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Area: Mechanical Engineering:

Exhaust Gas Re-Circulation (EGR) and OBD –II: Allocation procedure for the Indian Automobiles

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Abstract:
To control the Oxides of Nitrogen (NOx), there are only one method is available by Exhaust Gas Re-Circulation (EGR). NOx control system that recycles a small part of the inert exhaust gas back through the intake manifold through EGR valve, to the combustion temperature and this system is called EGR system.
OBD-II, systems were designed to maintain low emissions of in use vehicles, including light and medium duty vehicles.
As per Environment Protection Agency, (EPA) USA, and CARB standards the failure criteria for the catalyst monitor diagnostic are the following:
1. Linear EGR Flow rate: Abnormal low and high flow rate exceeding the specified low and high flow rate that will result in exceeding any of the applicable FTP x 1.5.
2. EGR system component: Any component of the systems performing outside of the speciation's that will result in exceeding any of the applicable FTP x 1.5.

Enable Linear Flow Diagnostic means, the inputs to Enable linear EGR flow diagnostics are : No fault active on TPS, MAP , vehicle speed, intake air temperature, Idle air control, EGR pintle , Misfire, Transmission and coolant temperature etc. EPA regulations required linear EGR system monitoring to determine if there is a restriction in the exhaust gas recirculation systems. The diagnosis is based on the fact in properly functioning systems, given all other things being constant and normal; there is a direct completion between linear EGR Flow rate and manifold air pressure (MAP) changes.

Key Words: Detonation, Smog, Air-Fuel ratio, Throttle valve, Microprocessor, Enable Linear EGR, Fuel Ignition system, Inert-gases, OBD-II , EGR Flow Diagnostics, decal cut off

I. Introduction:

The exhaust gas treatment aims at reducing the concentrations of the main pollutants i.e. CO, HC and NOx, before discharging them to the atmosphere. Therefore, EGR is the main method of exhaust gas treatment. However, we know that, a part of the exhaust gases is, allowed into the inlet manifold. These exhaust gases get mixed up with the air fuel mixture to lower the combustion temperature and hence the formation of NOx is greatly reduced.On board diagnostics regulations in the USA for light and medium duty (I.C. engines) are introduced to implement the air quality standard. California and the federal government used a driving cycle to certify 1966 vehicles and newer models which were referred to as either California cycle or the Federal Test Procedure (FTP).

In 1989, the California Code of Regulations (CCR) known as OBD – II was adopted by the California Air Resource Board (CARB) and Environment Protection Agency (EPA) regulations require monitoring of system and Illuminating MIL (Multifunction Indicator Light) storage of Diagnostic Trouble Code (DTC) if a fault is detected and EGR system (Proper exhaust flow rate into intake manifold) as per trip evaluation.

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2. Literature Review:

In our country after spending lot of money and also enacting several statutory laws, the country could not make much headway, because of several factors. However, problems are still there particularly in maintaining clean Air. It is no doubt that western countries are the major contributions globally for air pollutants like CO, CO2 and NOx and because of these pollutants have got two serious phenomenon of global warming and ozone layer.

In this regard, there has been remarkable change in the concept of I.C. engine i.e. design, MPFI (Multi Point Fuel Injection) and incorporation of EGR, Catalytic Converter respectively. In June 1999 the honorable Supreme Court in India ruled that vehicular emission had to be reduced at a much quicker pace than planned so far and engine manufactures are taking challenging task to quickly find solution by Bharat Norms.

As per experimental , it was found that, CO and HC emission limits are easily met with Direct Injection Diesel Engines and on the other side, NOx and SPM are more of a challenge , especially for heavy duty diesel engine.

As the Indian emission legislation corresponds to the European regulation, it is worth looking into limits planned for European in future and therefore, Indian automobiles manufactures have to change from Euro Norms to Bharat Norms (Recommendation of Interim Report of the expert committee on Auto Fuel, 28th December/2001, No. 6 (v).

Euro – II, III, IV (Petrol)			
Parameters IV	Euro-II 1996	Euro-III 2000	Euro-2005
Oxygen % Max.	2.7	2.7	2.7
Benzene % Max	5.0	1.0	1.0
Aromatic %	--	41	35
Sulphur Max.	0.05	0.015	0.005

Table 2.1.

Bharat Stage – II (Petrol)		
Density	gg/cc	0.710-0.770
Octane No	RON, Min	88
Sulphur	% mass	0.06
Benzene	% vol max	3 (metro) 5 (rest)

Table 2.2

Hence, for a Country like India, Containing pollution is of primary importance and OBD-II, system as on alternative method toward maintain low-emission. For example, OBD-II standards have been set for the vehicle half-life (5 years or 10000 miles). The following are enforced 100% after 1996.

HC: 0.31 gms/mile,
CO: 4.20 gms/mile,
NOx): 0.60 gms/mile (Non-Diesel)
1.25 gms/mile (Diesel)

3. Methodology:
(EGR Flow diagnostic is):

Linear EGR Flow rate: Abnormal high or low flow rate that will result in exceeding any of applicable

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FTP standards $\times$ **1.5** (specified low and high flow rate).

EGR systems component: EGR any component of the system outside of the sections in exceeding any of the applicable FIP standard $\times$ 1.5, etc.

EPA regulations require linear EGR system monitoring to determine if there is a restriction in the EGR system. The linear EGR flow diagnostics is performed to detect any malfunction of the linear EGR system. The diagnostics is based on the fact that in a properly functioning system and there is a direct correlation between linear EGR flow rate and manifold air pressure (MAP) changes.

Under specific conditions, such as decel-cut off the linear EGR valve is moved through a control sequence and the change in MAP in recorded and evaluated in decal made the throttle position is closed. In this mode the linear EGR valve is moved from a closed to an open position. A corresponding increase in MAP is expected when the valve is open. T
he of MAP change is correlated to the amount of linear EGR flow through the valve. This test is performed a calibrated numbers of times and the average MAP changes is computed resulting from the valve actuations.

Failure of the valve is indicated when this filtered value exceeds a calibrated threshold. The diagnostic code reported is PO401, EGR insufficient flow.

The following functions are performed by the linear EGR flow diagnostic.

Enable Linear EGR Flow Diagnostics,
Monitor decal Test Start conditions,
#Monitor decal enables criteria,
performed decal started.

Manage decal test:

perform decal intrusive testing,
perform decal open,
perform decel sample,
perform decel close,
Monitor decel intrusive testing.

The following functions are performed by the linear EGR flow diagnostic.

Manage decel Abort and Rest,
Control between Test Times,
determine EGR pass/Fail status,
Report EGR Flow Fault Status.

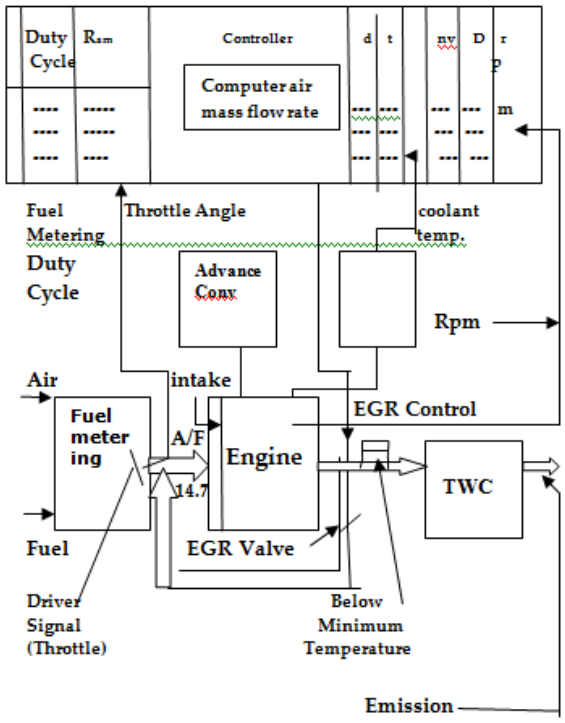

Fig. 3(a) Open Loop Control

The inputs to enable linear EGR flow diagnostics are:

No fault active on TPS, MAP, vehicle speed , intake air temperature , idle air , EGR pintle Misfire, Transmission and coolant temperature, EGR flow diagnostics status, EGR control data, EGR flow test mode, diagnostic history, AC data , coolant temperature barometric pressure, engine speed, vehicle speed, throttle position, decal total count and decal trip sample count.

The out-put of enable linear EGR flow Diagnostics are:

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Enable decal test status (true/false).
This function checks if the following conditions are true:
A calibrated amount of time a linear EGR flow diagnostic was run to permit the execution of another test.
The following enable condition are satisfied continuously for a calibrated period of decal enable delay:
» EGR diagnostic test mode is - decal.
» EGR flow test mode is - Idle.
»Coolant temperature is greater than coolant threshold value.
» Engine speed is greater than engine threshold value.
» IAC movement is less than IAC movement threshold value.

The following discrete status has not changed since last linear EGR flow diagnostic test mode.
Torque converter clutch: on/off
A/C clutch : on/off
Gear change: (park/Neutral/Run)

If the above conditions are satisfied then the enable decal test status to set to true and otherwise the enable decal test status is set to false. If enable decal test status is true then at EGR flow test mode equal to decal idle.

4. Result :

Functionally of power train Control Module (PCM) in OBD-II diagnostics.

PCM performs the following functions into OBD-II diagnostics.

Performs micro-processor – based self diagnostics to ensure correct operation of the PCM and safe storage of OBD-II diagnostics data in memory.
Performs on-board diagnostics in real time and alerts the driver by illuminating MIL in case of a fault.

Performs power-train control functions to reduce missions and meet OBD-II regulations in closed-loop control during normal operation.

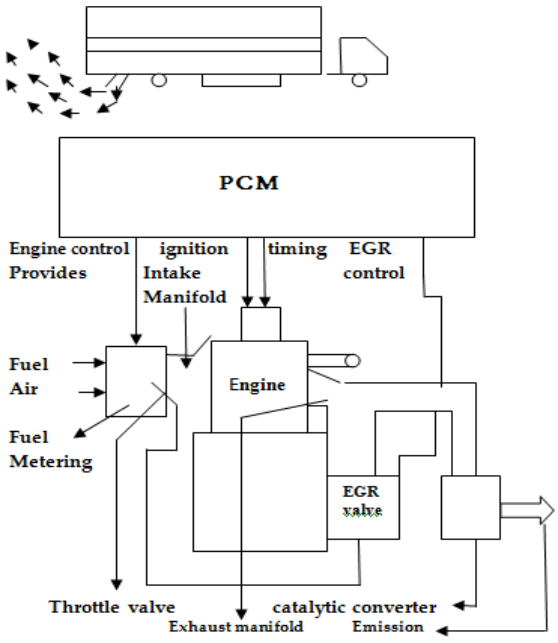

Fig: 4(a) Major Controller out-put to Engine.

Performs power-train control functions to reduce emissions and meet OBD-II regulations during open-loop operation at start up time.
Performs micro-processor – based self diagnostics to ensure correct operation of the PCM and safe storage of OBD-II diagnostic data in memory.

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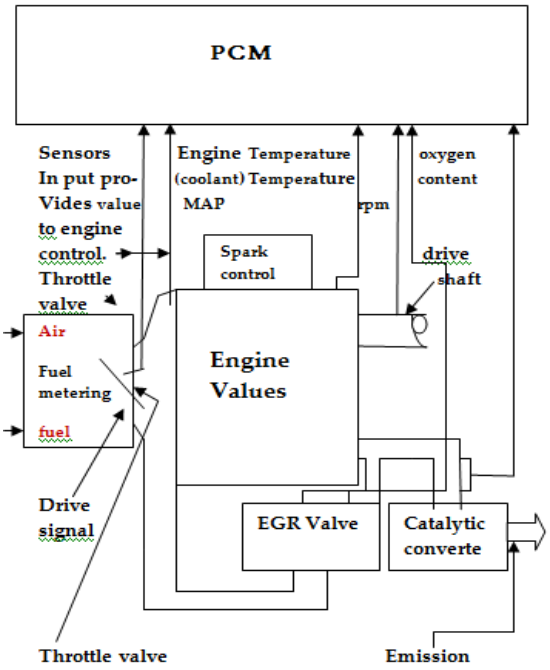

Fig: 4(b) Major Controller inputs from Engine.

5. Discussion:

5.1. Exhaust Gas-Recirculation:

EGR system that the PCM shall monitor, for low and high flow rate malfunctions. The algorithm is two folds:

At over run, the fuel is cut off and the EGR valve is completely opened. The flow exhaust gas to the intake manifold raises the manifold pressure, which is recorded.

Monitor the increase of the manifold intake temperature when the EGR valve is opened.

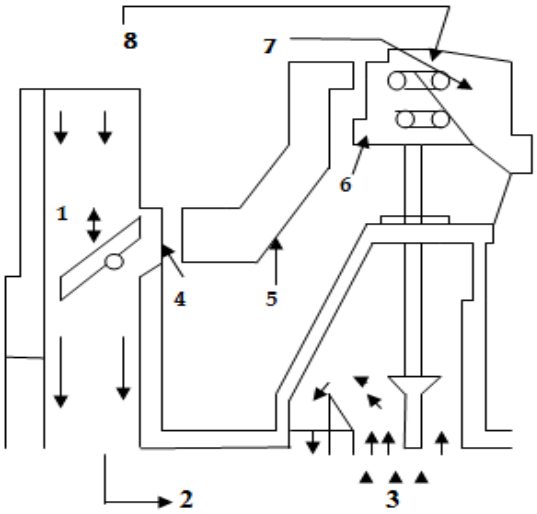

Fig: 5(a) Exhaust Gas Recirculation System:

1» Throttle valve,
2 » Intake Manifold,
3» Exhaust Gas,
4» Vacuum Port,
5» Vacuum Tube
6» Diaphragm arm,
7» Vacuum Chamber,
8»EGR Valve

While the throttle valve is open that time air entire and mixed with fuel and these air fuel mixture reached in the combustion chamber through intake manifold. During the combustion process burn gases goes to atmosphere through the exhaust manifold as well through the silencer pipe. While vehicular speed is high that time some inert gases has to burn and these inert gases come back to the combustion chamber through the EGR valve and again burn. In this way, the lesser percentage of NOx gases has to burn.

5.2. Highlight the problems:

5.2.1. Effect of air fuel ratio is the most important engine variable which affects not only the concentration of NOx emission but also the performance of the engine in general the effect of air fuel ratio on NOx emission at 1900 rpm.

5.2.2. The brake specific fuel consumption (bsfc) increase with increase in percentage recycling. While vehicle is higher speed, EGR does not reduce NOx emission. Because, EGR is a

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promising method of controlling NOx emission and EGR is reducing NOx emission up to 81% to 88%, at the 30% of recycling.

5.2.3. NOx emission increase with the increased speed and as a result, need of more fuel to overcome greater frictional losses. For example, 30% of recycling in 1900 rpm, fuel consumption 3.87% to 29%, etc

5.3. Highlight the suggestion:

5.3.1. High Octane number caused Carbon Monoxide (CO) increased. Therefore, is not required for the 2 stroke engine.

5.3.2. Oxygen content reduced CO emission. However, as per Ministry Of Environment and Forests, N Delhi ruled that oxygen content limit maximum 2.7% for the protection of Under Ground Water pollution.

5.3.3. Benzene reduces from 5% to 1%.

5.3.4. Aromatic compound caused increased of NOx emission. Therefore, it was reduced as aromatic in gasoline from 42% to 35% and in this way NOx emission increased 1.6%.

5.3.5. Olefins caused increased of HC emission. Because, lead is deposited on the engine head and creating lead smog and trying to reduce 30% from the year of 2005 to 2010.

5.4. Highlight the EGR Trouble:

5.4.1. Poor engine performance may cause EGR trouble. For example, rough engine idling, the main cause of leaky EGR valve or valve gasket.

5.4.2. If fuel performance is poor and rough acceleration, that is the main reason to damage the thermal vacuum switch.

5.4.3. If exhaust manifold is not a clean position i.e. dust, have to clean and refit, otherwise it is the cause of EGR valve damaged.

5.4.4. Detonation damaged valve and thermal switch etc.

5.5. Fuel Injection System:

The efficiency of combustion in I.C. Engine (Diesel), depends upon the degree of atomization of the fuel and the thoroughness of mixing with air. For good atomization high injection velocity is required. The purpose of a nozzle is to atomize and direct the spray of the fuel droplets into the combustion space in such a manner that proper penetration and distribution are obtained. Let the diameter orifice to spray a fuel quantity "Q" per cycle per cylinder is dr. The injection pressure is P1 , density of fuel is ρ_f and period of injection t-second.

Pressure difference causing the fuel flow through the orifice = (P1 – P2) kg/cm²

Pressure heading causing the fuel flow:

$$= hr = \frac{P1 - P2}{\rho f} \text{ cm of fuel}$$

Velocity of fuel through the Orifice:

$$V = \sqrt{2g - \rho t}$$

$$= \sqrt{2g - \frac{P1 - P2}{\rho f}} \text{ cm/sec}$$

Let cd = Coefficient of discharge of the orifice.

$\therefore$ Q = cd $\times$ Area of the orifice $\times$ Velocity of flow $\times$ Duration of flow.

$$= cd \times \frac{\pi}{4} \times dr^2 \times v \times t$$

Area of orifice = $\frac{\pi}{4}$ dr²

$$= \frac{Q}{cd.vt}$$

$$= \frac{Q}{cd.t\sqrt{2g\frac{P1 - P2}{\rho f}}} \text{ cm}^2$$

Diameter o orifice:

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$$dr = \sqrt{\frac{4Q}{\pi . Cd . V . t}} cm$$

For example: Determine for a four cylinder, Four Stroke I.C Engine, the quantity of fuel to be injected per cylinder per cycle , if it consumes 0.2 kg/bhp –hr and develop 500 bhp 200 rpm ; specific gravity of fuel being 0.9.

Solution of the example:

Fuel consumption/hr = 500×0.2

= 100 kg.

And number of cycles per hour:

$$= \frac{200}{2} \times 60$$

= 6000 cycles

$\therefore$ Weight of fuel per cylinder per cycle =

$$= \frac{100}{6000} \times \frac{1}{4}$$

= 0.00416 kg

Now, sp. gravity of fuel = 0.9

$\therefore$ Density of fuel = $0.9 \times \frac{1}{1000}$ kg.cc

$\therefore$Quantity of fuel injected per cylinder per cycle = $0.0416 \times \frac{1000}{0.9}$

= 4.6 cc.

6.0 Type of Data:

Emission related Sensors and Components:

6.1. EGR Actuator: (Sensors)

In generally, EGR Actuator is a diaphragm valve, which is operated by vacuum. Basically, EGR Actuator is consist by spring and holds the valve up to closed level, if no vacuum is applied. The vacuum that is operated by diaphragm which is supplied by the intake manifold and is controlled by a solenoid operated valve under control of the PCM. When the solenoid is energized by the PCM the EGR valve is opened by the applied vacuum. When the solenoid is reenergized the vacuum is cut off from the EGR valve and the spring holds the EGR valve closed. The amount of EGR is controlled by the duty cycle of the pulsed control current that is proportional to the average time of energized solenoid.

The duty cycle, and the valve opening properly controlled EGR is provided without adversely affecting emission.

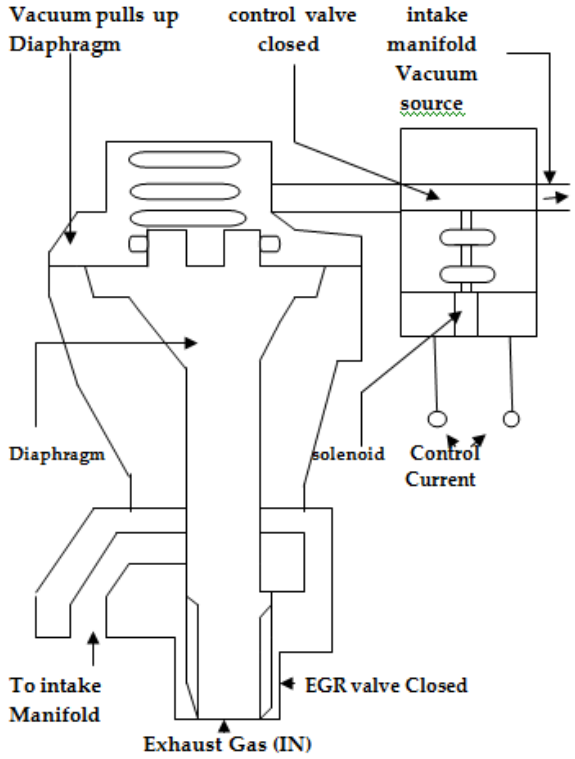

Fig. 6(a) EGR Actuator Control

7. Conclusion or Main Funding:

The rise civilization is closely related to improvement of transportation. In development of Transport of the I.C engine, both petrol and Diesel Engine, occupy in every important position. In India, near about 50% to 60% of automobiles exhaust emission goes to the atmosphere towards Air Pollution.

We know that, Nitrogen mixed with Oxygen, produced NOx emission in higher temperature. Because, in atmosphere have 78% Nitrogen and 21% of Oxygen and 1% CO2, H2 etc and in Hydrocarbon is consists by Hydrogen and Carbon respectively.

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HC+ O	H2+O,
H2O, CO2	Some CO2, some H2O
	Some CO and Some HC
(Complete combustion)	(in complete combustion)

It is true that pollutants from one don't amount to much say half kg of pollutants for a single day, but if we consider the very large number of automobiles in India, arising very rapidly, hence it will cause health problems for children and others.

However, problems are still particularly in maintaining clean air in recent times that I.C engine powered vehicles have come under heavy attack to various problems created by them.

After the experimental study, it was found that application of EURO-I, EURO-II, EUR)-III respectively, it is not possible to reduce NOx emission at the zero level, and therefore, need of application OBD-II system towards the Indian Vehicles .

Because, as India, prepare to make the use of Catalytic Converter compulsory, with a view of drastically reducing of air pollution. However, EPA of USA was observed that the Catalytic Converter has become significant and growing cause of Global warming. Because, automobiles fitted Catalytic Converter produce nearly half the Nitrous Oxide that contributes to global warming.

Nitrous Oxide in the atmosphere mixed with Nitrogen along with Oxygen produced NOx.

Therefore, OBD-II method as an answer to control the automobile exhaust emission in almost zero level and in this regard, our country like India , need to direct contact with development countries like USA.

8 Additional Approaches:

Throttle position (Angle) (TPS) sensor:

The goal of the OBD-II diagnostics is to alert the driver to the presence of a malfunction of the emission control system and to identify the location of the problem in order to assist mechanics in properly performing repairs. In addition, the OBD-II system should illuminate the Malfunction Indicator Light (MIL) and store the Trouble Code in the computer memory for all malfunctions that will contribute to increased HC emissions.

TPS sensor is a rotary potentiometer driven by the shaft of the butterfly valve in the throttle and a linear potentiometer driven by the connecting rod between the accelerator pedal and the throttle. The sensor uses a continuous resistive film manufactured with thick film technique. The material is a cerement or resistive plastic compound. As the throttle butterfly valve rotates the potentiometer voltage varies in proportion to the angle of rotation of throttle.

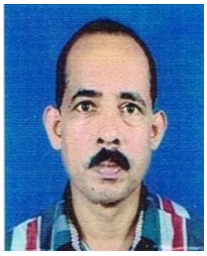
Diagnostics:

The electrical characteristics of the Throttle position sensor may deteriorate resulting in incorrect output, out of range /performance values, stuck at low signal stuck at high signal and intermittent failure.

OBD-II DTCs:

The failure modes of throttle sensor are diagnostics by OBD-II DTCs for these faults are 120-124.

9 Acknowledgements:



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10 BIOGRAPHIES

The author as Engineering Graduate, MBA along with Ph.D. in Automobile Engineering from International University, Washington, USA/2001 and Published numbers of research paper/projects completed i.e.

1. UGC sponsored national seminar: 87Nos.
2. NAAC sponsored national seminar: 05 Nos.
3. CTE International Conference: 05 Nos Guwahati University/Dibrugarh University/Assam University/: 34 Nos. Tezpur University/ Assam Agricultural university/UST, Shillong/ Institution of Engineers, etc National/International seminar/ Conference.
4. SAE International Conference/Exposition i.e. USA/France: 07 Nos.
5. Recipient of BOLT Award from AIR India Ltd, Mumbai/ Gold Medal etc: 05 Awards
6. Publication of Books: 07 Nos.

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12. Definition/Acronyms/Abbreviation

Definition:

Air Injector: This system of injecting fuel, into the combustion chamber of a diesel engine using a blast of compressed air.

Pintle: A small extension of the needle valve tip projecting through the discharge nozzle. When the needle lifts, the oil passes through the opening between the circumstance of the orifice and that of the pintle.

Smog: A term coined from the words, "Smoke" and "fog", first applied to the froglike layer that hangs in the air under certain atmosphere conditions. Now, generally used to describe any a condition of dirty air and or fumes or smoke.

Acronyms

Idle Air Control valve (IACV): The valve is an electronically controlled throttle by pass valve which allows air to flow around throttle plate (which is closed due to low engine rpm and vehicle being stationery) and produces the same effect as if the throttle slightly opened.

Solenoid: A type of electro-magnet often used to operate the starter motor switch.

Abbreviation

CARB = California Air Resource Board.
CCR = California Code of Regulations.
DTC = Diagnostic Trouble Code,
FTP = Federal test Procedure.
I.C. ENGINE = Internal Combustion Engine.
MIL = Malfunction Indicator Light.
MAP = Manifold Air Pressure