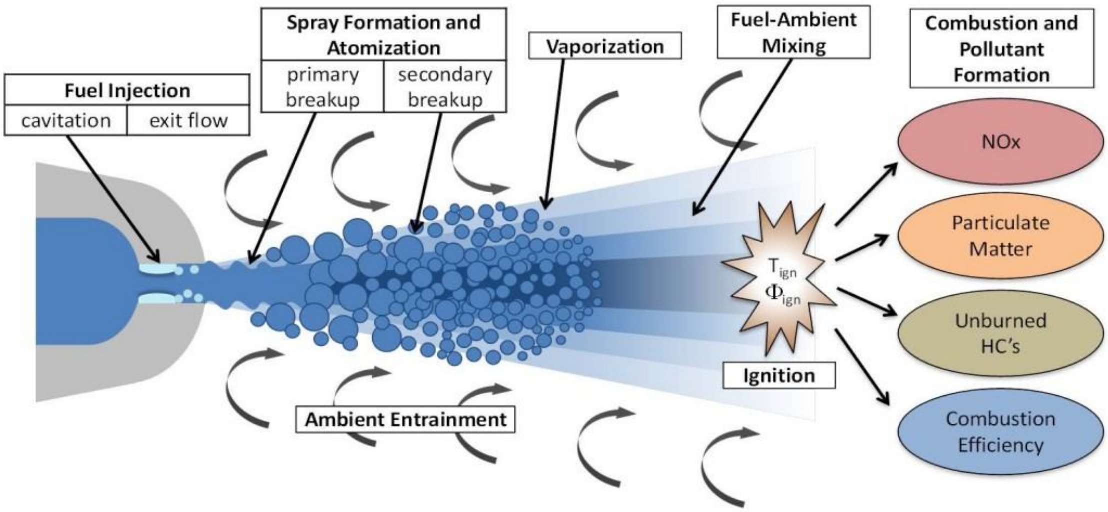
Understanding Combustion



Combustion occurs when fossil fuels (e.g. fuel oil, diesel or gasoline) react with oxygen in the air to produce heat. The heat from burning fossil fuels is used for industrial purposes, environmental heating, or to expand gases in a cylinder, and push a piston. Boilers, furnaces and engines are important users of fossil fuels.

Fossil fuels are hydrocarbons, meaning they are composed primarily of Carbon and Hydrogen. When fossil fuels are burned, Carbon Dioxide (CO_2) and Water (H_2O) are the principle chemical products formed from the reactants, Carbon and Hydrogen in the fuel, and Oxygen (O_2) in the air.

The simplest example of hydrocarbon fuel combustion, is the reaction of methane (CH_4), the largest component of natural gas, with Oxygen (O_2) in the air. When this reaction is balanced, or stoichiometric, each molecule of methane reacts with two molecules of O_2, producing one molecule of CO_2, and two molecules of H_2. When this occurs, energy is released as heat.

The combining of oxygen in the air and carbon in the fuel to form carbon dioxide and generate heat is a complex process, requiring the right mixing turbulence, sufficient activation temperature and enough time for the reactants to come into contact and combine. Unless combustion is properly controlled, high concentrations of undesirable products can form.

Carbon Monoxide (CO) and soot, for example, result from poor fuel and air mixing or too little air. Other undesirable products, such as Nitrogen Oxides (NOx), form in excessive amounts when the burner flame temperature is too high. If a fuel contains Sulphur, Sulphur Dioxide (SO_2) gas is formed.

Combustion Analysis Combustion analysis is part of a process intended to improve fuel economy, reduce undesirable exhaust emissions and improve the safety of fuel burning equipment. Combustion analysis begins with the measurement of the flued / exhaust gas concentration, and may include the measurement of draft pressure and soot level.

To measure gas concentration, a probe is inserted into the exhaust flue and a gas sample is drawn out. Soot is measured from a gas sample drawn off the exhaust fluid. Once these measurements are made, the data may be interpreted and evaluated. More in depth analysis will examine the concentration of the undesirable products described earlier.

WHY PERFORM A COMBUSTION ANALYSIS

Improve Fuel Efficiency

Heat energy leaving the system exhaust flue (or stack) is often the largest single source of lost fuel energy and is made up of the Dry Gas loss and Latent Heat Loss. Although some flue loss is unavoidable, and equipment tune-up using combustion analysis data can often significantly reduce this source of heat loss and save fuel costs by improving fuel efficiency.

Reduce Emissions

Carbon monoxide, sulphur dioxide, nitrogen oxides and particles are undesirable emissions associated with burning fossil fuels. These compounds are toxic, contribute to acid rain and smog and can ultimately cause respiratory problems. Combustion analysis is performed to monitor toxic and acid rain forming emissions in order to meet regulations.

Improve Safety

Good equipment maintenance practice, which includes combustion analysis, enables the technician to fully verify and maintain the equipment operating at specifications for safe and efficient operation (E.g. A reduction in excess air, due to barometric pressure, can cause, in turn, a rapid increase of highly toxic carbon monoxide and explosive gases, resulting in rapid deterioration in system safety and efficiency).

WHAT IS MEASURED

Oxygen (O_2), Carbon Monoxide (CO), and Carbon Dioxide (CO_2)

As described earlier, simple combustion involves the reaction of oxygen in the air with carbon and hydrogen in the fuel, to form carbon dioxide and water and produce heat. Under ideal conditions, the only gases in the exhaust flue are CO_2, water vapour and nitrogen from the combustion air.

When Oxygen appears in the flue exhaust, it usually means that more air (20.9% of which is O_2) was supplied than was needed for complete combustion to occur. Some O_2 is left over. In other words, the measurement of O_2 gas in the flue indicates that extra combustion air, or Excess Air, was supplied to the combustion reaction.

When too little air is supplied to the burner, there is not enough oxygen to completely form CO_2, with all the carbon in the fuel. Instead, some oxygen combines with carbon to form Carbon Monoxide (CO). CO is a highly toxic gas associated with incomplete combustion and efforts must be made to minimize its formation. This effort goes hand-in-hand with improving fuel efficiency and reducing soot generation.

As a rule, the most efficient and cost-effective use of fuel takes place when Carbon Dioxide (CO_2) concentration in the exhaust is maximized. Theoretically, this occurs when there is just enough O2 in the supplied air to react with all the Carbon in the fuel supplied. This quantity of supplied air is often referred to as the theoretical air.

The theoretical air required for the combustion reaction depends on fuel composition and the rate at which the fuel is used. In real-world combustion, factors such as the condition of the engine and the engine design also influence the amount of air that is needed. The theoretical air is rarely enough.

Nitrogen Oxides (NOx)

Nitrogen Oxides, principally Nitric Oxide (NO) and Nitrogen Dioxide (NO_2), are pollutant gases that contribute to the formation of acid rain, ozone, as well as smog. Nitrogen Oxides result when Oxygen combines with nitrogen in the air or in the fuel. Nitric Oxide (NO) is generated first at the high flame temperatures, then oxidizes further to form Nitrogen Dioxide (NO_2) at cooler temperatures in the exhaust or after being exhausted.

The Nitric Oxide (NO) concentration is often measured alone, and the Nitrogen Dioxide (NO_2) concentration is generally assumed to comprise an additional five percent of the total nitrogen oxides. The Nitrogen Oxide gas concentrations are often combined and referred to as the Nitrogen Oxide (NOx) concentration.

Hydrocarbons (HCs) / Volatile Organic Compounds (VOCs)

Organic compounds are sometimes present in the combustion exhaust products because of incomplete combustion. Hydrocarbons (HCs), or volatile organic compounds (VOCs), are best reduced through proper burner maintenance and by maintaining the proper air / fuel mixture.

Soot

Soot is the black smoke commonly seen in the exhaust of diesel trucks, and is present whenever fuel oils or solid fuels are burned. Excessive soot is undesirable because it indicates poor combustion and is responsible for coasting internal heat transfer surfaces, preventing good thermal conductivity. Over time, serious damage to the heat exchanger can occur.

Soot is primarily unburned Carbon, and is formed for the same reasons Carbon Monoxide (CO) is formed – insufficient combustion air, poor mixing and low flame temperature. As with Carbon Monoxide (CO), it is usually impossible or impractical to entirely eliminate soot formation for some fuel types.

Oxygen and Excess Air

Insufficient combustion air causes a reduction in fuel efficiency, creates highly toxic carbon monoxide gas and produces soot. To ensure there is enough oxygen to completely react with the fuel, extra combustion air is usually supplied. This extra air, called "Excess air", is expressed as the percent air above the amount theoretically needed for complete combustion. In real-world combustion, the excess air required for gaseous fuels is typically about 15%. Significantly more may be needed for liquid and solid fuels.

Although required, higher excess air comes with a price - it wastes fuel. There are a number of reasons why this occurs, but stated simply, supply-air cools the combustion system by absorbing heat and transporting it out the exhaust flue. The more air, the more cooling. Consider too, that nitrogen, which makes up about eighty percent of the air, plays no role chemically to produce heat. It does however add significantly to the weight of gas that absorbs heat energy. Therefore, an improvement in combustion efficiency, usually requires a reduction in excess air / oxygen.

HOW DIESELCURE IMPROVES COMBUSTION PERFORMANCE

When water is present in diesel fuel, sulphuric acid and nitric acid is formed from sulphur and nitrogen, respectively. Sulphuric acid also causes oxidation of diesel fuel resulting in the formation of resin, which is deposited on surfaces in contact with the diesel fuel. This is commonly known as "gumming". Gumming in the fuel pumps and fuel injectors of diesel engines has an adverse effect on fuel optimization and spray-pattern, and also on volumetric efficiency of the fuel injectors.

As detailed above, this typically leads to over-supply of fuel to the combustion chamber, characterized by emission of black smoke (incompletely burned fuel) from the exhaust, causing loss of fuel efficiency and increased fuel consumption.

DIESELCURE is most effective in treating suspended water in diesel fuel (please view Würth Product Demonstration video as tested in laboratory in Germany, which highlights this feature).

Specifically, DIESELCURE prevents and eliminates the build-up of resins and gums, which lead directly to over fuelling and the increase of harmful environmental emissions.

During development and premarket trials, a marked improvement in combustion performance of diesel, treated with DIESELCURE, as compared to untreated fuel was observed, as a result of DIESELCURE'S unique treatment of water and other contamination in diesel fuel.

Detailed exhaust analysis showed that on average, Carbon Monoxide (CO) was reduced by 6.25%, and Carbon Dioxide (CO_2) increased by 14.1%, Hydrocarbons reduced by 21%, Oxygen reduced by 4%, Nitrogen Oxides (NOx) gasses reduced by 9.1%, and Smoke Opacity reduced by 8%.

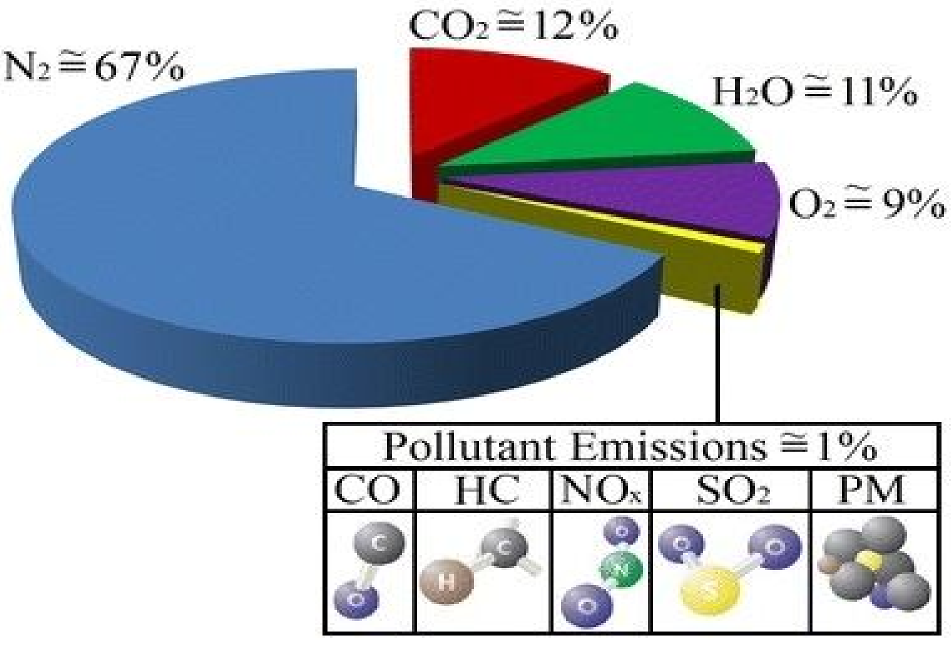
These readings show an unmistakable trend towards improved combustion performance and better efficiency, which resulted in reduced REGENS, reduced filter replacement and downtime, but also reduction in fuel usage.

Clean fuel, passing through a clean system, is more efficient. Multiple product trials have highlighted trends towards, cleaner injectors, less filter usage and less operational downtime.

Basically, when the smallest amount of moisture is present in diesel, Sulphuric Acid and Nitric Acid is formed from Sulphur and Nitrogen respectively. Sulphuric Acid also causes oxidation of diesel fuel, resulting in the formation of resin, which is deposited on surfaces in contact with the diesel, also known as "gumming".

Put simply in layman's terms, the water content or moisture bonds with DIESELCURE, thereby prohibiting the water or moisture content from interacting with the Sulphur that is present in fuel. In use, when inert with oxides of sulphur and nitrogen, this allows moisture contamination to safely pass through the fuel system.

The Figure below shows the composition of diesel fuel exhaust gas. Pollutant emissions have a rate of 1% in diesel fuel exhaust gas.



Nitric Acid (HNO_3) has the highest proportion of diesel pollutant emissions (More than 50%). After Nitrogen Oxides (NOx) gas emissions, Particulate Matter (PM) has the second highest proportion in pollutant emissions.

The basic fractions of Particulate Matter (PM) are carbonaceous solids such as soot particles and heavy hydrocarbons derived from the fuel and lubricating oil. In cases where fuel contains significant Sulphur, hydrated Sulfuric Acid can also be a major component. PM contains a large portion of the poly nuclear aromatic hydrocarbons (PAH) found in engine exhaust.

In a study, typical PM composition of a heavy-duty diesel engine is classified as 41 % carbon, 7 % unburned fuel, 25 % unburned oil, 14 % sulphate and water, 13 % ash and other components. In another study, PM consists of elemental carbon (≅31 %), sulphates and moisture (≅14 %), unburnt fuel (≅7 %), unburnt lubricating oil (≅40 %) and remaining are metals and other substances.

DIESELCURE is specifically designed to reduce all these emissions, and also solving the water problem in diesel. Water reacting with Sulphur and Nitrogen in diesel causes Sulphuric Acid (SO_2) and Nitric Acid (HNO_3).