Gasoline Quality

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The quality of gasoline burned in our vehicle engines may have a profound effect on engine performance, life expectancy and emissions. While everyone has or knows someone who has an opinion on the subject, little factual information is available to the layperson on what effects performance and how the gasoline distribution system may cause problems. This report represents a significant update and expansion of one published in 2003.

In this report, the author hopes to accomplish seven objectives:

- provide a primer on gasoline,
- discuss the origins of gasoline contaminants and their removal,
- provide information on the effect of contamination on dispensing components,
- provide a primer on current and future biofuels requirements,
- discuss which grade of gasoline to purchase,
- provide information on fuel consumption in modern engines, and
- discuss special fuel issues for motorcycles, boats and small engines for power equipment.

Gasoline Properties

Gasoline is a mixture of hydrocarbons distilled from crude oil containing specified maximum levels of impurities and some minimum level of performance-enhancing additives. The overall characteristics of the blend were traditionally defined by an allowable maximum vapor pressure and a performance index called an octane number. Over the last 30 years, efforts to reduce air pollution have extended these definitions to include restrictions on the chemical composition of gasoline blends.

In a typical gasoline engine, a pre-mixed charge of fuel and air is admitted into a cylinder, compressed, combusted and exhausted. The exhaust constituents depend on the completeness of the combustion, which is influenced primarily by engine design, but to some degree by gasoline composition. Complete or stoichiometric combustion of a hydrocarbon fuel, including gasoline, results in carbon dioxide and water as by-products:

$$C_xH_y + (x + y/4)\ O_2 \text{ -----> } xCO_2 + y/2H_2O$$

where x and y are the numbers of carbon and hydrogen atoms in the fuel.

Since air is used as the primary source for oxygen, secondary reactions occur between nitrogen and other molcules present in air under the extreme conditions inside the cylinder. Additionally, trace impurities such as sulfur and other incomplete combustion products contribute to the emission of volatile organic carbons (VOCs), nitrogen oxides (NOx) and sulfur oxides (SOx) .

The majority of the 200-some gasoline components are alkanes, i.e. saturated hydrocarbons, with 4 to 12 carbon atoms. The balance of gasoline consists of cycloalkanes (or naphthenes), alkenes (or olefins) and aromatics, all of which have different combustion characteristics than alkanes, and some polynuclear aromatics (PNAs), which are high boiling and the source of some residues and gums.

In 1995, nine metropolitan areas were required to switch to reformulated gasolines (RFGs) for VOC controls. RFG requirement resulted in limits on benzene, sulfur and aromatics to achieve reductions in VOC, NOx and toxics emissions. In addition, oxygen content of at least 2.1% by weight was required to improve cold-start emissions from older cars and, according to some, reduce the reactivity of emitted VOCs. In order to increase the fuel's oxygen content the oil industry used alcohols and ethers, both of which boost the octane rating, which was reduced with lower aromatics limits. Methyl tertiary butyl ether (MTBE)

and ethanol became the primary oxygenates of choice. However, widely publicized environmental problems with MTBE have mostly eliminated its use in gasoline blending.

Gasoline specifications are set by regulatory agencies and must conform to industry standards established in ASTM D4814 (ASTM: American Society for Testing and Materials). These specifications ensure that evaporative emissions and drivability parameters are met by specifying volatility, define combustion characteristics through octane ratings, maximize product stability and minimize its corrosiveness. Following is a short description of the primary specifications:

Volatility Properties include vapor pressure, distillation curve, and drivability index properties with the objectives of controlling startability, evaporative emissions, and cold-start/warm-up performance emissions. For most regions, gasoline volatility is adjusted seasonally, with higher volatility during winter months to allow start-up in cold climates.

Antiknock Index (Octane) defines the resistance to autoignition or knocking in an engine. There are two methods of determining the index, motor octane (MON) and research octane (RON); the posted octane here in the United States is the average of the two. The octane rating scale is defined by two compounds, iso-octane (C_8H_{18}) which is extremely resistant to auto-ignition and assigned a RON and MON of 100, and n-heptane (C_6H_{16}) which is highly susceptible to self-ignition and assigned an octane value of zero. A gasoline blend exhibiting the same knock properties as a mixture of 90% iso-octane and 10% n-heptane is assigned an octane rating of 90. Since most aromatics, alcohols and ethers have greater resistance to auto-ignition than iso-octane with a rating at 100, it is possible to have fuel octane ratings greater than 100. The two indices, RON and MON, are determined by operating the same standard test engine but differ in the operating conditions of the engine; RON measurements are generally about 10-12 octane numbers higher than MON. In Europe, octane postings appear higher than domestic ones since RON rather than an average of MON plus RON is used.

The oil industry has done significant work on engine octane requirements. When new, engines generally run well on the fuel recommended by the manufacturer. However, as engines age and experience combustion chamber or intake valve deposits, they also experience an increase in octane appetite, known in the industry as ORI, or Octane Requirement Increase.

While volatility and octane represent the parameters most important to motorists, other requirements in ASTM D4814 cover potential quality issues: controls on *Maximum Solvent Washed Gum*, *Copper Strip Corrosion*, *Sulfur* and *Lead* contents are designed to limit to non-distillable residue and minimize corrosive components and air toxics.

Gasoline Distribution

The great majority of gasoline today is blended at refineries to either regular or premium specifications and shipped to distribution terminals via pipelines or on barges. From the terminal, it is delivered via tank truck to the service station. If ethanol is used as the oxygenate, it will be blended at the terminal truck rack during loading. Since the pipeline system may have water present and ethanol has a great affinity to water, ethanol containing fuels may not be shipped via common carrier pipeline. Generally only regular and premium products are delivered to stations now; the mid-grade product is blended at the dispenser.

Most gasoline is fungible, or interchangeable; while a terminal may supply the same base gasoline to different branded outlets, specific brands are differentiated by addition of the detergent additive package for that brand at the truck rack. Terminal rack blending operations have become quite sophisticated by providing automated additive injection and data logging for many different additives. Prior to loading into delivery tankers, the product may be filtered to minimize contaminants. Some major oil companies routinely filter gasoline delivered to their stations. At the station, product is generally dropped into underground storage tanks. Each tank contains a submersible pump which delivers the specific product to each dispenser. The final quality assurance step is a cartridge filter for each product in most dispensers at service stations. These filters are designed to minimize the possibility of water and solids reaching a vehicle tank.

Gasoline Contamination

Most of us have experienced or know someone who has experienced drivability problems which can be related to the fuel. A recent example is that of a major oil company delivering regular gasoline contaminated with fuel oil to several stations during cold Midwestern winter days. The results were serious drivability problems for many customers. This type of problem is very rare and usually

isolated to a small area; however, more frequent problems result from water or solids reaching a customer's vehicle tank.

Product contamination may actually start at the refinery. A number of refinery processes use acid catalysts and require a neutralization step which may result in occasional carryover of caustic. In addition, final polishing or "sweetening" processes used to remove high boiling contaminants also use caustic to remove residual catalysts. If small amounts of caustic are carried over into the product, they may react with other gasoline components or additives and form solids which can appear either as gray/black particles, waxy slime which deposits on dispenser or vehicle fuel filters, or other types of solids.

Shipping products via barges or pipelines can also result in contamination. Barge compartments are generally fabricated of steel. The humid environment can cause rust when empty. Additional problems may occur when ballast water admitted to the product compartments for leveling the vessel is not properly removed prior to loading petroleum products. Pipelines experience occasional settling of solids within the pipeline. When pressure drops increase, operators may send a solid plug, known as a pig, up the pipeline in order to remove the obstruction. The fate of contaminants produced depends entirely on the amount of care exercised when cutting product streams at the nearest terminal tank.

A different set of problems manifests itself as a source for contaminants at terminals. Most terminal tanks today are large diameter steel vessels with floating roof tanks. When a roof is down, the steel walls above are exposed to the atmosphere and rust. Water from condensation or leaks may also accumulate on the floating roofs. The edges of the roof are sealed to the sidewall via seals made of fuel resistant materials. As the roof moves up and down, small particulates are formed from abraded seal material, rust and water and find their way into the product.

The last area for creating contamination is the station storage tank. Steel tanks may experience rust formation in the vapor space. Particulates may also enter through drain valves in spill buckets. In warmer climates, soil particulates may introduce microbes into the tank, which may thrive in any existing water-product interface and produce additional contaminants. Product delivery into station tanks is via drop tubes to the bottom of the tank, providing vigorous agitation during each delivery. If contaminants are present they may experience sufficient shear to form emulsions with long settling times.

Removing Gasoline Contaminants

Having discussed various scenarios for contaminating gasoline, how can oil companies and station owners/operators ensure that their customer is receiving a quality product? The answer is, of course, somewhat obvious: attention to detail by eliminating the source whenever possible or removing the contamination if the source cannot be eliminated. Little can be done about the particulate generation process in terminal tanks. However, the product can be filtered prior to loading into tank trucks. Periodic cleaning of tanks and tank bottoms water management can minimize the problem. At the station, attention to detail is again the key to success. Keeping spills buckets clean and periodically cleaning tanks will minimize contamination. The last line of defense is the dispenser filter, which must be maintained and changed periodically to ensure high flow rates and continued customer satisfaction. Something which should never occur is that owner/operators of stations replace filter cartridges with blanks if repeated plugging occurs.

Dispensing Equipment Problems

If contaminants are allowed into the dispenser piping, serious problems are inevitable. The most immediate problem is the potential of plugging a customer's fuel filter or injectors. However, at the station, contamination can manifest itself in other equipment failures which may become expensive to repair and can affect the station's safe operation. One of the more expensive items to repair or replace in a dispenser is the product meter. Depending on the degree of contamination, its operation may become erratic or it may stop working.

The effect of contaminants on hanging hardware, i.e. hoses, nozzles and breakaways, is less predictable. The potential of coating inside surfaces with deposits may lead to corrosion and pitting of the surfaces, especially if they are aluminum. In the extreme, serious contamination may result in failure of some components. The industry has experienced recurring malfunctions of breakaways failing open rather than closed when accidentally separated and nozzles that fail to shut off.

One very important safety item resulting from contaminated dispenser filters is often overlooked: gasoline

dispensing nozzles require a minimum flow rate of gasoline and may fail to shut off when the flow rate drops below the minimum necessary. Any potential fuel spill will result in a safety as well as environmental hazard.

A number of years ago, the Petroleum Equipment Institute documented numerous vehicle fires resulting from static electricity discharge during fueling. While direct links between contamination and static discharge have not been established, inspection of failed components suggests that contaminant induced surface coating and corrosion may be responsible for reducing the conductivity of affected components. A number of equipment manufacturers of nozzles, swivels and breakaways require the use of an electrical conductivity test following the installation of new equipment or re-installation of used items.

Blending Dispensers

While most quality gasoline marketers have favored multi-hose dispensers having one product hose for each product in the past, the California Air Resources Board (CARB) mandated the use of single hose dispensers for newly constructed stations about 15 years ago. CARB's objective was to reduce the occurrence of potential leaks, since each additional hose with its associated fittings and nozzle represents a possible leak. During the last decade, most new dispensers installed throughout the country have been the single hose variety, i.e. one hose for each dispenser side.

Motorists in need of mid-grade or premium gasoline have been concerned about product co-mingling, especially since some sources have claimed that the holdup of product in the hose, piping and meter is as much as 3/4 of a gallon. Fortunately, this number is incorrect; long ago the National Weights and Measures Conference, which governs consumer issues on the accuracy of dispenser meters, has set an upper limit of 0.3 gallon (not .75 gallon) for product co-mingling. While this amount of co-mingled fuel should not concern the typical motorist, it may affect high-performance motorcycles with small tanks.

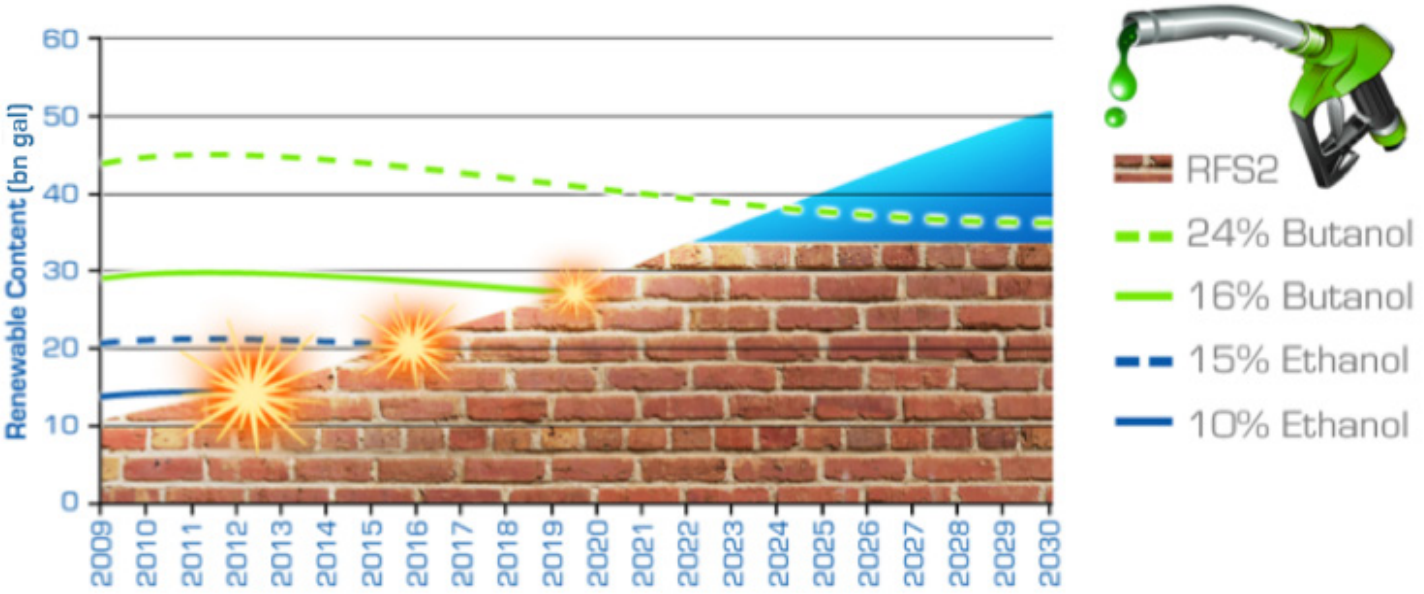
Biofuels - Current and Future Requirements

Ethanol was one the first fuels available to early motorists. As the oil industry developed, ethanol was replaced with products that could be refined from crude oil. Following the oil embargo of the 1970s, oil companies looked at alternative fuels, including alcohols. Blends containing methanol, ethanol, butanols and other oxygenates were approved by the EPA.

The Renewable Fuel Standard (RFS) established by the Energy Policy Act of 2005 mandates blending renewable fuels into gasoline. The Energy Independence and Security Act of 2007 (EISA) substantially expanded the renewable fuels mandate (RFS2) and incorporates specific biofuel categories. Under RFS2, the total blending requirement for refiners increases each year from 10 billion gallons in 2009 to 36 billion gallons of renewable fuel in gasoline and diesel by 2022. While RFS2 mandates volumes of renewable fuels, it does not authorize new fuel formulations or mandate changes to vehicles. Most vehicles on the road in the U.S., as well as the retail and distribution infrastructure, have been designed for compatibility with 10% ethanol blends (E10). RFS2 leaves resolution of the conflict between increasing biofuel requirements and infrastructure compatibility to the market place. The graphic on page 5 shows the mandated biofuels volumes over time, known in the industry today as the "blend wall".

Unfortunately, regulators did not foresee a decline in gasoline consumption but assumed that domestic consumption would increase at a constant rate. While our annual domestic consumption of gasoline was about 145 billion gallons a decade ago, today's consumption is about 135 billion gallons, making it increasingly difficult to use the 20 billion gallons of biofuels mandated for 2015. Much to the dismay of the farm and biofuel lobbies, the EPA has been revising the RFS2 requirements annually in order to accommodate biofuel availability and the size of the blending pool. The graphic on page 5 was done several years ago and does not reflect the current smaller gasoline blending pool; if all E10 fuel blends were replaced with E15 today, we would not be able to accommodate the mandated biofuels volumes.

What does all this mean to the motorist? Biofuel groups want to blend 15% ethanol into the gasoline pool, claiming that E15 is perfectly safe, has been proven to work in most modern engines and that any questions regarding infrastructure problem are a "myth perpetuated by Big Oil". The reality is quite different. On the vehicle side, car makers have marketed so-called flex-fuel vehicles for many years, vehicles capable of operating on any ethanol mixture between E10 and E85. While many of today's vehicles may be able to run on E15, some may not. With some carmakers providing warranties up to 10 years, owners should consult their instruction manuals prior to fueling E15 and possibly voiding their warranty. For vehicles out of warranty, drivers should weigh the potential risks of damage to seals and polymer components.



While increased ethanol production has been a boon to domestic farmers and may have contributed to energy security, it is not nearly as beneficial to the motorist. Ethanol has an energy content of about 65% compared to gasoline; modern engines will experience an increase in fuel consumption proportional to the amount of ethanol blended into the fuel. Although it has a higher octane rating than gasoline, it also has a significantly higher blending vapor pressure and contributes to additional fugitive emissions. Finally, its affinity for water prevents blending ethanol at the refinery; it must be blended into the delivery truck at a distribution terminal. This requires that ethanol be transported via trucks or rail; it cannot be shipped via common carrier pipeline like other liquid fuels.

Two companies have been working on commercializing isobutanol as an alternative to ethanol. Since the alcohol is a larger molecule compared to ethanol, it can be blended into gasoline at 16% (Bu16) and achieve the same oxygen concentration as E10; E15 blends correspond to isobutanol at 24% (Bu24). It may be produced from the same feedstocks as ethanol, has much lower vapor pressure, no affinity for water and may be blended at the refinery and transported via common carrier pipeline. A summary of isobutanol's advantages over ethanol was published by this writer in the October 2012 issue issue of the *PEI Journal* (pei.org). The table below lists important properties of regular gasoline, ethanol and isobutanol. The graphic above shows that replacing ethanol with isobutanol will enable the industry to meet mandated biofuel volumes over the next 5-6 years. Moving to higher alcohol concentrations, i.e. the E15 equivalent of Bu24, will enable us to meet all future mandates.

Potential problems with elevated ethanol levels in the product distribution infrastructure have been documented

GASOLINE & OXYGENATE PROPERTIES

	Gasoline	Ethanol	Isobutanol
Anti-Knock Index, (R+M)/2	87	120*	100*
Reid Vapor Pressure - RVP, psi	7-15	~19*	~6*
Energy Content (% compared to gasoline)	100	66	84
Oxygen Content (%w/w)	N/A	34.7	21.6
Water Solubility	Insoluble	Infinite	Low

*blending values in gasoline

in recent experimental work at Underwriters Laboratories (UL) and the National Transportation Center at Oak Ridge National Laboratories (ORNL), who have shown conclusively that elevated ethanol levels (even E15) may cause premature failure of some elastomers and plastics used in infrastructure equipment. The reports from this work as well as material compatibility of isobutanol fuels are readily available from ORNL and have been summarized in three recent articles in the *International Journal of Fuels & Lubricants* and an article in the October 2015 issue of the *PEI Journal* (this writer has been a contributor to the former and authored the PEI article).

An important additional consideration is the fact that, during the last few years, most major oil companies have divested themselves of retail operations; the great majority of gas stations are now owned and operated by independent third parties, many of whom may not be able to afford the extensive and costly retrofits necessary to achieve full compatibility with E15.

Which Grade Gasoline?

This question has always been of great interest to the consumer who has little basis for his choice other than advertising and old wives' tales. Let us start by stating that today's engines are much different than those built decades ago. Modern engine management systems today rely on more computing power than most of the Apollo Space Program, with an objective of minimizing exhaust pollutants and evaporative losses. Tailpipe and crankcase losses have been reduced by more than 99% of their unregulated levels in the 1960s. In fact, ultra low emissions vehicles, or ULEVs, emit less than 0.3% VOC of the pre-regulation era.

With the increased sophistication of modern engine management systems, comes the ability to effectively utilize a wide range of fuels. Knock sensors are used by the engine to retard timing should the engine experience knock caused by burning fuels with insufficient octane ratings. Engine power may be reduced by the intervention of the knock sensor, but the reduction is usually brief. Under this scenario, regular gasoline will suffice for most vehicles. Generally, high-performance engines for which the manufacturer recommends premium fuel, will not be damaged by the use of regular gasolines, but the loss of power and corresponding acceleration performance can drop noticeably when the vehicle's octane requirement is not met. The most important factor to consider when choosing fuel types is the normal duty cycle of the engine: an aggressive driving style which keeps the engine at high performance levels calls for using the type of gasoline specified by the manufacturer.

With many gasoline quality parameters regulated, the obvious question is if there is a difference among gasoline brands. The answer is a resounding yes. Differentiation is achieved through proprietary additive packages which contain anti-oxidants, metal deactivators, surfactants, deposit modifiers, corrosion inhibitors, and, of course, octane enhancers, most of which are not required to meet minimum regulatory compliance. In addition, gasoline retailers vary significantly in the level of care taken to prevent contamination; some companies have specific quality control procedures and special equipment to avoid contamination, while others do not.

While many of us have suffered through countless television ads claiming superior performance for particular gasolines, the reality is that those claims must be backed by substantial test data in order to meet the Federal Trade Commission (FTC) advertising requirements. While there has been a debate concerning the value of premium gasolines in engines that really do not need them (which is the majority of today's engines), the facts are that major brand premium gasolines generally contain higher dosages of premium additives designed to reduce intake valve deposits, spark plug fouling and keep fuel injectors clean. A number of major oil companies have demonstrated that their additive packages reduce emissions and have the ability to restore engine performance; most take extra care in ensuring that their premium product exceeds customer expectations.

About a decade ago, automakers and their industry associations noted a decline in gasoline quality and in the level of deposit-control additives in gasoline. With longer warranties, automakers had been absorbing substantial cost increases due to the repair of fuel system problems caused by poor gasoline quality. In addition, customers were also experiencing significant costs in repairing older vehicles that were failing mandated emissions tests due to fuel related problems. In order to address the problem, seven automakers formed a new trade group called *TopTier Gasoline* and set out to test and certify gasolines for adequate deposit-control additives. The group maintains a web site which explains the required testing and lists certified gasoline marketers. Current smart phone apps such

as *GasBuddy* provide motorists with *TopTier* information on their listings of local gas stations; unfortunately, *GasBuddy* does not appear to include the *TopTier* designator uniformly in all locations.

The American Automobile Association (AAA) now recommends vehicle owners to use gasoline that meets *TopTier* standards after their latest study showed that non-*TopTier Gasoline* brands caused more engine deposits. AAA conducted independent laboratory testing on non-*TopTier* and *TopTier* brands; the study revealed that non-*TopTier* products caused 19 times more engine deposits than *TopTier Gasoline* brands after just 4,000 miles of simulated driving.

Vehicle Fuel Consumption

While not directly related to fuel quality, fuel consumption, especially a comparison between EPA listed data and actual on-road performance, is a mystery to most drivers and often associated with the quality of the fuel. Modern engine management systems do sense the fuel's energy content. This is one reason why fuel consumption for alcohol-gasoline blends will be higher when compared to gasoline alone; the table on page 5 shows the energy content of ethanol and isobutanol compared to regular gasoline.

Fuel consumption data provided to the motorist by the vehicle sales sticker is based on well-defined driving cycles using fuels blended to defined specifications as listed on EPA's website:

> *Testing vehicles in controlled laboratory conditions establishes a level playing field for all cars and ensures that the test results are consistent, accurate, repeatable, and equitable among different vehicle models and manufacturers. Vehicles are driven on a dynamometer (a device similar to a treadmill) using five standardized driving patterns or test cycles. These test cycles represent a variety of driving conditions including speed, acceleration, braking, air conditioning use, and ambient temperatures. The test results from the five driving cycles are combined to yield individual "city" and "highway" values, and a "combined" fuel economy value that assumes a 55% city/45% highway split.*

The results of testing vehicles to EPA's specifications are internally consistant but not generally comparable to the experience of day-to-day driving. Actual fuel consumption is a factor of variables such as weather, terrain, vehicle loading, driver behavior, etc., all factors which are difficult to capture in a standardized testing protocol. Individual fuel consumption may vary considerably and is a strong function of driving style.

Special Fuel Issues: Motorcycles, Boats & Power Equipment Engines

Motorcycles: Fuel issues related to motorcycles have been covered in *Motorcycle Consumer News* (MCN) for years. In 2003 the publication featured the article "Octane for Dummies" which was followed by an editorial on octane in 2012. In 2012, the magazine also featured an editorial on ethanol. Major issues with fuel quality as related to motorcycles are similar to cars and are covered in earlier sections of this report; the special case of product commingling in a small tank has already been covered as well. Any potential material compatibility issues for plastics and seals are equally applicable to any gasoline consuming equipment. Of particular concern for motorcycles is the seasonal use, resulting in long-term inactivity and potential exposure of the fueling system components to the alcohol if phase separation of ethanol should occur upon exposure to small amounts of water. The American Motorcyclist Association (AMA) has requested the U.S. EPA to lower ethanol content in fuel. In their recent Press Release (July 15, 2016), the association states:

> *To meet the proposed standards, the EPA is calling for increased use of E15 fuel in model year 2001 and newer vehicles and expanded use of E85 in flex-fuel vehicles. E15 fuel has 50 percent more ethanol than E10, and none of the estimated 22 million motorcycles and ATVs in use in the United States is approved to use E15 or higher ethanol blends. For engines and fuel systems not designed for E15, serious damage can occur. The AMA is fighting to ensure a safe fuel supply for motorcyclists, ATV riders and users of other small engines. As the volume obligations continue to rise, even as fuel consumption declines or remains the same, the risk of inadvertent misfueling increases dramatically.*

Boats: Seasonal activity poses the same problems to fuel systems of boats. The marine industry has long complained about reported tank and other fuel system component failures due to exposure to ethanol and has been opposed to the implementation of E15; the boating literature is full of reports of fiberglass as well as aluminum tank failures. The National Marine Manufacturers Association's (NMMA)

web site makes the following statement regarding high level ethanol blends:

> *The potential for consumers to use fuel with a percentage of ethanol above 10 percent in boat engines is detrimental to the U.S. recreational boating industry, an important economic driver for large parts of the country. There are serious and well-documented human safety, environmental, and technology concerns associated with ethanol blends over 10 percent in recreational boat fuel tanks and engines. The NMMA is hard at work to prevent this dangerous fuel from affecting our industry.*

After a five-year study, the NMMA has recently endorsed the use of biobutanol, i.e. isobutanol, as the fuel blending component of choice for recreational boating.

Power Equipment Engines: According to data from the Outdoor Power Equipment Institute (OPEI), there are more than 250 million engines installed in legacy outdoor power equipment in this country. Material compatibility issues with higher ethanol blends are equally applicable to these engines as are the seasonal use considerations discussed above for motorcycles and boats. There is one additional, very important issue with fuel quality and these engines: most of this equipment is operated at peak power output much of the time, making it much more susceptible to fuel and material compatibility problems. In a recent letter to the EPA (July 13, 2016), OPEI expressed:

> *significant concerns about the expansion of E15 in the marketplace without a solid consumer education program. Because all gasoline-fueled outdoor power equipment is designed and warranted to operate on E10 or less fuel, OPEI and its members are gravely concerned about the risk of inadvertent mis-fueling by consumers. Mis-fueling can damage or destroy small engines, leaving the consumer with costly repair or replacement costs…. If you are going to introduce blender pumps and more E15 into the marketplace, then you also need a robust consumer education campaign so consumers understand which fuel blends are safe for which product.*

The letter notes that labeling for E15 and other blended fuels is inadequate, not consistent and that national polls conducted by OPEI show that consumers remain confused about the changing fuels marketplace.

References on Biofuels

The recent articles listed below have been co-authored by Wolf Koch and cover comparative material issues with ethanol and isobutanol fuel blends:

Isobutanol - Biofuel of the Future (with J. Baustian), PEI JOURNAL, October 2012

Compatibility Assessment of Elastomer Materials to Test Fuels Representing Gasoline Blends Containing Ethanol and Isobutanol (with M. Kass, T. Theiss, S. Pawel, J. Baustian, L. Wolf, C. Janke), SAE Int. J. Fuels Lubr. 7(2):2014, doi:10.4271/2014-01-1462

Compatibility Assessment of Plastic Infrastructure Materials to Test Fuels Representing Gasoline Blends Containing Ethanol and Isobutanol (with M. Kass, C. Janke, T. Theiss, S. Pawel, J. Baustian, L. Wolf), SAE Int. J. Fuels Lubr. 7(2):2014, doi:10.4271/2014- 01-1465

Compatibility Assessment of Plastic Infrastructure Materials with Test Fuels Representing E10 and iBu16 (with M. Kass, C. Janke, T. Theiss, J. Baustian, L. Wolf), SAE Int. J. Fuels Lubr. 8(1):2015, doi:10.4271/2015-01-0894

Isobutanol Compatibility - What the Research Shows (with J. Baustian), PEI JOURNAL, October 2015

Wolf Koch is Founder and President of Technology Resources International, Inc. in Sterling, IL. He provides consulting services in technology evaluation, development and testing, and litigation and expert witness support. He managed fuel distribution and service station technology at a major oil company for many years and is an avid motorcyclist and sailor. Dr. Koch has authored more than 50 publications, has 30 patents and volunteers on Standards Technical Panels (STPs) for Underwriters Laboratories covering 24 safety standards for most equipment used in fuels distribution; STPs author and maintain test procedures for equipment certification. He has been a Professor of Chemical Engineering and lectures extensively on energy and biofuels related topics. TRI's past clients include government agencies, major oil companies, industry associations, insurance companies and manufacturers of service station and distribution terminal equipment; the company has developed, tested and commercialized new products for clients and has provided technology evaluation services to domestic and international investors in energy related areas.