LNG as an energy efficient eco-friendly cryogenic fuel

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Abstract
The use of an old fuel in a new form has progressed at a rapid space for the last couple of years, due to its several advantages. The fuel in question is natural gas and, its new form, is liquefied natural gas designated as LNG. LNG transported in cryogenic vessels offers several advantages over pipe line transport of natural gas when the gas consuming areas are far away from the gas producing areas. Moreover, LNG as an automobile fuel has also a definite edge over other fuel. However, the LNG age in India is of very recent origin and, only in January, 2004, the first LNG cargo had reached an Indian port in the state of Gujarat.

In this juncture, this paper presents an effective study on the characteristics of LNG, advantages and disadvantages of various natural gas liquefaction cycles, the present state of affairs of LNG in India, its import and CNG versus LNG as an automobile fuel, eco-friendliness of natural gas fuel etc. It also discusses the potential of natural gas generation from different sources, and the need for indigenous development of LNG technology for import substitution in the Indian context.

Keywords: liquefied natural gas, compressed natural gas, cryogenic fuel, automobile fuel

1 Introduction

The LNG production schemes in different countries have gained tremendous momentum in recent times because of i) economics of energy generation, ii) the growing concern about environmental pollution, iii) the necessity of fuller utilization of natural resources, and iv) the objections raised against the flaring of by product gas from crude oil operations.

Natural gas can be transported from the gas producing areas to the gas consuming areas, either by pipeline or in a container or tanker in liquid form. However, pipelines and piped gas transported have a number of drawbacks. Among others, pipelines cannot be laid at depths of more than 100m below sea level and, in any case, under water pipelines are expensive and sometimes risky. Furthermore, pipelines are a permanent fixture leading from a given gas field to a particular consuming area. Finally, pipeline natural gas cannot meet the fluctuating gas demand, if any.

Liquefied Natural Gas (LNG), on the other hand, is ideally transported in Cryogenic tankers by road, ships and rail wagons. There is a distinctive advantage on liquefaction as there is a volume reduction of about 630 times on liquefaction, and liquid natural gas handling is more like handling oil. In recent times, the use of LNG has gained much popularity globally and it is the right moment to review the status of LNG development with regard to various resources of natural gas, gas liquefaction, storage, transport, utilization of LNG and to trace the desirability of LNG technology.

2 Special characteristics of liquefied natural gas

Natural gas is a mixture of paraffinic hydrocarbons such as methane, ethane, propane, butane etc. Small amounts of higher hydrocarbons such as ethylene may be present (nitrogen may also be present) apart from carbon dioxide and a trace amount of hydrogen sulphide. Since most natural gas contains over 90% methane, natural gas becomes synonyms to methane.

Details of useful properties and applications of natural gas are given in the literature. Some important properties and applications are highlighted here. Natural gas is a low density (0.789 basis air), low sulphur content fuel, and it is cleaner fuel when compared to gasoline and is practically free from sulphur and carbon monoxide emission.

The various important properties of natural gas are given in Table 1. Typical composition of indigenous natural gas from Bombay High and the Tripura Field as presented in Table 2, could be taken into consideration while studying different, existing natural gas liquefaction cycles, as well for proposing any new design for the purpose.

2.1 LNG versus CNG

The energy density of LNG is 435Kg/m^3 as compared to 175 Kg/m^3 for compressed natural gas (CNG) at 200 bars. This means that for a given capacity fuel tank, an LNG powered vehicle can travel up to 2.4 times the distance of the CNG

Table 1: Important properties of natural gas

Auto ignition point	811K
Flammable range	5-15%
Laminar burning velocity	0.4 m/sec
Atmospheric boiling point	111.5K
Latent heat of vaporization	29.04KJ/Kg
Critical temperature	190.9K
Critical pressure	45.8 bar

Table 2: Indigenous natural gas composition

Components	*a) Tripura Field Percentage by Volume*	*b) Bombay High Percentage by Volume*
Methane	98.75	77.72
Ethane	1.07	6.74
Propane	0.08	4.54
Isobutane	0.04	0.84
N butane	Traces	1.17
I Pentane	Traces	0.23
N Pentane	Traces	0.23
Hexane	Traces	0.18
Carbon dioxide	0.1%	6.51
		1.87

counterpart, or in another way, for a given vehicle range, an LNG powered vehicle needs up to 2.4 times less fuel tank capacity than its CNG counterpart. Again, an LNG powered vehicle costs less to manufacture than a CNG powered vehicle.

The capital and maintenance costs of LNG refuelling stations are a fraction of their CNG counterparts and they do not require any electricity. LNG is portable, so it is free from the pipes, and the fuelling stations can be built at any places and for large vehicles, LNG would be preferred than CNG. LNG as a road fuel has already been introduced in the UK (www.petronas.com; The Statesman 2000 & 2004; Petronet, LNG Limited 2004).

3 Gas liquefaction cycles

It is well known that most natural gas contains more that 90% methane along with some higher hydrocarbons, moisture, carbon dioxide, nitrogen and trace amounts of hydrogen sulphide. To prevent blockage during liquefaction, impurities such as moisture, carbon monoxide etc. are invariably removed prior to liquefaction.

Higher hydrocarbons have also to be removed prior to liquefaction, if there is no such arrangement in the liquefaction plants for their separation by condensation. If the amount of impurities are comparatively less, then it is possible to remove all the impurities by adsorption in a carbon molecular sieve, and only methane is liquefied. Moreover, it is always economical to purify the gas than to provide extensive separation facilities in the liquefaction section of the plant.

Carbon dioxide and hydrogen sulphide can also be removed in absorbers containing mono ethanol amine, and water vapour can be removed in Al_2O_3 dryers and a diethylene glycol absorber. Details of purification methods for natural gas are available in the literature.

The basic practical cycles for natural gas liquefaction are (Timnerhaus & Flynn 1994; Lom 1975; Sarkar 2001; Sarkar et al. 1992; Sarkar 1997):

(i) Classical cascade cycle based on separate pure components such as propane, ethylene and methane.
(ii) Mixed Refrigerant Cycle (MRC) using a refrigerant comprising a mixture of nitrogen and hydrocarbons such as methane, ethane, propane, butane and pentane.
(iii) Expansion cycle using either the expansion of feed stock or nitrogen.

The alternative cycles have the following features:

i) A Classical cascade has low power consumption and uses several compressors.
(ii) A Mixed refrigeration cascade has medium power consumption with one compressor.
iii) An Expander cycle consumes very low power to liquefy a large flow of feedstock gas.

A Nitrogen expander cycle has very high power consumption and is suitable for small capacity plants with a low utilization rate.

4 LNG as an automobile fuel

LNG is superior to gasoline and fuel oil in terms of calorific value, which is evident from Table 3 (Sarkar & Bose 1992; Sarkar & Bose 1994; www.petronas.com; The Statesman 2000 & 2004; Petronet, LNG Limited 2004).

Table 3: Comparison of calorific values

Fuel	*Gasoline*	*Fuel oil*	*LNG*
Wt Calorific value Kj/Kg	48,238	43,781	55,446

LNG has special characteristics to make it a popular engine fuel in the future. It makes available 41KJ /Kg for refrigeration as compared to 21.2 KJ /Kg for liquid nitrogen. The higher refrigeration obtainable with LNG can be used towards cooling in water jackets or improving the inter-cooling between compressor stages.

In a high output turbo-charged piston engine, the refrigeration effect lowers the overall intake charge temperature. This improves power output and reduces the tendency towards knock and pre-ignition. It could be efficiently used as aircraft engine and ships engine fuel owing to its high octane number and easier maintenance.

LNG can be used for feedstock for various chemicals, fertilizers, petrochemicals and for iron ore reduction to sponge iron. The cold available during regasification of LNG can be utilized in the liquefaction of industrial gases like oxygen, nitrogen etc.

LNG is the fuel of the future. Big power companies like Tata Electric are moving away from coal towards LNG and, in future, it is likely to replace naptha as the main fuel for the plants.

A government-sponsored study has revealed that LNG would be the preferred feedstock for power and fertilizer plants in future for its thermal efficiency and non-polluting nature. Its consumption is expected to grow 400 percent in the next 16 to 17 years from the present 12.5 million tons to 50 million tons by 2016-2017 (www.petronas.com).

5 Storage and transport of LNG

Storage facilities for LNG are required whether the liquid is to be used to meet winter shortages of gas (Peak shaving facilities) or to supply base load gas by long distance shipment. In the latter case, complete ships cargos have to be loaded into and unloaded from LNG tankers.

Apart from the necessary insulation for minimizing evaporation loss, it is essential to keep the LNG cargo away from contact with the ship structure as mild steel becomes brittle below 223K, and could lead a disastrous situation. Evaporation loss may be as low as 0.1% per day for the tank contents, provided insulation is sufficient. For ocean going vessel reliquefaction facilities, facilities usually cater for about a 0.3 % boil-off.

LNG on shore can be contained in double walled metal tanks not dissimilar to those used in ships, i.e. aluminium or nickel steel inner vessels or membranes, surrounded by insulation and external weather-proofing. In addition, pre stressed concrete tanks can also be erected above ground, or can be cast below the surface. Finally, existing underground spaces specially prepared for LNG storage can be used.

The main advantage of in-ground tanks, both concrete and natural, is that they do not require containment dykes to collect products from leaking or burst containers. The attraction of above-ground tanks, on the other hand, is improved control of heat leakage and also the possibility of repairs.

6. LNG technology with particular reference to India

The LNG plants around the globe are either Peak Shaving plants to meet the seasonal fluctuating gas demand, or Base load facilities for export. There are several Peak shaving plants in the USA as well.

PETRONAS is playing a major role in proliferation of LNG production, distribution and utilization. The PETRONAS LNG Complex in Bintulu, Malaysia, is currently the World's largest integrated LNG facility at a single location with a combined production capacity of about 23 MMTA. LNG is being supplied from this installation to South Korea (The Statesman 2000 & 2004).

LNG technology and its uses in India is still in its infancy. India has just entered into the LNG Age with the formation of Petronet LNG Limited, and its first LNG terminal had started functioning in February, 2004.

Petronet Limited is a consortium of national companies like BHPL IOC, ONGC, GAIL, and foreign companies like Gaz de France, which have ventured into the high risk and capital intensive business of LNG to implement an extensive network of pipelines and related infrastructure facilities for import and distribution of LNG. Petronet LNG will import 7.5 million tonnes of LNG from Qatar through its long-term fuel supplier, Ragas – Mobil consortium, for its terminals in Dahej, Gujrat and Kerala. Salient features of the project are highlighted below (Petronet, LNG Limited, 2004; M/S Chive Fuels UK, 2004).

a. A Rupees 2600 core project to supply 5 MMTPA of re-gassified LNG;
b. The first LNG terminal facilities with a re-gasification unit at Dahej, Gujrat (India), opened in February, 2004.
c. A project will supply re-gasified LNG to seven states in India namely; Gujrat, Madhya Pradesh, Rajasthan, Uttarpradesh, Delhi, Haryana and Punjab.
d. LNG supply will be used in application as power generation, fertilizer petrochemicals, automobile fuel as well as heating and cooling in homes.

The Shipping Corporation of India has received the approval from the Government of India to form a joint venture company with Mitsui OSK - a consortium from Japan. This is for the transportation of LNG in India, and to gain experience in the LNG field for the ultimate indigenous development because the Government of India has also decided to import 7.5 million tones of LNG from Iran. The specialised vessels required for the purpose would cost anywhere between 230 - 250 million dollars.

7 Potential of natural gas vis-à-vis LNG in India

The domestic production of natural gas was expected to reach more than 90 million cubic meters per day, by the end of 2004.

The coal bed methane gas resources in India are of the order of 200 billion tonnes, which can sustain 40-50 million cubic meters per day of natural gas production. Again, the estimated coal reserve in India is about 204 000 tonnes of which 80% is that of a low grade, which could be converted to substituted natural gas (SNG). The potential of biomass is 1250 MMTPA, which is equivalent to 300 MMT of oil. All these resources can open up avenues for augmentation of natural gas /LNG production in India.

8 Conclusion

With the prospect of the availability of natural gas from various offshore/onshore sites, the scope of utilization of low grade coal for SNG production and recovery of coal bed methane and biogas, the time has come when the development and utilization of piped natural gas/CNG/LNG from a much wider perspective is needed. However, detailed investigations are required in pilot plant facilities for assessing the design parameters before putting up any LNG liquefaction plants in the country.

The existing cryogenic gas industries can suitably diversify in the LNG field because of their background knowledge and expertise in handling and storage of cryogenic liquid.

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