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The Clean and Green CNG Future Fuel for Transport Sector in Kalaburagi City

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Abstract—*The Gulbarga city is worried about the Climate change and Global warming. : The Kalaburagi city stands second highly polluted next to Bengaluru city due to emissions by transport vehicles and cement factories around the city. All the cities including Gulbarga are seriously thinking on the environmental issues and planning to reduce the Green House Gases. The transport sector is also worried for its sustainability because of rapidly depleting of fossil fuel reserves. It is estimated that overall local reserves of Natural Gas in India amounts to 27 years of supply with the current demand whereas local reserves for crude oil amount to less than 5.5 years. The rate of discovery of natural gas reserves in India also seems to be higher than oil reserve discoveries. The CNG is proven alternative fuel for Transport sector and the use of the use of CNG we can find 84% reduction in CO, 58% reduction in NOx and 97% reduction in PM. The present paper initially presents the structure, composition and properties of the CNG and layout of Injection system used in Automobiles.*

Keywords*: Climate change, Green House gases, Transport Sector, Pollutants, CNG*

1. INTRODUCTION

The world's crude oil reserve is depleting very rapidly. In India reserves of crude oil amount to less than 5.5 years. The fossil fuels emitting more pollutants compared to natural gas. Particularly the Euro III diesel cars emit 7.5 times more toxic particulate matter (PM) than comparable petrol cars. This means, one diesel car is equivalent to adding 7.5 petrol cars to the car fleet in terms of PM. Diesel Vehicles are legally allowed to emit nearly three times more NOx as per the Bharat Stage III (Euro III equivalent) norms. Therefore it is essential for us to go for alternative fuels particularly for Transport sector in India.

The alternative fuels available in India are

1. Bio-Diesel
2. Alcohol (Methyl and Ethyl Alcohol)
3. Hydrogen
4. Solar Power
5. Battery operated power
6. Natural Gas
7. Auto LPG
8. CNG
9. LNG
10. Biogas etc.

Out of all these the CNG is used as future Alternative fuel for Transport Sector in India for another 30 years because It is estimated that overall local reserves of Natural Gas in India amounts to 27 years of supply with the current demand (As per Indian Petroleum and Natural Gas Statistics 2010-11)

Scenario of CNG in Karnataka

- The work of laying natural gas pipeline from Dhabol to Bangalore by Gas Authority of India Ltd (GAIL) is expected to be completed in this fiscal year. A Joint Venture Company with GAIL and Karnataka State Industrial Infrastructure & Development Corporation has been formed to provide clean fuel for power plants, transport vehicles, industries and households in and around Bangalore. (Source: Govt. of Karnataka, Budget 2012-13, Part-II, General, 21st March,2012)
- Karnataka State Industrial Infrastructure and Development Corporation (KSIIDC) has the in-depth knowledge of the industrial sector in the state, experience in promoting and nurturing business ventures and the mandate to pursue the stated objectives of state government.
- GAIL brings along technical and project execution expertise, knowhow, skilled manpower and its gas sourcing capabilities to this venture.
- Faster clearances for laying of P/L infrastructure and availability of land for CNG filling stations, SV stations , RT/DT, DRS installations etc., with State Government assistance

Scenario of CNG availability at Gulbarga

City Gas Distributors (CGD) Bidding Rounds for grant of Authorization to develop CGD networks has been notified the

Public Notice by Petroleum and Natural Gas Regulatory Board 1st Floor, World Trade Centre, Babar Road, New Delhi -110001 on 8th September, 2014 for the Kalaburagi District of Karnataka by its Annex-II.

Benefits of CNG are mentioned below.

- No visible tail pipe emissions.
- Eliminates sulphur and lead from the exhaust emissions.
- Reduction in CO, NOx and Particulate emissions.
- Significant reduction in benzene and other toxic emissions.
- Higher octane value of CNG reduces knocking problems of a vehicle.
- Reduces noise from running vehicles.
- CNG cannot be adulterated.
- Reduce noise in operation.

2. STRUCTURE OF NATURAL GAS

Natural Gas significantly reduces CO_2 emissions by 20-25% compared to gasoline because of its simple chemical structure (Primarily Methane- CH_4) contain one carbon compared to diesel ($C_{15}H_{32}$) and gasoline (C_8H_{18}). The molecular structure of Natural Gas and Diesel is shown in the following figure.

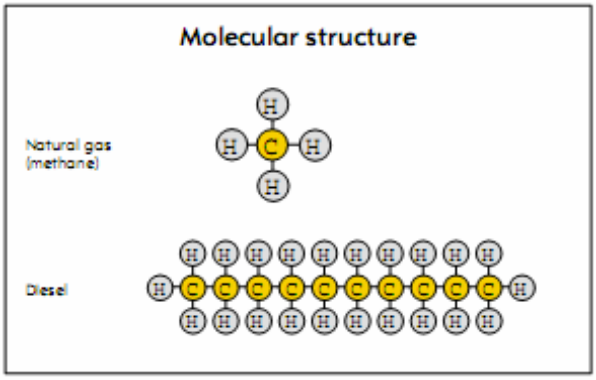

Fig. 1: Molecular structure of Natural Gas and Diesel

Natural gas octane number is about 120 which means the natural gas engine can operate at a compression ratio up to 16:1 without "Knock" or detonation and improve thermal efficiency by about 10 percent above that compared to petrol engine. It has also wider flammability range as compared to Petrol and Diesel fuel.

3. CNG THE LEAST POLLUTING

The table 1 shows the comparative pollutions of Petrol, Diesel, LPG and CNG Vehicles in gm/100km. And by referring the table we can easily say that the CNG is one which is least Polluting one, and we can conclude that the CNG is the least polluting alternative fuel.

Table 2 shows the various fuels with their NOx emissions. Cost of various fuels compared the gasoline. The advantages and disadvantages of various fuels.

Table 1: Comparative Statement of Various Pollutants in gm/100km

FUEL/EMMISSION	CO2	UHC	CO	NOx	Sox	PM
PETROL	22000	85	634	78	8.3	1.1
DIESEL	21000	21	106	108	21	12.5
LPG	18200	18	168	37	0.38	0.29
CNG	16275	5.6	22.2	25.8	0.15	0.29

Source: US Energy Department

Table 2: Various fuels and their NOx emissions cost and advantage/disadvantages.

Fuel	NOx Emissions	Cost	Advantages/Disadvantages
CNG	80% Less	20 – 30% < than gasoline	Longer engine life / Higher vehicle cost
LNG	80% Less	20 – 30% < than gasoline	Fuel is stored as a cryogenic
LPG	Slightly > than gasoline	20% less than gasoline	By product of natural gas processing
Ethanol	2% < than gasoline	Comparable to gasoline	Contains 25% less energy than a gallon of gasoline and fuel system seals are made from a different material but does help reduce the demand for foreign oil
Methanol	Slightly > than gasoline	Slightly less than gasoline	Has 60% < energy than a gallon of gasoline but can be used as a source of hydrogen for fuel cell vehicles
Bio-diesel	1 % greater than diesel	Slightly more than diesel	Harmful to natural rubber engine seals
Hydrogen	Zero NOx	Not publicly available	Three times > energy than in gasoline
Fuel Cell	Zero NOx	Not publicly available	

(Source: Centre for Science and Environment & Ref: Alternative Fuels & Vehicle Technologies, Division of Air Quality's {DAQ} Mobile Sources)

Table 3: Comparative Emissions from Diesel and CNG for Buses

Fuel	Pollution Parameter		
	CO	NOx	PM
Diesel	2.4 g/km	21 g/km	0.38 g/km
CNG	0.4 g/km	8.9 g/km	0.012 g/km
% Reduction	**84**	**58**	**97**

Source: Frailey *et al*. (2000) as referred in World Bank (2001b: 2).

Natural gas is a mixture of hydrocarbons-mainly methane (CH4) and is produced either from gas wells or in conjunction with crude oil production. Due to its low energy density for use as a vehicular fuel, it is compressed to a pressure of 200-250 bars to facilitate storage in cylinders mounted in vehicle and so it is called compressed natural gas (CNG).India's recoverable resources of more than 690 billion cubic meters make it a long-term substituted fuel for use in petrol and diesel engines. Low exhaust emissions, low noise, less maintenance, not prone to adulteration, driver's comfort, etc. are some of the attractive features of CNG as an automotive fuel. **For all these reasons we must consider CNG as alternative future fuel for Transport Sector in India.**

Composition of CNG: Compressed Natural Gas is composed of Methane, Ethane, Propane, Butane and other contaminants. The main constituent of CNG is Methane which will be up to minimum of 90%. The composition of CNG varies from place to place and manufacturer to manufacturer.

Table 4: Typical composition on CNG

Typical composition on CNG	Symbol	(Volume %)
Methane	CH_4	94.2
Ethane	C_2H_6	2.29
Carbon dioxide	CO_2	0.57
Propane	C_3H_8	0.03
Butane	C_4H_{10}	0.25
Nitrogen	N_2	0.44
Others	(H_2, O_2, S , etc)	2

(Source: PETRONAS)

4. PROPERTIES OF CNG

Properties of CNG are almost similar to Methane. The researches on CNG fuelled engine are progressing throughout the world because of its potential as an alternative fuel for the Spark Ignition (SI) engine.

Table 5: Combustion related properties of CNG and Gasoline

Properties	Gasoline	CNG
Motor Octane Number	80-90	120
Molar Mass(kg/mol)	110	16.04
Carbon weight fraction (Mass %)	87	75
Stoichiometric Air Fuel Ratio (A/Fs)	14.6	16.79
Stoichiometric Mixture Density (kg/M^3)	1.38	1.24
Lower Heating Value(MJ/Kg)	43.6	47.377
Lower Heating Value of Stoich. Mixture (MJ/Kg)	2.83	2.72
Flammability limits (Vol % in air)	1.3-7.1	5-15
Spontaneous Ignition Temperature (^{0}C)	480-550	645

The difference between the operation of the conventional gasoline fueled and the CNG engine system arises from the physical and chemical properties of these two fuels. It is a well known fact that petroleum fuels are liquid at room temperature and CNG remains in a gaseous state at a much lower temperature (-161 0 C). CNG has a lower density but higher octane number then gasoline. It can easily operate in a high compression ratio and higher self/spontaneous ignition temperature makes it a safer fuel in case of leakage. Owing to better antiknock quality of CNG it can be safe used in engines with a compression ratio as high as 12:1 compared with patrol (maximum 10:1). CNG is non to-toxic and lighter than air so when leakage occurs, it quickly disappears unlike gasoline which paddles and evaporates.

5. CNG RESERVES IN INDIA

Natural gas is the second most abundant fuel available In India. India has twice as much gas reserves as oil reserves. This is obtained from Mumbai high. CNG is available in the cities of Baroda, Ahmedabad, Surat and Bharuch along NBJ line from Hazira to Delhi. In addition to this, it is also available in Krishna-Godavari basin, Assam and Tripura in the North-East and Cauvery basin.

6. WHY CNG IS PROMINENT ALTERNATE FUEL?

Natural gas has been identified as a leading candidate for transportation applications among other fuels for several reasons. The first reason is availability; Natural gas is the second most abundant fuel available in India. The second attraction reason of natural gas is its environmental compatibility and the third attraction reason of natural gas is that it can be used in conventional diesel and gasoline engines. The operating costs are other reasons. The basis for this argument is the lower cost per energy unit of natural gas as compared to petroleum. It is true that in the vast majority of the country natural gas is cheaper than gasoline or diesel. Also it is a safer fuel in case of leakage due to higher self ignition temperature.

7. CNG INJECTION METHOD

Compressed natural gas (CNG) is the most favorite for fossil fuel substitution. There are four methods to inject the CNG into the engine cylinder such as gas mixer /carburetor injection, single point injection, sequential injection and direct injection. There are four methods to inject the compressed natural gas into the engine cylinder.

- Gas Mixer / Carburetor Injection.
- Single Point Injection.
- Sequential or Multi Point Injection. and
- Direct Injection.

The actual metering and mixing of the fuel may be accomplished using either a mechanical gaseous fuel mixer or carburetor, or an electronically controlled gaseous fuel

metering system. This approach strives to achieve a homogeneous mixture of air and fuel before the air stream splits in the intake manifold. As failure to achieve a homogenous mixture at this point can cause significant cylinder–to-cylinder variations in air-fuel ration, this can be increases emissions and the possibility of knock phenomena. Single point injection is use gaseous fuel injector to mix the gaseous fuel with the intake air in the manifold at one location or single point injection. In this case, fuel is injected in a single location much like a gas mixer or carburetor. Single point electronic injection offers the advantage of more precise control of the amount of gaseous fuel entering the intake charge of the engine as well as economy of using a minimum number of injectors. The sequential or multi point injection is to inject the fuel into the intake air in front of each cylinder intake port via intake valve. This system uses one or more fuel injectors for each cylinder intake port of an engine and allows the designer to remove the fuel supply from the air supply section of the intake manifold. Direct injection is to inject the gaseous fuel directly into each combustion chamber. In this case, it is necessary to improve considerable turbulence during the compression stroke to achieve adequate air-fuel mixing. A high turbulence, high swirl combustion chamber is desirable for this type of injection.

8. CNG SYSTEM OVERVIEW

This schematic diagram shows a standard conversion of a gasoline vehicle to a bi-fuel gasoline and CNG system. The driver can simply use CNG by flipping the switch. The gasoline electro-valve is not energized and the gasoline fuel flow is interrupted. The natural gas flows with high pressure from the CNG cylinder to the first reducer heated stage, where the pressure is reduced. The CNG solenoid valve is still not energized and the gas flow is stopped. When the motor is activated the electronic control energizes and opens the gas electro valve between the second and third reducer stage, immediately the gas flows with a negative pressure through the gas hose and the high regulator toward the mixer installed in the carburetor. The gas is then blended with the air at the same time that is given to the engine according to the power demand.

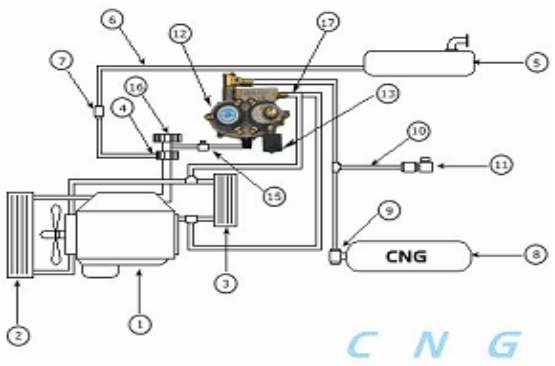

Fig. 2: Schematic diagram of a bi-fuel gasoline vehicle.

Legend:

1. Engine, 2. Radiator, 3.Heator, 4. Carburetor, 5. Gasoline tank, 6. Gasoline hose,
7. Gasoline solenoid valve, 8. CNG Cylinder, 9. Cylinder Valve, 10.CNG pipe,
11. CNG loading valve, 12.CNG Reducer, 13.CNG Solenoid valve, 14.CNG Hose,
15. High Regulator, 16.Mixer, 17. Water Hoses

The CNG reducer should be heated to avoid freezing due to the decompression made in the first stage. For the heating process, the reducer is provided water by a circuit connected through the hoses to the engine cooling system. The best connection is the one that is carried out interleaving the reducer in the vehicle heating system. If the vehicle does not provide heating, this connection will be made in the hoses that go from the engine to the radiator. When the driver wishes to use gasoline, flipping the switch back to the appropriate position, the CNG solenoid valve located in the reducer is not energized. The gasoline solenoid valve will be energized and will let the gasoline flow to the carburetor, allowing the normal operation of the gasoline system

9. NATURAL GAS KIT FOR HEAVY VEHICLES

A natural gas conversion kit system is available in the laboratory to enable compressed natural gas to be used as fuel in the test engine. The conversion kit is of model TMB Tartarini Natural Gas Conversion Kit and consists of components such as the gas pressure regulator, solenoid valve, air mixer, fuel select switch and gauges as shown in Fig. 3.

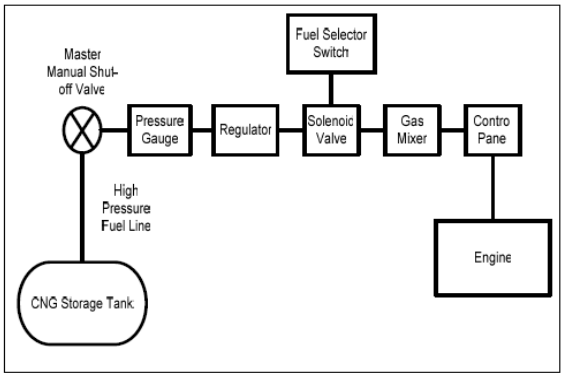

Fig. 3: Layout of Natural Gas Converter Kit

Natural Gas Pressure Regulator

The pressure regulator decreases the CNG pressure to near atmospheric pressure from 20MPa in the storage tank to allow natural gas to flow into the gas mixer. Apart from that, the regulator also acts as a control to modulate the flow of natural gas to the gas mixer.

Natural Gas Solenoid Valve

The solenoid valve is used as a main control switch to allow natural gas to flow from the pressure regulator to the gas mixer and engine. The solenoid valve is electronic timer

controlled and contains a built-in gas filter and attached pressure gauge. It also acts as an emergency shut off device to stop the flow of natural gas into the system when a leak is detected or when other devices malfunction. Apart from that, the solenoid valve improves ignition during cold temperature start up of the engine.

Natural Gas Mixer
Natural gas is mixed with air in the gas mixer to obtain the optimum ratio for combustion before being transferred into the combustion chamber of the engine through the control panel which measures the flow rate of the mixture.

Fuel Selector Switch and Gauge
A fuel selector switch is used for the user to switch between diesel and dual-fuel system in the experiment. The amount of natural gas in the system can also be monitored through the attached measurement gauge.

(Source: WONG, Wei Loon, October, 2005, University of Southern Queensland Faculty of Engineering and Surveying, "COMPRESSED NATURAL GAS AS AN ALTERNATIVE FUEL IN DIESEL ENGINES")

10. CONCLUSION

The major benefits of CNG as a transportation fuel in Gulbarga city

Economics
On a gallon-equivalent basis, natural gas costs an average of 15 to 60 percent less than gasoline and diesel. Natural gas is a clean-burning fuel that reduces vehicle maintenance. Many NGV owners report that oil changes are needed only every 16,000 - 32,000 Km. Standard spark plugs last as long as 120,000 Km. Natural gas, unlike liquid fuels, cannot be siphoned from a vehicle. Fuel theft is an on-going concern of fleet managers. Vehicles can be "fast filled" in five to six minutes using compressed gas stored in cascades of natural gas cylinders or fueled overnight on a "timed fill" basis in about five to eight hours. Many private fleet fuelling stations use a combination of fast fill and timed fill.

Emissions
Natural gas is the cleanest burning alternative fuel. Exhaust emissions from NGVs are much lower than those from equivalent gasoline-powered vehicles. For instance, NGV emissions of carbon monoxide are approximately 70 percent lower, non-methane organic gas emissions are 89 percent lower, and oxides of nitrogen emissions are 87 percent lower. In addition to these reductions in pollutants, NGVs also emit significantly lower amounts of greenhouse gases and toxins than do gasoline vehicles.

Dedicated NGVs produce little or no evaporative emissions during fuelling and use. For gasoline vehicles, evaporative and fuelling emissions account for at least 50 percent of a vehicle's total hydrocarbon emissions. Dedicated NGVs also can reduce carbon dioxide exhaust emissions by almost 20 percent. Exposure to the levels of suspended fine particulate matter found in many U.S. cities has been shown to increase the risk of respiratory illness. Diesel exhaust is under review as a hazardous air pollutant. Natural gas engines produce only tiny amounts of this matter.

Greenhouse gases
Per unit of energy, natural gas contains less carbon than any other fossil fuel, and thus produces lower CO_2 emissions per vehicle mile travelled. While natural gas vehicles (NGVs) do emit methane, another principle greenhouse gas, any slight increase in methane emissions would be more than offset by a substantial reduction in CO_2 emissions compared to other fuels.

NGVs also emit very low levels of carbon monoxide (approximately 70 percent lower than a comparable gasoline vehicle) and volatile organic compounds. Although these two pollutants are not themselves greenhouse gases, they play an important role in helping to break down methane and some other greenhouse gases in the atmosphere, and thus increase the global rate of methane decomposition.

The economics of small vehicle conversion
In very general terms the smaller the vehicle the longer is the payback period for the cost of conversion. This is because the fuel consumption - and therefore savings - for the smaller vehicles is lower, and at the same time the cost of conversion does not go down much with vehicle size. The cost of the fuel control system stays much the same and the price of a smaller storage cylinder will not be much lower (and in a small vehicle it is more difficult to find a space for the cylinder).

It may be difficult to justify the conversion on an economic basis, but this does depend on annual mileage. Do a rough sum on the basis of saving half (or whatever the price differential is in your area) of your fuel costs in a year. You should expect better than a three year payback on the basis of economics. Environmental benefits and lower maintenance costs will be small. Check where you would be able to find space for the storage cylinder which must be sized to meet commuter needs. And of course allow something for the satisfaction of knowing that you are lowering your output of hydrocarbon emissions.

The conversion factors for natural gas
Methane values are fixed and can be found in any chemical handbook, while the composition of natural gas varies with source and time so try to find a local value. Approximately, 1kg NG is equivalent to about 1.33 liters (L) of petrol or 1.22 L diesel. And 1 cu meter of NG is equivalent to about 1.10 L of petrol or 1.00 L diesel.

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