GASOLINE FUEL - PERFORMANCE DETERMINING FACTORS

The most important factors determining the performance of a gasoline in a spark-ignited engine are volatility, antiknock quality, storage stability, component compatibility and deposit control.

Volatility
Spark-ignition engines need a volatile fuel for ease of starting, rapid warm-up and good drivability. In practical terms, this means a fuel that boils in the range of 30 to 215°C (85 to 420°F). A gasoline too light, or too volatile, may lead to poor fuel economy, carburetor icing, increased evaporative emissions and vapor lock in the fuel pump. A gasoline too heavy, or low in volatility, may cause poor starting, inferior drivability, engine deposits and crankcase oil dilution.

Two methods of measuring gasoline volatility are Distillation (ASTM D 86) and Reid Vapor Pressure (ASTM D 323). Distillation measures the boiling range of the hydrocarbons that make up the finished gasoline. Reid Vapor Pressure (RVP) measures the pressure that the fuel exerts under standard conditions at 37.8°C (100°F). From these measurements, the vapor to liquid (V/L) ratio can be calculated using the ASTM D 2533 procedure.

The temperature where V/L = 20 indicates the tolerance of modern vehicles to vapor lock. Higher temperatures increase the likelihood of vapor lock. At low temperatures, other factors such as cold start and warm-up drivability must be considered. This type of performance can be controlled by the ASTM D 86 distillation properties of the gasoline.

In many countries, gasoline volatility specifications change seasonally. In developing national specifications for the U.S. market, ASTM takes into account summer and winter ambient temperatures and elevation above sea level. Gasoline specifications are divided into Volatility Classes for different regions at different times of the year. Regulatory restrictions have significantly lowered summertime gasoline volatility in the U.S. to aid in reducing evaporative emissions

The Coordinating Research Council (CRC) has conducted a number of studies on the effects of gasoline volatility on vehicle performance. These studies, as well as others relating to octane, deposit control and emissions can be accessed online at www.crcao.com.

Antiknock Quality
Under certain conditions, spark-ignition engines can be knock limited. High temperatures, high compression ratios, lean mixtures and advanced ignition timing can lead to knock. Knock is the explosive combustion, or autoignition, of the last portion of the fuel/air mixture. A gasoline's chemical composition determines its ability to resist knock.

Historically, knock has been of concern because of consumer reaction to the audible knock, increased NOx emissions and the potential for engine damage in severe cases. Many modern engines are equipped with knock sensors, and engine-operating conditions such as ignition timing can be continuously adjusted to eliminate knock. However, these adjustments can result in a loss of engine power, which results in a loss in acceleration ability.

Octane is a measure of the ability of a gasoline to resist knock. The antiknock value of a gasoline can be measured in two standard laboratory engine tests. Both methods use the same single-cylinder, variable-compression ratio engine attached to a dynamometer. Different operating conditions characterize each method.

ASTM D 2699 measures the Research Octane Number (RON) of a gasoline; ASTM D 2700 measures the Motor Octane Number (MON). In both tests, the engine compression ratio is adjusted to produce a measured level of knock with the test fuel. This fuel is compared with primary reference fuels producing slightly higher and slightly lower levels of knock. The octane number of the test fuel is determined by interpolating between the two primary reference fuels that bracket the test sample. The reference fuels are blends of iso-octane (octane number defined as 100) and n-heptane (octane number defined as 0).

Of the two procedures, the MON test is more severe, correlating with high-speed, high-temperature, part-throttle conditions in a vehicle. The MON for most gasoline is lower than the less severe RON test, which primarily correlates to a gasoline's ability to resist run-on, after-run or dieseling. The difference between the two ratings (RON - MON) is called the sensitivity of the gasoline.

Neither test exactly correlates with actual service in a car, where driving conditions vary continuously. Road Octane Number (RdON) is a better predictor of quality, and various procedures are available to measure this value, either on the road or a chassis dynamometer. Because no two cars rate gasoline exactly alike, RdON cannot be used as a controlled test. As a compromise, some markets use the Antiknock Index (AKI), which is the arithmetic average of the RON and MON values, shown as (R+M)/2. In the U.S., gasoline octane values are posted as AKI values on gasoline pumps. Other markets choose to express octane value as RON or MON only.

Various organizations around the world have regularly conducted programs to determine the octane requirements of representative car models. In performing this work, the laboratories determine the lowest octane quality that will allow a vehicle to operate knock free under standard test conditions. This test data can be used to generate car satisfaction curves to determine the aggregate octane requirement of a vehicle population.

A vehicle's octane requirement does not remain constant over its life. As the vehicle ages, octane number requirement (ONR) can increase from 1 to 13 octane numbers due to deposit build up on the intake valves and in the combustion chambers.

Storage Stability

Gasoline deterioration in storage is due mainly to oxidative processes. Oxidation leads to the formation of gum, a varnish-like material that can build up in fuel systems and intake systems, interfering with engine operation. In extreme cases, it can cause ring sticking and engine seizure. To guard against this problem, refiners include antioxidants and metal deactivators that reduce the catalytic effect of certain metals in promoting oxidation.

Specifications limit the amount of gum in fresh gasoline to 5 mg per 100 ml, and laboratory oxidation tests are used to control the extent to which oxygen will attack gasoline. Compliance with these limits usually ensures that gasoline will remain usable for up to 12 months. Any gasoline known to have been in storage longer than one year should be retested before use. Because the rate of oxidation doubles with every 10°C increase in temperature, storage conditions play a very important role in stability.

Component Compatibility

Minor amounts of non-hydrocarbon material found in, or added to, gasoline can have adverse effects on engine life and performance. Naturally occurring sulfur, for instance, can result in metal corrosion and exhaust catalyst deactivation; phosphorus and lead also deactivate catalysts; and oxygenated materials, such as alcohols and ethers, can result in damage to certain materials used in fuel systems.

Sulfur Content

Sulfur occurs naturally in all crude oils and is present in refined products. It has been shown (see industry-sponsored studies on www.crcao.com) that sulfur is a temporary poison to three-way catalytic converters. The activity of catalytic converters decreases in vehicles run on high sulfur gasoline, and recovers when the vehicle is run on low sulfur gasoline. Also, currently available lean NOx reduction catalysts are very sensitive to poisoning from sulfur in the fuel. To enable current and future advances in spark-ignited engine emissions, a number of countries have, or are in the process of, regulating gasoline sulfur to very low levels. The European Union, for example, has mandated the use of "sulfur-free" (less than 10 ppm sulfur) gasoline to be phased in over a period of years.

Deposit Control

The intake system includes either a carburetor, throttle body injector (TBI) or port fuel injector (PFI), intake manifold runners and intake valves. Many gasolines contain unstable components that can lead to deposit formation in these high-temperature areas of the induction system. Detergent additives can be used in gasoline to reduce or eliminate deposit formation in critical fuel delivery system components.

Reducing or eliminating these deposits can lead to improved engine power, better drivability, improved fuel economy and reduced emissions. In many cases, gasoline marketers use these additives to differentiate their gasoline. In some countries, the use of these additives is mandatory to aid in emission reductions. In the U.S., the Environmental Protection Agency (EPA) requires these additives at or above a minimum performance dosage, known as the Lowest Additive Concentration (LAC).

Deposits also form in the much higher temperature conditions of the combustion chamber. The formation of these deposits can be influenced by the composition of the gasoline and the type of detergent additives used. Combustion Chamber Deposits (CCD) can result in increased octane number requirement and increased NOx emissions.