ADD-ON SYSTEMS FOR CONTROL OF ENGINE-OUT EMISSIONS

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ADD-ON SYSTEMS FOR CONTROL OF ENGINE-OUT EMISSIONS

Crankcase Emission Control (PCV System)

A small amount of charge in the cylinder leaks past piston rings into crankcase of the reciprocating engines. Near top dead centre (TDC) when the rings change their position in the grooves at the end of compression stroke, combustion has already begun and the cylinder pressures are high. A significant part of charge stored in the piston- ring-cylinder crevice leaks into the crankcase. These gases are known as 'crankcase blow by' and their flow rate increases as the engine is worn out and the piston - cylinder clearances and ring gaps increase. In the homogeneous charge engines, the crankcase blow by gas is high in HC concentration. Only a small fraction of the gas stored in the ring crevices and hence blow by gases may consist of partially burnt mixture. This source contributes about 20 percent of total hydrocarbons emitted by an uncontrolled car.

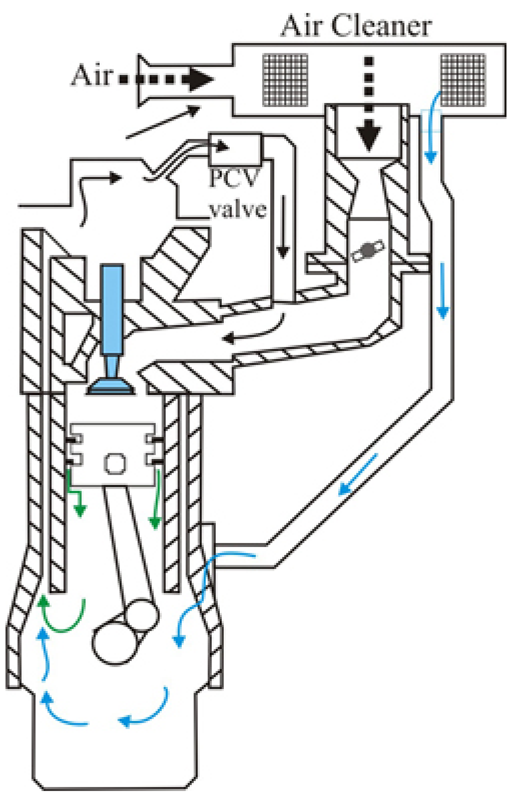

Figure 5.6	Schematic of a PCV system.

The crankcase blowby gases in the uncontrolled engines were ventilated to atmosphere under the effect of pressure difference occurring naturally between the crankcase and atmosphere. For control of crankcase emissions, the blowby gases are recycled back to the engine assisted by a positive pressure drop between the crankcase and intake manifold. When engine is running and intake charge is throttled the intake manifold is at a lower pressure than the crankcase. The blow-by gases mix with the intake charge to be burned inside the engine cylinder to CO_2 and H_2O. A typical PCV system is shown in Fig. 5.6. A tube connects crankcase or cylinder head cover to the intake manifold below throttle valve, which leads the blowby gases back to the engine. Due to suction effect of intake manifold as the pressure in the crankcase falls, ventilation air
from the air cleaner is drawn into the crankcase that continuously purges it. A one-way valve (PCV

valve) is used to control the flow of blowby gases PCV valve restricts flow of blowby gases during idling and very light loads which otherwise would cause excessive leaning of the charge by ventilation air.Under normal engine operation, PCV valve is fully open providing free flow of the gases while under high intake manifold vacuum the flow is restricted.

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Evaporative Emission Control

In the uncontrolled vehicles, fuel vapours from the fuel tank and carburettor were vented into the atmosphere that constituted about 20% of all hydrocarbon emissions from a gasoline passenger car. From 1970, evaporative emission control was required to be employed on production gasoline vehicles in the USA.

- The evaporative emission control system consists of a device to store fuel vapours produced in the fuel system due to evaporation.
- A canister containing activated charcoal is used to store the fuel vapours.
- The vapours produced in the fuel tank normally collect in the fuel tank itself and are vented to the charcoal canister when fuel vapour pressure becomes excessive. The fuel vapours from the tank and carburettor led to and adsorbed into the charcoal. In the PFI engines only the fuel tank is connected to the canister.
- When engine is running, the vacuum created in the intake manifold is used to draw fuel vapours from the canister into the engine. Purging air is sucked through the canister which leads the fuel vapours from canister to the engine. An electronically controlled purge valve is used.
- During engine acceleration additional mixture enrichment can be tolerated and under these operating conditions the stored fuel vapours are usually purged into the intake manifold.
- This system is a fully closed system. A sealed fuel tank filler cap is used and a stable fuel tank pressure is maintained by the purging process of the canister.

A typical schematic layout of evaporative control system is shown in Fig. 5.7. Given below are some of the measures adopted to achieve near zero evaporative emissions as required in California;

- Sealed fuel tank is kept under vacuum to prevent permeation of fuel through walls of a polymer fuel tank and leakage of fuel vapours through filler cap.
- Fuel tubing made of high density polymer or steel to reduce/prevent fuel permeation.
- Better canister technology and more effective activated charcoal.
- Employment of refuelling vapour recovery (ORVR) system as during vehicle refuelling maximum share of fuel evaporative emissions escape..
- A carbon trap to arrest the escape of fuel vapours from intake manifold. When the vehicle is standing and is under hot soak fuel vapours can escape past the throttle body into atmosphere.

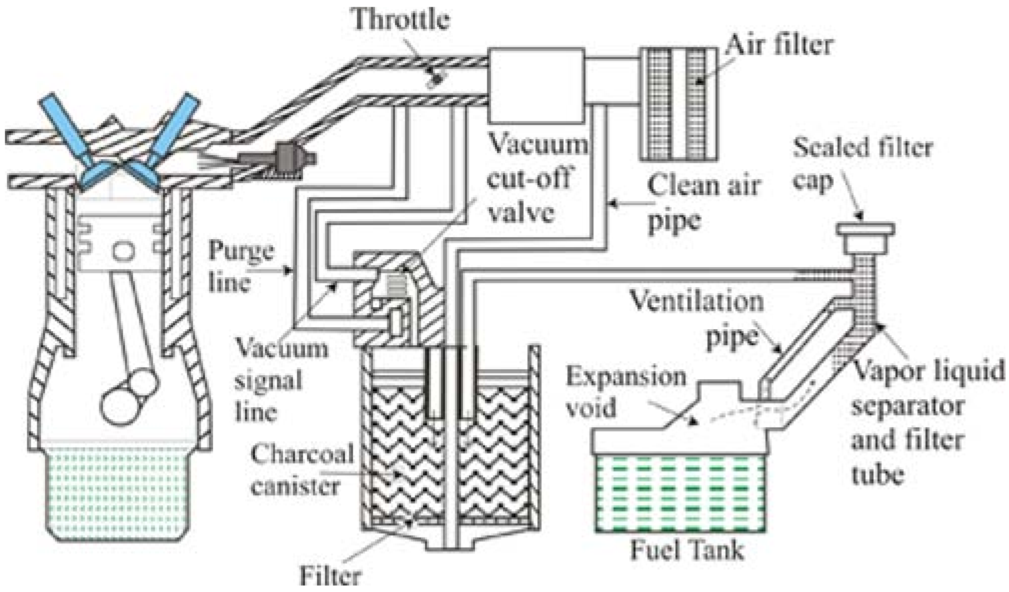

Figure 5.7	Schematic of an evaporative emission control system for a PFI engine.

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Exhaust Gas Recirculation

Effect of addition of diluents to the intake charge for lowering of combustion temperatures and consequently reducing the formation of NO_x has been discussed in Module 2 .The heat capacity of the exhaust gas is higher than the air as it contains significant amount of tri-atomic gases CO_2 and water vapours. Therefore, addition of exhaust gas to fresh intake charge has a higher effect in lowering the combustion temperatures compared to simple leaning of the charge..

EGR is defined as a mass percent of total intake flow:

$$EGR = [\dot{m}_{EGR}/\dot{m}_i](100), \% \qquad (5.1)$$

where $\dot{m}_i$ is the total mass flow into the engine.

Typically, only about 5 to 10 % EGR rates are employed. At higher EGR rates, frequency of partial and complete misfire cycles increases resulting in unacceptably higher HC emissions and loss in fuel economy and power. EGR systems are made to operate mostly in the part-load range. These are deactivated at engine idle, because large amount of residual gas is already present in the cylinder. Many times the system is deactivated at full throttle conditions as the vehicle rarely operates under these conditions during city operation.

A schematic layout of EGR system is shown in Fig 5.8. An EGR control valve is used to regulate flow of EGR depending upon engine operating conditions. The intake manifold pressure or exhaust back pressure may be used to control EGR rate as these parameters vary with engine load. In the modern engines, EGR rate is controlled by the engine electronic control unit. A pressure sensor in the exhaust or intake provides signal to the electronic control module of the engine, which in its turn regulates the operation of the EGR valve.

Electronically controlled EGR valves actuated by high-response stepper motor are being used on modern engines. Their fast response during transient operation makes it possible to reduce NO_x more than what is obtained by use of a mechanically controlled EGR valves. Effectively a lower rate of EGR can be employed to obtain the same reduction in NO_x that results in a lower penalty on HC emissions

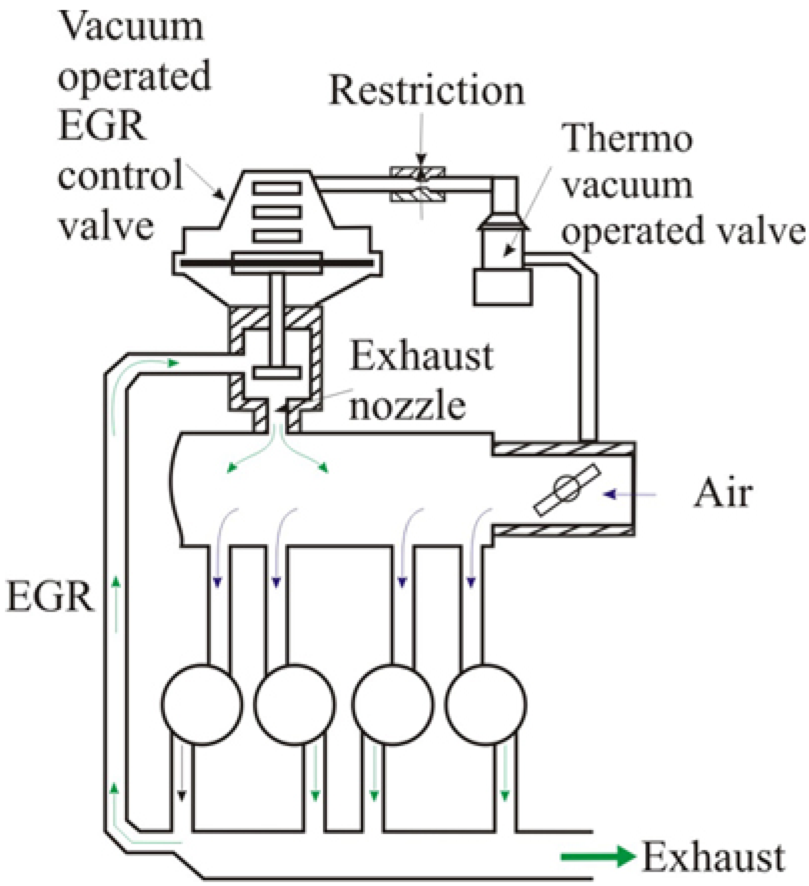

Figure 5.8	EGR system mechanically controlled by intake manifold pressure

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Water Injection

Water has been added to the high performance, reciprocating aero SI engines during Second World War to suppress engine knock. Water addition to intake charge has been investigated by many researchers to reduce NOx formation. Water addition to intake charge is another form of charge dilution to reduce combustion temperatures.

Water has been directly injected into intake manifold or used as water-fuel emulsion. Emulsifying chemicals in about 2 percent by volume are added to form water-gasoline emulsions. The stability of emulsion may be around a few days. The addition of emulsifiers usually reduces the fuel octane number. With water addition ranging from 10 to 30% by volume of gasoline, large reductions in NO_x are possible However, high increase in HC is observed although only a slight increase in CO occurs. Some times a small improvement in BSFC with small addition of water is observed but the BSFC increases with higher amounts of water addition. This approach has not been found practical due to harmful effects of water addition as HC and BSFC increase, and corrosion of engine components is also encountered.

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