Gasoline / Ethanol and Octane Issues

by Terence McKillen

In June 2008, the Canadian Federal Parliament passed Bill C-33, an Act to amend the Canadian Environmental Protection Act (1999), allowing the government to regulate renewable content in fuels with a requirement for an average of 5% renewable content in gasoline by 2010. This is regulated as an average per brand, so 5% of the overall gasoline volume must be ethanol, not necessarily 5% content in all gasoline sold under that brand. Although these are federal regulations, many of the provinces in Canada including British Columbia, Manitoba, Ontario[1], and Saskatchewan already had similar regulations in force provincially.

Despite being hailed by some as a greener alternative to pure crude oil derived gasoline, ethanol is not without its drawbacks when used in vehicles that were not designed with this fuel in mind.

In the United States, the Environmental Protection Agency (EPA) is responsible for developing and implementing regulations to ensure that transportation fuel sold in the United States contains a minimum volume of renewable fuel. The Renewable Fuel Standard (RFS) program regulations were developed in collaboration with refiners, renewable fuel producers, and many other stakeholders. The United States is the world's largest producer of ethanol fuel with 13.9 billion U.S. gallons (52.6 billion litres) of ethanol fuel in 2011, an increase from 13.2 billion U.S. gallons (49.2 billion litres) in 2010, and up from 1.63 billion gallons in 2000. In the U.S, ethanol is mainly used as an oxygenate in gasoline in the form of low-level blends up to 10 per cent, and to an increasing extent, as E85 fuel for flex-fuel vehicles.

Figure 1: The author's 1972 late Mk 1 Triumph Stag runs nicely on 91 octane ethanol-free Premium gasoline.

The ethanol market share in the U.S. gasoline supply grew by volume from just over 1 per cent in 2000 to more than 3 per cent in 2006 to 10 per cent in 2011. Domestic production capacity increased fifteen times after 1990, from 900 million U.S. gallons to 1.63 billion U.S. gallons in 2000, to 13.5 billion U.S. gallons in 2010. The Renewable Fuels Association reported 209 ethanol distilleries in operation located in 29 states in 2011, and 140 under construction or expansion as of December 2011, that upon completion, would bring U.S. total installed capacity to 15.0 billion U.S. gallons.

By 2011 most cars on U.S. roads could run on blends of up to 10% ethanol (E10), and manufacturers had begun producing vehicles designed for much higher percentages. Flexible-fuel cars, trucks, and minivans use gasoline/ethanol blends ranging from pure gasoline up to 85% ethanol (E85). By early 2013 there were around 11 million E85-capable vehicles on U.S roads. Regular use of E85 is low due to lack of fuelling infrastructure but is common in the Midwest. In January 2011 the U.S. Environmental Protection Agency (EPA) granted a waiver to allow up to 15% of ethanol blended with gasoline (E15) to be sold only for cars and light pickup trucks with a model year of 2001 or later. The EPA waiver authorizes, but does not require stations to offer E15. Like the limitations suffered by sales of E85, commercialization of E15 is constrained by the lack of infrastructure as most fuel stations do not have enough pumps to offer the new E15 blend, few existing pumps are certified to dispense E15, and no dedicated tanks are readily available to store E15. In Canada however, many of the largest car makers have

cautioned drivers that filling up with E15 fuel could void their new vehicle warranty.

Ethanol production was expected to continue to grow over the next several years, since the U.S. Energy Independence and Security Act of 2007 required 36 billion U.S. gallons of renewable fuel use by 2022. The target for ethanol production from cellulosic feedstock was 16 billion U.S. gallons a year. The corn ethanol target was 15 billion U.S. gallons by 2015.

A somewhat similar picture emerges for our cousins in the UK and EU where the European Union has decreed (under the Renewable Transport Fuels Obligation "RTFO") that fuel companies are obliged to include 3.5% bio fuel in all their mineral petrol and diesel sales. Until recently there was no specific mandate as to the percentage in each individual fuel and so the oil companies focused more on adding a greater percentage of bio fuel to their diesel while leaving gasoline alone. However the amount of bio fuel that must be included in fuel sales increases each year and the fuel companies now have no choice other than to have a renewable element in their gasoline. The majority of gasoline sold at the pumps in the UK is set to increase from E5 to E10 in 2013.

Retail gasoline is actually a blend of several hundred different chemical compounds. Because the composition of the chemicals can vary widely, the quality of gasoline can also vary. High quality gasoline should have the right octane level to prevent knocking, strong cleaning power to prevent carbon build up, deliver more kilometres per litre (or miles per gallon) and be of the correct volatility to ensure a vehicle accelerates smoothly and starts easily. The level of additives is also changed on a seasonal basis to provide for peak performance as ambient temperatures change.

One should avoid refuelling at discount gasoline retailers in our classic cars. These retailers operate by purchasing batches of refined gasoline that did not reach the required quality requirements of the major oil companies. These products likely do not have the full complement of additives normally considered good for your internal combustion engine.

In recent years, some of the gasoline suppliers in Ontario (Shell, Sunoco and Petro-Canada) have joined an auto industry Top Tier certification system to provide a new class of fuel meeting the detergent standards of six major auto manufacturers (Audi, BMW, GM, Honda, Toyota and Volkswagen) that exceeds the requirements of the Canadian General Standards Board (CGSB) for such additives.

Most of the major gasoline suppliers where I live in Ontario currently appear to have excluded ethanol from their premium grades (refer table below) but in order to maintain the 5% (E5) brand average, the ethanol content of Regular grade gasoline may be as high as 10% (E10). The introduction of E15 fuel in Canada and the U.S. may not be far off, although many of the major auto manufacturers are not happy with E15 fuel. The ethanol content of gas can also vary by region across both Canada and the U.S., allowing some consumers, depending on their location, to have E0 regular gasoline and up to E10 or E15 in some Premium gasoline.

Gas stations selling ethanol-blended gasoline must place a label on the pump indicating which grades of gasoline may contain up to whatever per centage of ethanol. Despite its higher octane rating, Petro-Canada's Ultra 94 (formerly Sonoco Ultra 94) is an E10 gasoline. Consequently, those Petro-Canada gas stations selling Ultra 94 will have some ethanol in all of their gas grades.

What is Ethanol?

Ethanol, or ethyl alcohol, has the chemical formula C2H5OH. It is the same alcohol found in alcoholic beverages, but ethanol also makes an effective motor fuel. Ethanol has a lower energy content than gasoline. That means that about one-third more ethanol is required to travel the same distance as on gasoline. But other ethanol fuel characteristics, including a high octane rating, result in increased engine efficiency and performance. Ethanol does burn cleaner than gasoline and does reduce the toxicity of car exhaust but it can also be somewhat corrosive inside the engine block, fuel system and gas tank.

Pure ethanol has an octane rating of 113 endowing it with a far higher resistance to knocking or pinking than hydrocarbon fuel, indeed this explains why another version of alcohol (Methanol) has been used to fuel highly tuned dragsters and some very high performance racing cars of the past.

Ethanol is hygroscopic, meaning that it readily absorbs water, leading to phase separation and water contamination. It is also an excellent solvent not only capable of dissolving plastic, rubber, fibreglass and other materials and compounds, potentially leading to the premature destruction of fuel lines, pumps, gaskets, O-rings, rubber seals and diaphragms but can take sludge and other varnish like material from the bottom of a gas tank into solution allowing them to be ingested further down the combustion chain.

Blending ethanol with the gasoline is the final act that the fuel company undertakes. It is added only when the fuel is in the tanker, ready to be delivered. This is because if added sooner than this, the ethanol would attack the storage tanks in the fuel depot. It is for this reason also that ethanol can't be transferred along pipelines with the rest of the fuel (it eats

them too). It has also been known to damage the storage tanks in service station outlets and these need to be modified to contain ethanol fuel.

Below is a list of materials known to be damaged by ethanol - the list is not exhaustive:

Zinc and galvanised materials, Brass, Copper, Terne plate (lead/tin coated steel), Aluminium, Magnesium alloys, Zamak 5, Polyurethane, Polymers containing alcohol groups, Fibreglass-reinforced polyester and epoxy resins, Shellac, Acrylonitrile butadiene styrene (ABS), Polyvinyl Chloride flexible version (PVC), Natural rubber, Polyethylene Terephthalate (PET), Cork, Petseal, Nitrile rubber (NBR) [Buna N] with low acrylonitrile (CAN) content, Viton A, Polyamide 6 (PA 6) [Nylon 6], Polyamide 66 (PA 66) [Nylon 66].

The ideal fuel/air ratio for a gasoline engine (Stoichiometric Air/Fuel Ratio) is between 14.5 & 14.7 to 1. That is 14.7 parts air to 1 part fuel by volume. For pure ethanol this ratio is between 8.9 & 9 to 1. (9 parts air to 1 part fuel). This can partly be explained because ethanol contains 35% Oxygen by weight and therefore will naturally 'lean-off' the fuel/air mixture.

Even with E5 gasoline, ethanol will alter the correct fuel/air ratio and lead to unadjusted engines running weak. As a very crude guide slightly rich mixtures will result in wasting fuel. Slightly lean mixtures can result in significantly increased combustion temperatures.[2] Permanent damage may already have occurred to valves and pistons before any change is noticed in coolant temperature.

Although it may seem to be the case, the introduction of ethanol into petroleum spirit was not intended simply to attack motorists and destroy old cars. There are most definitely arguments to support finding alternatives to our dependence on fossil fuels. Engines and fuel systems can be designed to run on various blends of ethanol fuels. The Ford Model T did that more than 100 years ago. However, our classic Triumphs were not so designed.

Currently, research is being conducted at the University of Kettering, in Flint, MI to compare the use of E10 and E0 fuels in classic cars. Preliminary results of the study, published in Hagerty Insurance Agency's magazine[3] found that fuel lines didn't leak, carburettors didn't disintegrate and fuel pumps did not fail with E10 fuels. However, there was minor build-up and corrosion in the carburettors and fuel pumps when using E10 as opposed to gasoline with no ethanol.

The preliminary conclusion is 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 previously. Minor updates and maintenance should include draining fuel out of the carburettor fuel bowls and changing fuel filters more frequently and ensuring that the fuel tank is completely clean with no sediment or sludge. It may also be wise to consider replacing seals, gaskets and fuel lines with modern replacement materials since older fuel system components are often incompatible with ethanol blended fuels.

The Canadian federal government expects the regulations to lead to a total reduction of greenhouse gas (GHG) emissions of 23.8 Mt over 25 years, or an average annual reduction of 0.99 Mt.[4] To put this estimated reduction in perspective, the average annual reduction is about 0.13% of Canada's annual GHG emissions in 2008 – actually, only a very "small step for mankind."

Using Unleaded Gasoline in Vintage Cars

The tetraethyl lead additive in the older gasoline formula acted as a lubricant for the inlet and exhaust valves. With unleaded gasoline, the lubrication component has been removed, and this can result in valve seat recession (VSR).

Simply put, unleaded gasoline can burn out the valves and their seats, particularly on the exhaust side. The rapidity at which this might happen depends on the amount and type of motoring and could take many years before the effect is noticed on a car that is driven only a few thousand kilometres a season. Some people use lead substitute additives at each gasoline fill up but the only real permanent solution against VSR is to install hardened valve seats and valve guides.

The detergents present in modern unleaded gasoline offers benefits for all cars, no matter how old. Ignition timing and/or carburettor adjustment may be required to deal with changes in gasoline composition and octane rating.

Octane Rating

The octane rating is a measure of a fuel's resistance to knocking. Knock, also known as 'pinking', occurs during combustion when the fuel-air mixture detonates ahead of the compression stroke rather than burning smoothly (pre-ignition), thus causing a knocking noise. Using a method established in 1929, gasoline is rated on a scale of 0 - 100. In the 1920s gasoline had an octane rating of around 50 to 60. Octane rating does not relate to the energy content of the fuel. It is only a measure of the fuel's tendency to burn in a controlled manner, rather than exploding in an uncontrolled manner. Where the octane number is raised by blending with ethanol, energy content per volume is reduced.

The most common type of octane rating worldwide is the Research Octane

	Canada (AKI)	U.S. (AKI)	UK (RON)
Super Premium	94	94 (some 100)	99
Premium	91	91-93	97
Mid/Blend	89	89	
Regular	87	87	95

Octane rating of gasoline grades available in Canada, the U.S. and UK

Number (RON). RON is determined by running the fuel in a test engine with a variable compression ratio under controlled conditions, and comparing the results with those for mixtures of iso-octane and n-heptane. There is another type of octane rating, called Motor Octane Number (MON), or the aviation lean octane rating, which is a better measure of how the fuel behaves when under load, as it is determined at 900 rpm engine speed, instead of the 600 rpm for RON. MON testing uses a similar test engine to that used in RON testing, but with a preheated fuel mixture, higher engine speed, and variable ignition timing to further stress the fuel's knock resistance. Depending on the composition of the fuel, the MON of a modern gasoline will be about 8 to 10 points lower than the RON, however there is no direct link between RON and MON. Normally, fuel specifications require both a minimum RON and a minimum MON.

In most countries, including Australia and all of those in Europe, the "headline" octane rating shown on the pump is the RON, but in Canada, the United States, Brazil, and some other countries, the headline number is the average of the RON and the MON, often called the Anti-Knock Index (AKI), and is often written on pumps as (R+M)/2). It may also sometimes be called the Pump Octane Number (PON).

The octane rating of gasoline marked "premium" or "regular" is not consistent across the country. One state may require a minimum octane rating of 92 for all premium gasoline, while another may allow 90 octane to be called premium. In the Rocky Mountain (high elevation) states, 85 is the minimum octane, and 91 is the maximum octane available in fuel. The reason for this is that in higher-elevation areas, a typical naturally aspirated engine draws in less air mass per cycle because of the reduced density of the atmosphere. This directly translates to less fuel and reduced absolute compression in the cylinder, therefore deterring knock. It is safe to fill a carburetted car that normally takes 87 octane fuel at sea level with 85 octane fuel in the mountains, but at sea level the fuel may cause damage to the engine. To make sure you know what you're buying, check the octane rating on the sticker on the gas pump instead of relying on the name "premium" or "regular."

The fuel recommended in the Triumph Handbook[5] for use in Stags (and TR6s) is a 97 octane rating. This refers to the RON method0 used in the United Kingdom and was meant for the higher compression engines delivered there. The recommended fuel grade for the lower compression, carburettor aspirated Federal models exported to North America was 91 RON. These octane ratings were equivalent to the old British 4-Star and 2-Star petrol grades. Today, premium gasoline in Canada and the U.S. usually has a minimum octane rating of 91 while regular gasoline has a minimum octane rating of 87, which would be the equivalent of about a 96 RON and a 91 RON rating respectively. In effect, therefore, if it wasn't for the ethanol issue, our North American Triumphs should be quite comfortable running on regular gasoline – unless of course, you or a previous owner has increased the compression ratio of the motor.

Notes:

[1] Environmental Protection Act Ontario - Regulation 535/05 - Ethanol in gasoline

[2] The issue of Ethanol blended with petrol - Chris Thompson, Stag Owners Club magazine, April 2011

[3] Hagerty Insurance - http://www.hagerty.com/lifestyle/hobby_article.aspx?id=55960

[4] Canada's Federal Renewable Fuels Regulations: An example of poor decision making. Wood.J., Fraser Forum March/April 2011

[5] TR6 Repair Operation Manual, Triumph Motors British Leyland UK Limited, Pub. Part No. 545277/E2 Stag Repair Operations Manual, Triumph Motors British Leyland UK Limited, Pub. Part No. 545162

Premium Gas Brands (Ontario)	Octane (R+M/2)	Ethanol (%)	Comments
Shell V-Power Premium	91	None	
Beaver Premium	91	None	Same as Shell
Husky Premium	91	≤10%	All Husky gas grades in Ontario contain ethanol
Pioneer Platinum	91	?	Pioneer did not respond to query for information
Petro-Canada SuperClean	91	None to 10%	at Petro-Canada branded gas stations from Windsor to Belleville and north to Manitoba, not selling Ultra 94, the Premium 91 Octane gasoline does not contain ethanol. In Northern Ontario, North Bay, Sudbury, S.S. Marie, Timmins, Thunder Bay areas and in Eastern Ontario for the Ottawa area, including Pembroke, Cornwall and Brockville, both Regular and Premium gasoline currently do not contain any ethanol. When Ultra 94 is sold then All gas grades contain ethanol, including Premium.
Suncor Super	91	≤10%	All Suncor gas grades contain ethanol
Esso Supreme	91	None	
Canadian Tire Premium	91	None	
Ultramar Supreme	91	None	

Data in the table is based on information received from petroleum companies and/or from internet sources and is believed to be correct as at July 31, 2011. Neither the author nor the Triumph Stag Club USA accept any responsibility for such information which is provided for comparative purposes only – readers are advised to check pump stickers or confirm with a gas station manager or oil company representative for the actual ethanol content of a particular fuel in their local market area.