



CNG & LPG Technology



Dr. S.S. Thipse, Senior Assistant Director

Engine Development Laboratory

The Automotive Research Association of India, Pune

INTRODUCTION TO CNG AND LPG

- Natural Gas comprises of mostly Methane (CH₄) with varying content
- If the natural gas is compressed to a pressure of 200 bar and stored it is termed as CNG
- Auto LPG is a mixture of Propane and Butane
- Domestic LPG is 100 % butane

BENEFITS OF CNG AND LPG

- ❑ Environmentally Benign
- ❑ Reduction in Air Pollution
- ❑ Renewable in Nature
- ❑ Obtained from Diverse Sources
- ❑ Economically Cheaper
- ❑ Safer burning fuels
- ❑ Higher Octane Rating

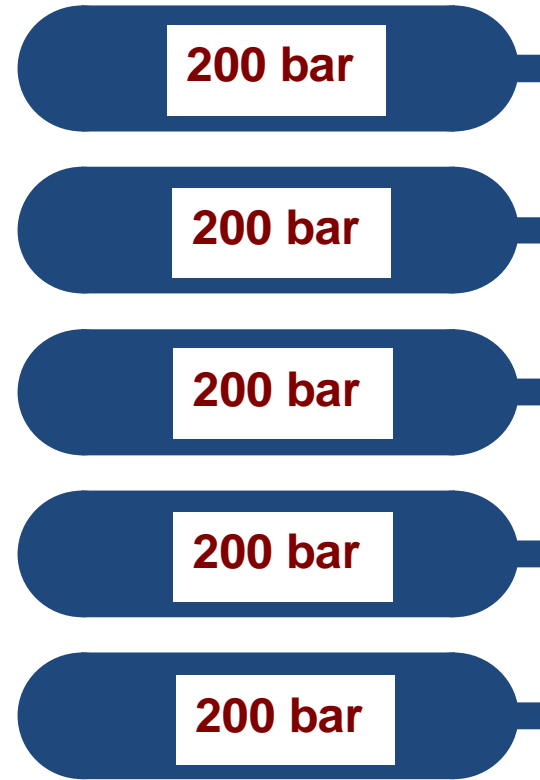
PROPERTIES OF CNG

- Formula = CH₄
- Molecular Weight = 16
- Stoichiometric AFR = 17.2
- Octane number = 120
- Auto-ignition Temp = 540°C
- Flammability Limits = 5 to 15
- Lower Calorific Value = 12000 KJ/L
- Temperature = -162°C for LNG
- Burns with Visible flame

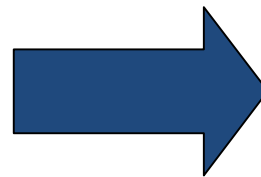
PROPERTIES OF LPG

- Formula = $C_3H_8 + C_4H_{10}$
- Molecular Weight = 44.09
- Stoichiometric AFR = 15.7
- Octane number = 97 to 112
- Auto-ignition Temp = $457^{\circ}C$
- Flammability Limits = 2.1 to 9.5
- Lower Calorific Value = 23000 kJ/L
- Density = 0.5 kg/L
- Burns with Visible flame

FUEL STORAGE RATIO OF CNG

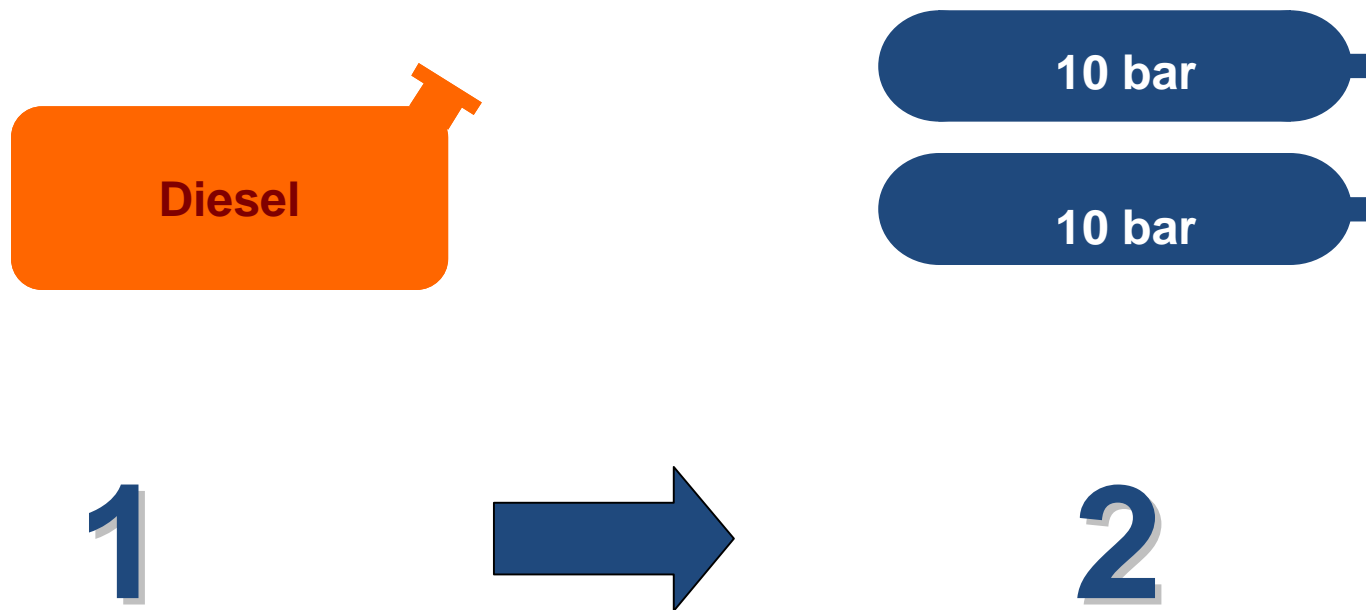


1

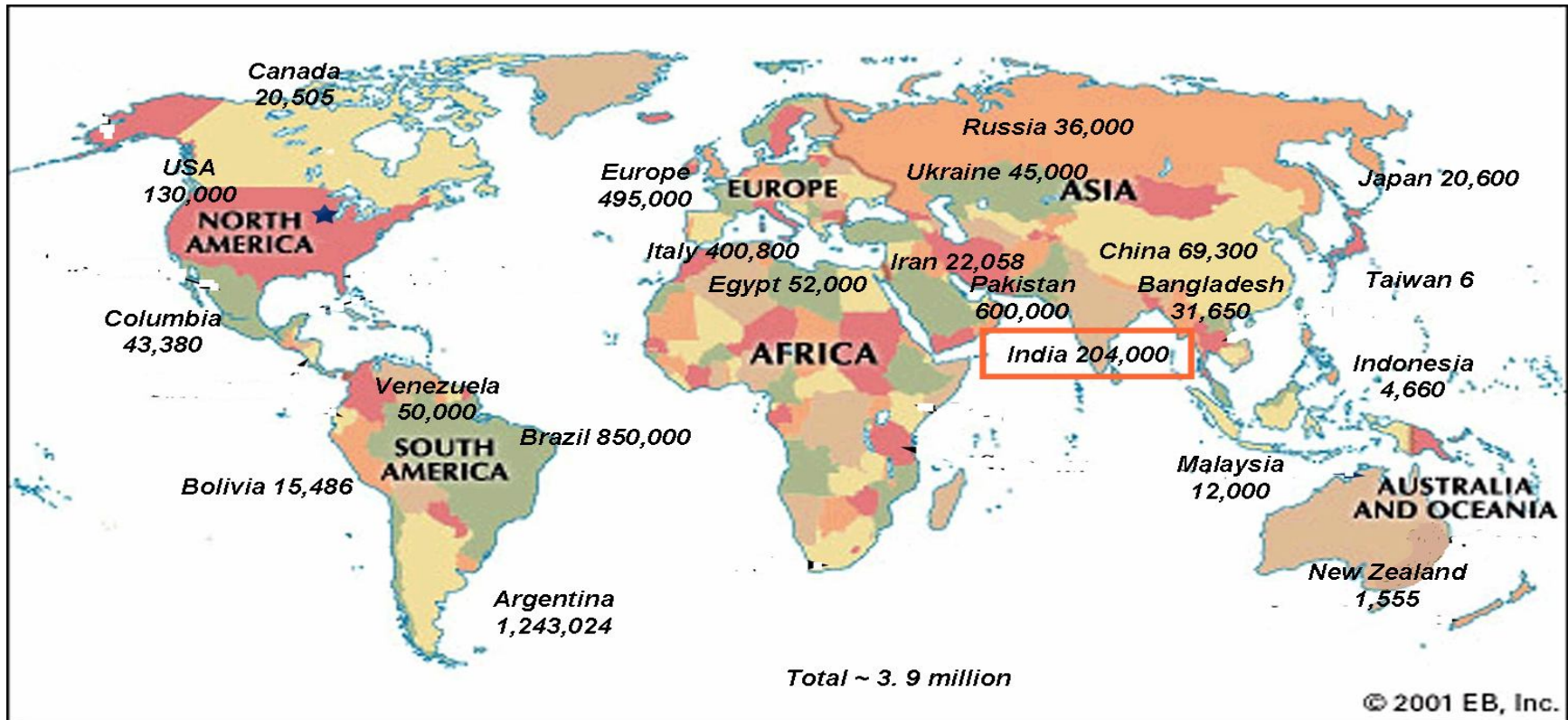


5

FUEL STORAGE RATIO OF LPG



WORLDWIDE CNG VEHICLES



CNG BUSES

Iveco



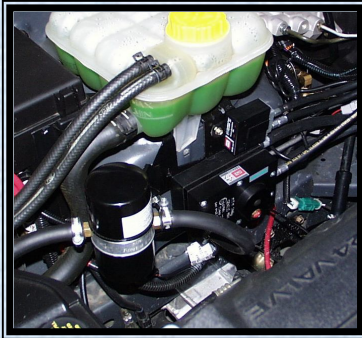
Volvo



TML

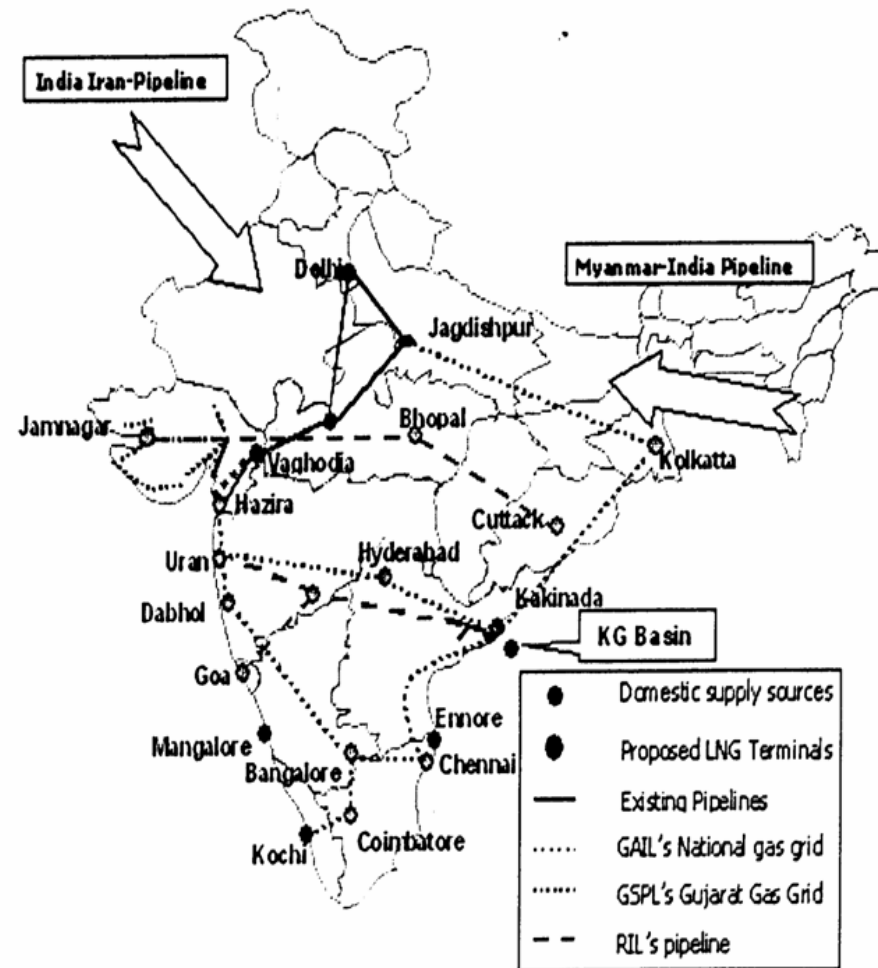


LPG CAR

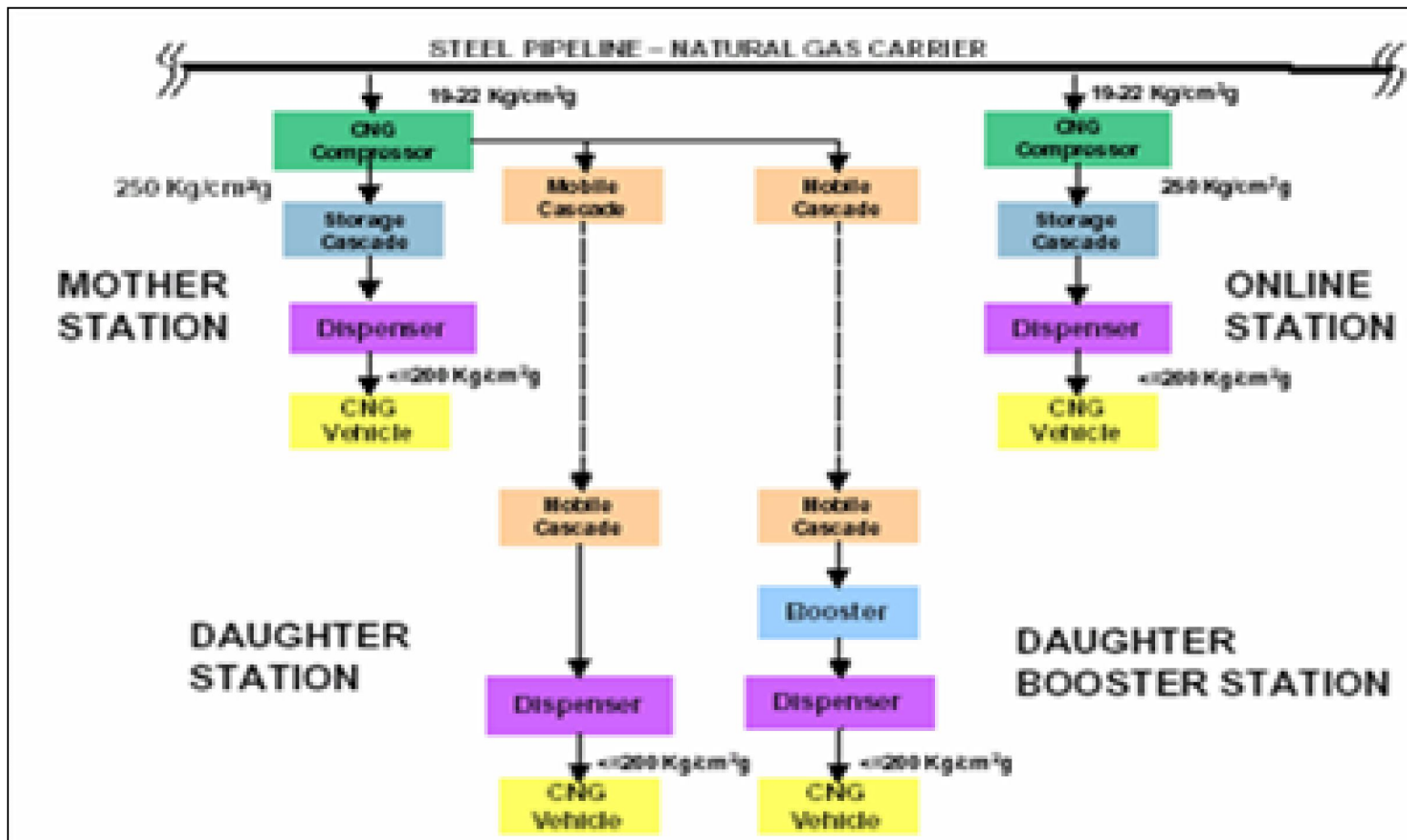


CNG IN INDIA

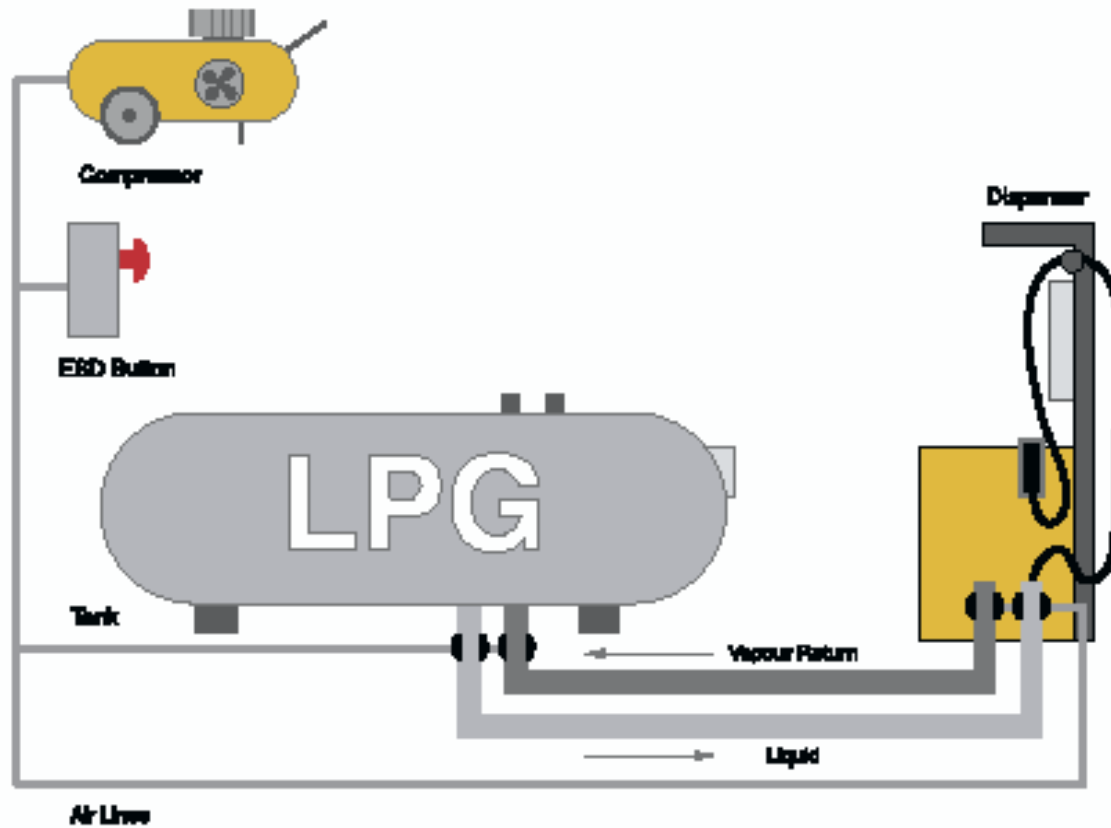
Pipeline Infrastructure Existing and Proposed



CNG SUPPLY MECHANISM



LPG STATION LAYOUT

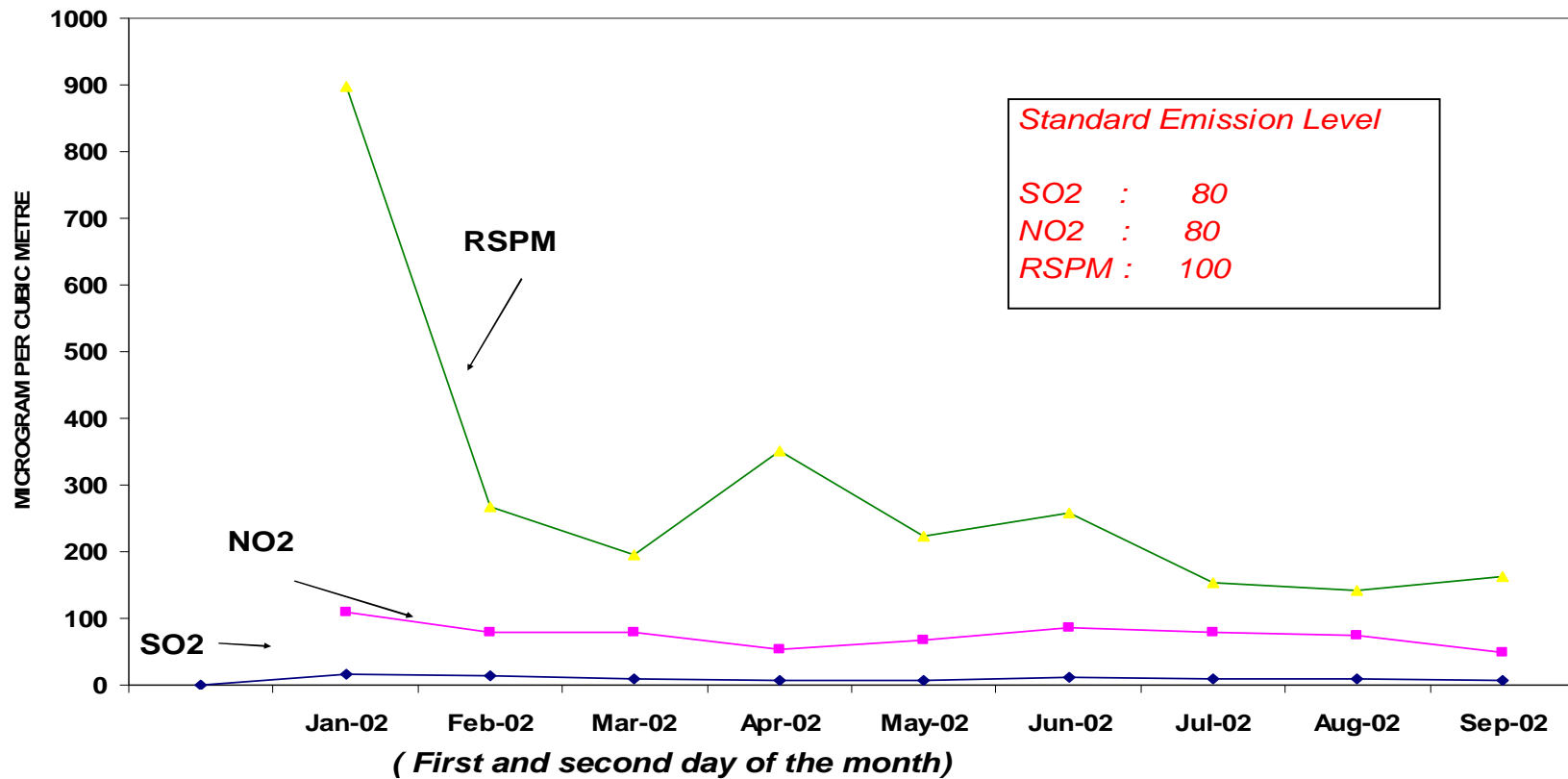


CNG & LPG IMPROVE AIR QUALITY

- Supreme Court directive led to implementation of CNG program in Delhi, which faced high pollution levels, almost 70% from automobiles.
- Delhi today boasts of the world's largest CNG bus fleet > 15,000 taking mini and RTVs together; Delhi breathes cleaner air today.
- Mumbai has also implemented a major drive to convert taxis and auto rickshaws to use of CNG and LPG.



CNG REDUCES POLLUTANTS IN DELHI



Economics of CNG and LPG

- CNG Cost = Rs. 25 to 27 per litre
- LPG Cost = Rs. 30 to 35 per litre
- Gasoline cost = Rs. 55 to 60 per litre
- Diesel cost = Rs. 40 to 42 per litre

CNG and LPG is economical

CNG & LPG – ARAI Regulatory Role

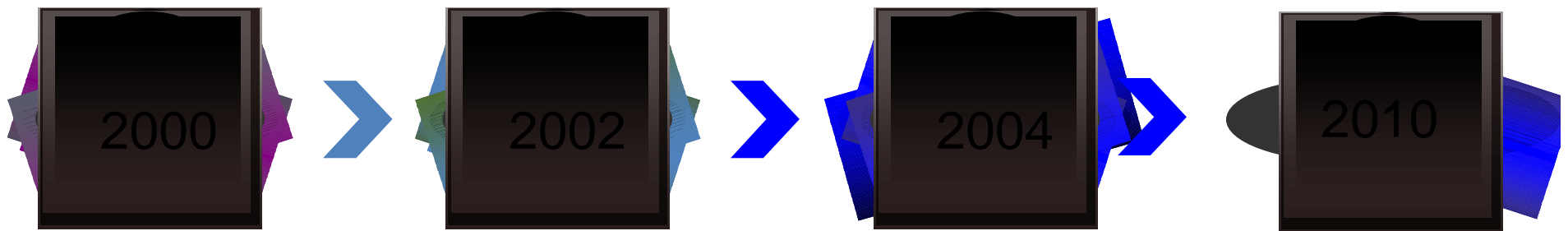
- Formulation of Automotive Indian Standards (AIS) for CNG and LPG Vehicles
- Testing and evaluation of CNG and LPG Vehicles as per CMVR requirements
- CNG and LPG Fuel kit testing as per ECE R 110 and ECE R 067
- CNG and LPG Engine performance and emission certification as per BS-III / BS-IV/ BS-V emission norms

CNG & LPG International Standards

- ISO 15500-1 to 19: CNG Vehicle Fuel System Components standards
- ECE Regulation 110 and 067 : CNG and LPG Component testing and Installation requirements on Vehicles
- AS/NZS: 2739 :Code of practice for the use of CNG and LPG fuels in internal combustion engines
- AIS 024 & AIS 025 : Code of practice for the use of CNG and LPG fuels in India
- NGV 3.1 Canadian standard for CNG vehicles

CNG & LPG Emission Standards In India

1992 - Certification Started



GSR 99 (E)

- Prevalent TA norms
- Separate approval for vehicles with Engine cc range
 - Up to 750 cc
 - 751 cc
 - 1300cc
 - 1301 and above
- 5 year certificate validity

GSR 853 (E)

- India stage I for vehicles manufactured before 2000
- Bharat Stage II for vehicles manufactured after 2000
- Engine cc range +/- 25%, separate approval for 2S /4S /carburetted /MPFI
- 3 year certificate validity
- AIS 024 and 028 for type approval requirements and safety code practice
- Third party inspection and safety code practice

GSR 111 (E)

- Provision for Pre 1991 vehicle approval
- Stringent PUC norms for in-use CNG/LPG vehicles with improved instrumentation and test procedure

BS-IV Regulations

PUC Emission Norms for CNG/LPG vehicles

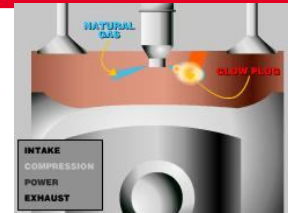
Sr. No.	Vehicle Type	Previous Norms		Current Norms	
		CO %	HC ppm	CO %	HC ppm
1	2 wheeler (2/4 -stroke) & 3 wheeler (pre year 2000)	4.5	-	4.5	9000
2	2 wheeler (2-stroke) & 3 wheeler (post year 2000)	4.5	-	3.5	6000
3	2&3 wheeler 4-stroke vehicles (post year 2000)	4.5	-	3.5	4500
4	4 wheeler vehicles	3.0	-	3.0	1500
5	CNG Buses	3.0	-	0.5	750

CNG/LPG Fuel Kit Introduction

- CNG/LPG Kit consists of the CNG fuel delivery system which is fitted on to the engine.
- The components of a CNG/LPG fuel kit are:
 - 1) Pressure regulator – Primary & Secondary
 - 2) ECU & Sensors
 - 3) Solenoid Metering Valve & Throttle body
 - 4) Wiring harness
 - 5) Ignition coils & Spark plugs
 - 6) Injector / Gas air mixer
 - 7) CNG Cylinder
 - 8) CNG Hoses & Filter
 - 9) Vaporizer for LPG

CNG/ LPG Fuel Kit Generations

BS-V Direct Injection



BS-IV Manifold Injection



BS-III Throttle Body Injection



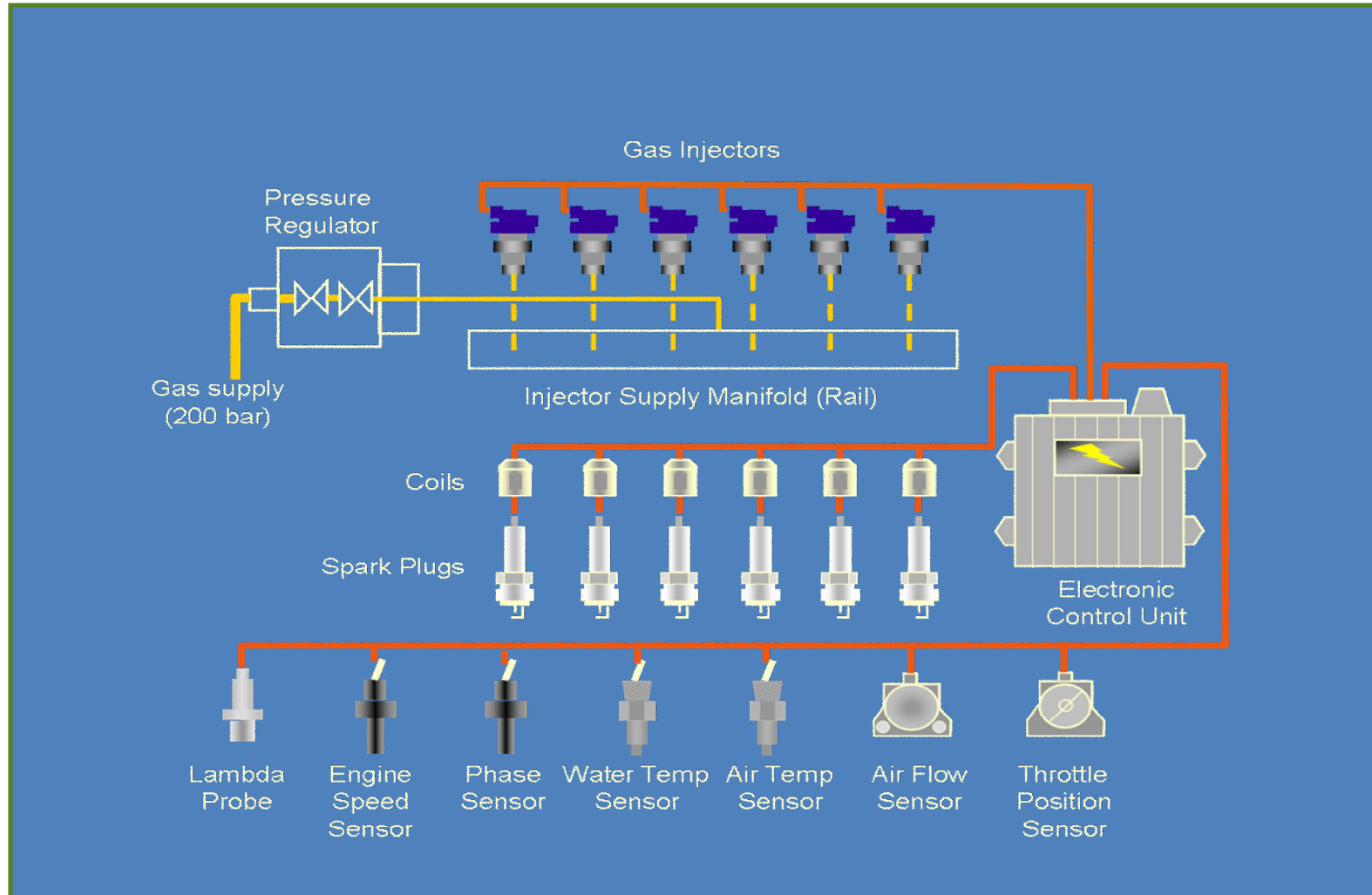
BS-II Air/Gas Valve



BS-I Venturi

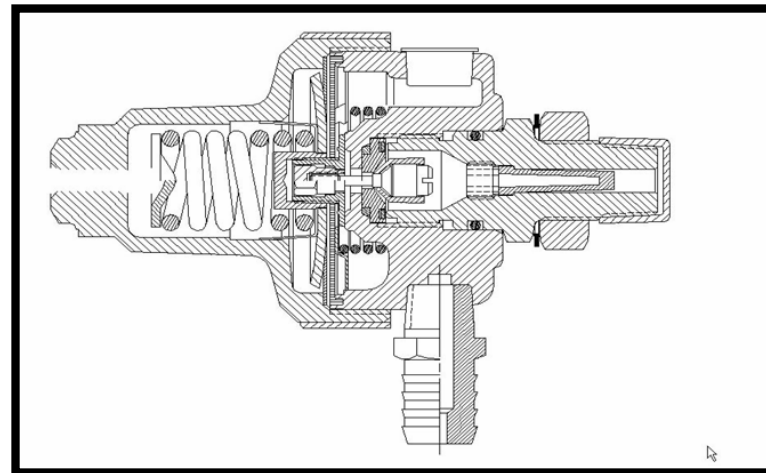
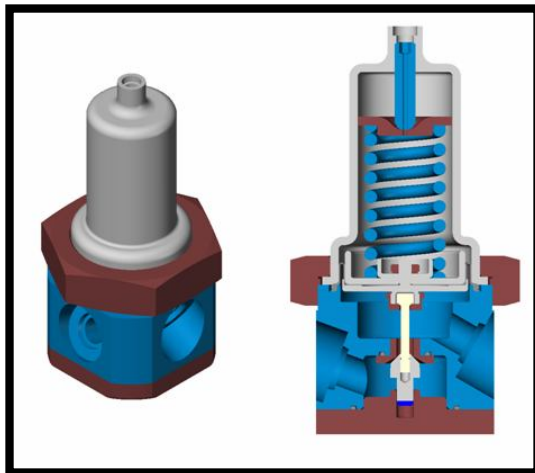


CNG/LPG Injection Kit Layout



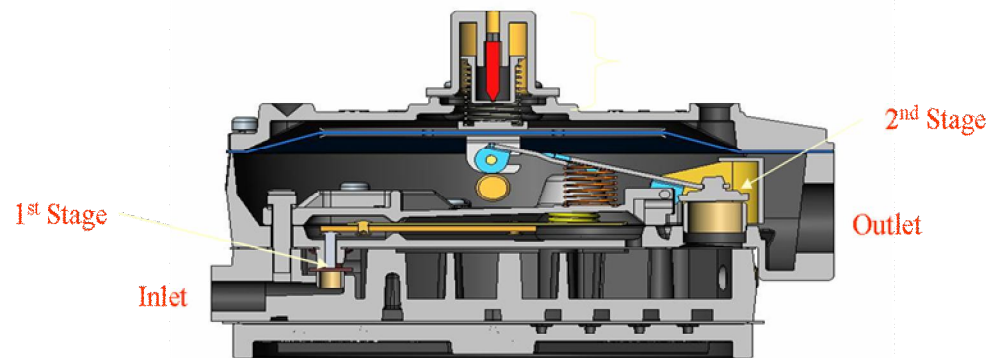
CNG/LPG Primary Pressure Regulator

- Reduces gas pressure from 200 bar to 10 bar for CNG and from 10 bar to 4.5 bar for LPG
- Carbureted or Fuel Injected Type
- Metallic body with springs



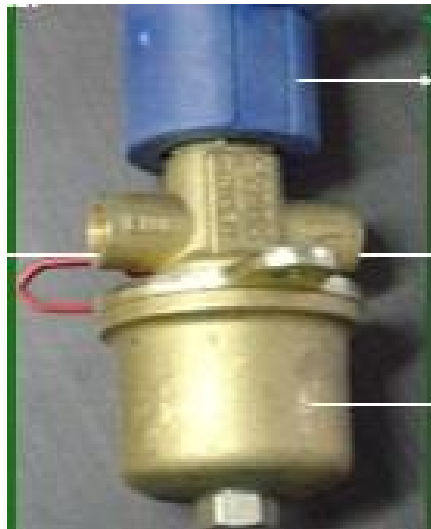
CNG/LPG Secondary Pressure Regulator

- Single stage or integrated two stage design
- Reduces gas pressure from 10 bar or 4.5 bar to below 1 bar for CNG and LPG carburetion in one or two stages
- Reduces gas pressure from 10 bar or 4.5 bar to approx 3-4 bar for CNG and LPG injection in one stage
- Metallic body with diaphragm



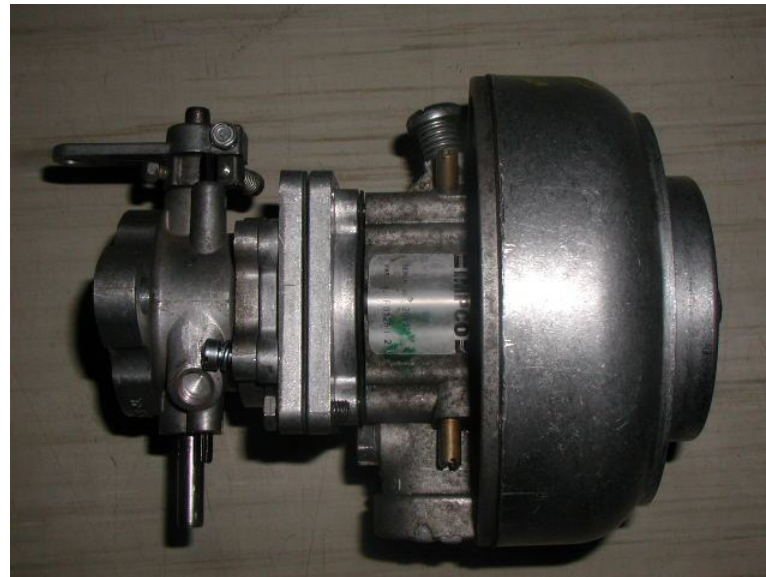
CNG/LPG Metering valve

The CNG/LPG metering valve is a solenoid valve which acts as a fuel metering device in addition to acting as a non-return valve as well as a fuel cutoff in case of emergency.



CNG/LPG Gas Air Mixer

The CNG/LPG Gas air mixer facilitates the mixing of fuel with air to provide a homogeneous charge to the engine. It consists of vanes for mixing gas and air.



CNG / LPG Injectors

The CNG Injectors are low pressure injectors which operate at a pressure of 4-5 bar and inject CNG into the throttle body or manifold.



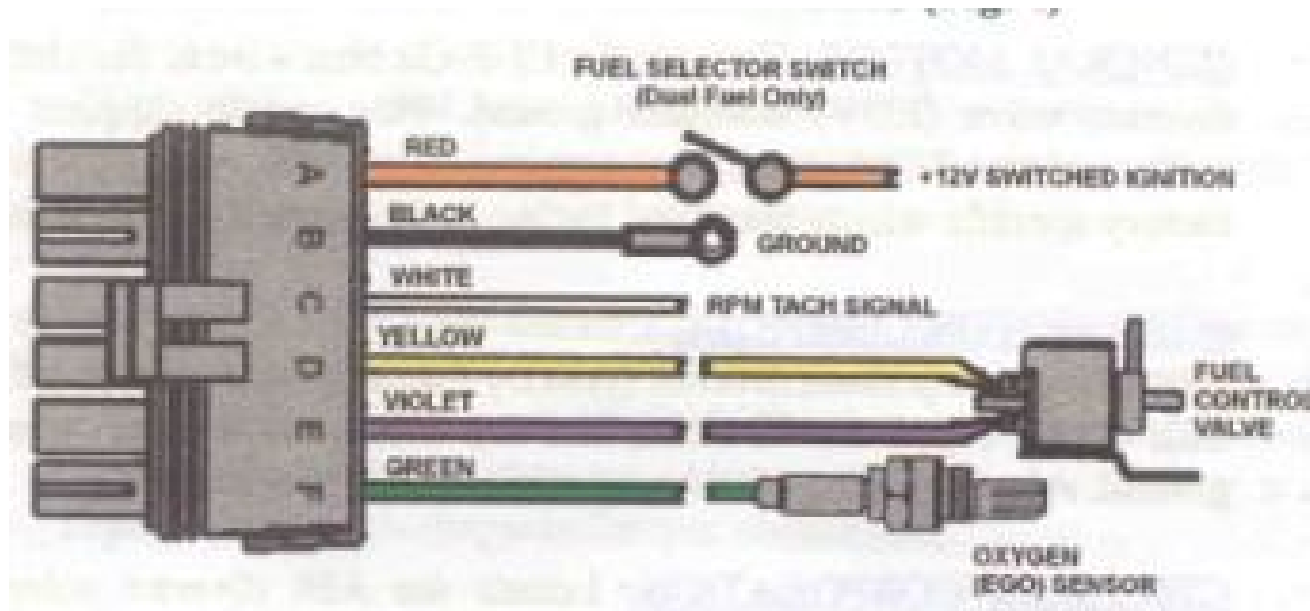
CNG/LPG Electronic Control Unit

- Micro-processor based controller
- Contains 16 bit / 32 bit / 64 bit micro processor
- Calibration done by maps in form of tables
- Communicates with PC through data cable
- Operates in Master/Slave configuration



CNG/LPG Wiring Harness

The CNG / LPG wiring harness is a collection of cables connecting different sensors to the ECU as well as wires from the battery to the ECU.



CNG/LPG Sensors

CNG/LPG Kit contains the following sensors

Intake air temperature sensor - thermocouple

Manifold air pressure sensor - piezoelectric

Exhaust Gas Oxygen Sensor (Lambda Sensor)

Engine Coolant temperature Sensor - thermocouple

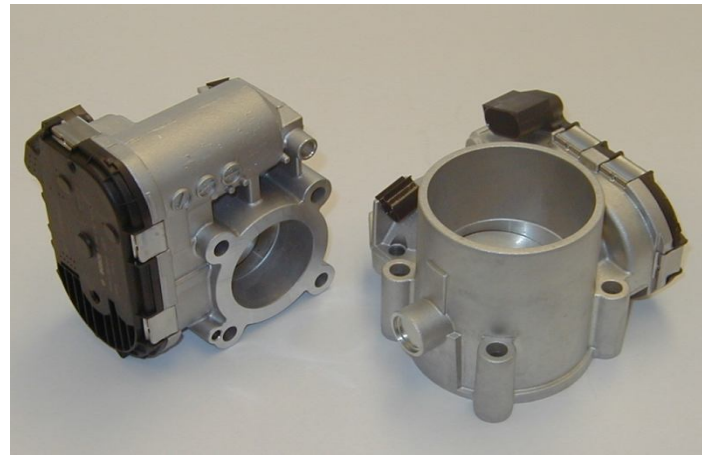
Throttle position Sensor – variable reluctance type

Crankshaft Position Sensor – Hall effect type



CNG/LPG Throttle body

The CNG/LPG Throttle body is a butterfly valve which supplies fuel air mixture in varying amounts in response to load. The Throttle body can be electronically controlled by the ECU and is known as drive by wire system.



CNG/LPG Ignition Coils & Spark Plugs

The CNG/LPG Ignition coils are distributor less coils which provide high voltage for generating spark.

The Spark plugs provide the spark at appropriate timing for ignition of the CNG or LPG - air mixture.



CNG/LPG Cylinder

The CNG Cylinders store CNG at a storage pressure of 200 bar. They are made of stainless steel material. They are painted white with a red neck. They are held in place with straps.

LPG cylinders store pressure at 10 bar. They are also made of stainless steel and are painted gray. They come in cylindrical or torroidal shapes.



CNG / LPG Hoses & Filter

CNG/ LPG Hoses are of two types

High pressure : Connects cylinder to primary pressure regulator

Low Pressure : Connects secondary regulator to gas air mixer or throttle body

CNG Filter prevents debris from entering the engine



CNG/LPG fuel Kit Component Testing

- **Hydrostatic strength test** : Pressurize the component at 5-times the working pressure (i.e 1000 bar) to check the strength of the parts.
- **High temperature leakage tests (at 120°C OR 85°C)**: Pressurize the component at 300 bar at 120°C / 85°C according to the location of the component on the vehicle.
- **Low temperature leakage tests (at -40°C)**: Pressurize the component at 300 bar at - 40°C
- **Corrosion resistance test (for 96 hrs)** : Subject the component to corrosive environment (i.e. Fog of salt solution) to check the corrosion resistance properties of metallic parts.
- **Continued operation test** : (for 50,000 cycles at different temp. and pressures)
Operate the component for 50,000 cycles at 200 bar / 300 bar at 120°C / - 40°C to check quality of the moving parts like diaphragms, valve seats ,springs of the CNG/LPG kit components after continuous cycling.

CNG/LPG fuel Kit Component Testing : Contd

- **Vibration resistance test (at 1.5 mm with 17 Hz amplitude in each axis) To check the CNG/LPG kit components for Vibration resistance.**
- **Excess torque resistance test: To check the threaded fittings for excess torque (i.e. 150% of the rated torque) application.**
- **Bending moment test: To check the joints and connections of the kit components for their strength against bending moment.**
- **Oxygen aging test : This test is applicable to non-metallic parts like diaphragms, 'O' rings, Valve seats etc. used in the CNG/LPG kit components to check their resistance against Oxygen present in the environment.**
- **Non-metallic synthetic immersion test :This test is applicable to non-metallic parts to check their material properties (weight and volume)**
- **Brass material compatibility test : This test is applicable for threaded brass material parts of the CNG/LPG kit components to check their resistance against ammonia.**

CNG/LPG Engine Development

- CNG/LPG has to be used in spark ignition engines with carburettion or single point or multi point fuel injection systems
- Compression ignition of a CNG/LPG-air mixture is not feasible due to high autoignition temperature
- Reduced volumetric efficiency & partial pressures in the intake manifold cause power loss
- Energy density of CNG/LPG is poor
- Variable fuel composition affects performance and emissions
- Engine Valve seat wear due to lack of lubricity

Use of CNG/LPG in SI Engines

- SI Engines operate on OTTO cycle
- The differences in engine parameters and operating characteristics is very limited for Petrol and CNG/LPG Engines
- CNG/LPG is having high octane rating (MON 130) suitable for SI Engine
- Except the addition of CNG/LPG kit no other modification is required in SI Engines to run on CNG/LPG

Typical CNG Engine



Combustion Options For CNG/LPG

Stoichiometric

$$\lambda = 1$$

Required:

- optimised combustion
- accurate I-control
- exhaust gas recirculation (EGR)
- three-way catalyst

Advantages:

- low emissions
- small combustion variability

Disadvantages:

- lower efficiency
- higher thermal loading and heat rejection

Lean Burn

$$\lambda > 1$$

Required:

- combustion system with high rate of heat release by high turbulent kinetic energy in the spark region
- very accurate I-control towards the lean limit
- oxidation catalyst with capability to reduce methane emissions

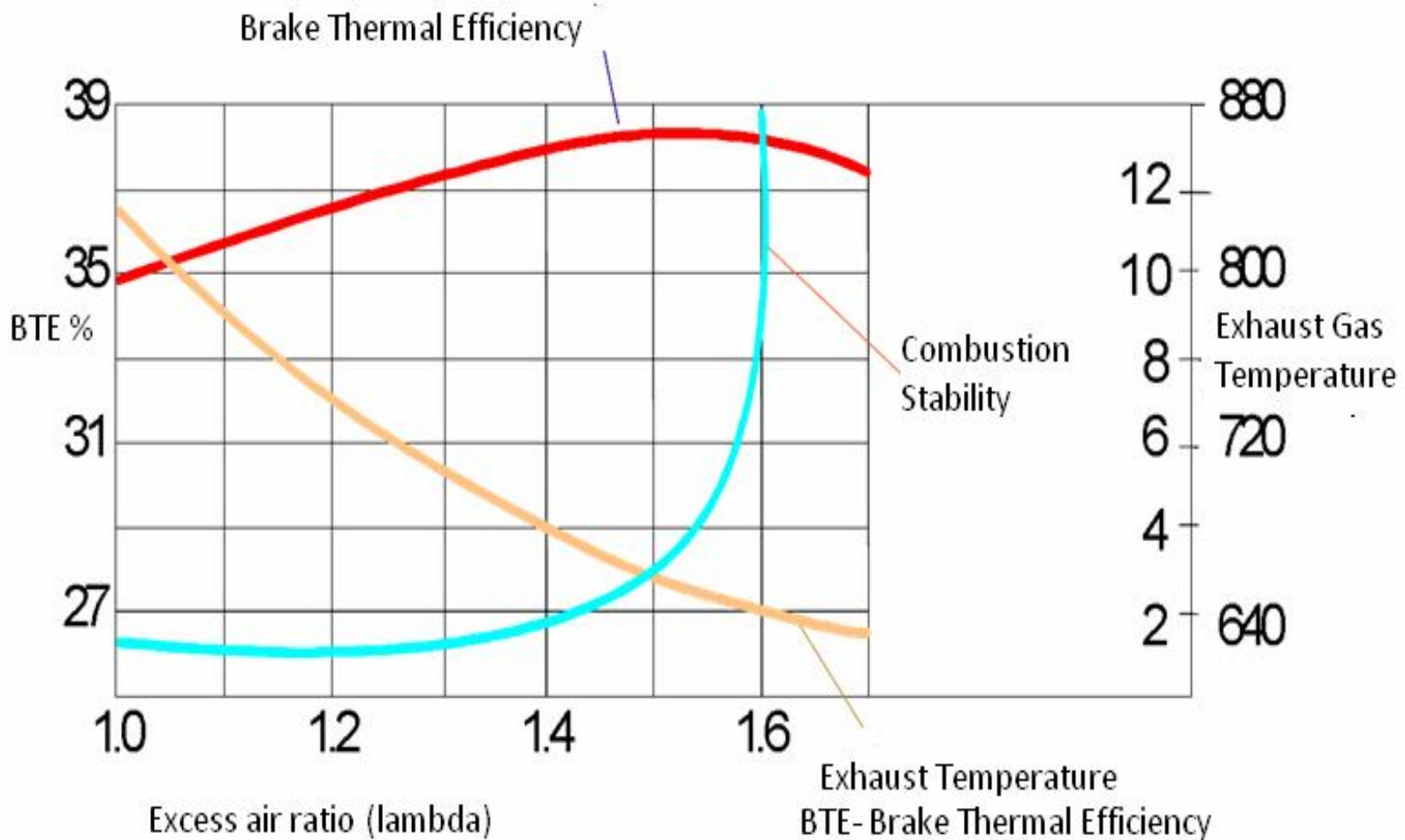
Advantages:

- higher efficiency
- higher BMEP-potential
- reduced thermal load and heat rejection

Disadvantages:

- higher emissions
- sensitivity to gas composition variation
- oxidation catalyst for CH₄-reduction

Effect Of Excess Air For CNG/LPG Engine

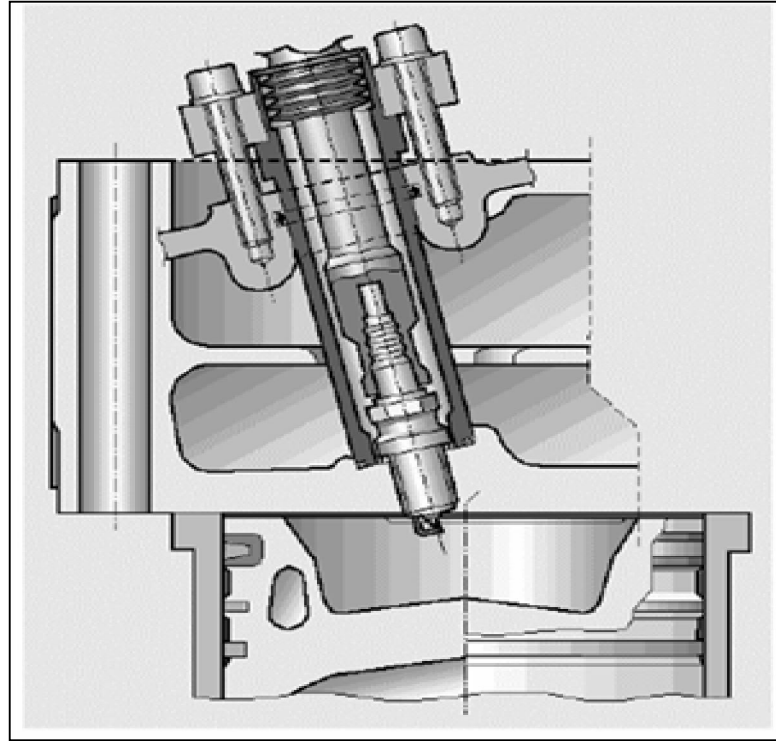


Calculation of AF Ratio for CNG/LPG Engine

The Air fuel ratio calculation depends on the discharge coefficient of air and fuel, the cross section area of air venturi and fuel jet and the density of air and fuel

$$\frac{A}{F} = \frac{C_{d,a}}{C_{d,f}} \frac{A_2}{A_f} \sqrt{\frac{\rho_a}{\rho_f}}$$

CNG/LPG Engine Combustion Chamber



The SI engine combustion chambers for CNG/LPG engines have deeper combustion bowls as compared to combustion chambers for Diesel engines.

CI Engine Modifications for Use of CNG/LPG

- CI Engines operate on DIESEL cycle
- The differences in engine parameters and operating characteristics is large for Diesel and CNG/LPG Engines
- Thus, it is necessary to make significant changes in the engine hardware of the diesel engine in order to burn CNG/LPG
- CNG/LPG does not have good auto-ignition properties (cetane rating) hence is not suitable for direct use in Diesel Engines but can be used in dual fuel mode.

CI Engine Modifications for Use of CNG/LPG

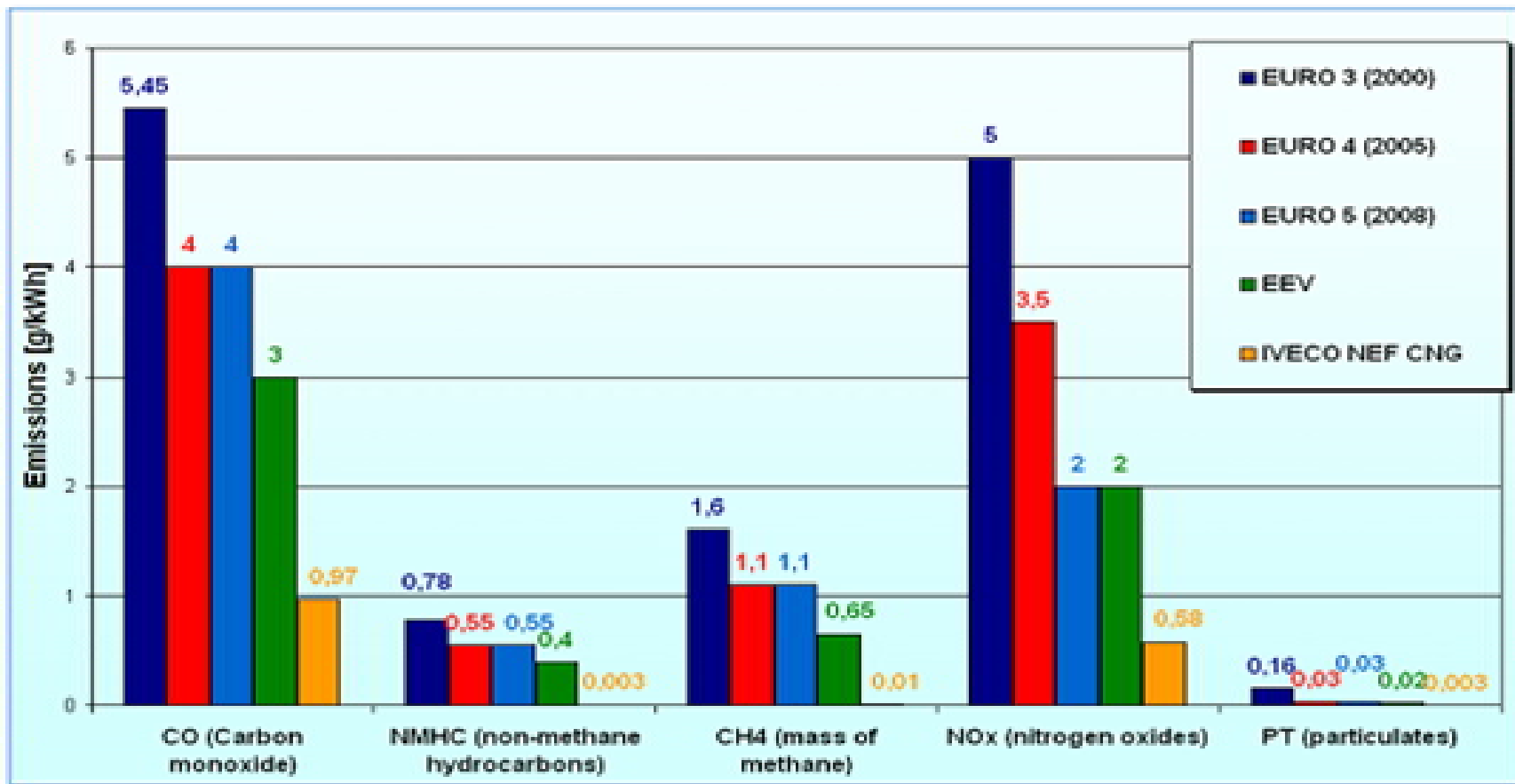
Following changes are required in CI engine

- Addition of ignition system with coils & spark plugs
- Addition of CNG/LPG fuel carburetion/Injection system
- Modification in intake manifold to increase volume
- Increasing the cooling capacity of engine
- Reduction of compression ratio by modifying piston
- Combustion chamber bowl to be made deeper
- Reduction of engine swirl by machining ports
- Using a higher grade lubricant
- Change of valve seat material to stellite
- Minimising valve overlap by modifying camshaft
- Cylinder head modifications

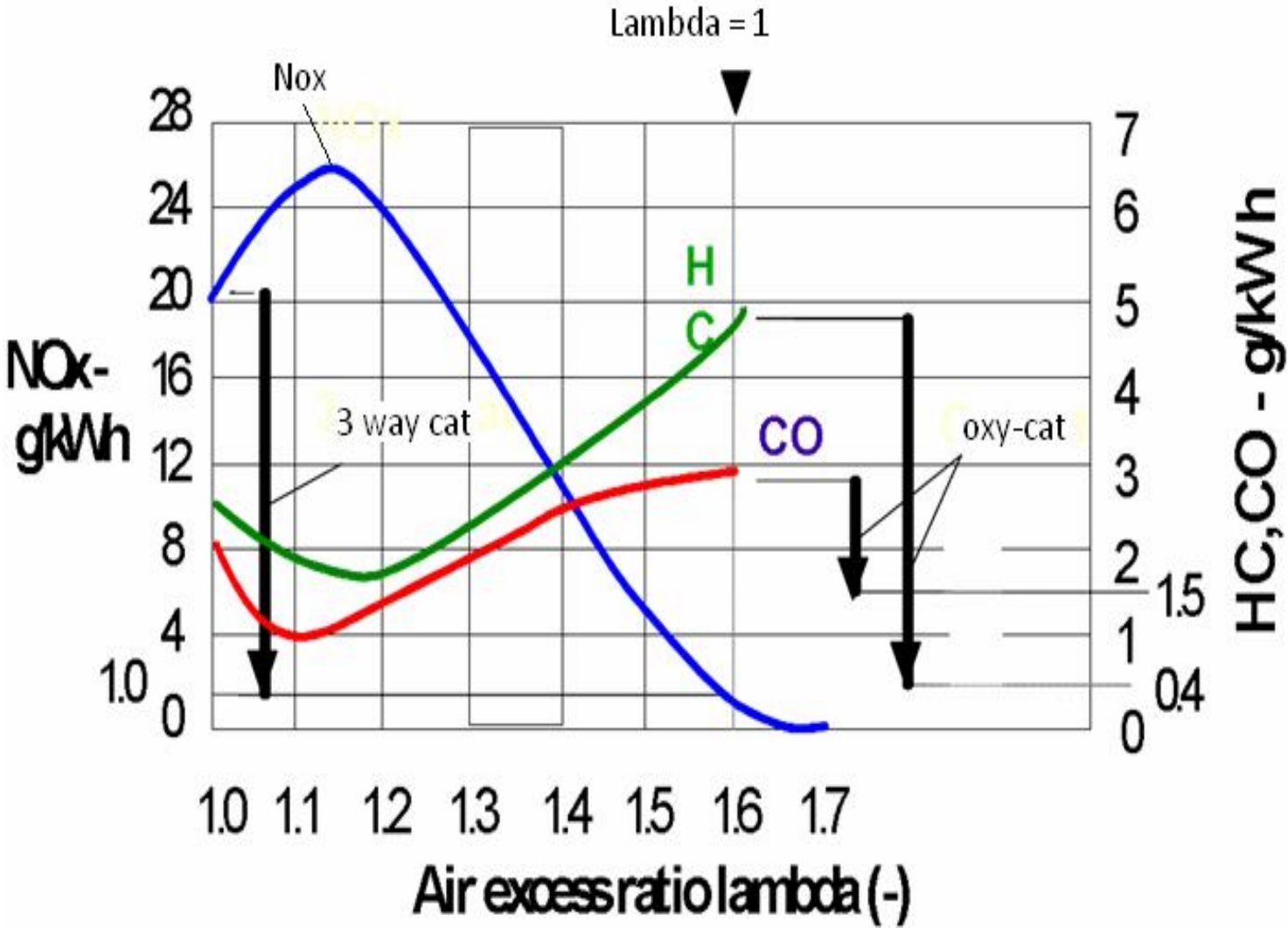
CNG/LPG Engine Emissions

- Because it contains less carbon, CNG/LPG combustion produces less HC and CO.
- PM and smoke emissions are absent.
- NOx emissions are on the same order as conventional diesel engine
- CO2 emission are higher than CI engines

CNG Engine Performance



Effect of Excess Air on CNG/LPG Emissions



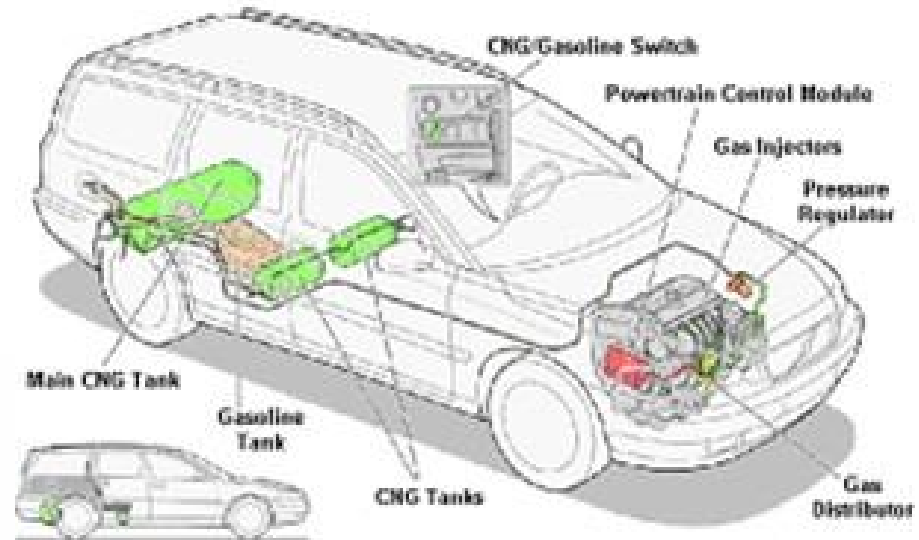
CNG/LPG Vehicle Types

- **Mono-fuel Vehicles** : These run on CNG/LPG alone
- **Bi-fuel Vehicles** : These run on CNG/LPG or Gasoline; however use only one fuel at a time
- **Dual fuel CNG/LPG vehicles** : These run on LPG/CNG and Diesel; however use both fuels simultaneously

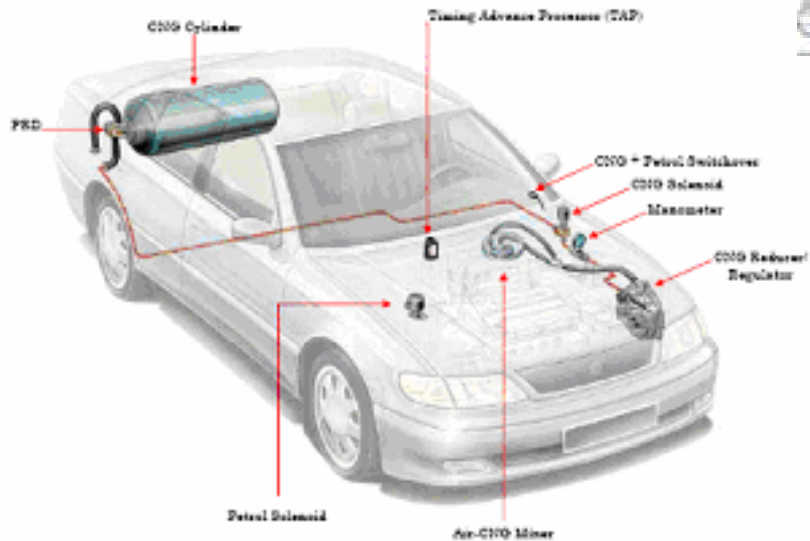
Vehicle Modifications for CNG/LPG

- Removal of existing fuel tank and fitment of CNG/LPG cylinders to chassis by mounts and brackets. Mounting strength should be minimum 20 times mass of CNG/LPG cylinder in any direction
- Chassis frame durability due to mounting of cylinders and effect of increase in vehicle weight on axle distribution should be assessed
- Outlets from all bust discs should be manifolded together and vented from a pipe with roof discharge
- In case of roof mounted CNG cylinders for low floor bus, body structure should be strengthened to meet the cylinder load.

CNG Vehicle Layout



CNG LAYOUT IN VEHICLE



CNG Passenger Car Layout

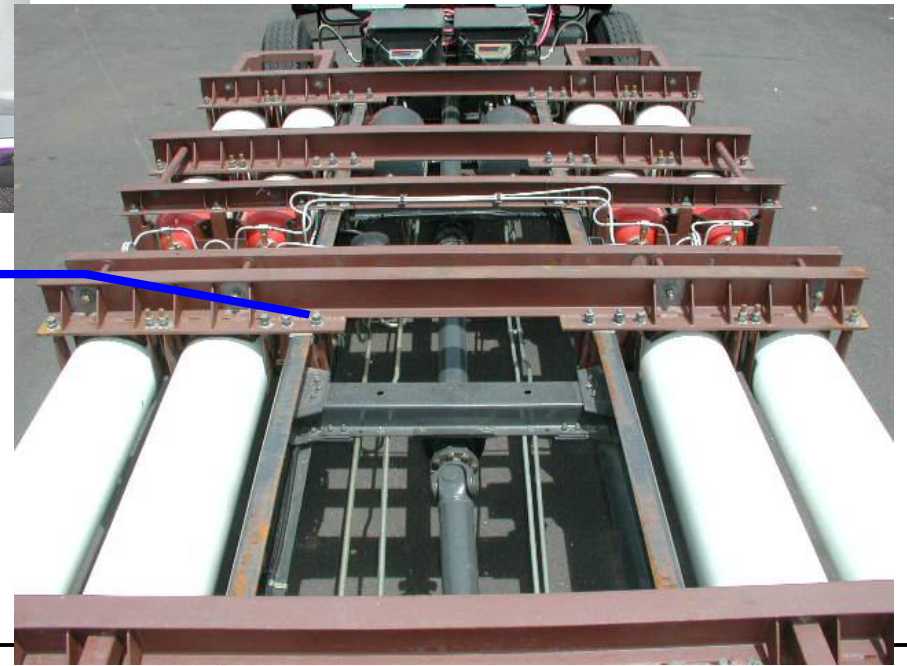
CNG/LPG Vehicle Certification Review



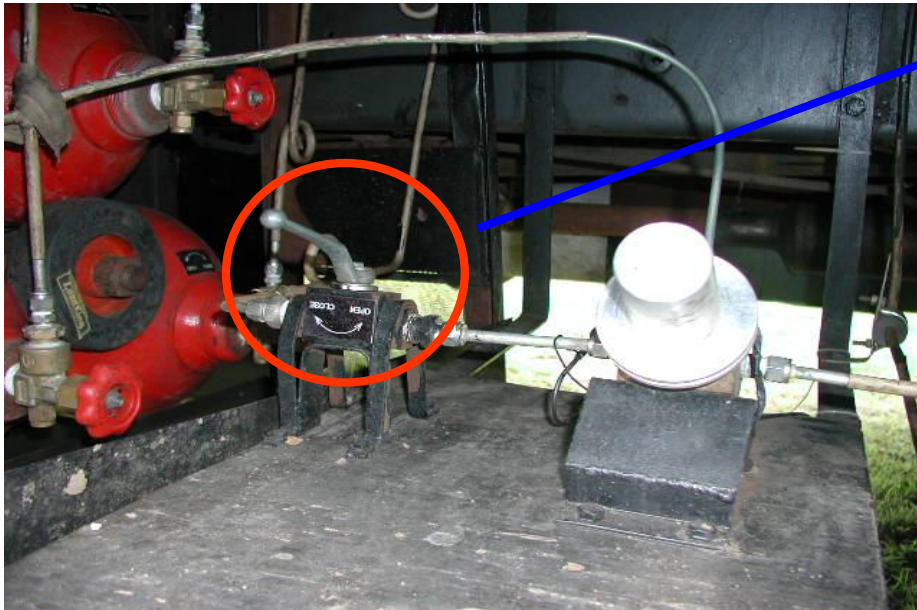
Two bands are used

1. Cylinder Mounting

An air gap of 5mm is maintained between cylinders to avoid metal to metal contact by using non-moisturizing rubber pads

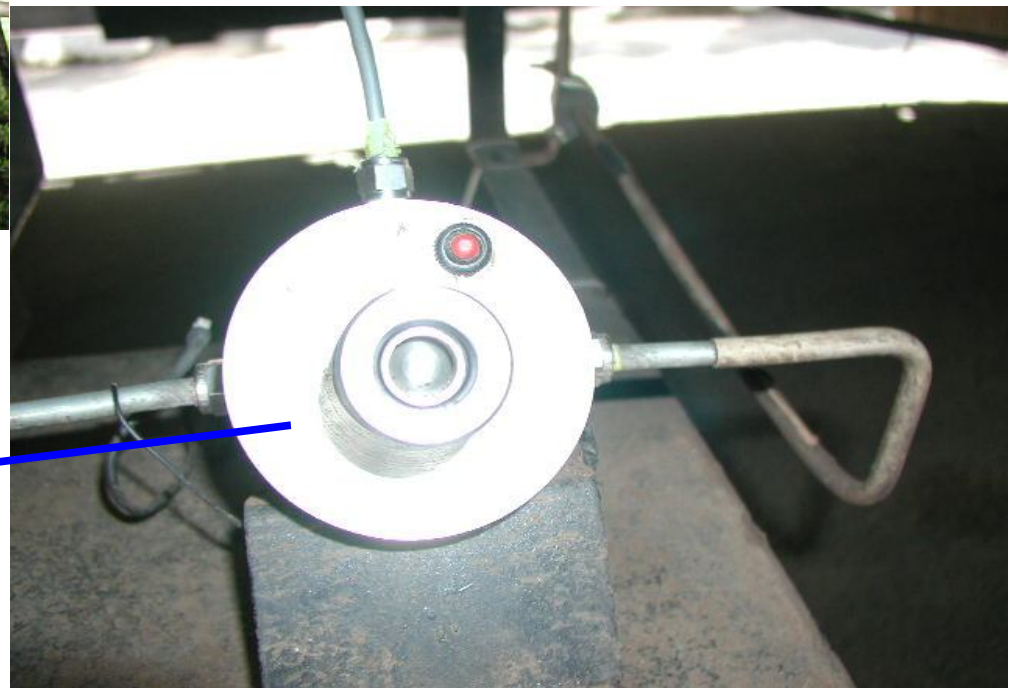


CNG/LPG Vehicle Certification Review



Provided to carry out maintenance

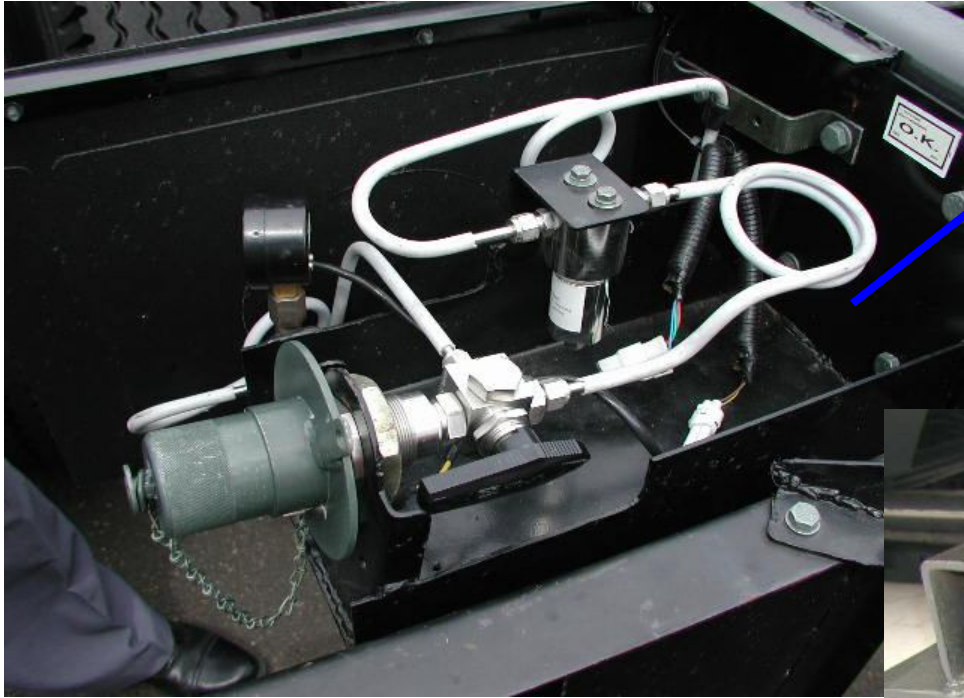
2. Service Shut Off Valve



3. Refueling Interlock Device

Cuts-off the ignition while the vehicle is being refueled

CNG/LPG Vehicle Certification Review

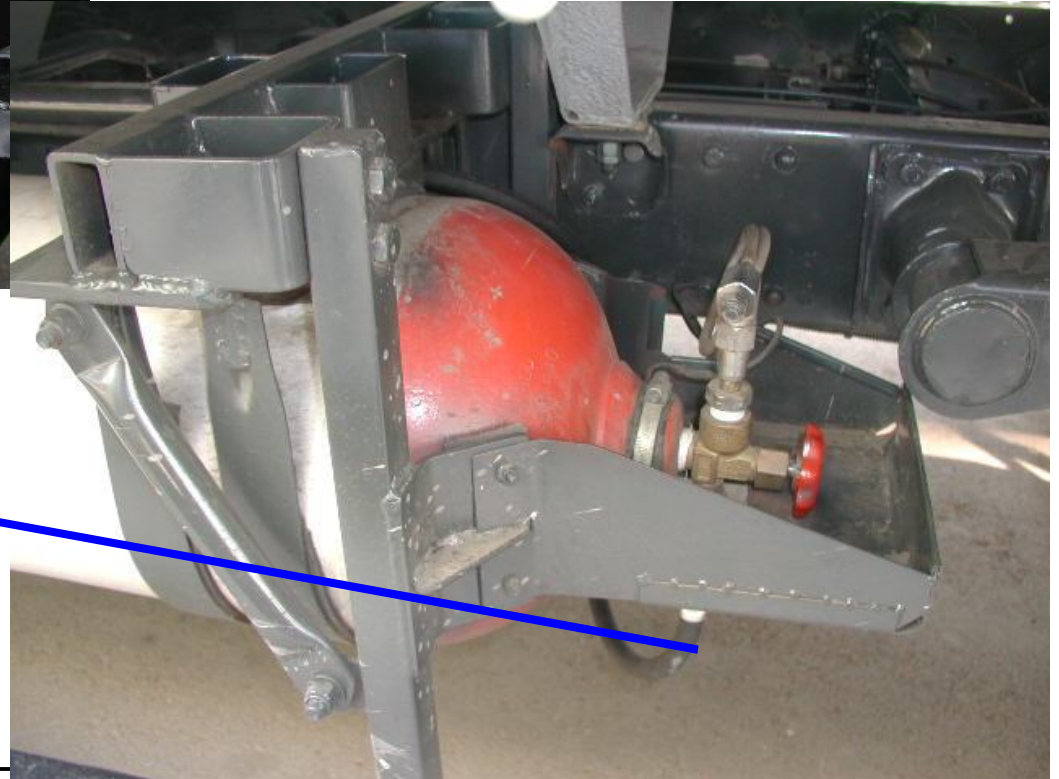


Provided to ensure sufficient flexibility

4. CNG/ LPG Piping

5. Safety Plate Shield

Protection of cylinder valves and joints from flying debris under the vehicle



CNG/LPG Vehicle Certification Review



Ensures safe removal of gas from cylinder

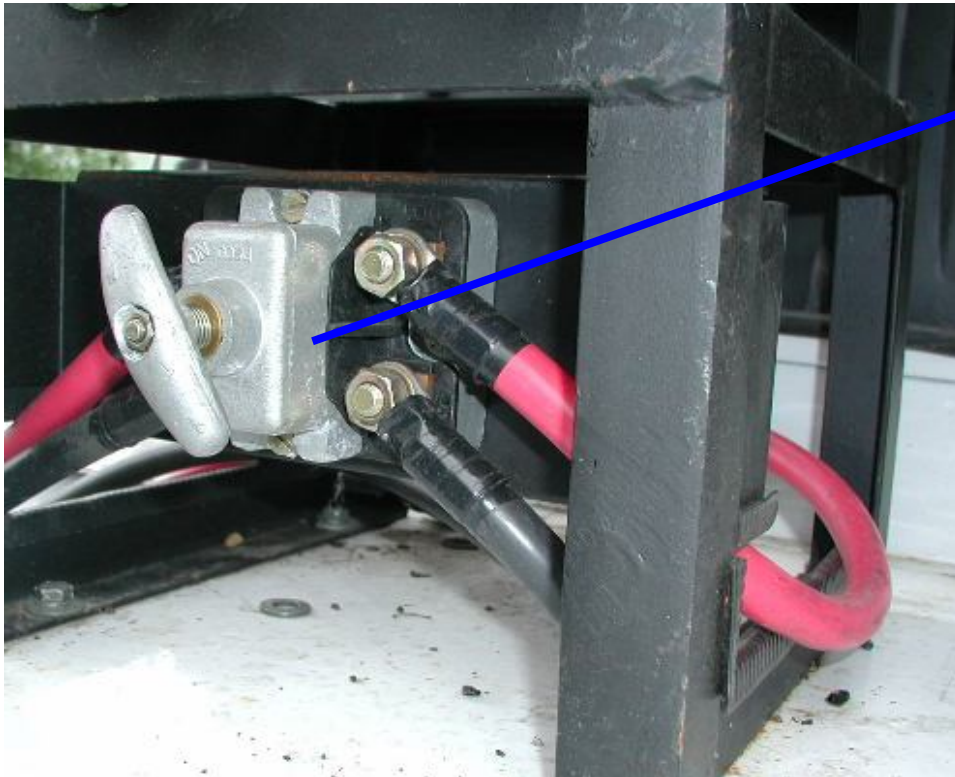
6. Ducting For CNG/LPG Cylinders

Directs the gas leakage to the roof of the vehicle

7. Venting For CNG/ LPG Vehicles



CNG/LPG Vehicle Certification Review

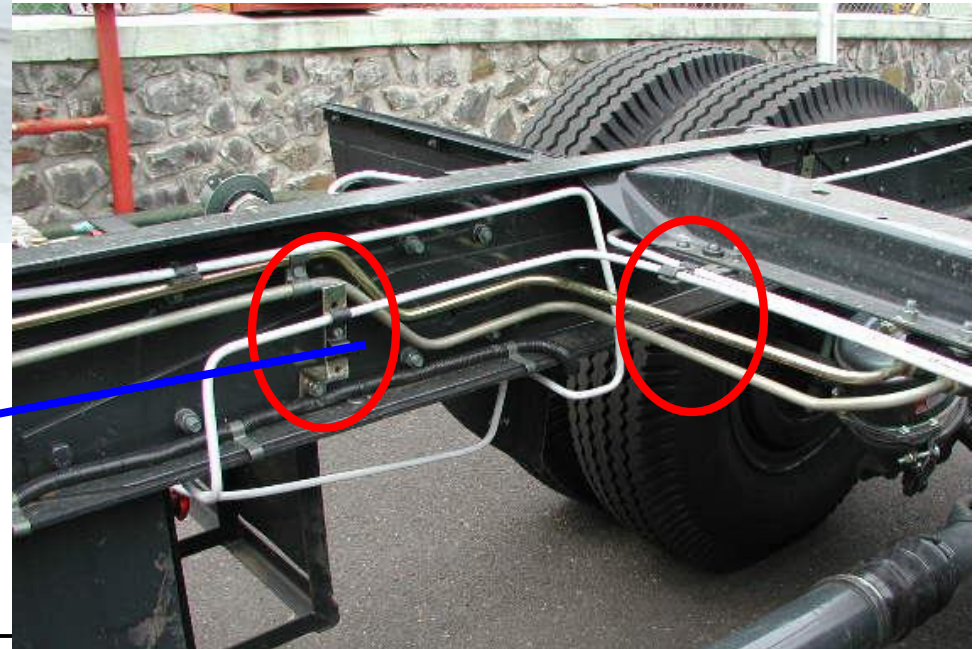


Enables driver to cut off electrical supply in the event of fuel leakage

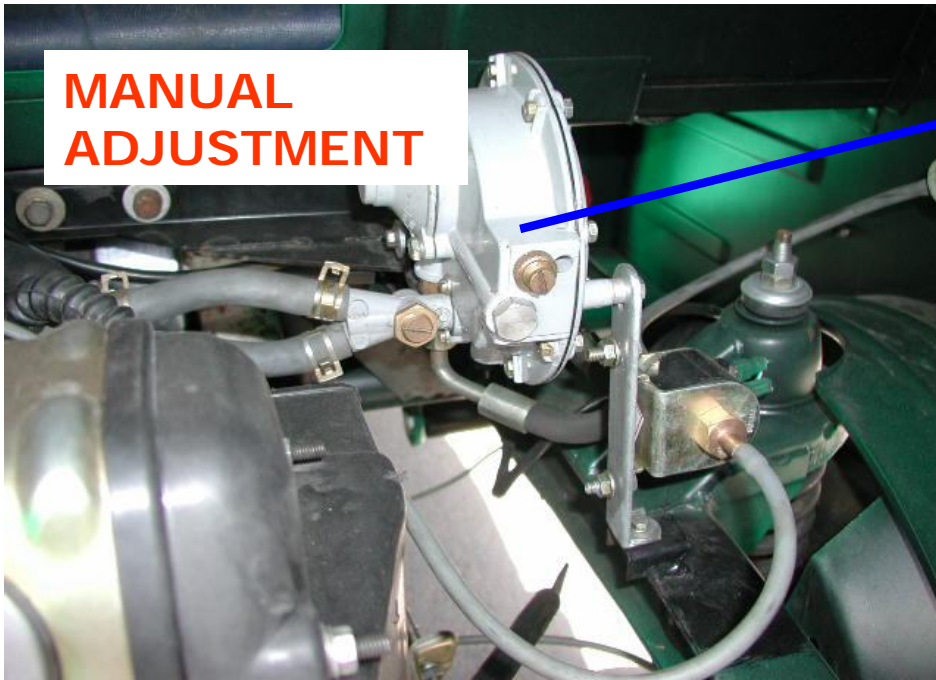
7. Battery cut off Switch

8. Clamps and Fittings

Distance between clamps should be less than 600 mm to avoid excessive stresses

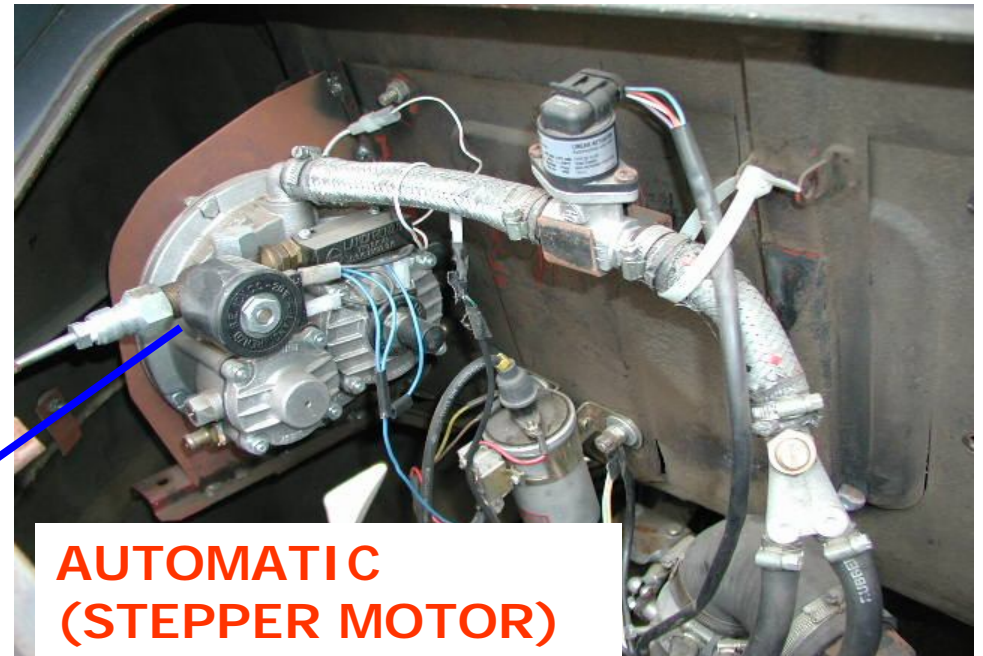


CNG/LPG Vehicle Certification Review



**MANUAL
ADJUSTMENT**

Example of an Open loop system



**AUTOMATIC
(STEPPER MOTOR)**

Example of a Closed loop system

9. Fuel Control Valve

CNG/ LPG Vehicle Certification Review



Selection of CNG/LPG or
Petrol for bi-fuel vehicles

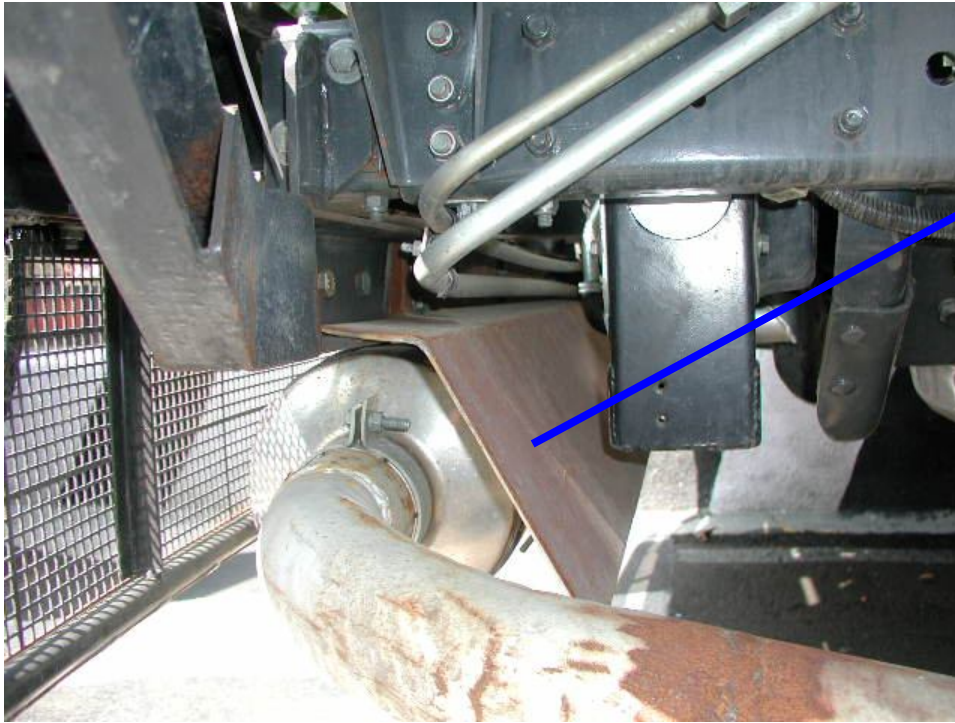
10. Fuel Selection Switch

11. Compliance Plate

Shows the cylinder details
along with certificate
validity

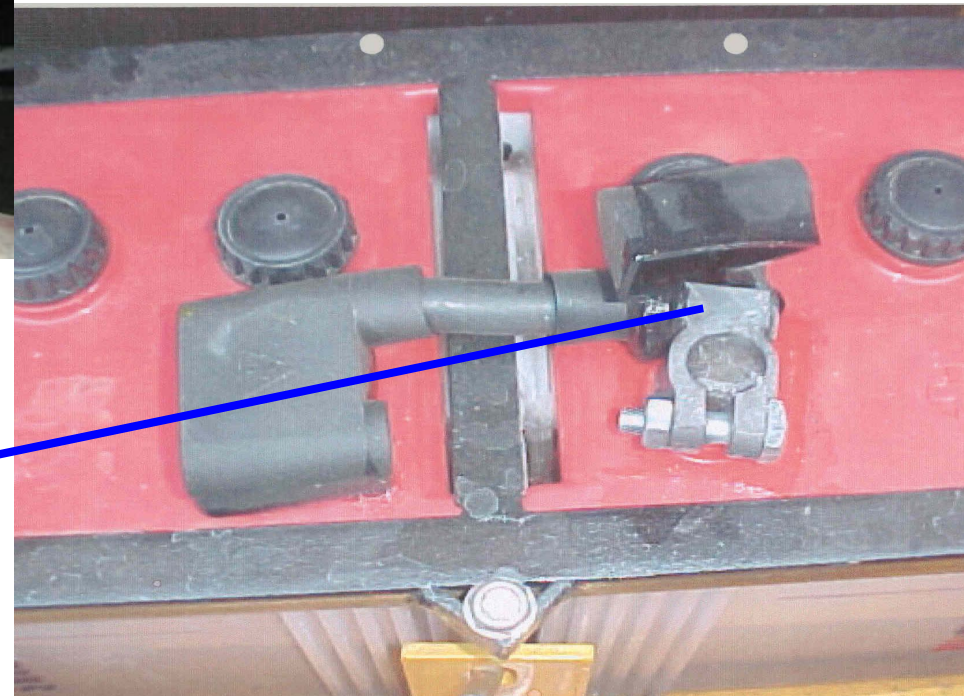


CNG/LPG Vehicle Certification Review



Avoids impinging of leakage exhaust gas on CNG/LPG kit

12. Heat Shield



13. Battery Terminal Clamping

Effective locking of battery terminals to avoid stray sparks

CNG/LPG Vehicle Certification Review



Easily accessible fire extinguisher

14. Fire Extinguisher



First aid kit must be available

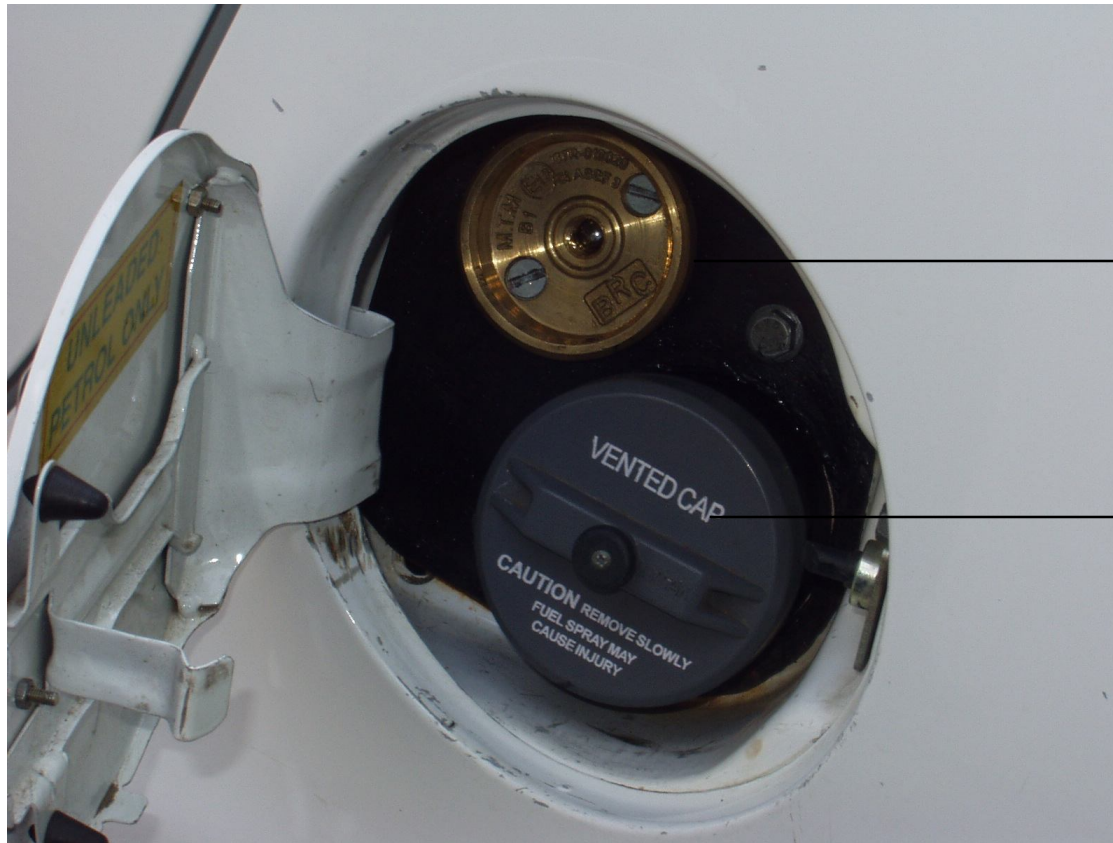
15. First Aid Kit

CNG/LPG Nozzle



No fouling
Observed
While filling
LPG/CNG at
Dispensing
station

CNG/LPG Receptacle



→ Filling receptacle
For CNG/LPG

→ Modified location
For Gasoline filling

Third Party Inspection for CNG/LPG Vehicles

- Authorized third party should carry out periodic maintenance and inspection as per the checklist prescribed in AIS standards.
- Periodic maintenance / inspection should cover examination of cylinder piping and all components of the system for corrosion, deterioration and for any modification
- CNG and LPG cylinders to be retested after 5 years as per Gas Cylinder Rules 2004.

CMVR Tests for CNG/ LPG Vehicles

Test Parameters	OE / Retro Gasoline Vehicle	OE/ Retro Diesel Vehicle
Mass emission	Yes	Yes
Engine performance	Yes	Yes
Gradeability	No	Yes
CSFC	Yes	Yes
EMI	No	Yes
Range test (250 km for buses)	No	Yes
Cooling performance	No	Yes

CNG/LPG vehicle Testing

Following tests are to be conducted for CNG/LPG vehicles

- **Drivability** – Assessment of on road performance of vehicle.
- **Gradeability** – To assess gradient climbing capability of vehicle (at least 18 % gradient).
- **Acceleration** – To achieve 0 to 60 km/h in 30 seconds.
- **Constant Specific Fuel Consumption (CSFC)** – Assessment of fuel consumption under standard conditions.

CNG/ LPG vehicle Testing

- **Electro Magnetic Interference (EMI) – Assessment of electronic components from Interference point of view.**
- **Electro Magnetic Compatibility (EMC) - Assessment of electronic components from Compatibility point of view.**
- **Cooling Trials – Assessment of cooling system of vehicle.**
- **Cold Startability – Assessment of Vehicle starting at - 10 deg C**
- **Range test – Minimum range of 250 km for Buses.**

Thank You !