[Issue, 2(1):10oct, 2013] ISSN: 2321-8134

IJFEAT

INTERNATIONAL JOURNAL FOR ENGINEERING APPLICATIONS AND TECHNOLOGY

CLEAN AUTOMOBILE FUEL: LIQUEFIED NATURAL GAS

S.C. Jirapure[1], M.W.Andure[2]

[1]*Assist. Prof, DES'S College of Engineering & Technology, Dhamangaon Rly,* ***sagarjirapure@rediffmail.com***

[2]*Assist. Prof. & W/S Supdt. DES'S College of Engineering & Technology, Dhamangaon Rly,****maheshandure@yahoo.com***

Abstract

Developing countries like India depend heavily on oil transport. More than 75 % of India's total oil requirement is met by imported crude oil. Refining the crude results into increased air pollution. Utilizing its refined products (petrol as well as diesel) further increases air pollution. Diesel being the main transport fuel in India, finding a suitable alternative to it is an urgent need. With increasing pressures for reduction in emissions, the share of natural gas based vehicle has been used as a compressed natural gas in various automobiles and gas dispensing infrastructure has also developed accordingly. However, certain limitations in terms of limited range with single fill and need for heavy gas cylinders on automobile chassis have been attracting the attention of various developers. In the mean time liquefied natural gas industry has been expanding at very rapid rate throughout the world and this coupled with various technological developments of gas based vehicles. The limitations of CNG can be overcome by using gas as LNG in automobile fuel tanks. This particular development has very large potential for popularizing gas as automotive fuel for even very heavy vehicles like buses and trucks. Based on these fundaments, it is felt that the potential for LNG as automobile fuel needs to be studied in more details in academics and create necessary awareness about the potential for this concept.

Index Terms: *Emission Standards, Economics, Fuelling stations.*

1. INTRODUCTION

The concern and care for environment is emerging as a major factor resulting in the technological developments aimed at addressing these issues arising in every sphere of economic activity. The automobile sector has been no exception to this trend and, infact, this is one of the prominent sectors where solutions are being sought to reduce environmental impact arising out of use of vehicles.

Automobile exhaust is one of the major sources of air pollution and some of the components in exhaust emissions which pose environmental problems are: Carbon monoxide, Oxides of nitrogen, unburnt hydrocarbons, Lead, Smoke, Respirable particulate matter, Sulphur dioxide. These pollutants have varying effects on health of people and some of them are known to have larger impact in terms of destroying protective ozone layer around the globe.In view of this various standards have been evolved stipulating maximum allowable limits for various components in the automobile exhaust. These standards are changing with respect to future time frame and becoming more and more stringent for the future period. This trend is expected to continue and the emission norms will become more and more strict posing challenges before the automobile industry in terms of technological developments required.

Some of the standards applicable for automobile exhausts in India are discussed in the following sections.

1.1 Indian Emission Standards:

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

On October 6, 2003, the National Auto Fuel Policy has been announced, which envisages by 2010. The implementation schedule of EU emission standards in India is summarized in table 1.

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

Standard	Reference	Date	Region
India 2000	Euro I	2000	Nationwide
Bharat Stage II	Euro II	2001	NCR*, Mumbai, Kolkata, Chennai
		2003	NCR*, 10 cities#
		2005	Nationwide
Bharat Stage III	Euro III	2005	NCR*, 10 cities#
		2010	Nationwide
Bharat Stage IV	Euro IV		NCR*, 10 cities#
*National Capital Region (Delhi)			
# Mumbai, Kolkata, Chennai, Bangalore, Hyderabad, Ahmedabad, Pune, Surat, Kanpur, Agra.			

Table 2. 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 85Kw					

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 requirement 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.

In India even judicial interventions have been made to ensure control on automotive exhausts so as to protect health of citizens. Hence technological developments have been made in following major areas whereby these emissions are eliminated or reduced to reasonable limits so as to minimize the possible impact on health and environment. The major developmental areas are as follows.

Fuel alternatives
Fuel additives modification
Fuel efficiency improvements
Engine design
Vehicle without engines e.g. electric or fuel cell based car
Exhaust gas treatment facility installation

Though there have been considerable development in the each of the above mentioned areas, the most prominent technological development have been with respect to development of alternate automotive fuels to reduce emissions from exhaust. The trend of increasing costs of crude oil and stringent quality specifications on petrol and diesel has resulted in development of other alternative gaseous automobile fuels.

Some of the alternative gaseous fuel options are as follows:
Natural gas
LPG
Biogas
Hydrogen

This paper proposes to examine the developments in fuel alternatives and study the emerging technological development in terms of using gas in liquefied form (LNG) as automobile fuel.

2. FORMS OF NATURAL GAS AS AN AUTOMOTIVE FUEL:

The natural gas is currently supplied in two different ways to the automobiles. These two different modes are as follows:
1. As compressed natural gas (CNG)
2. As liquefied natural gas (LNG)

Currently CNG is a more popular way of dispensing gas to automobiles. CNG is the natural gas in gaseous form at ambient temperature and at 250 kg/cm^2 pressure. This gas is stored in steel cylinders fitted on automobile chassis and at the dispensing stations there are compressors installed to compress the gas obtained from pipelines to the required pressure for filling in the automobiles. CNG is becoming popular due to better economics of operation and consumers are eagerly awaiting creation of necessary infrastructure for ensuring easy availability of CNG throughout the country.

This has given rise to a big potential for development of natural gas as a major fuel for automobiles. However development of natural gas based vehicles is possible in a very big way only if following prerequisites are met:
1. Natural gas as fuel should be easily available in different parts of the country where the vehicle has to travel.
2. New vehicles with gas engines are made available in the market and conversion of existing vehicles is carried out in an organized manner by qualified garages.

However use of natural gas as CNG poses some constraints especially when used in vehicles like buses and trucks. CNG cylinders fitted on chassis of such vehicles add a dead load of almost one tones of steel because of high pressure cylinders and the amount gas filled in such cylinders, normally, can take vehicles for about 250 km without refilling. This calls for extensive development of filling infrastructure and gives rise to problems in fuel efficiency or load carrying of such vehicles.

Recent technological developments have made it possible to consider filling of liquefied natural gas (LNG), at very low temperature (-163^{0}C) and near atmospheric pressure, as an automobile fuel. This development has potential to overcome the above mentioned constraints faced in use of natural gas as automotive fuel in heavy vehicles. Such vehicles are now commercially available and gaining rapid acceptance in USA and other parts of the world.

2.1 Natural Gas as Automobile Fuel:

Spark ignition engines based on natural gas fuel have been developed and successfully used in various types of automobiles. Natural gas generally consists of light hydrocarbons with more than 90% constituted by Methane.
The use of natural gas as automobile fuel is far better from environmental considerations and currently only better fuel option (better than natural gas) is hydrogen. Though hydrogen economy is the ultimate goal from environmental considerations, the commercialization of hydrogen based vehicles is seen to be a couple of decades away.

3. WHAT IS LNG?

Liquefied Natural Gas or LNG is natural gas in a liquid form. When natural gas is cooled to -1620C, become a clear, colorless, odorless liquid. It is a nontoxic and non corrosive. LNG is burned as a gas when used as a fuel, and it can provide significant reductions in CO, HC, NOx, Particulate matter. Natural gas has an octane rating of 130 and excellent properties for spark ignited internal combustion engines.
LNG is a mixture of fluids consisting primarily of methane and other alkenes such as ethane, propane, and butane. Unlike diesel or gasoline the makeup of LNG is continually changing as heat enters the system and methane is vaporized over the other alkenes. The removal of methane vapor will enrich the remaining LNG liquid with ethane, propane etc. Methane has an octane number of about 140; while enriched LNG has an octane number of about 134.

3.1 LNG Properties:

Some of the properties of LNG and its implications on its use as automobile fuel are as follows:

Cryogenic Liquid -1620C: LNG is cold; but vacuum jacketed piping and dispensing components keep the cold inside, and not outside the pipes and dispensers.

98% Methane: In the process of liquefaction, most natural gas impurities are filtered out. LNG is the feed stock that produces the highest quality natural gas for vehicle engines.

Lighter than air: Unlike diesel or propane, fumes don't linger at ground level where they might contaminate ground water. Instead, they quickly dissipate.

Low pressure: LNG is stored at pressures of 3.5 bars to 10.3 bars versus a pressure of 206.8 bars to 248.2 bars for CNG. Reduced pressure lessens the chance for a leak, and reduces the consequence of a leak if it should occur.

High Ignition Temperature: LNG has high ignition temperature of about 5370C versus 2490C for diesel.

Small Flammability Range: It has varied flammability range of about 5% to 15% of atmosphere versus 1% to 99% for gasoline.

High energy Density: It has 2.4 times the density of CNG. The benefit is we need a lot less on board storage for LNG than we do for CNG.

Basic Physical Properties:
Boiling range : -1620C
Vapour Pressure: 40 atm @ -860C
Vapour Density (air=1): 0.6 kg/m3
Specific Gravity (H2O=1):0.4 @ -1640C
Solubility (H2O): 3.5%

4. ECONOMICS OF NATURAL GAS AS AN AUTOMOTIVE FUEL:

The international market for oil is very volatile and since couple of years the crude oil prices have remained at very high markets. This trend in oil prices, coupled with very stringent specifications for gasoline and diesel, have made conventional liquid fuels for automobiles very expensive. Though the gas prices, also, tend to follow international oil prices in terms of its trend, the relative price differential between gasoline, diesel and gas as CNG has been very favorable for gas. The price of CNG in India varies from place to place as there is dual pricing mechanism in operation in gas sector in India. CNG prices vary from Rs. 25 to 40 per kg in India. As against this, the price of gasoline and diesel are Rs. 47 and Rs.41 per liter respectively. Based on fuel equivalence, this result in CNG price varying in the range of 35-50% of gasoline price and 40-55% of diesel price. Since CNG availability in India is a very recent phenomenon, there are not many vehicles available in the market, as OEMs, which can use CNG as fuel. Buses and three wheelers are available as OEMs since conversion of public transport is primarily focus in Indian market. However, it is possible to convert three wheelers, cars and buses to run on CNG by modifying their engines.
Currently, such conversions for different categories of vehicles cost as per following table.

Table 3. Conversion cost for different categories of vehicles

Vehicle type	Cost of conversion (Rs.)
Three Wheeler	17000 - 20000
Cars	35000 – 40000
Bus/Truck	50000

Thus, based on average daily running of vehicle one can decide the economics of conversion of existing vehicle to CNG. It is estimated that payback period of conversions may vary from a few months to about 3 years depending on the daily running and current mileage obtained with existing fuel. Thus, under the current situation, natural gas is emerging as the best alternate fuel for automobiles both from environmental and economic considerations.

4.1 Basic Components of LNG Vehicle:

The Gas Engine: The engine required for firing gas as is essentially the same as the one used in CNG vehicles. This is an established product available commercially from a large number of reputed manufacturers.
The LNG Fuel Tank: The LNG fuel tank is a cryogenic container. This means that it stores the natural gas fuel as a highly refrigerated liquid at low pressure. The fuel temperature is about -1400C, and the fuel pressure is about 5 bars. The reason for cryogenic storage is that natural gas is much denser as a low temperature liquid than it is as a compressed gas. Normally, we can get three times as much gas in the same space at about half the weight if it is stored as a cryogenic liquid instead of as a compressed gas.
The Storage Tank: To contain this cryogenic fuel without the use of any outside source of refrigeration the tank has to be extremely well insulated. To achieve the high level of insulation efficiency the LNG pressure vessel is covered with insulation and enclosed by an outer vacuum vessel. A vacuum is pulled between the LNG tank and the outer shell. This combination of insulation and vacuum, called super insulation, has highest thermal efficiency. This type of insulation allows for standby times of over a week with no loss of product. Both the inner pressure vessel and the outer vacuum vessel are constructed of stainless steel. Stainless steel has both the low temperature strength necessary to contain the cryogenic fuel and the high temperature toughness to allow the vacuum casing to inner pressure vessel. With an all stainless steel vessel support structure as well, the LNG fuel tank can withstand years of vehicular service with no loss of performance.
Fuel Delivery System: The driving force for delivery of the fuel to the engine is provided by the fuel pressure itself, there are no pumps in the system. When the engine demands fuel the pressurized liquid natural gas flows out of the tank towards the engine. The heat exchanger uses engine coolant to vaporize the liquid and turn it into a gas. Once out of the heat exchanger the fuel is a warm gas, at tank pressure, ready to be burned by the engine. Tank pressure is maintained by a tank mounted pressure control regulator that vents excess pressure into the fuel line during period of engine operation.

4.2 Working of LNG Station:

LNG stations are designed to deliver LNG to vehicle tanks at a pressure of 5.2 bars to 8.3 bars, which is the pressure natural gas engines need to run properly. The major components of the LNG vehicle fueling system are a storage vessel; two LNG pumps; cryogenic system; vaporizer; and a vehicle LNG dispenser. LNG tankers normally arrive cold, with pressure lower than 3.5 bars. The offload pump delivers LNG to the storage vessel. In storage vessel, an LNG pump pulls liquid back out of the tank through a warming vaporizer and places it into the tank until the pressure is approximately 5.5 bars to 6.9 bars. This process is called saturation. Thus the pressure is rising in the storage tank. From storage tank the high pressure LNG enter in to the dispenser. The dispenser activates the LNG pump that pulls fuel 5.5 bars to 6.9 bars out of the storage tank. A reservoir of LNG in the dispenser allows immediate dispensing. The displacer displays total price, liters dispensed, and price per liter.

The driver of the vehicle need only take the following steps to fuel the LNG vehicle;
1. Lift lever and remove fueling nozzle from the dispenser.
2.Insert fueling nozzle into LNG vehicle.
3.Wait for fueling to complete as indicated by a bell.
4.Lift lever and return nozzle to dispenser.
The driver need not be concerned about the vehicle LNG tank pressure or level. The dispenser will even cool-down warm or empty tanks automatically.

5. BENEFITS OF LNG

5.1 LNG versus CNG:

1. LNG has more than 2.4 times the energy density of CNG at 200 bars this means that for given capacity fuel tank, LNG powered vehicles can travel up to 2. 4 times the distance of its CNG counterpart.
2. LNG powered vehicles weigh less than CNG powered vehicles, and therefore can carry up to ¾ tones more payload.
3. LNG powered vehicles cost less to the manufactures than CNG powered vehicles.
4. LNG refueling stations need no electricity whereas CNG require 5 p/kg of electricity cost to compress the gas.
5. The capital cost of LNG refueling stations, are a fraction of their CNG counterpart.
6. The maintenance cost of LNG refueling stations, is a fraction of CNG refueling stations.
7. LNG fuel has a consistent quality & higher calorific value than CNG.

5.2 LNG versus Diesel

1. LNG can save up to 30% off fuel cost than diesel.
2. LNG offers significant emission reduction compared to diesel. So it is environment friendly road transport solution.

6. HAZARDS OF LNG:

Flammable Gas
Cryogenic Temperature

Large Expansion Ratio
Inert Gas

CONCLUSION

Rapid developments are taking place in gas based automobiles and currently use of gas as CNG is most popular. However, LNG technology has been developing at phenomenal rate and this opened up a new opportunity for developing gas based vehicles using gas as LNG in fuel tank. Use of gas as LNG has some inherent advantages in terms of improved fuel efficiency and long range (reduced refilling frequently) and because of this it appears to be an appropriate solution for heavy transport vehicles like buses and trucks.

ACKNOWLEDGEMENT

The authors are thankful to Dr. L.P.Dhamande Principal DES'S College of Engineering & Technology, Dhamangaon for providing guidance for this work.

REFERENCES

[1]. A paper on "Self- Serve" LNG Fueling Stations. By Jeffe Beale, Oct-1995

[2]. A paper on Liquefied Natural Gas for Trucks & Buses. SAE Paper No.2000-01-2210.

[3]. A report on the third national conference on arrival of Gas.Nov.13-14,2003,New Delhi.

[4]. A report on the fifth International Petroleum Conference & Exhibition "Petro-Tech 2003",New Delhi.

[5]. A report Of centre for monitoring Indian economy, Jan-2006.