Basic Products Course

Module 8: Gasoline
We will cover Gasoline in TWO steps:

This module will have some new information, as well as reemphasize some things discussed in earlier modules. In addition, there is a lesson on Product Application Manuals.

- Gasoline Basics
- Function & Performance

This lesson covers Both sections.
Module 8: Gasoline

Part 1: Gasoline Basics
As you’ve become accustomed to: Let’s kick this Module off with some questions to get you thinking about the subject matter.
Gasoline – Gasoline Basics

The three parts of the fire triangle are: source of ignition, fuel vapor, and oxygen.

QUICK QUESTION:
Which part do you think gasoline satisfies?

- Fuel vapor
- Ignition
- Spark
During normal combustion the flame starts at one point and spreads outward.

**QUICK QUESTION:**

From that one point, what should the flame spread be like?

- Rough and explosive
- Smooth and controlled
When the gasoline burns unevenly, the engine shakes and produces a "pinging" noise. What is this common condition called?

- Knock
- Deposit control
- Viscosity
- Volatility

The easiest gasoline "quality" for the motorist to recognize is knock. The most important gasoline quality(ies) is(are)

- Anti-knock.
- Volatility.
- Color.
- Both A and B.
Gasoline – Gasoline Basics

- A gasoline's resistance to knock is expressed by its octane number.
  - MINIMUM OCTANE RATING: (R+M)/2 METHOD ( 92 )
  - MINIMUM OCTANE RATING: (R+M)/2 METHOD ( 87 )

**QUICK QUESTION:**

If a gasoline's anti-knock quality is high, its octane number is

- High
- Medium
- Low
### QUICK QUESTION:

Additives blended with gasoline to increase the anti-knock quality can be:

- **Iron**
- **Alcohols**
- **Ethers**
- **Both B and C**

### QUICK QUESTION:

Most cars today have catalytic converters. Which type of gasoline cannot be used with catalytic converters?

- **Unleaded**
- **High octane**
- **Leaded**
- **Low octane**
High compression ratios tend to cause more knock. Engines with a high compression ratio require fuels with:

- High anti-knock quality.
- Low anti-knock quality.

The anti-knock additives TEL and TML cannot be used in unleaded gasoline. What kind of additives are TEL and TML?

- Lead-based
- Acid-based
- Oxygenates
Gasoline – Gasoline Basics

- A volatile liquid is one that changes to vapors at low temperatures.
- Good gasoline is volatile.

QUICK QUESTION:

Gasoline makes a good motor fuel because it:

- **Vaporizes at extremely high temperatures.**
- **Will not vaporize.**
- **Vaporizes at low temperatures.**
- **Always remains in its liquid state.**
QUICK QUESTION:
The temperatures at which gasoline vaporizes determine many engine operations. Starting, warm-up, and acceleration can be affected by

- Volatility.
- Grease.
- Passengers.
- The wheels.

★ You may be asking, is it all this easy?

★ Well, almost. You'll have to do a little work.
★ So let's get started
This lesson will cover what gasoline is made from, its properties, the different types and uses, and an introduction to its qualities.

**GASOLINE BASICS:**

- We will cover gasoline basics in FOUR steps:
  - Definition of Gasoline
  - Gasoline Properties
  - Types and Uses of Gasoline
  - Introduction to Gasoline Qualities
Definition of Gasoline

What is gasoline?

Gasoline is a blend of more than 200 different types of hydrocarbons.

REVIEW: Hydrocarbons are organized into four classifications, with various degrees of:

- Volatility
- Stability
- Potential heat output
Gasoline – Gasoline Basics

Gasoline has FIVE major components: the four classifications plus additives

- Paraffins
- Naphthenes
- Olefins
- Aromatics
- Additives

The two most important reasons for blending additives into gasoline are:

- Increase octane (such as in aviation fuel)
- Keep the engine clean (required by law)

Gasolines have different combinations of these five major components.
QUICK QUESTION:

Gasoline is composed of naphthenes, olefins, aromatics, paraffins and…

- Asphalt.
- Bright stock.
- Additives.
- Liquid methane
Gasoline – Gasoline Basics

Gasoline Properties

Gasoline is a liquid fuel that has certain properties. In order to function as a fuel it must:

- Form an ignitable air/fuel mixture.
- Burn in a smooth and controlled manner.

Gasoline properties are discussed in more detail in Lesson 2. For now, you should be able to identify properties.
Gasoline – Gasoline Basics

Form an ignitable air/fuel mixture:

In the Chemistry Module, we learned about the Fire Triangle. For combustion to occur, three conditions are necessary:

- Spark from spark plug
- Oxygen from the air
- Fuel vapor from gasoline (Gasoline must be in its vapor state at the proper temperature for it to ignite.)

Gasoline is highly volatile, so it makes an excellent fuel.
QUICK QUESTION:

To function well as a motor fuel, gasoline must:

- Vaporize at the proper temperature.
- Never change its state.
- Explode with great power.
- Burn slowly to prevent vapor lock.
Burn in a smooth and controlled manner:

Gasoline must form an ignitable mixture and burn in a smooth, controlled manner.

What does that mean?

- The fuel-air mixture must ignite at only one point in the combustion chamber. From that one point, the flame spreads outward in a smooth, controlled progression.
- If the mixture burns unevenly, the car will knock or ping.
QUICK QUESTION:

Gasoline's most important properties are to form an ignitable air/fuel mixture, and to:

- *Burn in an explosive manner.*
- *Burn in a smooth, controlled manner.*
- *Change states at regular intervals.*
- *Change the pressure of the combustion chamber.*
Gasoline – Gasoline Basics

Types and Uses of Gasoline

There are several different types of gasoline. We will discuss two:

- Aviation Gasoline
- Motor Gasoline

**Aviation Gasoline:**

- Aviation gasoline is made to very strict specifications. Its use is limited to propeller driven piston type aircraft. These planes are predominantly for private use. Jet engines do not use this type of fuel.
- Commercial and military aircraft generally do not use this type of fuel.
QUICK QUESTION:

Aviation gasoline is used in which kinds of aircraft?

- Piston-type
- Jets
- Outboard
- All of the above
Motor Gasolines:

Motor gasoline is the most common type of fuel. It is used in all kinds of vehicles including:
- Cars
- Trucks
- Buses
- Farm tractors
- Marine engines

Leaded and Unleaded are the two types of motor gasoline. However, the sale of leaded gasoline was prohibited in 1996 for vehicles. Aviation gasoline may still contain lead. (But even that is changing.)
- Of all types, motor gasoline represents by far the greatest volume usage.
QUICK QUESTION:

The two types of motor gasoline are:

- Aviation and white.
- High octane and low octane.
- Leaded and unleaded.
- Aviation and factory-fill.
Unleaded Gasoline:

- Required by all cars now as of 1996 due to environmental and health issues.
- Cannot be blended with lead for anti-knock.
- Anti-knock quality achieved by blending gasoline stocks having naturally high octane and by using other octane improvers.

Unleaded gasoline is designed for 1975 and later cars, but it can be used in older cars.
QUICK QUESTION:

Why is unleaded gasoline a blend of stocks having naturally high octane?

- Increase anti-knock quality
- Decrease anti-knock quality
- Produce many different types of lead
- Combine non-combustible
Gasoline has SIX important qualities. They are listed by order of importance from anti-knock (most important) to color (least important).

1. Anti-knock (Most Important)
2. Volatility
3. Deposit Control
4. Storage Stability
5. Corrosion Prevention
6. Color (Least Important)

These qualities are covered in more detail in Lesson 2. For now, we will define each quality.
1. **Anti-knock:** Anti-knock components are added to gasoline to prevent knock. But first, what is knock?

- Knock comes from the uneven burning of fuel. When the end gas (the last portion of the air/fuel mixture to burn) explodes rather than burning evenly, the engine KNOCKS. It produces "ping" or "knock" sounds which shake the engine and the motorist.

- Besides being an annoyance to the driver, knock can also cause power and economy loss, and severe engine damage. This is why ANTI-KNOCK is a very important gasoline quality.

- ANTI-KNOCK prevents the uneven burning of fuel.

- Historically, knock was the gasoline "quality" easiest for a motorist to recognize. But with most modern engines, the knock sensor will temporarily retard the spark timing to eliminate knocking. This makes it more difficult to know if the octane is too low for the engine because the characteristic knocking can't be heard. The symptoms on more modern vehicles would often be a loss of power and acceleration caused by the retarded spark.
**QUICK QUESTION:**

*Engine knock can cause:*

- **Power and economy loss.**
- **Evaporation loss.**
- **Vapor lock.**
- **Deposits.**

**QUICK QUESTION:**

*Anti-knock quality helps to prevent:*

- **Undesirable materials from forming in gasoline.**
- **Deposits which build up in the fuel system.**
- **Evaporation loss.**
- **Uneven burning of fuel.**
2. Volatility: Measures how easily a liquid vaporizes.

- You should be familiar with volatility from the Chemistry Module. Let's briefly review volatility...

- REVIEW: A liquid turns to vapor at its boiling point. The lower a liquid's boiling point, the more volatile it is. Gasoline vaporizes at low temperatures.

- Gasoline is composed of parts which vaporize at different temperatures. Consequently, gasoline has a boiling range.
QUICK QUESTION:

What measures how easily a liquid vaporizes?

- Anti-knock
- Volatility
- Octane
- Knock
Gasoline – Gasoline Basics

- At proper temperatures volatility affects:
  - Starting
  - Warm-up
  - Vapor lock
  - Fuel mileage
  - Acceleration
  - Crankcase dilution
  - Manifold distribution
  - Evaporation loss

- This one quality affects so many aspects of vehicle performance...
QUICK QUESTION:

Proper _________________ provides quick starting and warmup, no vapor lock, and good fuel economy.

- Acceleration
- Octane
- Anti-knock
- Volatility
3. Deposit Control:

Deposit Control is the third most important quality of gasoline. Where are these deposits and how are they controlled?

Deposit control additives prevent the formation of deposits in the fuel system and combustion chambers. It is required by the EPA (Environmental Protection Agency) that you must control deposit formations that can lead to poor engine operation and increased emissions.

Gasoline with the proper additives controls deposits.
QUICK QUESTION:

What are the three most important qualities of gasoline?

- Volatility, non-corrosive, anti-knock
- Anti-knock, octane, deposit control
- Anti-knock, volatility, deposit control
- Volatility, deposit control, storage stability
4. **Storage Stability:**

- Gasoline must be stable enough to keep its composition during storage. In other words, gasoline with storage stability prevents undesirable materials from forming in gasoline.

- Gasoline additives must also retain their composition.
Quick Question:

Which gasoline quality prevents undesirable materials from forming over time?

- Color
- Anti-knock
- Volatility
- Storage stability
5. **Corrosion Prevention:**

Gasoline with a low sulfur content reduces the formation of acids that damage engine parts. Where do these acids come from?

Sulfur in gasoline burns in the combustion chambers with the fuel. When sulfur burns it forms sulfur dioxide. Sulfur dioxide, when combined with water, forms acids which attack metal.

Today, this quality is a minor factor as government regulations have brought sulfur to very low levels. The push for this low sulfur is primarily to avoid catalyst poisoning and Sulfur Dioxide emissions from exiting the tailpipe.
QUICK QUESTION:

To protect metal components from acid, gasoline must be:

- Non-corrosive.
- Vaporized.
- Sulphuric.
- Volatile.
6. **Color:**

- Color is the least important quality of gasoline.
- Colors (dyes) are added for product identification.
- The color of gasoline does not indicate the quality.
- The natural color of gasoline is water white.
**QUICK QUESTION:**

One indication of a gasoline's quality is its color.

- True
- False

**QUICK QUESTION:**

What is the most important quality of gasoline?

- Corrosion prevention
- Deposit control
- Volatility
- Anti-knock
THAT COMPLETES GASOLINE BASICS

Now it’s time for a quick BREAK!

Then go to FUNCTION AND PERFORMANCE, Lesson 2 in this Module.
Module 8: Gasoline

Part 2: Function and Performance
This lesson will discuss combustion, anti-knock, volatility, deposit control, and other gasoline qualities.

GASOLINE FUNCTION AND PERFORMANCE

The material will cover gasoline qualities in FOUR steps:

- Anti-knock
- Volatility
- Deposit Control
- Other Gasoline Qualities
Gasoline – Function and Performance

Anti-knock

Anti-knock is the most important quality of gasoline. In this section we'll discuss:

- a. Normal and abnormal combustion
- b. Compression ratio and knock
- c. Octane number and anti-knock
- d. Measuring anti-knock quality
- e. Increasing octane
- f. Unleaded gasoline
- g. Octane requirements
a. Normal and abnormal combustion:

- Normal Combustion: With normal combustion, the flame ignites the air-fuel mixture at one point in the combustion chamber. The flame spreads outward from the spark plug, in a smooth, progressive manner eventually burning all of the mixture.
  - Although the flame spreads rapidly, the ignited fuel-air mixture does not produce an explosion.

- During normal combustion, there should be no abrupt pressure changes in the combustion chamber.
QUICK QUESTION:

With normal combustion the air-fuel mixture is ignited at:

- Several points simultaneously in the combustion chamber.
- One point in the combustion chamber.
- One point in the carburetor.
- The exhaust port.
Abnormal combustion: Results in rough or explosive burning in the combustion chamber. It is caused by two conditions:

- Auto-ignition
- Surface Ignition

Auto-ignition: occurs when high temperature and high pressure cause combustion:

- before the spark plug fires (preignition)
- after the ignition switch is turned off (run-on).
- Auto-ignition causes knock and run-on.
QUICK QUESTION:

Auto-ignition results in abnormal combustion due to:

- High pressure and high temperature.
- High pressure and low temperature.
- Low pressure and low temperature.
- Low pressure and high temperature.
Surface Ignition: a result of a hot, glowing surface in the combustion chamber. Combustion starts before the normal spark. The ignition source could be a hot surface such as:

- Valve face
- Spark plug
- Protruding head gasket
- Deposit from previous combustion

Surface ignition also causes knock and run-on.
QUICK QUESTION:

Surface ignition results in abnormal combustion due to:

- Cool surface.
- Low pressure.
- Low temperature.
- Hot surface.
Auto-ignition and surface ignition cause knock and run-on. Let's briefly review knock and define run-on.

REVIEW: Knock is a pressure wave created by auto-ignition. It shakes the engine and causes the noise known as "knock" or "ping". Knock lowers engine efficiency by overheating and overloading the engine parts, such as piston tops. This could lead to severe engine damage.

DEFINITION: Run-on (or dieseling) occurs when the engine continues to run after the ignition switch has been turned off. The fuel is ignited by high compression temperature. Although not as potentially severe as knock, run-on can cause engine damage.

Both auto-ignition and surface ignition are caused by extra sources of ignition.
b. **Compression ratio and knock:**

- The compression ratio is the volume in the cylinder with the piston at the bottom divided by the volume with the piston at the top.

\[
\text{Compression Ratio} = \frac{\text{Volume at bottom}}{\text{Volume at top}}
\]

- The larger the difference, the higher the compression ratio. In effect, with higher compression ratios the air-fuel mixture is "squeezed" harder.
Gasoline – Function and Performance

- High compression ratios are beneficial because they increase engine performance resulting in:
  - Higher power output
  - Increased engine efficiency
  - Fewer gallons of fuel required to do the same job

- However, high compression ratios also have adverse effects.... let's see why:

- High compression ratios create higher temperatures and pressures at the end of the compression stroke. These can cause:
  - Combustion process to start at a high temperature
  - Unburned portion of fuel to be exposed to higher temperatures for longer time

- To put it simply, higher compression ratios tend to cause more auto-ignition and knock. Therefore, these engines require fuels with higher anti-knock quality.
**QUICK QUESTION:**

Higher compression ratios tend to cause:

- More auto-ignition and knock.
- Lower engine efficiency.
- Less auto-ignition and knock.
- More auto-ignition and less knock.

**QUICK QUESTION:**

The tendency of engines with high compression ratios to auto-ignite is offset by fuels with:

- High volatility.
- Low volatility.
- High anti-knock quality.
- Low anti-knock quality.
A gasoline with a high anti-knock quality will:

- Resist auto-ignition
- Withstand more heating from the first part of combustion and still not ignite before the normal flame reaches it

High anti-knock quality gasolines have a greater resistance to being ignited suddenly by the heat of compression.
QUICK QUESTION:

A gasoline with high anti-knock quality resists:

- Auto-ignition.
- Deposits.
- Corrosion.
- Vaporization.
c. **Octane number and anti-knock:**

- **Octane Number**: Rating of gasoline's anti-knock quality or resistance to auto-ignition.
- A high resistance to auto-ignition gives a high anti-knock quality, which is shown by a fuel's high octane number.
- Higher octane does not make an engine run with more power. If an engine is knocking, increased octane can improve performance. If the engine runs smoothly, higher octane will not increase power.
- Octane does not indicate gasoline quality, or the amount of energy in the gasoline.
QUICK QUESTION:

A gasoline's resistance to auto-ignition is expressed by its:

- Distillation curve.
- Compression ratio.
- Octane number.
- Volatility range.
QUICK QUESTION:

Octane numbers are determined by a rating procedure which uses standardized test equipment. A gasoline with a high resistance to auto-ignition has a:

- Low anti-knock quality and low octane number.
- Low anti-knock quality and high octane number.
- High anti-knock quality and low octane number.
- High anti-knock quality and high octane number.

QUICK QUESTION:

More power is always produced by using higher octane gasoline.

- True
- False
d. Measuring anti-knock quality:

- Measuring a gasoline's anti-knock quality involves reference fuels, comparison tests, and standardized methods.
- The two reference fuels are pure, simple compounds which have known anti-knock values. They are iso-octane (100) and normal heptane (n-heptane) (0).
- Iso-octane and n-heptane are used in every method of measuring for anti-knock quality.
These fuels are mixed together to make different blends with varying octane values. For example...

- 80% iso-octane blended with 20% n-heptane ➞
  - New reference fuel with octane value of 80
- 90% iso-octane blended with 10% n-heptane ➞
  - New reference fuel with octane value of 90

To test a gasoline's anti-knock quality, the reference fuels are used in the comparison testing.
Quick Question:

Iso-octane is a compound with an anti-knock value of 100.

- True
- False

Quick Question:

What would the octane rating of a reference fuel be if it were 75% iso-octane and 25% n-heptane?

- 100
- 75
- 50
- 25
Gasoline – Function and Performance

**Comparison Test**

Gasolines are tested for their anti-knock value in a special, stationary engine. The engine is made to knock on the gasoline with the unknown anti-knock quality.

Under the same conditions, the stationary engine is then run with a blend of iso-octane and n-heptane. The engine is operated on different blends until a blend matches the knock intensity of the "unknown" gasoline. The percentage of iso-octane in that blend is the octane value assigned to the original "unknown" gasoline.

In this example, the gasoline tested has the octane rating of 85.
An octane number is assigned to the "unknown fuel" by using this comparison test; however, the engine can have a strong effect on the results.

To standardize the testing of gasolines, the American Society for Testing and Materials (ASTM) has established common measures for testing gasolines in the lab. Laboratory octane numbers are determined in much the same way as the comparison test. Two similar methods are used:

- Research Method: Provides an estimation of how the gasoline will perform under low speed and low heat.
- Motor Method: Provides an estimation of how the gasoline will perform under high speed and high heat.

Let's look at the similarities between the Research Method and Motor Method.

- Both methods use single cylinder engines for use in standard laboratory octane number measurements.
- Both engines are designed so the compression ratios can be easily changed while the engine is running.
Gasoline – Function and Performance

**Laboratory Octane Numbers**

The steps for the Research and Motor Methods are also the same:

- An unknown fuel is placed in the engine.
- If it does not knock, the compression ratio is increased until moderate knock is obtained.
- Different blends are then run in the engine until it knocks at the same compression ratio.
- The percentage of iso-octane in that blend is the octane number of the unknown fuel.

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<thead>
<tr>
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<th>Motor</th>
<th>Research</th>
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<tbody>
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<td>600</td>
</tr>
<tr>
<td>Intake Air Temperature</td>
<td>100°F</td>
<td>125°F</td>
</tr>
<tr>
<td>Mixture Temperature</td>
<td>300°F</td>
<td>not controlled</td>
</tr>
<tr>
<td>Spark Advance</td>
<td>From 19° to 26° BTDC</td>
<td>13° BTDC</td>
</tr>
<tr>
<td>Unknown fuel Octane Rating</td>
<td>85 octane value</td>
<td>95 octane value</td>
</tr>
</tbody>
</table>
Although research and motor methods are much the same in design, their operating conditions are very different...

The Motor Method is more severe and yields lower octane numbers than the Research Method. The typical octane difference between the methods is 8 to 12 points.

The Motor Method determines the Motor Octane Number, or MON. The Research Method determines the Research Octane Number, or RON.

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</tbody>
</table>
QUICK QUESTION:

The engines used for both the research and motor methods have variable:

- Compression ratios.
- Intake temperatures.
- Engine speeds.
- Spark advances.

QUICK QUESTION:

Which of the two laboratory octane number methods produces the more severe (lower) octane numbers

- Motor
- Research
Since there is a difference between RON and MON, the two are averaged to assign an octane number to a gasoline. The formula is:

- For example, if the results from testing the same gasoline were:
  - RON at 91 & MON at 83
  - Add RON and MON and divide by 2 (91 + 83 = 174, 174/2 = 87)
  - This gasoline would be rated at 87 octane.
  - This measure of gasoline anti-knock quality is referred to as the Anti-knock Index (AKI).
  - Its formula should be familiar......you've seen it many times
  - (RON + MON) / 2
  - 87

By federal law this must be posted on gasoline dispensers.
Now that we know how an octane rating is determined for fuels, let's see how the anti-knock quality can be increased.

e. **Increasing octane:** There are three ways to increase the octane in a gasoline: Add lead-based additives (Aviation only), Blend lower octane stocks with higher octane stocks, and Add oxygenated-blending agents or chemicals

- **Add lead-based additives:** Lead-based additives are a very economical way to increase octane, but for environmental reasons this can now only be done to aviation gasoline.
  - Tetraethyl lead (TEL) and tetramethyl lead (TML) are two lead alkyls. TEL is used in concentrations of about 0.1 grams per gallon in leaded gasoline. Although once common, TML is no longer used.
  - Since unleaded gasoline cannot use lead to improve octane, it must rely on other methods.
Gasoline – Function and Performance

- Blend lower octane stocks with higher octane stocks: The process of blending stocks naturally high in octane is expensive and must be done at the refinery.
- Add oxygenated-blending agents: This is usually ethanol, but there are various others:
  - Tertiary Amyl Methyl Ether (TAME)
  - Methyl Tertiary Butyl Ether (MTBE)

  TAME & MTBE are no longer used in the U.S.

**SUMMARY**

- Lead-based additives are an inexpensive and very effective way to increase the octane rating of gasoline. However, due to health concerns, the lead phase-down has nearly eliminated their use.
- Other ways have been developed (oxygenates and refinery processes) to increase octane, but none have proven to be as inexpensive.
- Since it is not economical to produce unleaded high-octane gasolines, car manufacturers have redesigned engines for lower octane.
QUICK QUESTION:

What is the purpose of anti-knock additives?

- Reduce autoignition
- Reduce vapor lock
- Increase gasoline octane
- Both A and C

QUICK QUESTION:

Lead-based additives cannot be used in unleaded gasoline.

- True
- False
f. Unleaded gasoline:

- The Environmental Protection Agency (EPA) has eliminated leaded gasoline for the protection of the environment and the motorist (the Law was enforced in 1996).

- The EPA has restricted the amount of lead to reduce lead contamination of the environment, and to protect catalytic converters.

- Phosphorous is also restricted to protect against deactivation and deterioration of catalytic converters.

<table>
<thead>
<tr>
<th>Legal Restriction</th>
<th>Lead</th>
<th>Phosphorous</th>
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<tbody>
<tr>
<td>Reason for Restriction</td>
<td>Hazardous to environment and to catalytic converters</td>
<td>Hazardous to catalytic converters</td>
</tr>
<tr>
<td>Maximum accidental contamination of 0.05 grams per gallon</td>
<td>Maximum accidental contamination of 0.005 grams per gallon</td>
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</table>

The combination of catalytic converters and unleaded gasoline meets the EPA regulations and also leads to a cleaner environment.
QUICK QUESTION:

The EPA regulates the use of lead and _____________ in unleaded gasoline.

- Octane
- Additives
- Phosphorous
- Anti-knock quality
Gasoline – Function and Performance

In addition to meeting the requirements of catalytic converters, unleaded gasoline has other benefits:

- Extends spark plug life: Leaded gasoline tends to foul spark plugs, reducing engine power, economy, and smoothness.
- Extends exhaust system life: With an unleaded gasoline, a muffler will have one and one-half times the life it would have with a fully-leaded gasoline.
- Reduces engine rusting: Unleaded gasoline does not have lead scavengers which can cause rust. Lead scavengers are especially damaging to engines running in stop-and-go traffic.
- Reduces wear of hydraulic valve lifters, piston rings, and cylinder walls: Wear between camshaft and hydraulic valve lifter bottoms is directly related to the lead content of gasolines. It has been greatly reduced by the use of unleaded gasoline.
Gasoline – Function and Performance

Unleaded gasoline also has a few disadvantages:

- Higher cost to manufacture: Refining processes required for high anti-knock are expensive.
- Octane Requirement Increase (ORI) may be higher: The ORI of unleaded gasoline is generally higher than the ORI for leaded gasoline. We'll talk more about ORI later.
- Potential problems with some smaller and older engines: With unleaded gas some small engines (lawnmowers, motorcycles, outboards) have shown problems such as ring wear. In some older engines, it may cause valve seat wear and stem scuffing.
g. Octane requirements:

Octane Number Requirement (ONR) is the octane level an engine must have to prevent knock. With brand new cars, the engine ONR is determined by:
- combustion chamber design
- compression ratio

However, after the first several thousand miles, the ONR of a new car may change.

Knock occurs when end gases explode. If end gases are ignited by the flame front started at the spark plug, combustion is normal.
- Extremely high compression temperatures may cause the end gas to autoignite (INCREASED COMBUSTION TEMPERATURES)
- The longer the flame front takes to reach the end gas, the greater the probability that the end gas will autoignite (INCREASED COMBUSTION TIME)

Increased combustion temperatures or increased combustion times can be caused by engine design by operating conditions.
QUICK QUESTION:

End gas autoignition could be caused by engine design or by:

- EPA regulations.
- Volatility reduction.
- ONR index.
- Operating conditions.
Temperature and time changes can be caused by Engine Design or by Operating Conditions.

ENGINE DESIGN:
- Combustion chamber design
- Compression ratio

Combustion Chamber: Combustion chamber design affects both flame speed and the temperature of the end gas.

Compression Ratio: The compression ratio of the engine affects the heat of compression. To reduce autoignition, engines with high compression ratios require high octane fuel.
QUICK QUESTION:

What single factor most affects the heat of combustion?

- Atmospheric pressure
- Compression ratio
- Anti-knock index
- Air-fuel ratio
OPERATING CONDITIONS:
- Air temperature
- Barometric pressure
- Humidity
- Power output
- Engine speed
- Air-fuel ratio
- Transmission type

Air temperature: As the intake air temperature rises, the compression temperature increases. This increases the knocking tendency of the engine.

Barometric pressure: Large changes in altitude have an effect on octane requirement. At 6000 feet, the octane decrease will range from 9 to 14 points.
Gasoline – Function and Performance

- Humidity: Moisture in the air can decrease an engine's octane requirement in two ways:
  - Moisture enters the engine intake and cools the combustion process.
  - Water vapor is added to the air/fuel mixture entering the engine.

- Power Output: The engine burns large amounts of fuel at high power output. This heats up the valves and the chamber. High power outputs result in higher compression temperatures. High combustion temperatures can produce knock. Most engines have their highest octane requirement at high power output.

- Engine Speed: Most engines tend to knock less at higher rpm. This is a result of faster flame speeds (more combustion turbulence) and poorer breathing ability of the engine.
Air-fuel Ratio: An engine has its highest octane requirement at lean mixtures. At rich mixtures, the flame speed increases, reducing combustion time. The added fuel also provides a cooling effect as it vaporizes.
- Rich 8.0:1 Ideal 14.7:1 Lean 12.0:1

Transmission Type: Manual transmissions can load the engine down to very low speeds. At low speed and high load, the engine has a high octane requirement. Automatic transmissions use torque converters which cannot completely load the engine below about 1500 rpm. Automatics usually have a lower octane requirement than the same engine with a manual transmission.
- Under some operating conditions, a higher-octane gasoline is required.
- Under other operating conditions, a lower-octane gasoline is adequate.
QUICK QUESTION:

What effect do higher air temperatures and more power output have on the ONR of an engine?

- No effect
- Increase ONR
- Decrease ONR

QUICK QUESTION:

What effect do higher altitude and increased humidity have on the ONR of an engine?

- No effect
- Increase ONR
- Decrease ONR
Gasoline – Function and Performance

- As combustion chamber deposits build up, an engine may require a higher octane fuel. This is called Octane Requirement Increase (ORI).

- When a car is new, the combustion chamber is clean. However, over time deposits begin to accumulate. These deposits create hot spots. Combustion temperatures increase. Fuel additives may reduce deposits, but ORI will not usually return to its original level.

- The ORI varies model-to-model and even among cars of the same model. The increase is usually about 5 points, but can be as high as 13 points. Generally, cars that use unleaded fuel have a higher ORI than cars using leaded fuel. Cars with manual transmissions have a higher ORI than do cars with automatic transmissions.
We will discuss the volatility of gasoline in SIX sections:

- 1. Volatility Range
- 2. Measuring Volatility
- 3. Front End Volatility
- 4. Midrange Volatility
- 5. Back End Volatility
- 6. Blending to Control Volatility
1. Volatility Range:

- The ability of gasoline to form vapors is critical for engine operation. To burn, gasoline must be a vapor. When gasoline vaporizes too soon or too late it can cause engine problems. Correct volatility provides for:
  - Quick starting
  - Quick warm-up
  - No vapor lock
  - Good fuel mileage
  - Good acceleration
  - Minimum crankcase dilution
  - Uniform manifold distribution
  - Low evaporation loss

- Correct volatility allows the vehicle to operate under all normal operating conditions.
QUICK QUESTION:

Vapor lock, fuel mileage, warm-up, and starting are all affected by:

- Anti-knock.
- Volatility.
- Deposit control.
- All of the above.
Gasoline is a blend of hydrocarbons that have different boiling points. Some hydrocarbons have very high volatility and others have low volatility. The temperature range can be from 90°F (high volatility) to 420°F (low volatility). The proportion of high, medium, and low volatility hydrocarbons must be correct for efficient engine operations.

Each hydrocarbon (high, medium, and low volatility) has specific functions in engine operation. Proportions of each type are critical.
2. **Measuring Volatility:**

- To determine a gasoline's volatility range, different tests are run on a sample of the gasoline. Two of the tests are:
- **Reid Vapor Pressure (RVP):** This test measures gasoline volatility. RVP varies from about 9 psi to 15 psi depending on seasonal requirements and restrictions imposed by environmental agencies.
ASTM Distillation Test: This test measures the temperatures at which given percentages of the sample are evaporated. From these temperatures a distillation curve is generated. The curve separates the sample into three ranges of volatility:
- front end (high)
- midrange (medium)
- back end (low)

This provides an indication of how the gasoline will function under different conditions.
Gasoline – Function and Performance

Let's look at a typical distillation curve and some of the effects of front end, midrange, and back end volatility.

The temperatures shown on the distillation curve are not precise. They indicate a general range of temperatures.
QUICK QUESTION:

Two methods of measuring volatility are:

- ASTM Distillation and Distillation Curve.
- Front End and Back End Methods.
- Motor and Research Methods.
- ASTM Distillation and Reid Vapor Pressure.
3. **Front End Volatility:**

   Front end volatility affects cold starting, vapor lock, intake manifold distribution, and evaporation losses.

   **Cold Starting**
   - In cold weather, there is no engine heat to vaporize the fuel. If the fuel is not volatile enough, the mixture will be too lean and the engine will not fire.
   - Keep in mind that the fuel may not be at fault in cold starting failure. It could also be the condition of the battery, ignition, or choke setting.

   **Vapor Lock**
   - If the fuel is too volatile, it changes to vapor in the fuel system. Vapor formed in the system causes a gradual lean-out of the air-fuel mixture, resulting in loss of power. Too little fuel will reach the engine for it to run.
   - Complete vapor lock stops the engine.
Gasoline – Function and Performance

- **Intake manifold distribution**
  - Improper manifold distribution results in poor fuel distribution to each cylinder. Liquid fuel in the manifold is the prime cause of poor distribution. A more volatile fuel helps manifold distribution, but engine design can also be the problem.

- **Evaporation Losses**
  - Fuel vapor is generated at several points in the fuel system. Vapors form, for example, in the fuel tank vent and carburetor vent. The amount of vapor is normally small, and is controlled by the front end volatility and the fuel system temperatures.

- There is a delicate balance among the three volatility ranges.
QUICK QUESTION:

Cold starting is possible because of:

- Front end volatility.
- Midrange volatility.
- Back end volatility.
Gasoline – Function and Performance

4. **Midrange Volatility:**

- Midrange volatility is important for warm-up and acceleration.

  **Warm-up**

- Warm-up is the time needed after starting for the engine to give a smooth, powerful response when the driver "steps on the gas." Besides midrange volatility, the warm-up time is affected by the engine's design including:
  - Lean air/fuel ratios
  - Retarded spark timing
  - Fast-opening automatic chokes required for low exhaust emissions
Gasoline – Function and Performance

Acceleration

- After warm-up, the engine may still tend to hesitate on acceleration if the midrange volatility is too high. When midrange volatility is too high, the fuel may not vaporize completely.

- For smooth acceleration, the air/fuel mixture must be sufficiently volatile to ensure adequate vaporization.

Midrange volatility is important for warm-up and acceleration.
QUICK QUESTION:

Midrange volatility is important for acceleration and:

- Warm-up.
- Cold starting.
- Engine deposits.
- Hot engines.
5. **Back End Volatility:**

Back end volatility affects crankcase dilution and fuel mileage. Crankcase dilution occurs when fuel gets into the crankcase oil. This is caused by:

- Fuel system leaks
- Liquid fuel and fuel vapors leaking past piston rings

If back end volatility is too high, it could cause dilution. However, the major causes of dilution are mechanical factors.

**Fuel Mileage**

- The fuel economy is determined by the amount of higher energy (heavier) molecules in the gasoline blend. These molecules have a higher boiling point.

Next, we'll look at how a balance is achieved through blending for proper volatility. But first,
QUICK QUESTION:

Fuel mileage is largely affected by _________ volatility.

- Front end
- Midrange
- Back end
6. **Blending to Control Volatility:**

- One gasoline blend cannot supply the best performance for all conditions.
  - The best fuel for starting in cold weather could cause vapor lock and evaporation loss in hot weather.
  - The best fuel for fuel mileage could cause crankcase dilution.
- Gasolines are blended to meet a wide range of volatility requirements.
  - To ensure that the best blend is provided to the customer, the volatility changes with the seasons and geography.
  - "Winter" blend: To provide for cold starting, a winter blend vaporizes readily at low temperatures.
  - "Summer" blend: To prevent hot engine (vapor lock) problems, a summer blend is less volatile than a winter blend.
Blends are also changed to comply with air resources laws in some states.

Fuels are seasonalized on an ongoing basis. There is no deadline for the last day of "winter" blend and the first day of "summer" blend.

**QUICK QUESTION:**

A "summer" blend has a lower volatility than a "winter" blend.

- True
- False
There are some other potential blending problems. For example...

- If fuel is blended for cold weather and is used in hot weather, it could result in hot engine problems such as vapor lock.

- If fuel is blended for hot weather and is used in cold weather, it could result in poor starting and warm-up.

Gasolines will also "weather" or lose volatility during storage because of evaporation.
Gasoline – Function and Performance

_deposit control_ is an important quality of gasoline. Engine deposits can cause: _Reduced fuel economy, Loss of power, and Increased exhaust pollutants._

Deposits can be caused by:
- **Blowby Material:** Blowby is leakage of air-fuel mixture and some burned gases past the piston rings into the crankcase during the compression and combustion strokes.
- **Exhaust Gas**
- **Dust and Dirt**
- **Gum:** Gum is formed by the oxidation of fuel during storage.

In the engine, deposits are most critical in:
- 1. Intake System
- 2. Combustion Chamber
1. Intake System: In the intake system, deposits can form on the carburetor or fuel injectors, intake manifold, intake ports, and intake valves. Valve deposits are the most troublesome of all intake deposits. They can cause:

- Valves to stick, reducing flow area
- Valve burning and power loss
2. Combustion Chamber: Deposits on the walls of the chamber act as insulation, blocking heat transfer. The deposits form hot spots, causing autoignition and knock.
The gasoline blend can help to control these deposits by:

- **Additives**: Some additives cause a coating of the surface which prevents the deposits from sticking. Detergent additives break up deposits so that they can be removed.
- **Volatility**: Low volatility "heavy ends" can contribute to the formation of deposits.

Deposits can also be controlled by certain operating conditions including:

- **Reducing stop-and-go driving**: Stop-and-go driving causes the most rapid buildup of deposits.
- **Running the engine with a high power output**: A high load can "shuck off" a large portion of non-burnable material.
In this last section we cover three other gasoline qualities: a. Storage Stability, b. Corrosion Prevention, c. Color

a. Storage Stability: Hydrocarbon products stored for long periods of time tend to break down into unusable components. Some of these components can end up in the engine as deposits. To have good storage stability...

- Gasoline is treated to prevent gum forming and to ensure that additives stay in the solution during storage.

- Metal deactivator additives are included to prevent fuel from reacting with any metals in the system.
b. Corrosion Prevention: In Lesson 1, we discussed the problems with sulfur in gasoline. When sulfur oxides contact water, they form acids which attack metal. Corrosive wear is kept to a minimum by:

- Having low sulfur content of gasoline
- Avoiding low temperature operation

The use of properly formulated motor oils also helps to prevent corrosion.
QUICK QUESTION:

One cause of corrosion is sulfur in the gasoline

- True
- False
The natural color of gasoline can vary from water white to a light red or brown color. Some grades of gasoline are dyed for identification.

- **Unleaded gasoline**: clear (no dye), sometimes dyed green
- **Aviation gasoline**: various colors

The gasoline color does not indicate gasoline quality.

The Federal Government required dye because lead compounds are potential health hazards. Leaded products were dyed red.

**QUICK QUESTION:**

Gasoline color indicates the gasoline quality.

- True
- False
THAT COMPLETES
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Now it’s time for a BREAK!
At least 15 minutes!!!
Then on to the review for Module 8.