EXHAUST EMISSIONS

Composition Of The Exhaust Gases

The exhaust gases emitted into the atmosphere are a combination of burned and unburned fuel. To understand the exhaust emission and its composition review some basic chemistry.

When the air/fuel mixture is introduced into the engine, we are mixing air, composed of nitrogen (78%), oxygen (21%) and other gases (1%) with the fuel, which is 100% hydrocarbons (HC), in a semi-controlled ratio. As the combustion process is accomplished, power is produced to move the vehicle while the heat of combustion is transferred to the cooling system. The exhaust gases are then composed of nitrogen, a diatomic gas (N_2), the same as was introduced in the engine, carbon dioxide (CO_2), the same gas that is used in beverage carbonation and water vapor (H_2O). The nitrogen (N_2), for the most part passes through the engine unchanged, while the oxygen (O_2) reacts (burns) with the hydrocarbons (HC) and produces the carbon dioxide (CO_2) and the water vapors (H_2O). If this chemical process would be the only process to take place, the exhaust emissions would be harmless. However, during the combustion process, other pollutants are formed and are considered dangerous. These pollutants are carbon monoxide (CO), hydrocarbons (HC), oxides of nitrogen (NOx) oxides of sulfur (SOx) and engine particulates.

HYDROCARBONS

Hydrocarbons (HC) are essentially unburned fuel that have not been successfully burned during the combustion process or have escaped into the atmosphere through fuel evaporation. The main sources of incomplete combustion are rich air/fuel mixtures, low engine temperatures and improper spark timing. The main sources of hydrocarbon emission through fuel evaporation come from the vehicle's fuel tank and carburetor bowl.

To reduce combustion hydrocarbon emission, engine modifications were made to minimize dead space and surface area in the combustion chamber. In addition the air/fuel mixture was made more lean through improved carburetion, fuel injection and by the addition of external controls to aid in further combustion of the hydrocarbons outside the engine. Two such methods were the addition of an air injection system, to inject fresh air into the exhaust manifolds and the installation of a catalytic converter, a unit that is able to burn traces of hydrocarbons without affecting the internal combustion process or fuel economy.

To control hydrocarbon emissions through fuel evaporation, modifications were made to the fuel tank and carburetor bowl to allow storage of the fuel vapors during periods of engine shut-down, and at specific times during engine operation, to purge and burn these same vapors by blending them with the air/fuel mixture.

CARBON MONOXIDE

Carbon monoxide is formed when not enough oxygen is present during the combustion process to convert carbon (C) to carbon dioxide (CO_2). An increase in the carbon monoxide (CO) emission is normally accompanied by an increase in the hydrocarbon (HC) emission because of the lack of oxygen to completely burn all of the fuel mixture.

Carbon monoxide (CO) also increases the rate at which the photo chemical smog is formed by speeding up the conversion of nitric oxide (NO) to nitrogen dioxide (NO_2). To accomplish this, carbon monoxide (CO) combines with oxygen (O_2) and nitrogen dioxide (NO_2) to produce carbon dioxide (CO_2) and nitrogen dioxide (NO_2). ($CO + O_2 + NO = CO_2 + NO_2$).

The dangers of carbon monoxide, which is an odorless, colorless toxic gas are many. When carbon monoxide is inhaled into the lungs and passed into the blood stream, oxygen is replaced by the carbon monoxide in the red blood cells, causing a reduction in the amount of oxygen being supplied to the many parts of the body. This lack of oxygen causes headaches, lack of coordination, reduced mental alertness and should the carbon monoxide concentration be high enough, death could result.

NITROGEN

Normally, nitrogen is an inert gas. When heated to approximately 2500°F (1371°C) through the combustion process, this gas becomes active and causes an increase in the nitric oxide (NOx) emission.

Oxides of nitrogen (NOx) are composed of approximately 97-98% nitric oxide (NO). Nitric oxide is a colorless gas but when it is passed into the atmosphere, it combines with oxygen and forms nitrogen dioxide (NO_2). The nitrogen dioxide then combines with chemically active hydrocarbons (HC) and when in the presence of sunlight, causes the formation of photo chemical smog.

OZONE

To further complicate matters, some of the nitrogen dioxide (NO_2) is broken apart by the sunlight to form nitric oxide and oxygen. (NO_2 + sunlight = NO + O). This single atom of oxygen then combines with diatomic (meaning 2 atoms) oxygen (O_2) to form ozone (O_3). Ozone is one of the smells associated with smog. It has a pungent and offensive odor, irritates the eyes and lung tissues, affects the growth of plant life and causes rapid deterioration of rubber products. Ozone can be formed by sunlight as well as electrical discharge into the air.

The most common discharge area on the automobile engine is the secondary ignition electrical system, especially when inferior quality spark plug cables are used. As the surge of high voltage is routed through the secondary cable, the circuit builds up an electrical field around the wire, acting upon the oxygen in the surrounding air to form the ozone. The faint glow along the cable with the engine running that may be visible on a dark night, is called the "corona discharge.'' It is the result of the electrical field passing from a high along the cable, to a low in the surrounding air, which forms the ozone gas. The combination of corona and ozone has been a major cause of cable deterioration. Recently, different types and better quality insulating materials have lengthened the life of the electrical cables.

Although ozone at ground level can be harmful, ozone is beneficial to the earth's inhabitants. By having a concentrated ozone layer called the "ozonosphere'' between 10 and 20 miles (16-32km) up in the atmosphere, much of the ultra violet radiation from the sun's rays are absorbed and screened. If this ozone layer were not present, much of the earth's surface would be burned, dried and unfit for human life.

There is much discussion concerning the ozone layer and its density. A feeling exists that this protective layer of ozone is slowly diminishing and corrective action must be directed to this problem. Much experimenting is presently being conducted to determine if a problem exists and if so, the short and long term effects of the problem and how it can be remedied.

OXIDES OF SULFUR

Oxides of sulfur (SOx) were initially ignored in the exhaust system emissions, since the sulfur content of gasoline as a fuel is less than $^{1}/_{10}$ of 1%. Because of this small amount, it was felt that it contributed very little to the overall pollution problem. However, because of the difficulty in solving the sulfur emissions in industrial pollutions and the introduction of catalytic converter to the automobile exhaust systems, a change was mandated. The automobile exhaust system, when equipped with a catalytic converter, changes the sulfur dioxide (SO_2) into the sulfur trioxide (SO_3).

When this combines with water vapors (H_2O), a sulfuric acid mist (H_2SO_4) is formed and is a very difficult pollutant to handle and is extremely corrosive. This sulfuric acid mist that is formed, is the same mist that rises from the vents of an automobile storage battery when an active chemical reaction takes place within the battery cells.

When a large concentration of vehicles equipped with catalytic converters are operating in an area, this acid mist will rise and be distributed over a large ground area causing land, plant, crop, paints and building damage.

PARTICULATE MATTER

A certain amount of particulate matter is present in the burning of any fuel, with carbon constituting the largest percentage of the particulates. In gasoline, the remaining percentage of particulates is the burned remains of the various other compounds used in its manufacture. When a gasoline engine is in good internal condition, the particulate emissions are low but as the engine wears internally, the particulate emissions increase. By visually inspecting the tail pipe emissions, a determination can be made as to where an engine defect may exist. An engine with light gray smoke emitting from the tail pipe normally indicates an increase in the oil consumption through burning due to internal engine wear. Black smoke would indicate a defective fuel delivery system, causing the engine to operate in a rich mode. Regardless of the color of the smoke, the internal part of the engine or the fuel delivery system should be repaired to a "like new'' condition to prevent excess particulate emissions.

Diesel and turbine engines emit a darkened plume of smoke from the exhaust system because of the type of fuel used. Emission control regulations are mandated for this type of emission and more stringent measures are being used to prevent excess emission of the particulate matter. Electronic components are being introduced to control the injection of the fuel at precisely the proper time of piston travel, to achieve the optimum in fuel ignition and fuel usage. Other particulate after-burning components are being tested to achieve a cleaner particular emission.

Good grades of engine lubricating oils should be used, meeting the manufacturers specification. "Cut-rate'' oils can contribute to the particulate emission problem because of their low "flash'' or ignition temperature point. Such oils burn prematurely during the combustion process causing emissions of particulate matter.

The cooling system is an important factor in the reduction of particulate matter. With the cooling system operating at a temperature specified by the manufacturer, the optimum of combustion will occur. The cooling system must be maintained in the same manner as the engine oiling system, as each system is required to perform properly in order for the engine to operate efficiently for a long time.

Other Automobile Emission Sources

Before emission controls were mandated on the internal combustion engines, other sources of engine pollutants were discovered, along with the exhaust emission. It was determined the engine combustion exhaust produced 60% of the total emission pollutants, fuel evaporation from the fuel tank and carburetor vents produced 20%, with the another 20% being produced through the crankcase as a by-product of the combustion process.

CRANKCASE EMISSIONS

Crankcase emissions are made up of water, acids, unburned fuel, oil fumes and particulates. The emissions are classified as hydrocarbons (HC) and are formed by the small amount of unburned, compressed air/fuel mixture entering the crankcase from the combustion area during the compression and power strokes, between the cylinder walls and piston rings. The head of the compression and combustion help to form the remaining crankcase emissions.

Since the first engines, crankcase emissions were allowed to go into the air through a road draft tube, mounted on the lower side of the engine block. Fresh air came in through an open oil filler cap or breather. The air passed through the crankcase mixing with blow-by gases. The motion of the vehicle and the air blowing past the open end of the road draft tube caused a low pressure area at the end of the tube. Crankcase emissions were simply drawn out of the road draft tube into the air.

To control the crankcase emission, the road draft tube was deleted. A hose and/or tubing was routed from the crankcase to the intake manifold so the blow-by emission could be burned with the air/fuel mixture. However, it was found that intake manifold vacuum, used to draw the crankcase emissions into the manifold, would vary in strength at the wrong time and not allow the proper emission flow. A regulating type valve was needed to control the flow of air through the crankcase.

Testing, showed the removal of the blow-by gases from the crankcase as quickly as possible, was most important to the longevity of the engine. Should large accumulations of blow-by gases remain and condense, dilution of the engine oil would occur to form water, soots, resins, acids and lead salts, resulting in the formation of sludge and varnishes. This condensation of the blow-by gases occur more frequently on vehicles used in numerous starting and stopping conditions, excessive idling and when the engine is not allowed to attain normal operating temperature through short runs. The crankcase purge control or PCV system will be described in detail later in this section.

FUEL EVAPORATIVE EMISSIONS

Gasoline fuel is a major source of pollution, before and after it is burned in the automobile engine. From the time the fuel is refined, stored, pumped and transported, again stored until it is pumped into the fuel tank of the vehicle, the gasoline gives off unburned hydrocarbons (HC) into the atmosphere. Through redesigning of the storage areas and venting systems, the pollution factor has been diminished but not eliminated, from the refinery standpoint. However, the automobile still remained the primary source of vaporized, unburned hydrocarbon (HC) emissions.

Fuel pumped form an underground storage tank is cool, but when exposed to a warmer ambient temperature, it will expand. Before controls were mandated, an owner would fill the fuel tank with fuel from an underground storage tank and park the vehicle for some time in warm area, such as a parking lot. As the fuel would warm, it would expand and should no provisions or area be provided for the expansion, the fuel would spill out the filler neck and onto the ground, causing hydrocarbon (HC) pollution and creating a severe fire hazard. To correct this condition, the vehicle manufacturers added overflow plumbing and/or gasoline tanks with built in expansion areas or domes.

However, this did not control the fuel vapor emission from the fuel tank and the carburetor bowl. It was determined that most of the fuel evaporation occurred when the vehicle was stationary and the engine not operating. Most vehicles carry 5-25 gallons (19-95 liters) of gasoline. Should a large concentration of vehicles be parked in one area, such as a large parking lot, excessive fuel vapor emissions would take place, increasing as the temperature increases.

To prevent the vapor emission from escaping into the atmosphere, the fuel system is designed to trap the fuel vapors while the vehicle is stationary, by sealing the fuel system from the atmosphere. A storage system is used to collect and hold the fuel vapors from the carburetor and the fuel tank when the engine is not operating. When the engine is started, the storage system is then purged of the fuel vapors, which are drawn into the engine and burned with the air/fuel mixture.