenated gasoline and much much longer than that to saturate oxygenated gasolines.

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

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 every day 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.

Conclusion

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

By exercising a reasonable amount of care, especially regarding extended storage, the classic auto owner can run yesterday's car on today's fuel.

The information contained in this document is based on a variety of technical papers, test reports, and information sources. While presented in a condensed form, Downstream Alternatives Inc. has made every attempt to represent the information as accurately as possible, and it is believed to be accurate as of the date of printing.