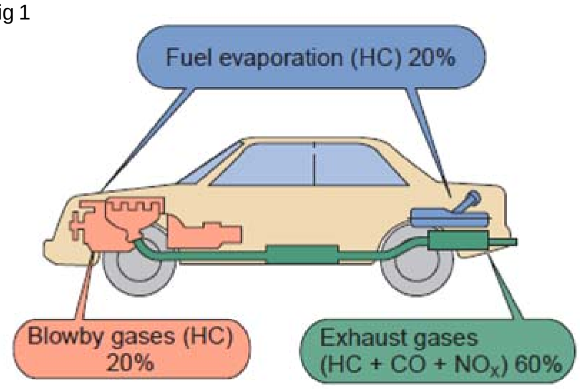
Sources of Emission

Objectives: At the end of this lesson you shall be able to
- **state sources of emission**
- **state different type of emission.**

The power to move a motor vehicle comes from burning fuel in an engine. Emissions from vehicles are the by-products of this combustion process. Emissions from a motor vehicle generally come from four sources

Fig 1



1 The fuel tank

2 The crankcase

3 The exhaust system

Evaporative Emissions

The fuel tank and carburetor allow fuel to evaporate and escape to the atmosphere. These are called evaporative emissions

Exhaust Emissions

The crankcase and exhaust system (Fig 1) emit pollutants directly from the engine into the atmosphere. They are caused when hydrocarbons, lead compounds, and oxygen and nitrogen from the air, are burned in the combustion chamber.

In a compression-ignition engine, emissions originate from the engine, and escape to the atmosphere from the exhaust, and the crankcase breather.

Vehicle emissions standards - Euro and Bharat

Objectives: At the end of this lesson you shall be able to
- **follow the European emission standards for gasoline of diesel passenger vehicle, light vehicle and heavy vehicle**
- **follow the bharat emission standards for gasoline passenger vehicle, light vehicle and heavy vehicle.**

Emission requirements for light road vehicles have existed in the European emission standards (EU) since the early 1970s, while the first requirements for heavy vehicles came in at the end of the 1980s. Today, vehicle emissions are controlled under two basic frameworks: the "Euro standards" and the regulation on carbon dioxide emissions.

Currently, emissions of nitrogen oxides (NOx), total hydrocarbon (THC), non-methane hydrocarbons (NMHC), carbon monoxide (CO) and particulate matter (PM) are regulated for most vehicle types, including cars, lorries, trains, tractors.

While the norms help in bringing down pollution levels, it invariably results in increased vehicle cost due to the improved technology & higher fuel prices. However, this increase in private cost is offset by savings in health costs for the public, as there is lesser amount of disease causing particulate matter and pollution in the air.

Exposure to air pollution can lead to respiratory and cardiovascular diseases, which caused 620,000 early deaths in 2010, and the health cost of air pollution in India has been assessed at 3 per cent of its GDP.

European emission standards define the acceptable limits for exhaust emissions of new vehicles sold in EU member states.

Emission standards for passenger cars and light commercial vehicles are summarised in the following tables.

European emission standards for passenger cars (Category M*), g/km.

Tier	Date	CO	THC	NMHC	NOx	HC+NOx	PM	P***
Diesel								
Euro 1†	July 1992	2.72 (3.16)	-	-	-	0.97 (1.13)	0.14 (0.18)	-
Euro 2	January 1996	1.0	-	-	-	0.7	0.08	-
Euro 3	January 2000	0.64	-	-	0.50	0.56	0.05	-
Euro 4	January 2005	0.50	-	-	0.25	0.30	0.025	-
Euro 5	September 2009	0.50	-	-	0.180	0.230	0.005	-
Euro 6	September 2014	0.50	-	-	0.080	0.170	0.005	-
Petrol (Gasoline)								
Euro 1†	July 1992	2.72 (3.16)	-	-	-	0.97 (1.13)	-	-
Euro 2	January 1996	2.2	-	-	-	0.5	-	-
Euro 3	January 2000	2.3	0.20	-	0.15	-	-	-
Euro 4	January 2005	1.0	0.10	-	0.08	-	-	-
Euro 5	September 2009	1.0	0.10	0.068	0.060	-	0.005**	-
Euro 6(future)	September 2014	1.0	0.10	0.068	0.060	-	0.005**	-

* Before Euro 5, passenger vehicles > 2500 kg were type approved as light commercial vehicles N1-I

** Applies only to vehicles with direct injection engines

*** A number standard is to be defined as soon as possible and at the latest upon entry into force of Euro 6

† Values in brackets are conformity of production (COP) limits

Emission standards for light commercial vehicles

European emission standards for light commercial vehicles ≤ 1305 kg (Category N1-I), g/km.

Emission standards for light commercial vehicles

European emission standards for light commercial vehicles ≤ 1305 kg (category N_1 - I), g/km

Tier	Date	CO	THC	NMHC	NOx	HC+NOx	PM	P
Diesel								
Euro 1	October 1994	2.72	-	-	-	0.97	0.14	-
Euro 2	January 1998	1.0	-	-	-	0.7	0.08	-
Euro 3	January 2000	0.64	-	-	0.50	0.56	0.05	-
Euro 4	January 2005	0.50	-	-	0.25	0.30	0.025	-
Euro 5	September 2009	0.500	-	-	0.180	0.230	0.005	-
Euro 6	September 2014	0.500	-	-	0.080	0.170	0.005	-
Petrol (Gasoline)								
Euro 1	October 1994	2.72	-	-	-	0.97	-	-
Euro 2	January 1998	2.2	-	-	-	0.5	-	-
Euro 3	January 2000	2.3	0.20	-	0.15	-	-	-
Euro 4	January 2005	1.0	0.10	-	0.08	-	-	-
Euro 5	September 2009	1.000	0.100	0.068	0.060	-	0.005*	-
Euro 6	September 2014	1.000	0.100	0.068	0.060	-	0.005*	-

* Applies only to vehicles with direct injection engines

European emission standards for light commercial vehicles 1305 kg - 1760 kg (Category N1-II), g/km

Tier	Date	CO	THC	NMHC	NOx	HC+NOx	PM	P
Diesel								
Euro 1	October 1994	5.17	-	-	-	1.4	0.19	-
Euro 2	January 1998	1.25	-	-	-	1.0	0.12	-
Euro 3	January 2001	0.80	-	-	0.65	0.72	0.07	-
Euro 4	January 2006	0.63	-	-	0.33	0.39	0.04	-
Euro 5	September 2010	0.630	-	-	0.235	0.295	0.005	-
Euro 6	September 2015	0.630	-	-	0.105	0.195	0.005	-
Petrol (Gasoline)								
Euro 1	October 1994	5.17	-	-	-	1.4	-	-
Euro 2	January 1998	4.0	-	-	-	0.6	-	-
Euro 3	January 2001	4.17	0.25	-	0.18	-	-	-
Euro 4	January 2006	1.81	0.13	-	0.10	-	-	-
Euro 5	September 2010	1.810	0.130	0.090	0.075	-	0.005*	-
Euro 6	September 2015	1.810	0.130	0.090	0.075	-	0.005*	-

* Applies only to vehicles with direct injection engines

N_1 - III & N_2, g/Km

Tier	Date	CO	THC	NMHC	NOx	HC+NOx	PM	P
Diesel								
Euro 1	October 1994	6.9	-	-	-	1.7	0.25	-
Euro 2	January 1998	1.5	-	-	-	1.2	0.17	-
Euro 3	January 2001	0.95	-	-	0.78	0.86	0.10	-
Euro 4	January 2006	0.74	-	-	0.39	0.46	0.06	-
Euro 5	September 2010	0.740	-	-	0.280	0.350	0.005	-
Euro 6	September 2015	0.740	-	-	0.125	0.215	0.005	-
Petrol (Gasoline)								
Euro 1	October 1994	6.9	-	-	-	1.7	-	-
Euro 2	January 1998	5.0	-	-	-	0.7	-	-
Euro 3	January 2001	5.22	0.29	-	0.21	-	-	-
Euro 4	January 2006	2.27	0.16	-	0.11	-	-	-
Euro 5	September 2010	2.270	0.160	0.108	0.082	-	0.005*	-
Euro 6	September 2015	2.270	0.160	0.108	0.082	-	0.005*	-
* Applies only to vehicles with direct injection engines								

Whereas for passenger cars, the standards are defined by vehicle driving distance, g/km, for lorries (trucks) they are defined by engine energy output, g/kWh, and are therefore in no way comparable. The official category name is heavy-duty diesel engines, which generally includes lorries and buses.

EU Emission Standards for HD Diesel Engines, g/k wh (smoke in m^{-1})

Tier	Date	Test cycle	CO	HC	NOx	PM	Smoke
Euro I	1992, < 85 kW 1992, > 85 kW	ECE R-49	4.5 4.5	1.1 1.1	8.0 8.0	0.612 0.36	
Euro II	October 1996 October 1998		4.0 4.0	1.1 1.1	7.0 7.0	0.25 0.15	
Euro III	October 1999 EEVs only	ESC & ELR	1.0	0.25	2.0	0.02	0.15
	October 2000	ESC & ELR	2.1	0.66	5.0	0.10 0.13*	0.8
Euro IV	October 2005		1.5	0.46	3.5	0.02	0.5
Euro V Euro VI	October 2008 31 December 2013[15]		1.5 1.5	0.46 0.13	2.0 0.4	0.02 0.01	0.5
* for engines of less than 0.75 dm^3 swept volume per cylinder and a rated power speed of more than 3,000 per minute.							

EEV is "Enhanced environmentally friendly vehicle".

Bharat stage emission standards are emission standards instituted by the Government of India to regulate the output of air pollutants from internal combustion engine equipment, including motor vehicles. The standards and the timeline for implementation are set by the Central Pollution Control Board under the Ministry of Environment & Forests.

The standards, based on European regulations were first introduced in 2000. Progressively stringent norms have been rolled out since then. All new vehicles manufactured after the implementation of the norms have to be compliant with the regulations. Since October 2010, Bharat stage III norms have been enforced across the country. In 13 major cities, Bharat stage IV emission norms have been in place since April 2010.

The phasing out of 2 stroke engine for two wheelers, the stoppage of production of Maruti 800 & introduction of electronic controls have been due to the regulations related to vehicular emissions.

Table 1: Indian Emission Standards (4-Wheel Vehicles)

Standard	Reference	Date	Region
India 2000	Euro 1	2000	Nationwide
Bharat Stage II	Euro 2	2001 2003.04 2005.04	NCR*, Mumbai, Kolkata, Chennai NCR*, 13 Cities† Nationwide
Bharat Stage III	Euro 3	2005.04 2010.04	NCR*, 13 Cities† Nationwide
Bharat Stage IV	Euro 4	2010.04	NCR*, 13 Cities†
Bharat Stage V	Euro 5	2020 (proposed)	Entire country
* National Capital Region (Delhi)			
† Mumbai, Kolkata, Chennai, Bengaluru, Hyderabad, Ahmedabad, Pune, Surat,Kanpur,Lucknow,Sholapur,Jamshedpur and Agra			

The above standards apply to all new 4-wheel vehicles sold and registered in the respective regions. In addition, the National Auto Fuel Policy introduces certain emission requirements for interstate buses with routes originating or terminating in Delhi or the other 10 cities.

Emission standards for 2-and 3-wheelers

Table 2: Indian Emission Standards (2 and 3 wheelers)

Standard	Reference	Date
Bharat Stage II	Euro 2	1 April 2005
Bharat Stage III	Euro 3	1 April 2010
Bharat Stage IV	Euro 4	1 April 2016 (proposed)
Bharat Stage V	Euro 5	1 April 2020 (proposed)

In order to comply with the BSIV norms, 2 and 3 wheeler manufacturers will have to fit an evaporative emission control unit, which should lower the amount of fuel that is evaporated when the motorcycle is parked.

Trucks and buses

Emission standards for new heavy-duty diesel engines-applicable to vehicles of GVW > 3,500 kg-are listed in Table 3.

Table 3: Emission Standards for Diesel Truck and Bus Engines, g/kWh

Year	Reference	Test	CO	HC	NOx	PM
1992	-	ECE R49	17.3-32.6	2.7-3.7	-	-
1996	-	ECE R49	11.20	2.40	14.4	-
2000	Euro I	ECE R49	4.5	1.1	8.0	0.36*
2005†	Euro II	ECE R49	4.0	1.1	7.0	0.15
2010†	Euro III	ESC ETC	2.1 5.45	0.66 0.78	5.0 5.0	0.10 0.16
2010‡	Euro IV	ESC ETC	1.5 4.0	0.46 0.55	3.5 3.5	0.02 0.03

* 0.612 for engines below 85 kW
† earlier introduction in selected regions, see Table 1 ‡ only in selected regions, see Table 1

Emission standards for light-duty diesel vehicles (GVW ? 3,500 kg) are summarised in Table 4. Ranges of emission limits refer to different classes (by reference mass) of light commercial vehicles; compare the EU light-duty vehicle emission standards for details on the Euro 1 and later standards. The lowest limit in each range applies to passenger cars (GVW ? 2,500 kg; up to 6 seats).

Table 4: Emission Standards for Light-Duty Diesel Vehicles, g/km

Year	Reference	CO	HC	HC+NOx	NOx	PM
1992	-	17.3-32.6	2.7-3.7	-	-	-
1996	-	5.0-9.0	-	2.0-4.0	-	-
2000	Euro 1	2.72-6.90	-	0.97-1.70	0.14-0.25	-
2005†	Euro 2	1.0-1.5	-	0.7-1.2	0.08-0.17	-
2010†	Euro III	0.64 0.80 0.95	-	0.56 0.72 0.86	0.50 0.65 0.78	0.05 0.07 0.10
2010‡	Euro 4	0.50 0.63 0.74	-	0.30 0.39 0.46	0.25 0.33 0.39	0.025 0.04 0.06

† earlier introduction in selected regions, see Table 1
‡ only in selected regions, see Table 1

The test cycle has been the ECE + EUDC for low power vehicles (with maximum speed limited to 90 km/h).

Before 2000,emissions were measured over an indian test cycle.

Engines for use in light-duty vehicles can be also emission tested using an engine dynamometer. The respective emission standards are listed in table 5.

Table 5: Emission Standards for Light-Duty Diesel Engines, g/kWh

Year	Reference	CO	HC	NOx	PM
1992	-	14.0	3.5	18.0	-
1996	-	11.20	2.40	14.4	-
2000	Euro I	4.5	1.1	8.0	0.36*
2005†	Euro II	4.0	1.1	7.0	0.15

* 0.612 for engines below 85 kW
† earlier introduction in selected regions, see Table 1

Table 6: Emission Standards for Gasoline Vehicles (GVW 3,500 kg), g/km

Year	Reference	CO	HC	HC+NOx	NOx
1991	-	14.3-27.1	2.0-2.9	-	
1996	-	8.68-12.4	-	3.00-4.36	
1998*	-	4.34-6.20	-	1.50-2.18	
2000	Euro 1	2.72-6.90	-	0.97-1.70	
2005†	Euro 2	2.2-5.0	-	0.5-0.7	
2010†	Euro 3	2.3 4.17 5.22	0.20 0.25 0.29	-	0.15 0.18 0.21
2010‡	Euro 4	1.0 1.81 2.27	-	0.1 0.13 0.16	0.08 0.10 0.11

* for catalytic converter fitted vehicles
† earlier introduction in selected regions, see Table 1 ‡ only in selected regions, see Table 1

Gasoline vehicles must also meet an evaporative (SHED) limit of 2g/test (effective 2000).

Emission standards for 3- and 2- wheel gasoline vehicles are listed in the following tables.

Table 7: Emission Standards for 3-Wheel Gasoline Vehicles, g/km

Year	CO	HC	HC+NOx
1991	12-30	8-12	-
1996	6.75	-	5.40
2000	4.00	-	2.00
2005 (BS II)	2.25	-	2.00
2010.04 (BS III)	1.25	-	1.25

Table 8: Emission Standards for 2-Wheel Gasoline Vehicles, g/km

Year	CO	HC	HC+NOx
1991	12-30	8-12	-
1996	5.50	-	3.60
2000	2.00	-	2.00
2005 (BS II)	1.5	-	1.5
2010.04 (BS III)	1.0	-	1.0

Table 9: Emission Standards for 2- And 3-Wheel Diesel Vehicles, g/km

Year	CO	HC+NOx	PM
2005.04	1.00	0.85	0.10
2010.04	0.50	0.50	0.05

Evaporation emission control

Objectives : At the end of this lesson you shall be able to
- **state the purpose of Evaporation emission control (EVAP) systems.**
- **Explain the working principle of evaporation emission control (EVAP) systems**
- **describe the EVAP system components.**

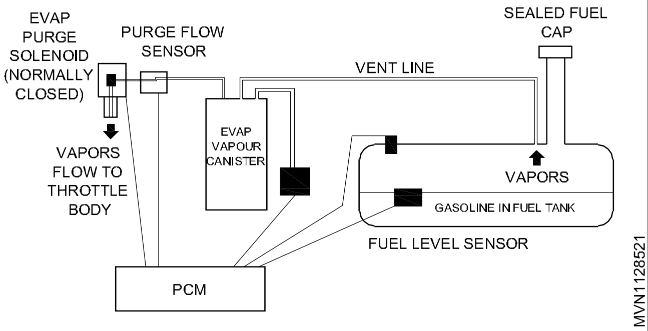
Purpose of Evaporation emission control (EVAP) systems

The Evaporation emission control (EVAP) systems totally eliminate fuel vapours going into the atmosphere.

Vent lines from the fuel tank and carburetor bowl route vapors to the EVAP storage canister, where they are trapped and stored until the engine is started.

When the engine is warm and the vehicle is going down the road, the PCM/ECU then opens a purge valve allowing the vapors to be drain off from the storage canister into the intake manifold. The fuel vapors are then burned in the engine (Fig 1)

Fig 1



Evap system components

The major components of the evaporative emission control system include

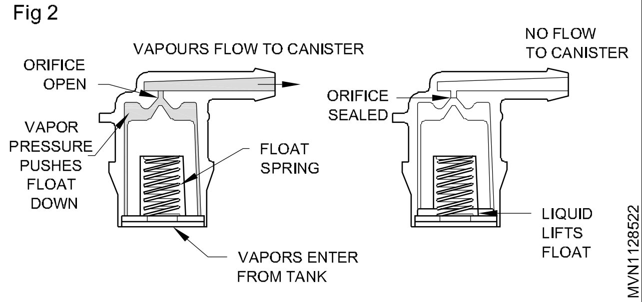
Fuel tank- This has some expansion space at the top so fuel can expand on a hot day without overflowing or forcing the EVAP system to leak.

Gas cap - This contains pressure/vacuum relief valve for venting on older vehicles (pre-OBD II), but is sealed completely (no vents) on newer vehicles (1996 & newer).

Liquid-Vapor Separator - This is located on top of the fuel tank or part of the expansion overflow tank. This device prevents liquid gasoline from entering the vent line to the EVAP canister.

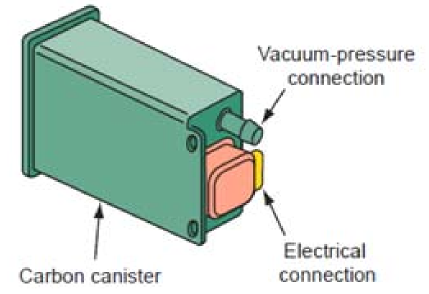
Some liquid-vapor separators use a slightly different approach to keeping liquid fuel out of the canister vent line. A float and needle assembly is mounted inside the separator. If liquid enters the unit, the float rises and seats the needle valve to close the tank vent. (Fig 2)

Fig 2



EVAP Canister - This is a small round or rectangular plastic or steel container mounted somewhere in the vehicle. It is usually hidden from view and may be located in a corner of the engine compartment or inside a rear quarter panel. (Fig 3)

Fig 3



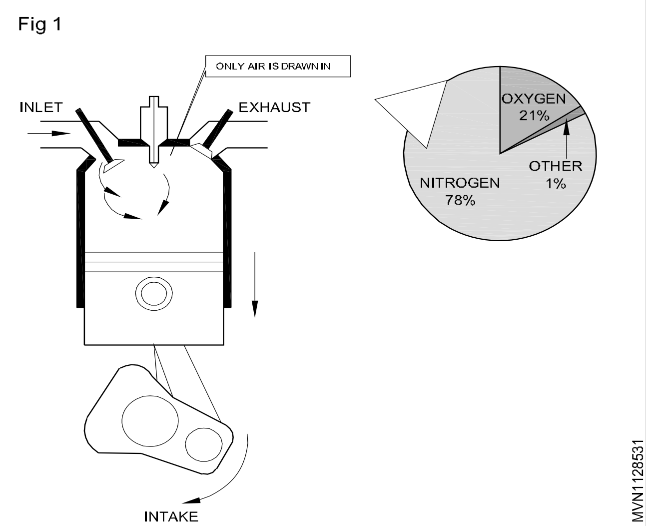
The canister is filled with about a kg of activated charcoal. The charcoal acts like a sponge and absorbs and stores fuel vapors. The vapors are stored in the canister until the engine is started, is warm and is being driven. The PCM then opens the canister purge valve, which allows intake vacuum to drain off the fuel vapors into the engine. The charcoal canister is connected to the fuel tank via the tank vent line.

Source of pollutants

Objectives: At the end of this lesson you shall be able to
- **state the characteristics of Oxides of nitrogen**
- **state the characteristics of Particulates**
- **state the characteristics of Carbon monoxide**
- **state the characteristics of Carbon dioxide (CO_2)**
- **state the characteristics of Sulfur content in fuels.**

Oxides of nitrogen

Air contains almost 78% Nitrogen (Fig 1). Under the high temperatures and pressure of combustion, this nitrogen combines with oxygen to produce oxides of nitrogen. Almost all internal combustion engine exhaust gases contains these chemicals.



If a lean mixture is used, formation of hydrocarbons and carbon monoxide is reduced, but for oxides of nitrogen, it is increased. This is due to the high temperature, and the increase in available oxygen.

Compression-ignition engines can produce high levels of oxides of nitrogen.

Particulates

Particulates from modern engines are usually carbon-based. Older vehicles may produce lead-based particulates. This is caused by lead compounds used in the fuel to raise its octane rating.

In spark ignition engines, particulates are caused by incomplete combustion of rich air-fuel mixtures.

In compression-ignition engines, they are caused by a lack of turbulence and lack of oxygen. Burning of lubricating oil inside combustar chamber leaves particulates in CI engine.

Carbon monoxide

Carbon monoxide is a colorless, odorless, tasteless, flammable, and highly toxic gas.

Carbon monoxide is a product of incomplete combustion and occurs when carbon in the fuel is partially oxidized rather than fully oxidized to carbon dioxide.

Carbon monoxide reduces the flow of oxygen in the bloodstream and is particularly dangerous to persons with heart disease.

Carbon dioxide (CO_2)

Carbon dioxide is produced, with water, when complete combustion of air and fuel occurs.

Catalytic converters in gasoline-engined vehicles convert carbon monoxide to carbon dioxide.

Carbon dioxide is also produced by diesel and LPG-fueled vehicles.

Carbon dioxide does not directly impair human health, but it is considered a "greenhouse gas". In other words, as it accumulates in the atmosphere, it is believed to trap the earth's heat and contribute to the potential for climate change.

Sulfur content in fuels

Gasoline and diesel fuels contain sulfur as part of their chemical composition.

Sulfuric acid is produced when sulfur combines with water vapor formed during the combustion process, and some of this corrosive compound is emitted into the atmosphere through the exhaust.

High sulfur levels in fuel, when combined with water vapor, can also cause corrosive wear on valve guides and cylinder liners, which can lead to premature engine failure. The use of proper lubricants and correct oil drain intervals helps combat this effect and reduces the degree of corrosive damage.

Although regulations have reduced the permissible levels of sulfur in fuel, there are some side effects from using low sulfur diesel fuel.

The refining process used to reduce the sulfur level can reduce the natural lubricating properties of the diesel fuel, which is essential for the lubrication and operation of fuel system components such as fuel pumps and injectors.

Characteristics and effect of hydrocarbons

Objectives: At the end of this lesson you shall be able to
- **state the of different type Hydrocarbon compounds**
- **state the Characteristics of Hydrocarbons**
- **state the Effect of Hydrocarbons.**

- Hydrocarbons are a major source of motor vehicle emissions.
- Gasoline, diesel, LP and natural gas are all hydro carbon compounds.
- Hydrocarbon emissions react with other compounds in the atmosphere to produce photo-chemical smog.
- Gasoline needs to evaporate easily to burn properly in an internal combustion engine.
- But this property also means it evaporates easily into the atmosphere at ordinary temperatures and pressures.
- When a vehicle is being refueled, hydrocarbon vapors can escape from the filler neck into the atmosphere.
- When the vehicle is left in the sun, its temperature increases, and fuel evaporates from the tank.

Hydrocarbons in exhaust gases

Objective: At the end of this lesson you shall be able to
- **state the release of Hydrocarbon compounds in produced during combustion.**

In a 4-stroke gasoline engine, during valve overlap at top dead centre (TDC), some intake charge is drawn out of the combustion chamber into the exhaust port. Raw fuel, a mixture of hydrocarbons and air, is released into the atmosphere.

When combustion occurs in the cylinder, the walls, piston and piston rings are slightly cooler than points closer to the burning mixture. Some of the air and fuel molecules come in contact with these cooler parts, and they cool down, until their temperature becomes too low for combustion to occur. They are left unburned, and when the exhaust port opens, they leave the cylinder.

Misfiring of the ignition can result in unburned fuel leaving the cylinder when the exhaust port opens.

If an excessively rich air-fuel mixture is used, there is too much fuel for the quantity of air. Combustion will be incomplete, and any unburned fuel will leave the cylinder through the exhaust port.

If an excessively lean mixture is used, then combustion takes longer, and the flame may extinguish before it is complete. When the exhaust port opens, unburned hydrocarbons will be exhausted from the cylinder.

Diesel Particulate Filters (DPF)

Objectives: At the end of this lesson you shall be able to
- **state the purpose of diesel particulate filters**
- **describe the working principle of diesel particulate filters**
- **state the importance of regeneration of diesel particulate filters**
- **describe the working principle of active regeneration of DPF**
- **describe the working principle of passive regeneration of DPF.**

Purpose of Diesel particulate filters

Diesel particulate filters (DPF) also called as 'particulate traps' have been developed to filter out PM from the diesel exhaust gases to meet very stringent emission limits.

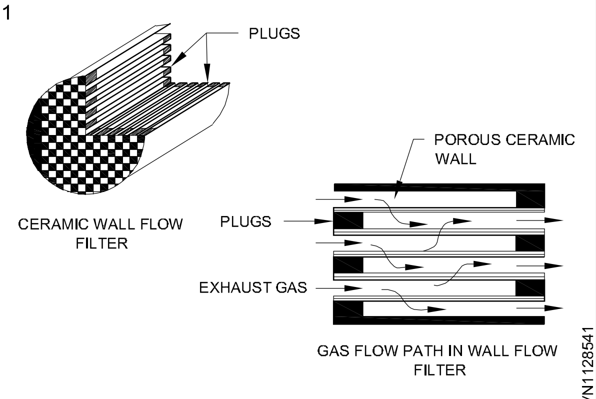
During combustion of the fuel and air mix,a variety of pollutant particles generically classified as diesel particulate matter is produced due to incomplete combustion.

Working principle of diesel particulate filters

Alumina coated wire mesh,ceramic fiber, porous ceramic monoliths etc., have been studied as filtration media. Presently, ceramicmonolith of honeycomb type structure is used to trap the particulate matter as the gas flows through its porous walls. These filters are also termed as 'ceramic wall flow filters'.

A ceramic honeycomb type particular filter is shown in Fig 1. In this cellular structure, alternate cells are plugged at one end and open at the oppasite end. The exhaust gas enters the cells that are open at the upstream end and flows through the porous walls to the adjacent cells. The adjacent cells are open at the downstream end from where the filtered gas exits to the atmosphere. Flow path of gas through walls of the filter is also shown on Fig 1

Fig 1



CERAMIC WALL FLOW FILTER FOR DIESEL PARTICULATE

Regeneration of DPF

It is relatively easy to filter and collect the particulate matter in the trap but the soot is to be burned in-suitable i.e., 'regenerate' the trap so that pressure drop across the filter is kept always at an acceptable level.

Burning of soot particles begins at about 540º C. Such high exhaust gas temperatures do not occur during engine operation for sufficiently long periods of time. The diesel exhaust gas temperatures in the exhaust pipe typically reach to about 300ºC only.

Two types of regeneration systems have been investigated and a few developed for employment on production vehicles

Active regeneration

Passive regeneration

Active DPF Regeneration

In the active regeneration systems, sensors are used to monitor pressure drop across the trap. On receiving the signal from the sensor, the exhaust gas temperature is increased above 500º C by any one of the following techniques

Engine throttling - Throttling of air reduces airflow that results in decrease of overall air-fuel ratio, which increases thecombustion and exhaust temperatures.

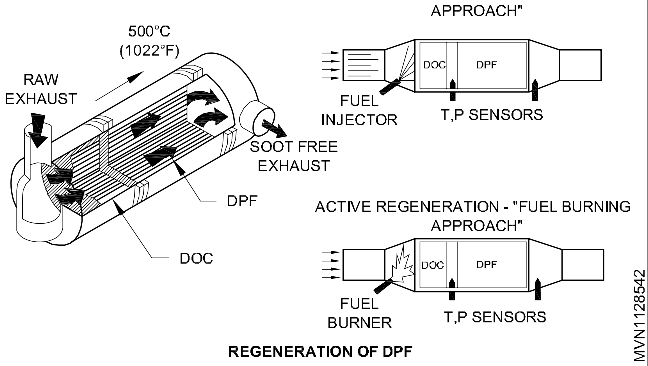
Use of electric heater upstream of filter - power to the electric heater is supplied by the engine alternator. A typical truck DPF regeneration system may require a 3 kw heater.

Use of burner upstream of filter - A diesel fuel burner is placed in the exhaust in front of the filter to regenerate the diesel particulate filter.

Passive regeneration

The passive regeneration systems (Fig. 2) employ catalysts to reduce soot oxidation temperatures to the levels that lie within the normal exhaust gas temperature range . The catalyst is either added to diesel added to diesel fuel in the form of additives or is impregnated on the surface of the filter substrate. Another approach for passive regeneration uses a special oxidation catalyst in the front of the ceramic wall flow particulate filter to promote soot oxidation. This system is known as the continuously regeneration trap (CRT).

Fig 2



Combustion chamber design

Objectives: At the end of this lesson you shall be able to
- **state the importance of combustion Chamber design**
- **state the purpose of air swirl combustion chamber design in CI Engine.**

The level of emissions can be controlled by suitable modification in the Combustion chamber design that increase gas flow rate, and promote vaporization, distribute the fuel more evenly in the combustion chamber.

The basic requirements of a good combustion chamber are to provide:

High power output

High thermal efficiency and low specific fuel consumption

Smooth engine operation

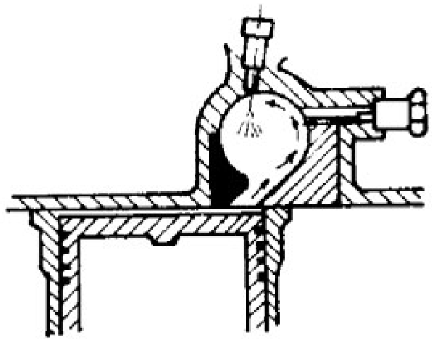
Reduced exhaust pollutants.

Gas flow rate, and volumetric efficiency, can be improved by using 2 intake valves in each cylinder. The effective port opening is increased, and the gas flow rate increases.

Changing valve timing also alters the combustion process. Reducing valve overlap reduces the scavenging effect. It also reduces hydrocarbon emission.

Most important function of CI engine combustion chamber is to provide proper mixing of fuel and air in short possible time. For this purpose an organized air movement called air swirl is to be produced to produce high relative velocity between the fuel droplets and air. (Fig 1).

Fig 1



Combustion process in CI engine

Objectives: At the end of this lesson you shall be able to
- **State combustion process**
- **define Perfect Combustion**
- **define typical Real-World Engine Combustion Process.**

Most vehicle fuels (gasoline, diesel, natural gas, ethanol, etc.) are mixtures of hydrocarbons, compounds that contain hydrogen and carbon atoms.

In a "perfect" engine, oxygen in the air would convert all of the hydrogen in fuel to water and all of the carbon in the fuel to carbon dioxide (carbon mixed with oxygen). Nitrogen in the air would remain unaffected.

In reality, the combustion process is not "perfect," and automotive engines emit several types of pollutants:

a. "Perfect" Combustion Process

FUEL (hydrocarbons) + AIR (oxygen and nitrogen) = CARBON DIOXIDE (CO2) + Water (H_2O) + Nitrogen

b. Typical Real-World Engine Combustion Process

FUEL (hydrocarbons) + AIR (oxygen and nitrogen) = UNBURNED or PARTIALLY BURNED HYDROCARBONS (VOCs) + NITROGEN OXIDES (NOx) + CARBON MONOXIDE (CO) + CARBON DIOXIDE (CO_2) + Water (H_2O)

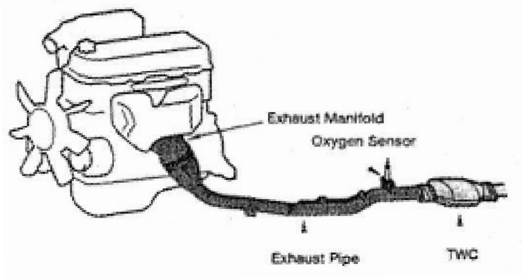
"Perfect" Combustion process is achieved by Ideal compression pressure is reached within the cylinder, condition of spark plug and timing accurate, Temperatures at correct value for engine, fuel, air, amount of fuel correct according to engines requirement, Precise valve timing, That the engine receives the correct amount of air, Electronically managed fuel injection systems use sensors and catalytic converters to control the combustion process and the air-fuel ratio supplied to the engine at all times.

Catalytic converter

Objectives: At the end of this lesson you shall be able to
- **state the purpose of Catalytic converter**
- **explain the conversion principle of Catalytic converter**
- **describe the EVAP system components.**

Passenger cars and light trucks have been equipped with catalytic converters. A Catalytic converter is located (Fig 1) within the exhaust system and converts to convert harmful emissions as HC, CO, NOx, produced by an internal combustion engine, to less-harmful elements: H_2O (Water), CO_2(Carbon Dioxide), and N2 (Nitrogen)

Fig 1



Block Diagram of three-way catalytic converters (TWC) (Fig 3)

Modern vehicles are fitted with three-way catalytic converters (TWC). The term 'three-way' is in relation to the three regulated emissions the converter is designed to reduce:

- Unburnt Hydrocarbons are oxidized into water/steam.
- Carbon monoxide is oxidized into carbon Dioxide
- Oxides are converted into Nitrogen and Oxygen

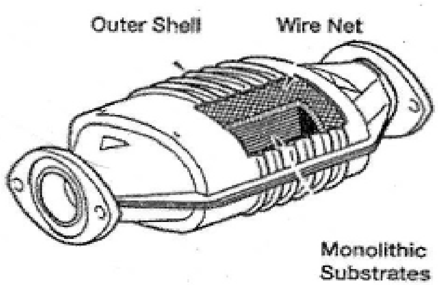
The converter uses two different types of catalysts to reduce the pollutants: a reduction catalyst and an oxidation catalyst.

A honeycomb structure (Fig.2) as either ceramic or metallic is treated with a wash-coat of precious metals usually platinum, palladium and rhodium through which the exhaust gasses flow. The Surface of the honeycomb material has a rough finish such that it allows the maximum contacts are available to the exhaust gasses.

The exhaust gases first pass over the reduction catalyst in the converter. The platinum and rhodium coating helps to reduce the oxides of nitrogen, together known as 'NOX' emission.

The three - way Catalyst, which is responsible for performing the actual feed gas conversion, formed by coating the internal substrate with the following type materials.

Fig 2

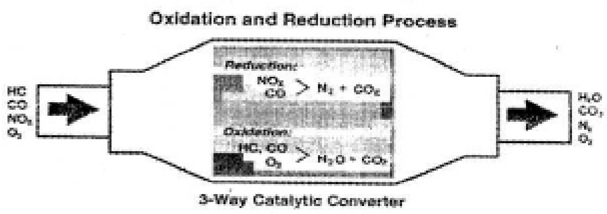


Material	Conversion for
Platinum/palladium	Oxidizing catalysts for HC and CO
Rhodium	Reducing catalyst for NOx
Cerium	Promotes oxygen storage to improve oxidation efficiency

The electronic control unit, or ECU, monitors the air-fuel ratio by using an exhaust gas oxygen, or EGO, sensor, also known as a lambda sensor. This sensor tells the engine computer how much oxygen is in the exhaust and uses this information via the ECU to control the fuel injection system.

The ECU can increase or decrease the amount of oxygen in the exhaust by adjusting the air-to-fuel ratio. The system ensures that the engine runs at close to the stoichiometric point in normal driving conditions. It also ensures that there is always sufficient oxygen in the exhaust system to allow the oxidization catalyst to deal with unburned hydrocarbons and carbon monoxide.

Fig 3

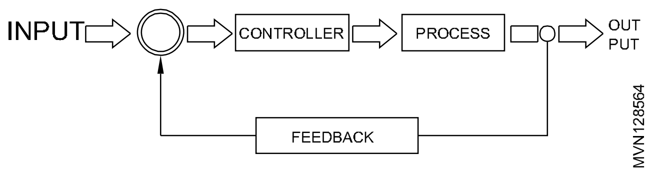


Closed loop control system

Control system in which the output has an effect on the input quantity in such a manner that the input quantity will adjust itself based on the output generated is called closed loop control system

In this way closed loop control system is called automatic control system.

Fig 4



Crankcase emission control

Objectives: At the end of this lesson you shall be able to
- **state the purpose of crankcase ventilation**
- **describe the working principle of positive crank case ventilation (PCV) system**
- **explain different stages of PCV valve operation**
- **describe the working principle of crankcase depression regulator valve (CDRV) for diesel engine.**

Purpose of crankcase ventilation

The firstcontrolled emission was crankcase vapors. While the engine is running during combustion some unburned fuel and other products of combustion leak between the piston rings and the cylinder walls, down into the crank-case. This leakage is called blow-by. Blow by gases are largely HC gases

Unburned fuel, and water from condensation, also find their way into the crankcase, and sump. When the engine reaches its full operating temperature , the water and fuel evaporate. To prevent pressure build - up, the crankcase must be ventilated.

In earlier vehicles, crackcase vapors were vented directly to the atmosphere through a breather tube, or road draught tube. It was shaped to help draw the vapors from the va-pors from the crankcase, as the vehicle was being driven.

Modern vehicles are required to direct crankcase breather gases and vapors back into the inlet system to be burned.

A general method of doing this is called positive crank-case ventilation, or PCV.

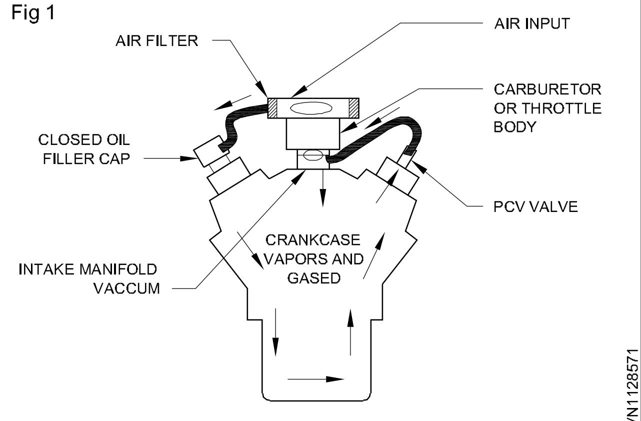
PCV working principle

The PCV vacuum circuit works as follows (Fig 1). Air for the system enters the air cleaner area. The air then goes through the air filter, through a tube, and through the closed oil filler cap.

The intake main fold vacuum the draws the crankcase vapors and gases back to the PCV valve. From the PCV valve, the vapors and gases are drawn into the intake of the engine to be burned by combustion.

If too many vapors and gases get into the intake main fold, it may upset the air-fuel ratio. The PVC valve helps to control the amount of vapors and gases going back into the intake main fold.

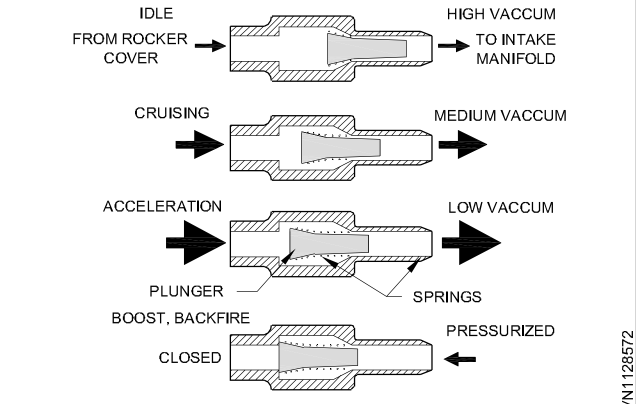
Fig 1



TYPICAL PCV SYSTEM

As shown in the diagram (Fig 2), the PCV valve consists of a tapered plunger and two springs, and limits the air flow based on intake main fold vacuum.

Fig 2



PCV VALVE DESIGN & OPERATION

During idle and deceleration when blow-by gases are mini-mal, the low pressure (or "high" vacuum) in the intake manifold pulls the plunger against the springs and restricts the airflow through the valve.

During acceleration and heavy-load operations when blow-by gases are at their maximum, low vacuum in the intake main fold allows the springs to keep the plunger " back" for maximum airflow through the PCV valve.

In the case when the intake main fold becomes pressur-ized, such as during boost on turbocharged engines or during backfire, the plunger's seat is forced against the valve case preventing air from entering the crankcase.

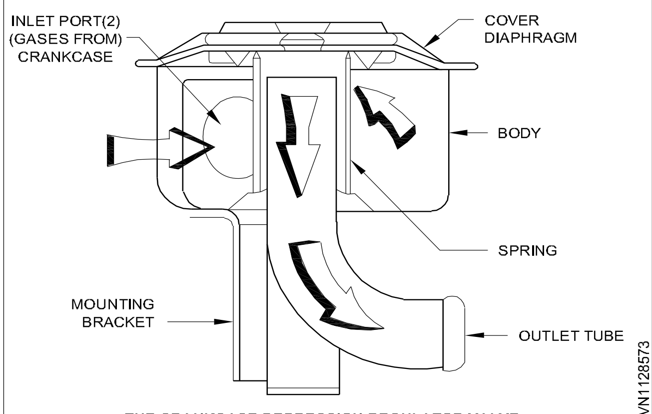
Crankcase depression regulator valve (CDRV) for diesel engine

A crankcase depression regulator valve (CDRV) is used to regulate the flow of crankcase gases back into the en-gine. This valve is designed to limit vacuum in the crank-case . The gases are drawn from the valve cover through the CDRV and into the intake main fold.

Fresh air enters (Fig 3) the engine through the combina-tion filter, check valve, and oil fill cap. This air mixes with blow-by gases and enters the opposite valve cover. These gases pass through a filter on the valve cover and are drawn into the connected tubing.

Intake main fold vacuum acts against a spring loaded dia-phragm to control the flow of crankcase gases. Higher vacuum levels pull the diaphragm close to the top of the outlet tube. This reduces the amount of gases being drawn from the crankcase and decreases vacuum in the crank-case. As intake vacuum decreases, the spring pushes the diaphragm away from the top of the outlet tube allowing more gases into the main fold. The diesel crankcase ventilation system should be cleaned and inspected every 15,000 miles (24,000 km) or at 12 month intervals.

Fig 3



THE CRANKCASE DEPRESSION REGULATOR VALVE

Exhaust Gas Recirculation (EGR) valve

Objectives: At the end of this lesson you shall be able to
- **state the purpose of exhaust gas recirculation (EGR) system**
- **describe the working principle of EGR valve**
- **describe the working principle of linear electronic EGR valve**
- **describe the working principle EGR system in diesel engines.**

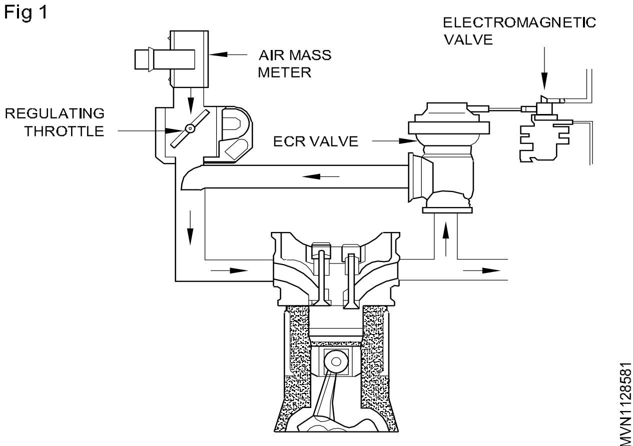
Purpose of exhaust gas recirculation (EGR) system

Purpose of exhaust gas recirculation (EGR) system's purpose is to reduce NOx emissions that contribute to air polution.

Working principle of EGR valve

Exhaust gas recirculation reduces the formation of NOX and engine knock control. By re-circulating a allowing a small amount of exhaust gas into the intake air-fuel mixture on intake manifold as shown in Fig 1.

Fig 1



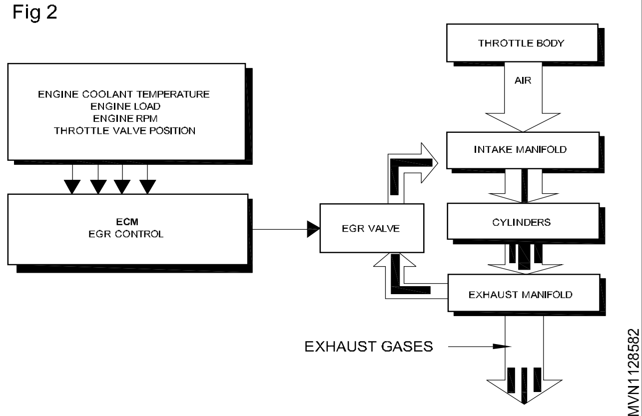
EGR,valve,connected between the exhaust port, or manifold, and the intake system.

If engine conditions are likely to produce oxides of nitrogen, the EGR valve opens, letting some gases is (only about 6 to 10% of the total) pass from the exhaust, into the intake system. During combustion, these exhaust gases absorb heat from the burning air and fuel. This lowers peak combustion temperatures (below 1500 degrees c) to reduce the reaction between the reaction between nitrogen and oxygen that forms NOx.

Older EGR systems use a vacuum regulated EGR valve while newer vehicles tend to have an electronic EGR valve to control exhaust gas recirculation.

When the engine is idling, the EGR valve is closed and there is no EGR flow into the manifold. The EGR valve remains closed until the engine is warm and is operating under load. As the load increase and combustion temperatures start to rise, the EGR valve opens and starts to leak exhaust back into intake manifold (Fig 2) This has a quenching effect that lowers combustion temperatures and reduces the formation of NOx.

Fig 2



The EGR valve opens and closed the passage between the exhaust manifold and intake manifold. Vacuum is removeEGR valves.

Inside the vacuum actuated EGR (Fig 3) valve is a valve, diaphargm and spring. When vacuum is applied to diaphragm lifts the valve off its seat allowing exahus gases into the intake air stream. When vacuum is removed the spring forces the diaphragm and valve downward closing the exhaust passage.

Current technology of EGR valve

Linear electronic EGR valves

Electronic EGR valve is the"linear" EGR valve. (Fig 4) This type uses a small computer - controlled stepper motor to open and close the EGR valve instead of vacuum.

Fig 3

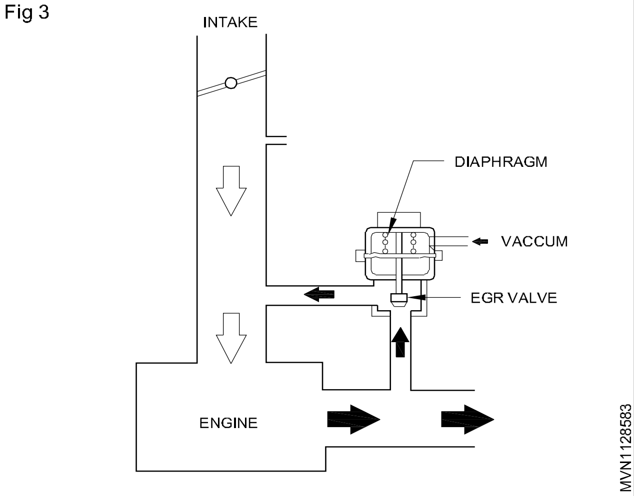
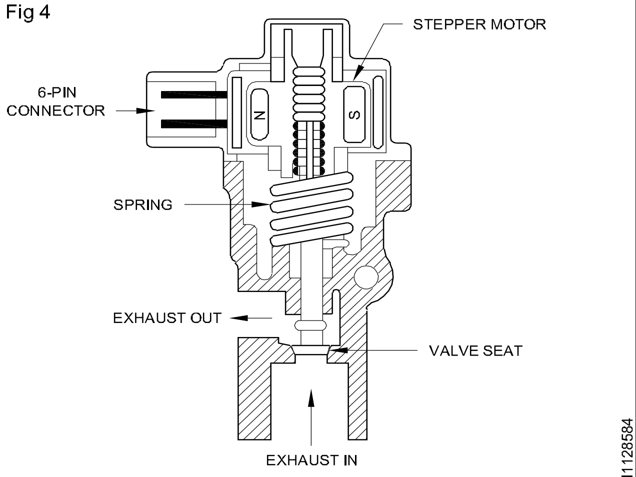


Fig 4



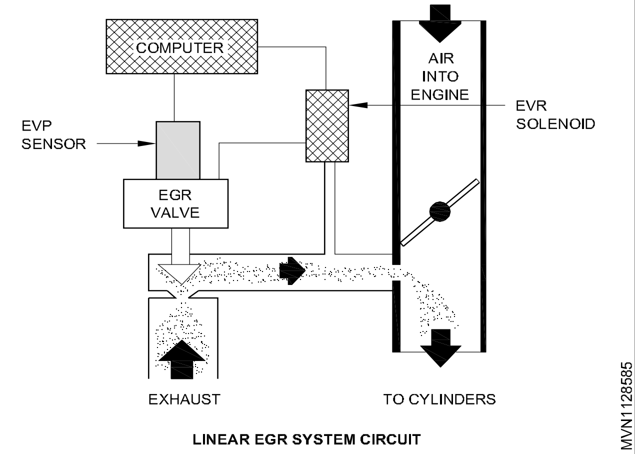
LINEAR EGR VALVE

The advantage of this approach is that the EGR valve operates totally independent of engine vacuum. It is electrically operated and can be opened in various increments depending on what the engine control module determines the engine needs at any given moment in time.

Liner EGR valves may also be equipped with an EGR valve position sensor (EVP) to keep the computer informed about what the EGR valve is doing.

The EVP sensor (Fig 5) also helps with self - diagnostics because the computer looks for an indication of movement from the sensor when the it commands the EGR valve to open or close. The sensor works like a throttle position sensor and charges resistance. The voltage signal typically varies from 0.3 (closed) to 5 volts (open).

Fig 5



LINEAR EGR SYSTEM CIRCUIT

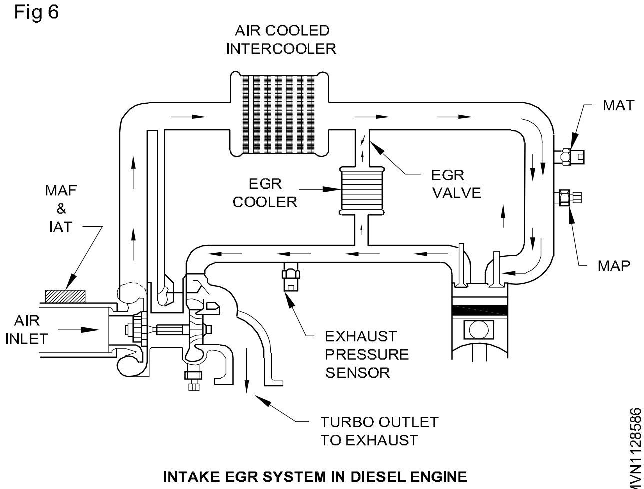
EGR system in diesel engines

The EGR systems (Fig 6) are quite the same as those used in gasoline engines, which means a sample of exhaust introduced into combustion chambers to reduce combustion temperatures. One of the main different is that most manufactures cool the incoming EGR gases before introducing them into the cylinders. This reduces the temperature of combustion and therefore reduces the amount of NOx emitted by the exhaust as shown in Fig 3.

Most systems with EGR coolers use engine coolant that passes through a seperate circuit to cool the recirculated exhaust gases.

The ECU/PCM operates and monitors the EGR system, EGR flow is controlled by the ECU/PCM through a digital EGR valve. EGR flow will occur only when the engine is at a predetermined level and conditions are.

Fig 6



INTAKE EGR SYSTEM IN DIESEL ENGINE

Selective Catalytic Reduction (SCR)

Objectives: At the end of this lesson you shall be able to
- **state the purpose of selective catalytic reduction (SCR)**
- **state the selective catalytic reduction (SCR) system components**
- **describe the working principle of selective catalytic reduction (SCR).**

Purpose of selective catalytic reduction (SCR)

selective catalytic reduction (SCR) is the process by which oxides of nitrogen (Nox) contained in diesel exhaust are reduced to nitrogen (N_2) and water (H_2O)

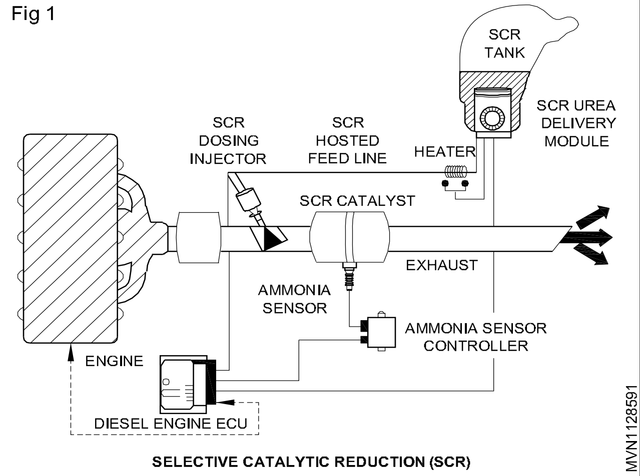
Selective catalytic reduction

Selective: targets NOx in diesel exhaust

Catalytic: reduires a catalyst

Reduction: NOx is reduced to nitrogen (N_2) (Fig.1)

Fig 1



SELECTIVE CATALYTIC REDUCTION (SCR)

SCR requires diesel exhaust fluid (DEF) - a urea based solution

SCR reduces NOX emissions up to 93%

Selective catalytic reduction (SCR) system components

- Diesel exhaust Fluid (DEF)
- DEF injector
- Mixing tube
- SCR catalyst

Working principle of SCR system

SCR works by injecting diesel exhaust fluid (DEF), into the hot exhaust stack. DEF works in conjunction with the hot exhaust gases and catalyst to break NOx into two components of our normal atmosphere air vapor and nitrogen.

Engine

The NOx reduction process starts with an efficient CRD engine design CRD engine design that burns clean ultra low sulfur diesel (ULSD) and produces inherently lower exhaust emissions- exhaust that is already much cleaner due to leaner and more complete combustion.

Diesel exhaust fluid (DEF) tank and pump

Under the direction of the vehicle's onboard computer, Def is delivered in precisely metered spray patterns into the exhaust stream just ahead of the SCR converter.

DEF is a urea based solution, Composition - 67.5% de-ionized water - 32.5% urea

Urea- Under heat, decomposes to ammonia (NH3) and carbon dioxide (CO_2)

Ammonia (NH3) reacts with NOx in the presence of a catalyst

DEF is required for the selective catalytic reduction (SCR) system to function

SCR catalytic converter

This is where the conversion happens. Exhaust gases and an atomized mist of DEF enter the converter simultaneously. Together with the catalyst inside the converter, the mixture undergoes a chemical that produces nitrogen gas and water vapor.

Control device

Exhaust gases are monitored via a sensor as they leave the SCR catalyst. Feedback is supplied to the main computer to alter the DEF flow if NOx levels fluctuate beyond acceptable parameters.

EGR vs SCR

Objective: At the end of this lesson you shall be able to

- **state the difference between exhaust gas recirculation (EGR) Vs selective catalytic reduction (SCR).**

EGR Vs SCR

For 2010, the environmental protection agency (EPA) requires that diesel truck emissions contain a 97 percent reduction in their Sulphur content. Engine manufacturers have come up with two advanced pollution control technology options for cars, trucks, and buses which include:

Exhaust gas recirculation (EGR) is an other way to reduce NOx formation. In an EGR system, engine exhaust is recycled back through the engine to dilute the oxygen. Almost all engine manufacturers use a form of EGR, as it takes both EGR and SCR to achieve near-zero NOx emissions.

While stand alone EGR systems help to reduce NOx, there are some disadvantages:

Selective catalytic reduction (SCR) is an exhaust after treatment system that injects a small amount of a chemical called diesel exhaust fluid (DEF) into the exhaust. DEF is mixed with exhaust in the presence of a catalyst turning NOx (oxides of nitrogen - a harmful pollutant that contributes to smog and acid rain) into harmless nitrogen and water vapor.

Majority of the engine manufacturers have added SCR to their exhaust systems such as; volovo, mack, daimler, and hino to name a few. Difference between EGR & SCR

EGR	SCR
Reduces overall engine efficiency	More power
Large cooling system	Fuel efficiency
Exhaust back pressure	Larger service intervals
Additional engine components	Reliability and durability
Recirculates 30% exhaust	Uses diesel exhaust fluid
Back pressure sensor	SCR chamber never requires service
No additional fluid	
Increased maintenance cost	