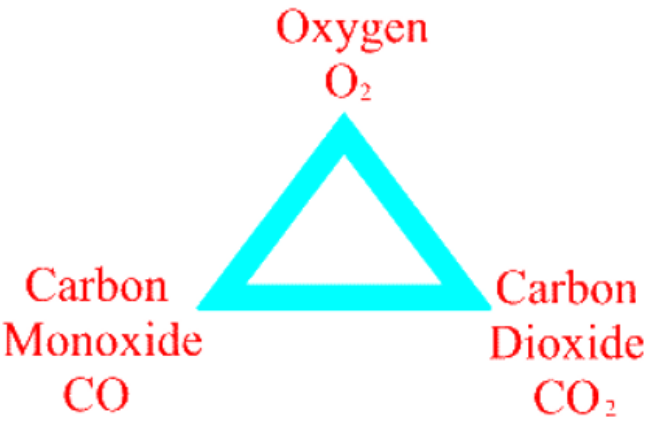
Exhaust Gas Triangle



Einstein's theory of relativity states that matter is indestructible. Knowing this and the fact that oxygen is a type of matter, one must conclude then that oxygen going through the kinetic engine is not burnt or destroyed but merely transformed from one type of matter to another and is not burned up as most people think. To alter the metaphor (what goes up must come down) what goes in must come out.

When the intake valve opens, the combustion chamber fills with air and fuel. Basic chemistry reminds us the air around us is made up of several different types of gasses, oxygen is about 21% of that mixture. The combustion process compresses the air/fuel mixture and then ignites it. The oxygen and fuel transform into a few different types of gasses Known as oxidation. Knowing there is about 21% oxygen in the air around us helps us in diagnosing the combustion process. Most of the oxygen in the exhaust gets transformed into other gas types such as:

CO (1 carbon atom and one oxygen atom)

CO2 (1 carbon atom and two oxygen atoms)

H20 (1 hydrogen atom and two oxygen atoms)

NOX (1 nitrogen atom with up to several oxygen atoms)

O2 is two oxygen atoms in its original state unconverted

When you add up CO, O2, and CO2 from the readings received from the five-gas analyzer they should equal approximately 16%, which is 16% oxygen of the total 21% oxygen that initially entered the combustion chamber, known as the exhaust gas triangle theory. The theory is not including NOX because its a minuscule amount of oxygen measured in parts per million. The other missing gas is H20; it accounts for about 5% when added to the 16%, making up 21% total oxygen intake. H20 cannot be measured on the five-gas analyzer and therefore not part of the gases included in the triangle theory.

No matter whether the air-fuel mixture is rich or lean the three gasses CO, O2, and CO2, when added together, should be close to 16%. A vacuum leak that creates a lean condition does not change the triangle; this excess air still enters the combustion chamber through the intake system and still must be put through the combustion process. This air contains 21% oxygen and won't affect the triangle unless it has leaned out the mixture enough to develop a lean misfire. A misfire doesn't transform oxygen; therefore, what goes in comes out the same.

EXAMPLES:

Rich HC 200PPM CO 3.0% O2 .20% CO2 12.8%

Lean HC 200PPM CO .20% O2 3.0 CO2 12.8%

In both examples the three gases that make up the triangle still total 16%

Knowing the exhaust gas triangle theory can help you diagnose emission failures. Here is an example of a 1989 Chevy Caviler that failed the smog test for a rich exhaust. The five gas readings are HC=300PPM, CO=5.4%, O2=6.55 CO2=8.1%. As you can see from these readings, the engine is running extremely rich. With this example, we see elevated O2 this should not happen with a rich running engine. If we apply the exhaust gas triangle to this example, we can see that CO, O2, and CO2 add up to 20% they should be roughly 16%, This means air is entering the exhaust from another location. The O2-sensor voltage was low 100 to 600 MV. The integrator was 145. The PCM was receiving a lean signal from the O2 sensor causing the PCM to richen the mixture. The cause of the problem was a malfunctioning air injection system. After pinching the air injection hose from the air pump, the O2 sensor voltage was normal 100 to 900MV; the integrator moved down toward 128 the five gas readings were normal HC= 50ppm CO= .50 % O2=.50 % CO2=15%.

While the air injection system is closed off the CO, O2 and CO2 equal 16%, the air injection malfunction was allowing oxygen to flow across the O2 sensor, therefore creating a false lean signal to the PCM. The PCM responded by increasing the pulse width for a rich command.

This exhaust gas triangle theory can be applied to help pinpoint problems with exhausts system leaks, air injection system malfunctions and misfiring cylinders. When there is a cylinder misfire Combustion does not occur within that cylinder and oxygen is not converted; this oxygen then gets released during the exhaust stroke and flows into the exhaust system; diluting the exhaust gasses with 21% oxygen. So it is possible to have more than 16% on a vehicle with a misfire.

Air injection systems malfunctions or exhaust leaks allow air to enter the exhaust that has not converted, and this air contains 21% oxygen, diluting the exhaust gases from the combustion process raising the CO, O2, and CO2 over 16%. CO2 is now lower than usual because of this dilution. Moreover, O2 is high because of not being converted. CO2 is a byproduct of combustion and is a measurement of the engine efficiency. When the engine is running at top efficiency, the engine can develop as much as 15.5% CO2. When there is a misfire, this typically results in lack of combustion causing unconverted O2 to enter the exhaust. CO2 drops because of the dilution of oxygen.