Driveability and Performance
Of
Reformulated and Oxygenated Gasolines
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Introduction

The introduction of cleaner burning gasoline to minimize the environmental impact of the automobile has drawn a great deal of attention in some areas. These programs include the introduction of oxygenated fuels in carbon monoxide non-attainment areas which began in 1992. More recently, certain ozone non-attainment areas have had to require the sale of reformulated gasolines (RFG) which, in addition to containing oxygenates such as methyl tertiary butyl ether (MTBE) and ethanol, have undergone certain other changes in composition and characteristics. Though these changes are relatively minor, they are difficult to explain to the lay person. The issues have been further clouded by inaccurate or incomplete information provided in media reports.

To the consumer, automobile performance and driveability is defined by certain criteria most notably, ease of start (whether engine is cold or hot), warm up performance, and smooth responsive acceleration. To understand how reformulated and oxygenated gasolines affect these criteria it is necessary to examine how these performance attributes are controlled through gasoline specifications and whether or not reformulated and oxygenated gasolines meet such specifications.

Cold Start, Hot Start, and Warm Up Performance

The ability of a fuel to provide good cold start depends upon its volatility, a measure of its ability to vaporize. Gasoline is adjusted seasonally so that it is more volatile (vaporizes at lower temperatures) in the winter to provide good cold start and warm up performance. Volatility is measured by a gasolines vapor pressure and its distillation properties. The volatility specifications for fall, winter, and spring grades of reformulated and oxygenated gasolines (September 15th through June 1st at retail) are no different from those of conventional gasoline. Consequently, cold start and warm up performance of these reformulated gasolines are comparable to that of conventional gasoline.

The volatility of summer grades of gasoline is reduced (requires higher temperatures to vaporize) to minimize vapor locking, hot driveability problems, and hot restart problems. In 1992 the U.S. Environmental Protection Agency (EPA) implemented regulations to dramatically reduce the vapor pressure of summer grade gasoline (those sold at retail between June 1st and September 15th). Though done to reduce evaporative emissions, this action also had the effect of reducing the incidence of vapor lock and hot restart/hot driveability problems. Conventional gasolines including those containing oxygenates must still comply with these summertime volatility standards. As a result, the cold start, hot restart, hot driveability and warm up performance of summer grade oxygenated fuels is comparable to conventional gasolines.

Summer grades of reformulated gasolines are even less volatile than today's summer grades of conventional gasoline. On the positive side, this means even less chance of problems with vapor locking, hot driveability, and hot restart.

Conversely, because these gasolines are less volatile, there is some potential for poor cold start and warm up performance on abnormally cold days in early spring when a gasoline of higher volatility would be more ideal. However, this problem is limited to only a few abnormally cold days and primarily to older carbureted vehicles.

The automobile manufacturers have expressed concern about the impact of lower volatility fuels on cold start and warm up performance. The American Automobile Manufacturers Association (AAMA) has advocated that a driveability index be incorporated into the ASTM specifications for gasoline. The ASTM gasoline specification is the recognized industry standard. The AAMA has established their own gasoline specification that refiners can adopt voluntarily. This specification calls for a driveability index of 1200 maximum. The driveability index is a numerical value established by a formula which utilizes the distillation properties of the fuel. Testing and debate on the use of a driveability index and the correct formula for such an index is ongoing.

Acceleration and Performance

Although there are usually no major concerns raised about driveability and performance of reformulated and oxygenated fuels, it is an area that occasionally prompts questions.

First some basics, absent oxygenates gasoline is comprised of hydrogen and carbon (hydrocarbons). Oxygenates are comprised of hydrogen, carbon, and oxygen. One might say that RFG or oxygenated gasolines are simply like other gasolines except containing a small amount of air. Chemically speaking, there is nothing in the composition of an oxygenate that isn't already present in the gasoline and air that comprise the air fuel charge. However, the amount of oxygen is increased slightly (to 2.0 weight percent in the case of RFG). Computerized vehicles adjust for this oxygen once the vehicle is at normal operating temperature. Older vehicles require no adjustments because the oxygen is not at a high enough level to have an impact on a properly tuned engine. To put this in perspective, the oxygen content of the atmosphere changes more with the temperature. Cold winter air is dense and contains more oxygen than in the summer. This seasonal change in oxygen content of the air would have more impact on the air fuel charge of a vehicle than would oxygenated fuels.

The suitable performance of oxygenated fuels has been documented through trillions of consumer miles and numerous fleet tests. In addition, various controlled tests using professional test drivers have been conducted. As an example, the Coordinating Research Council (CRC) conducted tests on various automobiles with total weighted demerits assigned by professional test drivers. In these tests, several oxygenated fuel blends had slightly better driveability (i.e., fewer demerits) than hydrocarbon fuels in both throttle body injected and port fuel injected vehicles. These types of vehicles now comprise the great majority of the current vehicle population.

Another measure of a fuels performance is its octane quality. Octane is a measure of a fuels ability to resist engine knock (pre-ignition or spontaneous combustion of the air/fuel charge). However since oxygenated and reformulated gasolines are available at the same octane levels as conventional gasolines, this is not an issue. Consumers should simply continue purchasing the octane level that has always provided knock free operation.

Because reformulated and oxygenated gasolines continue to meet the same performance specifications as conventional gasoline, motorists should notice no performance differences when using these fuels.

Fuel Economy

Although not a performance issue in the strictest sense, some motorists also consider fuel economy, as expressed in miles per gallon, as a performance characteristic.

Numerous tests have shown that the best predictor of the miles-per-gallon achieved on a given fuel is its energy content or btu content per gallon. The btu content of reformulated and oxygenated gasolines is about 2.0 % to 2.5% lower than conventional gasolines. Based on this a fuel economy penalty of about 2.0% to 2.5% should be expected. On most modern cars this equates to around a half mile per gallon. To some degree the actual change in fuel economy is dependent upon vehicle technology. Some older vehicles may actually experience an improvement in fuel economy as a result of the more complete combustion of these fuels. Newer vehicles have sensors and computer controls that will increase fuel flow to compensate for the oxygen content of the fuel. In these vehicles the fuel economy change is in the expected range of the 2.0% to 2.5% reduction. These fuel economy figures have been confirmed through numerous tests and fleet studies.

Fuel System and Engine Deposits

Another important performance consideration of gasoline is its deposit characteristics. Most gasolines tend to contribute to deposits in carburetors and fuel injectors as well as in the induction system such as on intake valves. These deposits can reduce fuel flow and alter spray patterns resulting in decreased performance and increased emissions. A more recent concern is combustion chamber deposits and the effect they have on engine operation.

Beginning on January 1, 1995 the EPA required that all gasoline contain detergents and deposit control additives that keep carburetors, fuel injectors, and intake valves clean. Subsequent regulations established specific test criteria to adequately demonstrate the cleanliness of additized gasoline. These regulations apply to all gasoline including oxygenated and reformulated gasolines. Consequently, the deposit characteristics of all gasolines are similar in that they should not contribute to carburetor, fuel injector, or intake valve deposits. Some petroleum companies may use additives or treat rates that exceed the requirements of the EPA regulation. For example, some gasolines are advertised to actually decrease or remove deposits that have already formed.

Work on the combustion chamber deposits (CCD) issue is still ongoing. Combustion chamber deposits can increase the octane requirement of a vehicle and in certain engine designs cause a metallic rapping noise (carbon rap) or distort the air/fuel charge in engines with low squish heights, referred to as combustion chamber deposit interference. In addition, excessive combustion chamber deposits can result in increased exhaust emissions. Though the EPA would like to control these deposits, the lack of a standardized industry test and insufficient data have precluded such regulations.

Early work has indicated that some detergents, though cleaning fuel system and induction system components, may increase CCD. The primary fuel factors relating to CCD include the detergent packages and gasoline composition, with heavier hydrocarbons appearing to contribute to the problem. Because oxygenates burn more completely than heavier hydrocarbons, fuels containing oxygenates could actually reduce combustion chamber deposits although the additive package is thought, by many, to be the more important factor.

Glossary of Terms

Given the various disciplines that readers of this paper may represent, the following is provided to clearly define certain terms used in this paper.

Cold Start: Starting a vehicle when the engine is cold such as after setting overnight or after the car has set for an extended period allowing the engine to cool to ambient temperature.

Driveability Index: An index for predicting the cold start and warm up performance of a gasoline. As defined in the AAMA specification, the driveability index (DI) is calculated as follows:

$$DI=1.5 \text{ x } T_{10} + 3.0 \text{ x } T_{50} + T_{90}$$

Where $T_{10,}$ $T_{50,}$ and T_{90} are the 10%, 50%, and 90% evaporated temperatures (˚F) determined by ASTM Test Method D 86.

There is currently a great deal of discussion about the accuracy of this equation when used across a wide range of vehicles. Also most work in developing this equation was done on hydrocarbon only fuels and it may not predict the warm up performance of oxygenated fuels with complete accuracy. Oxygenates do lower the DI (improve warm up performance). The AAMA currently recommends fuels with a DI of 1200 or lower.

Gasoline Specifications: Industry standard specifications for gasoline are set by ASTM on a consensus basis. The specification, ASTM D 4814 is entitled "Standard Specification for Automotive Spark Ignition Engine Fuel". Most states adopt all, or a portion of, ASTM gasoline specifications as state law. Some oil companies and pipeline companies may have specifications which are more stringent than ASTM. In addition the American Automobile Manufacturers Association (AAMA) has their own gasoline specification which refiners and petroleum marketers may adopt on a voluntary basis. The AAMA specification includes requirements over and above the ASTM specification.

Hot Driveability: The driveability and performance of a vehicle once reaching operating temperature especially when ambient temperatures are high.

Hot Start: Starting the engine when it is already at normal operating temperature such as when the engine has been shut off and is restarted in one to twenty minutes.

Vapor Lock: Excessively high volatility fuels or certain vehicle malfunctions can cause fuel to vaporize in the fuel pump, fuel line, or carburetor bowl. Fuel vapor takes up space normally occupied by the fuel resulting in a reduction in fuel flow which in turn leads to erratic acceleration and in severe cases, the engine dies lean (starved for fuel). Additionally when the engine is shut down and underhood temperatures rise, fuel vapor may prevent the vehicle from being restarted until the engine has cooled and the vapors condense back to liquid form.

Warm Up Performance: The driveability and performance of an engine between the time it is cold started until it reaches normal operating temperature.

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