

# Paper on Emission Control Techniques

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**ABSTRACT:** The need to control the emissions from automobiles gave rise to the computerization of the automobile. Hydrocarbons, carbon monoxide and oxides of nitrogen are created during the combustion process and are emitted into the atmosphere from the tail pipe. There are also hydrocarbons emitted as a result of vaporization of gasoline and from the crankcase of the automobile. The clean air act of 1977 set limits as to the amount of each of these pollutants that could be emitted from an automobile. The manufacturers answer was the addition of certain pollution control devices and the creation of a self-adjusting engine. 1981 saw the first of these self-adjusting engines. They were called feedback fuel control systems. An oxygen sensor was installed in the exhaust system and would measure the fuel content of the exhaust stream. It then would send a signal to a microprocessor, which would analyze the reading and operate a fuel mixture or air mixture device to create the proper air/fuel ratio. As computer systems progressed, they were able to adjust ignition spark timing as well as operate the other emission controls that were installed on the vehicle. The computer is also capable of monitoring and diagnosing itself. If a fault is seen, the computer will alert the vehicle operator by illuminating a malfunction indicator lamp. The computer will at the same time record the fault in it's memory, so that a technician can at a later date retrieve that fault in the form of a code which will help them determine the proper repair. Some of the more popular emission control devices installed on the automobile are: EGR valve, Catalytic Converter, Air Pump, PCV Valve, Charcol Canitiser etc.

Like SI engine CI engines are also major source of emission. Several experiments and technologies are developed and a lot of experiments are going on to reduce emission from CI engine. The main constituents causing diesel emission are smoke, soot, oxides of nitrogen, hydrocarbons, carbon monoxides etc. Unlike SI engine, emission produced by carbon monoxide and hydrocarbon in CI engine is small. Inorder to give better engine performance the emission must be reduce to a great extend. The emission can be reduced by using smoke suppressant additives, using particulate traps, SCR (Selective Catalytic Reduction) etc.

## II. . EMISSION CONTROL IN SI ENGINE

### 2.1. Methods to reduce emission in SI engine.

#### 2.1.1. Catalytic Converter

Automotive emissions are controlled in three ways, one is to promote more complete combustion so that there are less by products. The second is to reintroduce excessive hydrocarbons back into the engine for combustion and the third is to provide an additional area for oxidation or combustion to occur. This additional area is called a catalytic converter. The catalytic converter looks like a muffler. It is located in the exhaust system ahead of the muffler. Inside the converter are pellets or a honeycomb made of platinum or palladium. The platinum or palladiums are used as a catalyst (a catalyst is a substance used to speed up a chemical process). As hydrocarbons or carbon monoxide in the exhaust are passed over the catalyst, it is chemically oxidized or converted to carbon dioxide and water. As the converter works to clean the exhaust, it develops heat. The dirtier the exhaust, the harder the converter works and the more heat that is developed. In some cases the converter can be seen to glow from excessive heat. If the converter works this hard to clean a dirty exhaust it will destroy itself. Also leaded fuel will put a coating on the platinum or palladium and render the converter ineffective.

#### 2.1.2. PCV Valve

1. The purpose of the positive crankcase ventilation (PCV) system, is to take the vapors produced in the crankcase during the normal combustion process, and redirecting them into the air/fuel intake system to be burned during combustion. These vapors dilute the air/fuel mixture, they have to be carefully controlled and metered so as not to affect the performance of the engine. This is the job of the positive crankcase ventilation (PCV) valve. At idle, when the air/fuel mixture is very critical, just a little of the vapors are allowed in to the intake system. At high speed when the mixture is less critical and the pressures in the engine are greater, more of the vapors are allowed in to the intake system. When the valve or the system is clogged, vapors will back up into the air filter housing or at worst, the excess pressure will push past seals and create engine oil leaks. If the wrong valve is used or the system has air leaks, the engine will idle rough, or at worst engine oil will be sucked out of the engine.

### 2. 2.1.3. EGR Valve

The purpose of the exhaust gas recirculation valve (EGR) valve is to meter a small amount of exhaust gas into the intake system; this dilutes the air/fuel mixture so as to lower the combustion chamber temperature. Excessive combustion chamber temperature creates oxides of nitrogen, which is a major pollutant. While the EGR valve is the most effective method of controlling oxides of nitrogen, in its very design it adversely affects engine performance. The engine was not designed to run on exhaust gas. For this reason the amount of exhaust entering the intake system has to be carefully monitored and controlled. This is accomplished through a series of electrical and vacuum switches and the vehicle computer. Since EGR action reduces performance by diluting the air /fuel mixture, the system does not allow EGR action when the engine is cold or when the engine needs full power.

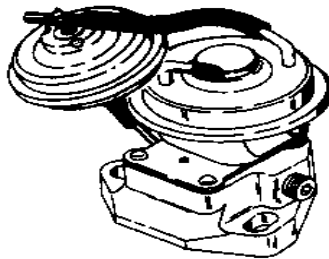


Fig.2.4.EGR Valve

### 2.1.4. Evaporative Controls

Gasoline evaporates quite easily. In the past these evaporative emissions were vented into the atmosphere. 20% of all HC emissions from the automobile are from the gas tank. In 1970 legislation was passed, prohibiting venting of gas tank fumes into the atmosphere. An evaporative control system was developed to eliminate this source of pollution. The function of the fuel evaporative control system is to trap and store evaporative emissions from the gas tank and carburetor. A **charcoal canister** is used to trap the fuel vapors. The fuel vapors adhere to the charcoal, until the engine is started, and engine vacuum can be used to draw the vapors into the engine, so that they can be burned along with the fuel/air mixture. This system requires the use of a sealed gas tank filler cap. This cap is so important to the operation of the system, that a test of the cap is now being integrated into many state emission inspection programs. Pre-1970 cars released fuel vapors into the atmosphere through the use of a vented gas cap. Today with the use of sealed caps, redesigned gas tanks are used. The tank has to have the space for the vapors to collect so that they can then be vented to the charcoal canister. A purge valve is used to control the vapor flow into the engine. The purge valve is operated by engine vacuum. One common problem with this system is that the purge valve goes bad and engine vacuum draws fuel directly into the intake system. This enriches the fuel mixture and will foul the spark plugs. Most charcoal canisters have a filter that should be replaced periodically. This system should be checked when fuel mileage drops.

### 2.1.5. Air Injection

Since no internal combustion engine is 100% efficient, there will always be some unburned fuel in the exhaust. This increases hydrocarbon emissions. To eliminate this source of emissions an air injection system was created.

Combustion requires fuel, oxygen and heat. Without any one of the three combustion cannot occur. Inside the exhaust manifold there is sufficient heat to support combustion, if we introduce some oxygen than any unburned fuel will ignite. This combustion will not produce any power, but it will reduce excessive hydrocarbon emissions. Unlike in the combustion chamber, this combustion is uncontrolled, so if the fuel content of the exhaust is excessive, explosions that sound like popping will occur. There are times when under normal conditions, such as deceleration, when the fuel content is excessive. Under these conditions we would want to shut off the air injection system. This is accomplished through the use of a diverter valve, which instead of shutting the air pump off diverts the air away from the exhaust manifold. Since all of this is done after the combustion process is complete, this is one emission control that has no effect on engine performance. The only maintenance that is required is a careful inspection of the air pump drive belt.

## **2.2. Modification in SI engine to reduce emission.**

- Multi-port fuel injection system to completely replace carburetors.
- Electronic engine management to accurately regulate fuel supply to cylinders by sensing various engine parameters.
- 4-valve system to replace 2-valve system, improved combustion chamber design and improved inlet manifold design for axial stratification of charge.
- Turbo-charged (TC) and Turbo-charged After Cooled (TCAC) engines.
- Turbo-compounded engines; they are found to be upto 18 per cent better than the conventional engines.
- After treatment, catalytic converter and exhaust gas recycling.

Some future directions for engines are:

- Lean burn technology, air-fuel ratio as lean as 22:1 is possible with 4-valves, high swirl and squish generated turbulence.
- Use of ceramic components (e.g., low density Silicon Nitride, Si<sub>3</sub>N<sub>4</sub>) such as piston pins, valves, blades in turbochargers.
- Variable Valve Activation (VVA) providing improved charge control of SI engines, reducing fuel consumption by 5 per cent at low/medium speed and 13 per cent at full engine speed.

## **III. EMISSION CONTROL IN CI ENGINE**

### **3.1. Methods to reduce emission in CI engine**

#### **3.1.1 Particulate filter.**

Particulate filters are highly effective in the elimination of particulate matter (PM<sub>10</sub>) or soot from diesel exhaust. It has a variety of filter coatings and designs, depending of the engine application and duty cycle.

#### **3.1.2. Selective catalytic reduction**

Selective Catalytic Reduction of NO<sub>x</sub> (generally abbreviated with SCR deNO<sub>x</sub>) is a very powerful technology to reduce the NO<sub>x</sub> emission and fuel consumption of truck and passenger car diesel engines. The European truck manufacturers starting in October 2005, when EURO-4 emissions legislation enters into force, will introduce SCR deNO<sub>x</sub> on a large scale. With SCR deNO<sub>x</sub> a 32.5% aqueous urea solution is injected upstream of the catalyst. Urea which converts to NH<sub>3</sub> (ammonia) in the hot exhaust gases reacts with NO<sub>x</sub> to form harmless N<sub>2</sub> and H<sub>2</sub>O. The urea quantity needs to be precisely dosed as a function of the engine NO<sub>x</sub> output and the catalyst operating conditions.

#### **3.1.3. Smoke Suppressant additives**

There are a number of additives, which are added in order to reduce the smoke from CI engine. **HYDRAX ATH** (hydrated alumina), **HYDRAMAX** (magnesium hydroxides and hydroxy-carbonates), **CHARMAX LS** (low smoke), **CHARMAX LS ZST & LS ZHS** (zinc stannates & zinc hydroxystannates), **CHARMAX AOM & MO** (ammonium octamolybdate & molybdc oxide), **CHARMAX ZB200 & ZB400** (zinc, magnesium, and calcium borates) etc. This reduces the amount of smoke produced by various chemical reactions. The smoke produced can also be controlled by deairating, maintenance, catalytic mufflers, fumigation etc.

### **3.1.4. Control of odour**

It is very difficult to estimate the odour produced by the diesel engine because the lack of standard tests has not allowed much work to be done in this direction. Catalytic odour control system muffler and or catalyst container are under development and it has been found that certain oxidation catalysts if used under favorable conditions reduce odour intensity. But the tests are still going on.

### **3.1.5. Exhaust Gas and After treatment Modeling**

While the diesel (compression ignition) engine is more efficient than the conventional spark ignition engine from a thermodynamics standpoint, it has the potential for a large negative environmental impact. The lean combustion of these devices provides the perfect environment for the production of NO<sub>x</sub>; relatively high temperatures and abundant oxygen. In addition, direct injection of fuel into the combustion chamber creates rich fuel pockets that can cause the formation of particulate matter (soot). Recently these emissions have come under increased scrutiny from the Environmental Protection Agency (EPA). Their radical nature (smog) in the atmosphere and subsequent health hazards has caused the EPA to act to increase the regulation standards for both 2007 and 2010. Unlike the three-way catalysts currently used on spark-ignition based platforms, diesel after treatment systems will not utilize one device for all problematic emissions. Instead, devices are targeted to take care of only one or a few issues at a time. For instance, Diesel Particulate Filters (DPF) might take care of the particulate matter while a Diesel Oxidation Catalyst (DOC) will eliminate the CO and HC and a Lean NO<sub>x</sub> Trap is used for the NO<sub>x</sub> emissions. Until now, diesel engine manufacturers have been able to meet the legislation through in-cylinder technology. The proposed EPA legislation has caused the diesel industry to work on finding cost-efficient after treatment technology while still looking in-cylinder for improvements.

## **3.2. Modification in CI engine to reduce emission**

### **3.2.1. Commercial vehicle emission control**

Several improvements are needed. These could be achieved through redesigning of engines and application of new technologies:

- Improvement in fuel injection system and use of higher injection pressure.

### **3.2.2. Passenger Car Diesel Engine**

In India, Indirect Injection (IDI) diesel engines are commonly used in passenger cars. Due to the pricing policies of fuels, the running cost of diesel cars is lower than those of petrol cars. Diesel engines are popular for taxis, most of which are retrofitted by diesel engines. Private cars with OE diesel engines are also in demand. Major directions for engine development to control different pollutants are as follows:

- HC emission control requires,
  - low sac volume nozzles;
  - Complete combustion of injected fuel;
  - minimum lube consumption.
- NO<sub>x</sub> emission control is helped by,
  - cooling of intake air before entering the engine;
  - Retarded combustion; and
  - Moderate air motion.
- Particulate emission control is helped by,
  - high injection pressure;
  - fine fuel atomization;
  - intensive air motion;
  - high excess air; and
  - minimum lube consumption.

**IV. EMISSION CONTROL NORMS IN SI AND CI ENGINE**

The first Indian emission regulations were idle emission limits which became effective in 1989. These idle emission regulations were soon replaced by mass emission limits for both gasoline (1991) and diesel (1992) vehicles, which were gradually tightened during the 1990's. Since the year 2000, India started adopting European emission and fuel regulations for four-wheeled light-duty and for heavy-duty vehicles. Indian own emission regulations still apply to two- and three-wheeled vehicles.

**4.1. Emission control norms in SI engine.**

Table.4.1: EMISSION CONTROL NORMS IN SI ENGINE

Level of Emission Norms	2/3 Wheelers ##		4 Wheelers
	2-Stroke	4-Stroke	4-Stroke
a. b. Euro I /India 2000	* Intake, exhaust, combustion optimization * Catalytic converter	* 4-Stroke engine technology	* Intake, exhaust, combustion optimization *Carburetor optimization
Euro II / Bharat Stage II	* Secondary air injection * Catalytic converter * CNG / LPG (3 wheelers only)	* Hot tube * Secondary air injection * CNG / LPG (3 wheelers only)	* Fuel injection * Catalytic converter * Fixed EGR * Multi-valve * CNG/LPG
EuroIII/ Bharat Stage III	* Fuel injection * Catalytic converter	* Fuel injection * Carburetor+ catalytic converter	* Fuel injection +catalytic converter * Variable EGR * Variable valve timing * Multi-valve * On-board diagnostics system * CNG/LPG
Euro IV / Bharat Stage IV	* To be developed	* Lean burn * Fuel injection+ catalytic converter	* Direct cylinder injection * Multi-brick catalytic converter * On-board diagnostics system

## Euro norms are not applicable for 2 / 3 wheelers in India

**4.2. Emission control norms in CI engine**

Level Of Emission Norms	Technology Options
Euro I / India 2000	<ul style="list-style-type: none"> <li>· Retarded injection timing</li> <li>· Open/re-entrant bowl,</li> <li>· Intake, exhaust and combustion optimisation</li> <li>· FIP~700-800 bar, low sac injectors</li> <li>· High swirl</li> <li>· Naturally aspirated</li> </ul>
Euro II / Bharat Stage II	<ul style="list-style-type: none"> <li>· Turbocharging</li> <li>· Injection pressure &gt; 800 bar, moderate swirl</li> <li>· High pressure inline / rotary pumps, injection rate control</li> <li>· VO nozzles</li> <li>· Re-entrant combustion chamber</li> <li>· Lube oil consumption control</li> <li>· Inter-cooling (optional, depends on specific power),</li> <li>· EGR (may be required for high speed car engines)</li> <li>· Conversion to CNG with catalytic converter</li> </ul>
Euro III / Bharat Stage III	<ul style="list-style-type: none"> <li>· Multi valve,</li> <li>· Low swirl – high injection pressure &gt; 120 bar</li> <li>· Rotary pumps, pilot injection rate shaping</li> <li>· Electronic fuel injection</li> <li>· Critical lube oil consumption control</li> <li>· Variable geometry turbocharger (VGT)</li> <li>· Inter-cooling</li> <li>· Oxycat &amp; EGR</li> <li>· CNG/LPG</li> <li>· High specific power output</li> </ul>
Euro IV / Bharat Stage IV	<ul style="list-style-type: none"> <li>· Particulate trap</li> <li>· NOx trap</li> <li>· On board Diagnostics system</li> <li>· Common rail injection-injection pressure&gt;1600 bar</li> <li>· Fuel Cell</li> <li>· CNG/LPG</li> </ul>

On October 6, 2003, the National Auto Fuel Policy has been announced, which envisages a phased program for introducing Euro 2 - 4 emission and fuel regulations by 2010. The implementation schedule of EU emission standards in India is summarized in Table 4.3

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.

For 2-and 3-wheelers, Bharat Stage II (Euro 2) is applicable from April 1, 2005 and Stage III (Euro 3) standards would come in force preferably from April 1, 2008, but not later than April 1, 2010.



Table.4.3. INDIAN EMISSION STANDARDS

Indian Emission Standards (4-Wheel Vehicles)			
Standard	Reference	Date	Region
India 2000	Euro 1	2000	Nationwide
Bharat Stage II	Euro 2	2001 2003-04 2004-05	NCR*, Mumbai, Kolkata, Chennai NCR*, 10 Cities† Nationwide
Bharat Stage III	Euro 3	2005-04 2004-10	NCR*, 10 Cities† Nationwide
Bharat Stage IV	Euro 4	2010-04	NCR*, 10 Cities†

\* National Capital Region (Delhi)

† Mumbai, Kolkata, Chennai, Bangalore, Hyderabad, Ahmedabad, Pune, Surat, Kanpur 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.

For 2-and 3-wheelers, Bharat Stage II (Euro 2) will be applicable from April 1, 2005 and Stage III (Euro 3) standards would come in force preferably from April 1, 2008, but not later than April 1, 2010.

Emission standards for new heavy-duty diesel engines—applicable to vehicles of GVW > 3,500 kg—are listed in Table 4.4. Emissions are tested over the [ECE R49](#) 13-mode test (through the Euro II stage).

Table 4.4 EMISSION STANDARDS FOR DIESEL TRUCK AND BUS ENGINES, G/KWH					
Year	Reference	CO	HC	NOx	PM
1992	-	17.3-32.6	2.7-3.7	-	-
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
2010†	Euro III	2.1	0.66	5.0	0.10
* 0.612 for engines below 85 kW					
† earlier introduction in selected regions, see Table 4.3					

Emission standards for light-duty diesel vehicles (GVW ≤ 3,500 kg) are summarized in Table 3. Ranges of emission limits refer to different classes (by reference mass) of light commercial vehicles; compare the [EU light-duty vehicle](#) emission standards page 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 4.5 EMISSION STANDARDS FOR LIGHT-DUTY DIESEL VEHICLES, G/KM					
Year	Reference	CO	HC	HC+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
† earlier introduction in selected regions, see Table 4.3					

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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 4.3

Year	Reference	CO	HC	NO <sub>x</sub>	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 <a href="#">Table 4.3</a>					

Emission standards for gasoline vehicles (GVW ≤ 3,500 kg) are summarized in Table 5. Ranges of emission limits refer to different classes of light commercial vehicles (compare the [EU light-duty vehicle](#) emission standards page). The lowest limit in each range applies to passenger cars (GVW ≤ 2,500 kg; up to 6 seats).

Year	Reference	CO	HC	HC+NO <sub>x</sub>
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
* for catalytic converter fitted vehicles				
† earlier introduction in selected regions, see <a href="#">Table 4.3</a>				

Gasoline vehicles must also meet an evaporative (SHED) limit of 2 g/test (effective 2000). Emission standards for 3- and 2-wheel gasoline vehicles are listed in the following tables.



Year	CO	HC	HC+NO <sub>x</sub>
1991	12-30	8-12	-
1996	4.50	-	3.60
2000	2.00	-	2.00

Year	CO	HC	HC+NO <sub>x</sub>
1991	12-30	8-12	-
1996	6.75	-	5.40
2000	4.00	-	2.00

## V. CONCLUSION

Efforts are being made to reduce the consumption of fossil fuels and maximize the utilization of environment-friendly energy sources and fuels for meeting energy needs. In India, the demand for oil for the transport sector is estimated to increase over the next decade. This sector is the largest consumer of petroleum products. Government is providing policy support, fiscal incentives and regulatory measures for development of alternative energy vehicles and fuels. Battery operated vehicles, fuel cell vehicles, hydrogen powered vehicles and bio-fuel powered vehicles have been identified in this context. The development activities of such fuels and vehicles need to be further encouraged particularly in view of their potential to protect the environment. Hybrid Electric Vehicles (HEVs) use the combination of engine of a conventional vehicle with electric motor powered by traction batteries and/or fuel cell. This combination helps in achieving both the energy and environmental goals. The deployment of a large number of this type of vehicles would help us in terms of environmental benefits, reduction of oil consumption and reduction in emissions. In hybrid electric vehicles propulsion, energy is available from more than one source of energy. The three configurations of HEV are series hybrid system, parallel hybrid system and split hybrid system. Fuel cells produce electricity, employing reaction between hydrogen and oxygen gases, electrochemically. Fuel cells are efficient, environmentally benign, compact, modular and reliable for power generation. Different type of Fuel cells currently under development are the Protons Exchange Membrane Fuel Cells (PEMFCs), Phosphoric Acid Fuel Cells (PAFCs), Molten Carbonate Fuel Cells (MCFCs), Solid Oxide Fuel Cells (SOFCs) etc. Hydrogen is receiving worldwide attention as a clean fuel and efficient energy storage medium for automobiles. Hydrogen can replace or supplement oil used in road transportation. Bio-fuel is an efficient, environment friendly, 100 per cent natural energy alternative to petroleum fuels<sup>9-10</sup>. In view of the potential of being produced from several agricultural sources and because of its low emission characteristics, bio-fuels in recent years are receiving a great deal of attention as a substitute to petroleum fuels. Ethanol and bio-diesel are the two bio-fuels which are being looked upon as the potential fuels for surface transportation.

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