OBD I & II (On Board Diagnostic)

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Abstract— OBD or On-Board Diagnostics refers to a system for emission control which has the capability to detect a malfunction and to store the related information in nonvolatile memory. The OBD system monitors the emission relevant components or systems, stores detected malfunctions indicating likely area of malfunction and activates Malfunction Indicator Lamp (MIL) if necessary. On-board diagnostics, required by governmental regulations, provide a means for reducing harmful pollutants into the environment. Since being mandated in 2010 in India, the regulations have continued to evolve and require engineers to design systems that meet strict guidelines.

The OBD system has a microcontroller based processing system and monitors the sensors installed at different parts of vehicle to observe various emission related parameters and emission control system/devices, processing unit will take input from these sensors and signal conditioners, calculate the real-time values of vehicle parameters and give output. System will be able to diagnose faults in parameters, abnormal abrupt changes, notify user of any abnormal condition, and indicate the cause of fault. The OBD system is installed in vehicles to improve in house emission compliance by alerting the vehicle operator when a malfunction exists and to aid automobile repair technicians in identifying and repairing malfunctioning systems in the emission control system.

I. INTRODUCTION

The internal combustion engine is an engine in which the combustion of a fuel (normally a fossil fuel) occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit. In an internal combustion engine, the expansion of the high-temperature and high-pressure gases produced by combustion apply direct force to some component of the engine. This force is applied typically to pistons, turbine blades, or a nozzle. This force moves the component over a distance, transforming chemical energy into useful mechanical energy.

All internal combustion engines depend on combustion of a chemical fuel, typically with oxygen from the air. The combustion process typically results in the production of a great quantity of heat, as well as the production of steam and carbon dioxide and other chemicals at very high temperature; the temperature reached is determined by the chemical makeup of the fuel and oxidizers, as well as by the compression and other factors. Internal combustion engines Require ignition of the mixture, either by spark ignition (SI) or compression ignition (CI).

A. Complete Combustion

In complete combustion, the reactant burns in oxygen, producing a limited number of products. When a hydrocarbon burns in oxygen, the reaction will only yield carbon dioxide and water. When elements are burned, the products are primarily the most common oxides. Carbon will yield carbon dioxide, nitrogen will yield nitrogen dioxide and sulfur will yield sulfur dioxide.

$CH_4 + 2\,O_2 \rightarrow CO2 + 2\,H_2O$

The generation of carbon dioxide, in automotive context, is not harmful.

B. Incomplete Combustion

Complete combustion is almost impossible to achieve. In reality, as actual combustion reactions come to equilibrium, a wide variety of major and minor species will be present such as carbon monoxide and pure carbon (soot or ash). Additionally, any combustion in atmospheric air, which is 78% nitrogen, will also create several forms of nitrogen oxides.

Incomplete combustion will only occur when there is not enough oxygen to allow the fuel to react completely to produce carbon dioxide and water. It also happens when the combustion is quenched by a heat sink.

$$2\,CH_4 + 3\,O_2 \rightarrow 2\,CO + 4\,H_2O$$
$$N_2 + O_2 \rightarrow 2\,NO$$
$$N_2 + 2\,O_2 \rightarrow 2\,NO_2$$

The quality of combustion can be improved by design of internal combustion engines. Further improvements are achievable by catalytic after-burning devices (such as catalytic converts) or by the simple partial return of the exhaust gases into the combustion process (EGR).

C. Emissions in Vehicles

Motor vehicle emissions are composed of the by-products that come out of the exhaust systems or other emissions such as gasoline evaporation. These emissions contribute to air pollution and are a major ingredient in the creation of smog.

During the first couple of minutes after starting the engine of a car that has not been operated for several hours, the amount of emissions is very high. This occurs for two main reasons:

1. Rich Air-Fuel ratio requirement in cold engines: Right after starting the engine the walls as well as the fuel are cold. Fuel does not vaporize and it would be difficult to create enough combustible gaseous mixture. Therefore very rich operation is required at the beginning, sometimes even 1:1. The excess of fuel in the chambers is subsequently burned generating great amount of Hydrocarbons, Nitrogen Oxides and Carbon monoxide.
2. Inefficient catalytic convertor under cold conditions: Catalytic convertors are very inefficient when cold. When the cold engine is started, it takes several minutes for the converter to reach operating temperature.

Before that, gases are emitted directly into the atmosphere.

D. Main motor vehicle emissions

1) The main emissions from vehicles are:

1. CARBON MONOXIDE (CO):
   Carbon monoxide is a product of incomplete combustion. Carbon monoxide poisoning is the most common type of fatal air poisoning. Carbon monoxide is colorless, odorless and tasteless, but highly toxic. It combines with hemoglobin to produce carboxyhemoglobin which is ineffective for delivering oxygen to bodily tissues.
2. HYDROCARBONS (HC):
   A class of burned or partially burned fuel, hydrocarbons is toxins. Hydrocarbons are a major contributor to smog, which can be a major problem in urban areas. Methane is not directly toxic, but is more difficult to break down in a catalytic converter. Prolonged exposure to hydrocarbons contributes to asthma, liver disease, lung disease, and cancer. Methane is not directly toxic, but is more difficult to break down in a catalytic converter.

II. OBD-I

OBD-I means an on-board diagnostic system for emission control, which shall have the capability of identifying the likely area of malfunction by means of fault codes stored in computer memory.

An auxiliary OBD ECU is designed to provide the diagnostic functionality for the current ECU. The OBD ECU has to diagnose the sensors and actuator of the ECU by parallel tapping the connections. The monitoring and diagnostic strategy is depended on the available engine functionality data, measured by trials on the vehicle for the engine operation, and will be restricted only to it.

The ECU will monitor the available sensors of the engine control system:

1. Coolant Temperature Sensor
2. Throttle Position Sensor
3. Fuel Cut Solenoid Valve
4. Timer Solenoid
5. Glow Plug Relay
6. RPM Sensor
7. EGR Solenoid

A. Tasks Performed By ECU:

1. The ECU will perform the diagnostic of the above for circuit discontinuity fault and generate the DTCs.
2. The ECU will drive the MIL ON via digital output pin, as soon as a single DTC is set.
3. The ECU will store the freeze frame data for the available monitoring components.
4. The ECU will store the DTCs, freeze frame and related monitoring data in the flash memory.
5. The ECU will have wheel speed sensor input either directly as a digital input from the sensor.
6. The ECU will use this signal to calculate the distance run since MIL was set ON. The value will be stored in flash before power off and will be augmented during subsequent driving.
7. The ECU will provide diagnostic information through K-Line communication to the External Universal Scan Tool meeting OBD requirements.

Sensors and Actuators on the Vehicle and how it contributes to Vehicle Emission and OBD-I

B. Coolant Temperature Sensor (CTS)

The coolant temperature sensor is used to measure the temperature of the engine coolant of an internal combustion engine. The readings from this sensor are then fed back to the Engine control unit (ECU). This data from the sensor is then used to adjust the fuel injection and ignition timing.

1. Operation:

Fig. 1 Coolant Temperature Sensor

The ECT (engine coolant temperature) sensor is basically a thermistor that changes resistance with temperature. The ECU sends out a regulated reference voltage typically 5 volts to the Coolant Temperature Sensor, through the sensor where the voltage is decreased in relation to the internal resistance within the sensor which varies with temperature. When the ECT is high (hotter), the resistance is low, and when the ECT is low (cooler) the resistance is high. This resistance reading is sent to the ECU (car's on-board computer). The ECU is then able to calculate the temperature of the engine, and then with inputs from other engine sensors to carry out adjustments to the engine actuators or can be used to activate emission controls or turn the engine's cooling fan on.

Sensor output is being tapped from the control harness and given to the OBD ECU.

III. TEST PROCEDURE FOR OBD-I

1. The test vehicle shall be mounted on the chassis dynamometer along with necessary equipments of test agency for carrying out test.
2. Switch on the ignition and check for MIL ON. MIL shall be ON for few seconds and then may turn OFF or may continue to glow.
3. Start the engine and check for MIL OFF.
4. Switch OFF the engine and ignition key to OFF position.
5. Vehicle soaking for 6 hours, if necessary for certain OBD parameters as specified by vehicle manufacturer.
6. Open or disconnect the circuit for the OBD parameters to be checked for circuit discontinuity.
7. Switch ON the ignition. Check for MIL ON.
8. Start the engine and check for MIL ON.

S. No	OBD codes	Description
1	P0118	Engine Coolant Temperature Circuit High Input
2	P0112	Throttle Position Sensor/Switch A Circuit Low Input
3	P0005	Fuel Cut-off Valve Control Circuit/open
4	P0216	Injection Time Control Circuit Malfunction
5	P0670	Glow Plug module Control Circuit
6		RPM Sensor
7	P0403	Exhaust Gas Recirculation A Circuit Malfunction
8	P045A	Exhaust Gas Recirculation B Circuit Malfunction

Table 1: OBD-I Output Codes

1. If the OBD parameter requires engine to be driven for MIL activation, vehicle shall be driven as per driving cycle (modified Indian driving cycle); including key ON OFF cycles, vehicle can be considered meeting circuit discontinuity when the MIL activates within maximum of 10 driving cycles.
2. If the OBD parameter does not require vehicle to be driven for MIL activation, vehicle can be considered meeting circuit discontinuity for the tested OBD parameters.
3. The DTC code shall be retrieved by the OBD Scan Tool or by any other method as mutually agreed between test agency and vehicle manufacturer.
4. The procedure shall be repeated for other OBD parameters to be checked for circuit discontinuity.
5. The requirements of distance travelled since MIL ON shall be checked along with one of the circuit discontinuity tests for OBD parameters as specified by vehicle manufacturer by running the vehicle on chassis dynamometer as per driving cycle preferred by the vehicle manufacturer.

The vehicle submitted for a type approval shall be tested for maximum four discontinuity demonstration test selected by the test agency out of the OBD parameters as declared by the vehicle manufacturer. 'Vehicle type' means a category of power-driven vehicles, which do not differ in such essential engine and OBD system characteristics.

Every modification in the essential characteristics of the vehicle model shall be intimated by the vehicle manufacturer to the test agency which type approved by vehicle model. The test agency may either consider that the vehicle with the modifications made may still comply with the requirements or require further tests to ensure further compliance.

IV. ON-BOARD DIAGNOSTIC SYSTEM (OBD-II)

Although OBD supplies valuable information about a number of critical emissions related system and components, there are several important items which were not incorporated into the OBD standards due to the technical limitations at the time that the system was phased into production (during 1988). Since the introduction of OBD, several technical breakthroughs have occurred. For example, the technology to monitor engine misfire and catalyst efficiency has been developed and implemented on vehicles. As a result of this technical breakthroughs and because existing I/M programs have proven to be less effective than desired in detecting critical emission control system defects which occur during normal road load operation, a more comprehensive OBD system was developed under the direction of CARB.

OBD II is strictly emission oriented. In other words, it will illuminate MIL anytime a vehicle's hydrocarbon (HC), carbon monoxide (CO), nitrogen oxides (NOx) or evaporative emissions exceed 1.5 times Federal Test Procedure (FTP) standards. That includes anytime random misfire causes an overall rise in HC emissions, anytime the operating efficiency of the catalytic convertor drops a certain threshold, anytime

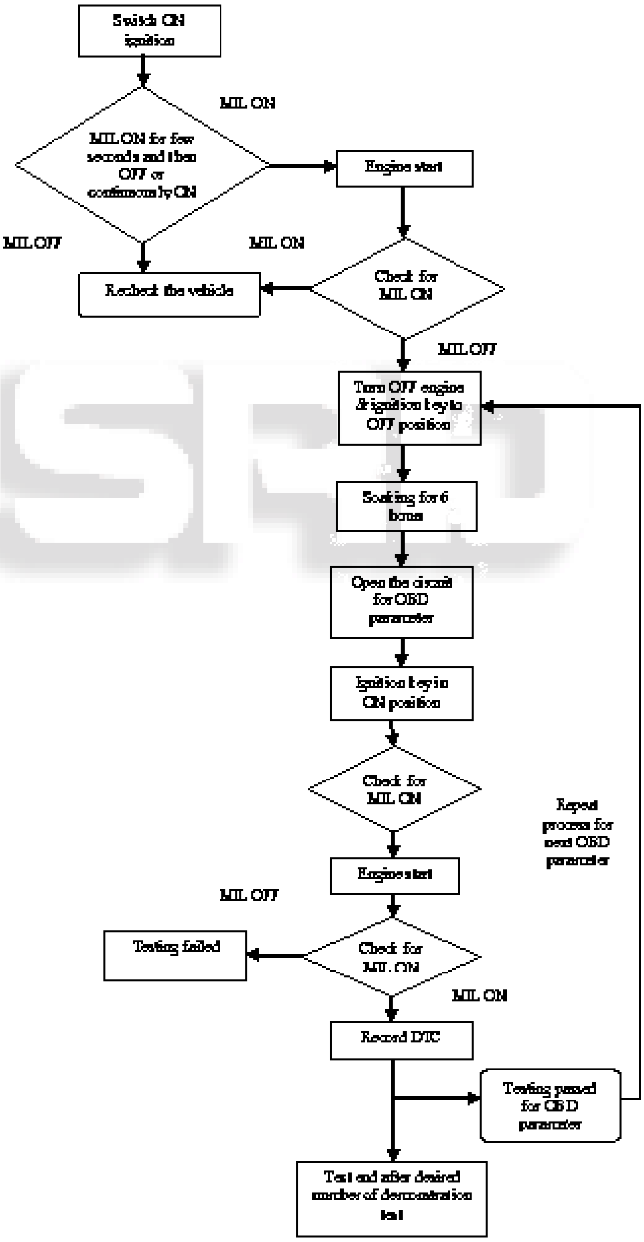

Fig. 2: Flow Chart for the Test Procedure

The system detects air leakage in the sealed fuel system, anytime a fault in EGR system causes NOx emissions to go up, or anytime a key sensor or other emission control

devices fails. In other words, the MIL light may come on even though the vehicle seems to be running normally and there are no real drivability problems.
OBD-II, which is implemented over the 1994 through 1996 model years, adds:

1. catalyst efficiency monitoring,
2. engine misfire detections,
3. canister purge system monitoring,
4. secondary air system monitoring and
5. EGR system flow rate monitoring.

The goal of the OBD-II regulation is to provide the vehicle with an on-board diagnostic system which is capable of continuously monitoring the efficiency of emission control systems and also to improve diagnosis and repair efficiency when a system failure occurs.

V. OBD-II FEATURES:

The following are the highlights of the OBD-II system features:

A. Oxygen Sensor (O2S):

An Oxygen sensor is a chemical generator. Oxygen sensors make modern and emission control possible electronic fuel injection. They help determine, in real time, if the air fuel ratio of a combustion engine is rich or lean. Since oxygen sensors are located in the exhaust stream, they do not directly measure the air or the fuel entering the engine. But when information from oxygen sensors is coupled with information from other sources, it can be used to indirectly determine the air-to-fuel ratio. Closed-loop feedback-controlled fuel injection varies the fuel injector output according to real-time sensor data rather than operating with a predetermined (open-loop) fuel map. In addition to enabling electronic fuel injection to work efficiently, this emissions control technique can reduce the amounts of both un-burnt fuel and oxides of nitrogen entering the atmosphere.
The sensor does not actually measure oxygen concentration, but rather the difference between the amount of oxygen in the exhaust gas and the amount of oxygen in air. Rich mixture causes an oxygen demand. This demand causes a voltage to build up, due to transportation of oxygen ions through the sensor layer. Lean mixture causes low voltage, since there is an oxygen excess.

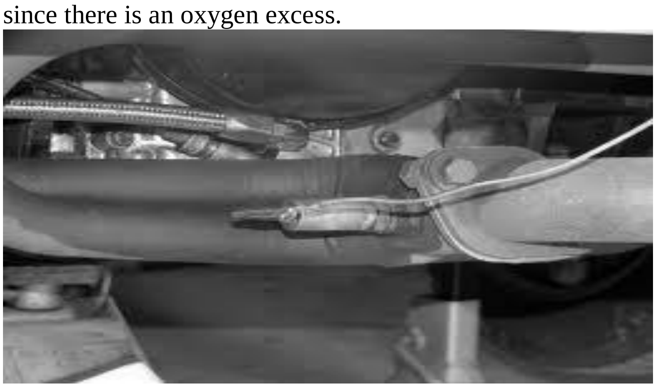

Fig. 3: Oxygen Sensor

Modern spark-ignited combustion engines use oxygen sensors and catalytic converters in order to reduce exhaust emissions. Information on oxygen concentration is sent to the engine management computer or ECU, which adjusts the amount of fuel injected into the engine to compensate for excess air or excess fuel. The ECU attempts to maintain, on average, a certain air-fuel ratio by interpreting the information it gains from the oxygen sensor. The primary goal is a compromise between power, fuel economy, and emissions, and in most cases is achieved by an air-fuel-ratio close to stoichiometric. By making sure that the mixture is at balance, you are assured that every bit of your fuel is burned and used so fuel economy is achieved.
Failure of these sensors, either through normal aging, the use of leaded fuels, or fuel contaminated with silicones or silicates, for example, can lead to damage of an automobile's catalytic converter and expensive repairs.

B. FUEL SYSTEM

The Fuel system in automobiles can be monitored by monitoring the fuel injection system and fuel pump. Fuel injection generally increases engine fuel efficiency. With the improved cylinder-to-cylinder fuel distribution of multi-point fuel injection, less fuel is needed for the same power output. Exhaust emissions are cleaner because the more precise and accurate fuel metering reduces the concentration of toxic combustion byproducts leaving the engine, and because exhaust cleanup devices such as the catalytic converter can be optimized to operate more efficiently since the exhaust is of consistent and predictable composition. Fuel-injected car include smoother and more dependable engine response during quick throttle transitions, easier and more dependable engine starting, better operation at extremely high or low ambient temperatures, increased maintenance intervals, and increased fuel efficiency.

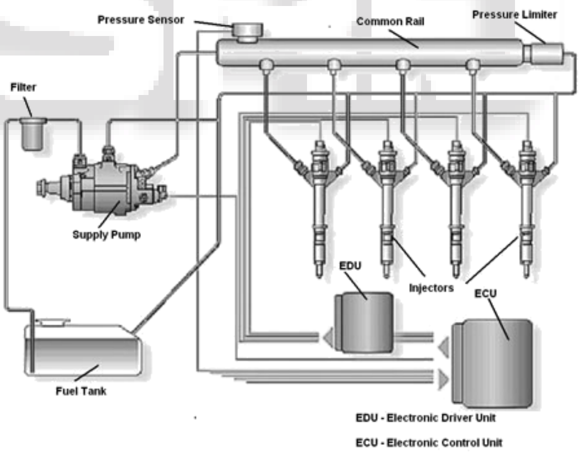

Fig. 4: Fuel System

The fuel pump creates positive pressure in the fuel lines, pushing the fuel to the engine. The higher fuel pressure raises the boiling point. Placing the pump in the tank puts the component least likely to handle fuel vapor well farthest from the engine, submersed in cool liquid. In most cars, the fuel pump delivers a constant flow of fuel to the engine; fuel not used is returned to the tank. This further reduces the chance of the fuel boiling, since it is never kept close to the hot engine for too long. Cars with electronic fuel injection have an electronic control unit (ECU) and this may be programmed with safety logic that will shut the electric fuel pump off, even if the engine is running. In the event of a collision this will prevent fuel leaking from any ruptured fuel line. ECUs may also be programmed to shut off the fuel pump if they detect low or zero oil pressure.

Category	Class	Reference Mass (RW) (kg)	Mass of CO (g/km)		Mass of HC (g/km)		Mass of NOx (g/km)		Mass of PM (g/km)
			Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Diesel
M*	-	All	3.2	3.2	0.4	0.4	0.6	1.2	0.18
N1 and M**	I	RW<=1305		3.2	0.4	0.4	0.6	1.2	0.18
	II	1305<RW<=1760	5.8	4.0	0.5	0.5	0.7	1.6	0.23
	III	1760<RW	7.3	4.8	0.6	0.6	0.8	1.9	0.28

Table 2: Official Gazette Notification (GSR) OBD

VI. Monitoring Requirements for the Vehicle Equipped with Positive Ignition Engines:

1. Catalytic converter monitor: Reduction in the efficiency of the catalytic converter with respect to HC emissions only. Each monitored catalyst or catalyst combination shall be considered malfunctioning when the emissions exceed the HC threshold.
2. Engine misfire: The engine operating region bounded by the following lines
    1. A maximum speed of 4500 rpm or 1000 rpm greater than the highest speed occurring during type 1 test cycle, whichever is lower.
    2. The positive torque line (i.e. Engine load with transmission in neutral).
    3. A line joining the following engine operation points: The positive torque line at 3000 rpm and a point on the maximum speed line defined in (1) above with the engines manifold at 13.33 kPa lower than that at the positive torque line.
3. Oxygen sensor deterioration
4. The electronic evaporative emission purge control must, at a minimum, be monitored for circuit continuity.
5. Any other emission related power train component connected to control unit, including any relevant sensor to enable monitoring function to be carried out must be monitored for circuit continuity.

VII. Monitoring Requirements for the Vehicles Equipped with CI

1. Where fitted, reduction in efficiency of the catalytic converter.
2. Where fitted, functionality and integrity of the particulate trap.
3. The fuel injection system electronic fuel quantity And timing actuators are monitored for circuit continuity and total functional failure.
4. Any other emission related power train component connected to control unit, including any relevant sensor to enable monitoring function to be carried out must be monitored for circuit continuity.

VIII. TEST PROCEDURE FOR OBD-II

1. Operating on the chassis dynamometer must meet requirements of MIDC (Modified Indian Driving Cycle).
    1. Vehicle preconditioning: After introducing of one of the failure modes, the vehicle must be preconditioned by driving at least two consecutive types I test (part I and part II). For compression ignition engines vehicles an additional preconditioning of two parts two cycles is permitted.
    2. Failure modes to be tested:

        1) Positive ignition engine vehicles
        - a. Replacement of catalyst with a deteriorated or defective catalyst or electronic simulation of such a failure.
        - b. Engine misfire conditions.
        - c. Replacement of oxygen sensor with a deteriorated or defective sensor or electronic simulation of such a failure.
        - d. Electrical disconnection of electronic evaporative purge control device. For the specific failure mode type I test need not to be performed.
        - e. Electrically disconnection of any other emission related component connected to power train management control unit.

        2) Compression ignition engine vehicles
        - a. Replacement of catalyst with a deteriorated or defective catalyst or electronic simulation of such a failure.
        - b. Electrically disconnection of any fuelling system, electronic fuel quantity and timing actuators.
        - c. Electrically disconnection of any other emission related component connected to power train management control unit.
    3. The manufacturer must make available the defective components and electrical devices which would be used to simulate failures. When measured over the type I test cycle, such defective components or devices must not cause the vehicle emission to exceed the limit given in the official gazette notification (GSR) by more than 20%.
    4. After vehicle preconditioning, the test vehicle is driven over type I test (part I & part II). The MI must activate before the end of this test under any of the conditions. However the total number of failures simulated must not exceed four for the purpose of type approval.

IX. Scanning Procedure

OBD-I and OBD-II Diagnostic Tool for Checking:

1) The OBD-I and OBD –II monitoring items can be checked by diagnostic scan tool with a standard connector that can be connected to the vehicle diagnostic connector which is required to be within 2 feet of the steering wheel.
2) In general, the MIL is not ON at the instance of problem being raised, it would take few driving cycles to indicate the MIL ON.
3) It is checked for the fault codes to determine the problem in the system.
4) The DTCs for OBD implies the following:
   a) EOBD fault codes consist of five characters. A letter followed by four numbers. The letter refers to the system being interrogated e.g. Pxxxx would refer to the power train system and likewise B and C for Body and Chassis respectively. The next character would be a 0 if complies to the EOBD standard. So it should look like P0xxx.
   b) The next character would refer to the sub system. *P*00xx - Fuel and Air Metering and Auxiliary Emission Controls. *P*01xx - Fuel and Air Metering. *P*02xx - Fuel and Air Metering (Injector Circuit). *P*03xx - Ignition System or Misfire. *P*04xx - Auxiliary Emissions Controls. *P*05xx - Vehicle Speed Controls and Idle Control System. *P*06xx - Computer Output Circuit. *P*07xx - Transmission. *P*08xx - Transmission.
   The following two characters would refer to the individual fault within each subsystem.
5) By analyzing the code the inspector can know where the problem is and rectifies it.

X. CONCLUSION

On-Board Diagnostics (OBD) has proven to be an effective implementation to control the emission levels as it monitors the emission control systems/devices and indicates any malfunctions in the system to the owner. Many states now use OBD-II testing instead of tailpipe testing in OBD-II compliant vehicles. Since OBD-II stores trouble codes for emissions equipment, the testing computer can query the vehicle's onboard computer and verify there are no emission related trouble codes and that the vehicle is in compliance with emission standards for the model year it was manufactured. Real world data has shown that the use of OBD for inspecting vehicle emission control systems offers many benefits to the consumer, the technician, and the environment:

1. Accurate diagnosis that leads to effective, durable repairs.
2. Short inspection time for the public.
3. Early vehicle maintenance opportunity, which leads to greater fuel efficiency and reliability.
4. Incentive to car manufacturers to produce more durable engines and emission controls.
5. Simple and affordable testing method.
6. Early detection of potential emission exceedance.
7. State-of-the-art evaporative emission detection.

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