ASE 8 - Engine Performance

Module 2
Products of Combustion
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Lesson 1: Objective

At the end of this module, the student will be able to;
• explain the combustion process in the internal combustion engine,
• explain the cause and effect of air pollutants related to the automobile,
• recognize and explain the strategies and components used to address unwanted vehicle emissions, and
• diagnose and repair excessive emission problems.

Overview

Automotive fuel is primarily composed of hydrocarbon compounds and additives. The process of combustion converts the chemical energy stored in the hydrocarbon mixture into heat energy by breaking apart the hydrogen and carbon atoms, and oxidizing them, creating new compounds. Theoretically, perfect combustion results in by-products of H2O (water) CO2 (carbon dioxide) and heat.

When less than perfect combustion takes place, other by-products are produced. These by-products include CO (carbon monoxide) HC (hydrocarbons) and NOX (oxides of nitrogen).

This module will address the cause and effect of unwanted vehicle emissions and the systems used to control those emissions.
Test Procedures

Federal Test Procedure

The test utilized by the federal government is called the federal test procedure (FTP). The FTP is run using a preset drive cycle on a loaded dynamometer. All of the exhaust emissions generated during the drive cycle are collected and analyzed using a mass spectrometer. The results are then used to estimate the amount of each component of the exhaust gasses. Every model of vehicle sold in the United States must meet the standards used to pass the FTP. California and the Northeast United States use a similar test with more stringent standards for vehicles sold in those areas.

Local I/M Tests

Local inspection and maintenance (I/M) tests are mandated by the EPA in non-attainment areas. These are areas that have failed to meet and maintain EPA standards for air quality. The state and local governments in the non-attainment area design an air quality program, which includes the I/M test. Test procedures vary from area to area. In some areas, a loaded mode test is used. This test requires putting the vehicle through a drive cycle on a dynamometer. In other areas, a two speed idle test is used. This test is run at idle and at cruise (typically about 2500 rpm). The test is referred to as an idle test because the vehicle is not under a load and the wheels are not moving.

Local I/M tests are designed to identify the worst of the polluting vehicles for repair. These vehicles are referred to as "gross emitters."

OBD II Test

Beginning in 2002, the EPA has mandated that I/M programs monitor the OBD II system. The idea behind this test is that the OBD II system is designed to monitor the emission control systems and should identify any vehicle that would pollute at 150% of the federal standard or greater.

The OBD II test is performed by accessing the on-board computer system through the ALDL. The test equipment checks to see that the required readiness indicators have been set and that there are no emissions related codes stored in the system. If these criteria are met, the vehicle passes.
Cause and Effect of Vehicle Emissions

As we stated earlier, perfect combustion would theoretically result in by-products of H2O (water) CO2 (carbon dioxide) and heat.

Unfortunately, perfect combustion rarely, if ever, takes place in the internal combustion engine. Great improvements have been made since the initial realization that vehicle emissions are a problem for the environment.

Engines have been redesigned with emissions in mind. Systems and components, such as egr, pcv, and catalytic converters, been designed to control specific emissions under specific conditions, and fuel systems have undergone dramatic changes based on the need to balance the consumer’s demand for performance and fuel economy with the need to attain and maintain a healthy level of air quality.

Air/Fuel Mixtures

The internal combustion engine operates by converting energy stored in chemical form (gasoline) to heat energy, and then to mechanical energy. It accomplishes this by oxidizing, or burning the fuel. In order to get the most energy out of each molecule of fuel, the ratio of air to fuel must be balanced. This chemical balance is known as the stoichiometric point. For gasoline engines, the stoichiometric point is generally accepted as 14.7:1. This ration means that for every 1 pound of fuel burned, the engine needs 14.7 pounds of air.

HC Emissions

Gasoline is made up mostly of hydrocarbon (HC) compounds. When a hydrocarbon molecule survives the combustion process unchanged, it is released into the atmosphere as HC emissions. HC emissions also result from evaporation fuel during refueling or operation of the vehicle.

HC emissions are an irritant to the eyes and mucous membranes. They are particularly hard on infants, the elderly, and people with pulmonary problems such as asthma.

HC emissions are a key component in photochemical smog (also known as Los Angeles type smog). Photochemical smog is formed when HC molecules combine with oxides of nitrogen NOX in the presence of sunlight. Smog is noticed as an odorous brown haze.

HC emissions can result from engine misfires, rich or lean air/fuel ratios, engine mechanical problems, ignition problems, vacuum leaks, malfunctioning emission control systems, or inefficient engine design. In short, any condition that will allow an HC molecule to pass through the engine unchanged will result in HC emissions.
Related customer concerns could include the following:
• failed emissions test
• engine misfire
• exhaust odor
• poor performance

An excessive HC emission condition that is not repaired will damage the catalytic converter and may damage other engine and exhaust components.

**NOX Emissions**
Earth's atmosphere contains 78% nitrogen. Nitrogen is generally an inert gas, but under the extreme conditions found in the combustion process, it can combine with oxygen to form NOX. The x in NOX is used because the compounds formed could be NO, NO2, or NO3. NOX forms at temperatures above 2500 degrees Fahrenheit (1370 degrees centigrade). When combined with HC in the presence of sunlight, NOX forms photochemical smog.

Excessive NOX emissions can be related to a lean air/fuel mixture, ignition timing, excessive compression due to engine modifications or carbon build-up, malfunctioning emission control systems, or engine overheating.

Related customer concerns could include the following:
• engine pinging or detonation
• engine overheating
• lack of power.

**CO Emissions**
During the combustion process, the carbon atom in the HC molecule combines with oxygen, forming CO2 (carbon dioxide). When the combustion process is incomplete, the resulting emission is CO (carbon monoxide). CO is an odorless, colorless, tasteless gas that is unhealthful to animal life. In sufficient concentrations, it can be deadly.

Safety Note: Carbon monoxide affects humans by displacing the oxygen content in the bloodstream. The body is designed to take in oxygen, and expel carbon dioxide. The human respiratory system has difficulty distinguishing between CO and O2 molecules, therefore the CO molecules are not easily expelled, and levels can build up over time. For this reason, it is extremely important to ensure that shop exhaust systems are in proper working order and are utilized.

The cause of excessive CO emissions is a rich air/fuel condition. The root cause of the rich condition could be a restricted air intake (such as a plugged air filter) or an uncontrolled fuel source.
Related customer concerns could include the following:
- black smoke from the tailpipe
- poor fuel-economy
- poor performance

**Exhaust Gas Analysis**

Traditional exhaust gas analysis is performed with an infra-red analyzer. A sample of the exhaust gas is electronically compared with a sample of inert gas within the analyzer, and the result is shown on a screen. Although this process usually follows a failed emissions test, it is also valuable for diagnosing other engine performance conditions.

Figure 1 shows the relationship in the content of various elements found in exhaust gas.

![Figure 1](image)

**Figure 2-1**

On OBD II equipped vehicles, exhaust gas oxygen is compared both before and after the catalytic converter(s). If the comparison between the 2 exhaust gas oxygen sensors does not indicate a functioning catalyst, a MIL light is illuminated and a Diagnostic Trouble Code is stored in the PCM. (This system is covered in detail in the OBD II module.)
Government Regulations

Since 1996, by law all automotive manufacturers must meet OBD II standards.

OBD II is a series of regulations intended to reduce vehicle emissions. The power train and its emission-control systems must be continuously monitored for failure and deterioration.

There are also provisions for standardization of diagnostic, repair, and other service-related information.

The Federal Test Procedure, or FTP, is a government-mandated emissions testing program required for vehicles to become certified for sale in the United States. The FTP sets maximum allowable emissions levels.

According to the OBD II standard, a Malfunction Indicator Lamp, or MIL, must illuminate if a system or component either fails or deteriorates to the point where the vehicle emissions could rise above one-and-a-half times the FTP standards.