LNG AS FUEL FOR SHIPPING - CHALLENGES AND IMPORTANCE

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Abstract

A major challenge for the marine industry today is 'transfer of technology' from laboratories to ships, in order to reduce harmful emissions and obtain benefits to wider society. Investments in upgrading older ships are necessary to make them 'greener', more efficient and also for setting a benchmark for future new ship buildings. Natural Gas is one of the principal sources of energy for many of our day-to-day needs and activities. Natural gas is a vital component of the world's supply of energy. It is one of the cleanest, safest and most useful of all energy sources. While commonly grouped in with other fossil fuels and sources of energy, there are many characteristics of natural gas that make it unique.

The natural gas industry has existed in this country for over 100 years, and it continues to grow. Restructuring and the moving towards cleaner-burning fuels have created an enormous market for natural gas across the country. New technologies are continually developed that allow Americans to use natural gas in new and exciting ways. With all of the advantages of natural gas, it is no wonder that it has become the fuel of choice in that country, and throughout the world. Liquefied Natural gas is also an economic alternative to gasoline and other transportation fuels especially in shipping industry as it assists in minimizing environmentally harmful emissions.

Keywords: *Marpol, IMO, Bunker, Green house gases, Propulsion, Dual fuel diesel engines*

Introduction

Liquefied Natural gas (LNG) is a mixture of hydrocarbons, predominantly methane (CH_4). It also contains hydrocarbons such as ethane and propane and other gases such as nitrogen, helium, carbon dioxide, hydrogen sulfide, and water vapor. The typical composition of natural gas is presented in table-1. Natural gas has a high octane rating and excellent properties for spark-ignited internal combustion engines. It is non-toxic, non-corrosive, and non-carcinogenic. It presents no threat to soil, surface water, or groundwater. Most natural gas is extracted from gas and oil wells. Much smaller amounts are derived from supplemental sources such as synthetic gas, landfill gas & other biogas resources, coal-derived gas.

TABLE 1: Typical Composition of Natural Gas

Methane	CH_4	70-90%
Ethane	C_2H_6	
Propane	C_3H_8	0-20%
Butane	C_4H_{10}	
Carbon Dioxide	CO_2	0-8%
Oxygen	O_2	0-0.2%
Nitrogen	N_2	0-5%
Hydrogen sulphide	H_2S	0-5%
Rare gases	A, He, Ne, Xe	trace

Source: EIA- Natural Gas

Methane is a chemical compound with the chemical formula CH_4. It is the simplest alkane, the principal component of natural gas, and probably the most abundant organic compound on earth. The relative abundance of methane makes it an attractive fuel. However, because it is a gas at normal conditions, methane is difficult to transport from its source. Methane is a relatively potent greenhouse gas. The concentration of methane in the Earth's atmosphere in 1998, expressed as a mole fraction, was 1745 nmol/mol (parts per billion, ppb), up from 700 nmol/mol in 1750. By 2008, however, global methane levels, had risen to 1,800 nmol/mol.[1]

Cooling natural gas to about -260°F at normal pressure results in the condensation of the gas into liquid form, known as Liquefied Natural Gas (LNG). LNG can be very useful, particularly for the transportation of natural gas, since LNG takes up about one six hundredth the volume of gaseous natural gas. Advances in technology are reducing the costs associated with the liquification and regasification of LNG. Because it is easy to transport, LNG can serve to make economical stranded natural gas deposits from around the globe for which the construction of pipelines is uneconomical. Methane in the form of Liquefied natural gas is used as a ship's fuel and is claimed to be more environmentally friendly than other fossil fuels such as gasoline/petrol and diesel.[2]

LNG- an Alternate Fuel for ships

Considering the staggering percentages of world cargo movement through vessels transport (9%), it is remarkable to note that shipping is already the most environmentally friendly mode of transport and that emissions emitted from ships are small (3%)[3]. Operational pollution has been reduced to a negligible amount with the prevailing marine rules and regulations. Marine Pollution (MARPOL) - 73/78 is the most important set of international rules dealing with the environment and the mitigation of ships pollution that

has dealt with certain issues. However, to attract customers many ship owners have also taken considerable improvements in the efficiency of engines, ship hull designs, propulsion, leading to a decrease of emissions and increase of fuel efficiency to prove they are more environmental friendly organizations. The present marine fuels used for propulsion are heavy fuel oil, diesel oil and gasoline on normal ships other than LNG Carriers some of which are now designed to propel using LNG as fuel.

LNG, when vaporized to gaseous form, will only burn in concentrations of between 5 and 15 percent mixed with air. In addition, LNG, or any vapor associated with LNG, will not explode in an unconfined environment. Thus, in the unlikely event of an LNG spill, the natural gas has little chance of igniting an explosion. Liquefaction also has the advantage of removing oxygen, carbon dioxide, sulfur, and water from the natural gas, resulting in LNG that is almost pure methane. LNG is typically transported by specialized tanker (LNG Ships) with insulated walls and is kept in liquid form by auto refrigeration, a process in which the LNG is kept at its boiling point, so that any heat additions are countered by the energy lost from LNG vapor that is vented out of storage and used to power the vessel.

It is used for Ship propulsion by burning it as a fuel in a gas turbine or steam boiler (called as Steam propulsion) or used in dual fuel engines or generators called as Motor propulsion. Compared to other hydrocarbon fuels, burning LNG produces less carbon dioxide for each unit of heat released. At about 891 kJ/mol, LNG's heat of combustion is lower than any other hydrocarbon but the ratio of the heat of combustion (891 kJ/mol) to the molecular mass (16.0 g/mol, of which 12.0 g/mol is carbon) shows that methane, being the simplest hydrocarbon, produces more heat per mass unit (55.7 kJ/g) than other complex hydrocarbons. In many cities, methane is piped into homes for domestic heating and cooking purposes. In this context it is usually known as natural gas, and is considered to have an energy content of 39 mega joules per cubic meter, or 1,000 British Thermal Unit (BTU) per standard cubic foot.[4]

The factors to be taken to in account to accept LNG as an alternate fuel to shipping industry are listed below:

- Retrofitting of existing ships
- Price evaluation of LNG
- Bunkering possibilities (almost nil on a European basis at this stage)
- Safety Rules on Board and for bunkering

As of now, the main projects with LNG as energy source are with new built ships. Retrofitting is possible but is expected to be very costly and can most probably be applied only on newer ships. The price evolution of LNG is difficult to estimate. For a long time the oil majors have linked the price of LNG to the price of oil. Recently we have seen a delinking from the oil price making LNG a slightly cheaper option. It is, however, unpredictable how the relation between the oil price and LNG will develop. The oil majors play a key role in this respect.

LNG has to be kept on board in temperature controlled tanks with well defined safety aspects. No big quantities can be bunkered on the ships; consequently bunkering of LNG should be made possible in all

ports that the ship is calling. At this stage the bunkering possibilities are limited to the places/ports where the tests with LNG are taking place such as Norway.

In cooperation with European Maritime Safety Agency (EMSA), the European Ports Organization (ESPO) and European Community Ship Owners' Association (ECSA) are making a survey on the currently available LNG infrastructure in Europe. Key points are:

- Is there an LNG terminal in the port (area)?
- Can you bunker for shipping?
- What safety legislation is applied?
- If not, are there intentions to provide LNG bunkering facilities in the port and what safety rules would apply for bunkering?

During the process, it has become evident that IMO has guidelines for dealing with LNG on board the ship which will probably become formal rules later. For bunkering (which falls not within the purview of IMO) the only rules available at this stage are The National rules applied in Norway. There is a lot of work going on for using LNG as energy source in shipping particularly in short sea shipping. Taking into account all these elements mentioned above it becomes evident that more time will be necessary to get the outstanding issues cleared. Moreover the cost issue may be an important stumbling block. All parties commercial and political, should coordinate and cooperate on the way forward.

Marine Air pollution

The European Maritime Safety Agency (EMSA) and the European Community Shipowners Association (ECSA) started in 2009 with Workshops to analyse the possible use of Liquid Natural Gas (LNG) as an alternative to oil. The rationale for this initiative was to a large extent driven by the problems caused with the 0.1 % sulphur as from 2015. Indeed LNG would be a solution to this request giving:[5]

- Sulphur (Sox): nil
- Nitrogen Oxide (Nox) and particle matter: sharp reduction.
- CO2: reduction estimated at 20% with some doubts on the methane slip.

The technology for using LNG as energy source is clearly available in particular for new ships. There are different types of engines on the market such as gas only engines and dual fuel engines (gas/oil). Methane in the Earth's atmosphere is an important greenhouse gas with a global warming potential of 25 compared to CO2 over a 100-year period (although accepted figures probably represents an underestimate [6]). This means that a methane emission will have 25 times the effect on temperature of a carbon dioxide emission of the same mass over the following 100 years. Methane has a large effect for a brief period (a net lifetime of 8.4 years in the atmosphere), whereas carbon dioxide has a small effect for a long period (over 100 years). Because of this difference in effect and time period, the global warming potential of methane over a 20 year time period is 72.

The Earth's atmospheric methane concentration has increased by about 150% since 1750, and it accounts for 20% of the total radiative forcing from all of the long-lived and globally mixed greenhouse gases (these gases don't include water vapour which is by far the largest component of the greenhouse effect).[7] Usually, excess methane from landfills and other natural producers of methane is burned so CO2 is released into the atmosphere instead of methane, because methane is a more effective greenhouse gas.

The shipping industry has taken a variety of measures to reduce air emissions from ships during the last decennium. The International Maritime organization (IMO), the UN body in charge of maritime safety and environment has taken in 2008 a range of measures to reduce the sulphur content in marine fuels (MARPOL Annex VI). This package of reductions will eventually result in a 0.5 % limit of sulphur content in marine fuels in 2025. Table 2 summarizing the package. Compliance can be achieved by alternative fuels or abatement equipment. Natural gas, emitting fewer harmful chemicals into the atmosphere than other fossil fuels, can help to mitigate some of these environmental issues. These issues include:

- Greenhouse Gas Emissions
- Smog, Air Quality and Acid Rain
- Pollution/ Emissions from the Transportation Sector - Natural Gas Vehicles

TABLE 2: Fossil Fuel Emission Levels - Pounds per Billion Btu of Energy Input

Pollutant	**Natural Gas**	**Oil**	**Coal**
Carbon Dioxide	117,000	164,000	208,000
Carbon Monoxide	40	33	208
Nitrogen Oxides	92	448	457
Sulfur Dioxide	1	1,122	2,591
Particulates	7	84	2,744
Mercury	0.000	0.007	0.016

Source: EIA - Natural Gas Issues and Trends 1998

Conclusion

LNG is a safe, environmentally-friendly fuel. LNG is odorless, non-toxic and non-corrosive. When exposed to the environment, LNG rapidly evaporates, leaving no residue on water or soil. If spilled, LNG would not result in a slick because it evaporates quickly and disperses. Once LNG is converted to natural gas, it produces relatively low emissions when burned to heat homes, generate electricity and fuel vehicles. Because of its clean burning nature, the use of natural gas wherever possible, either in conjunction with other fossil fuels, or instead of them, can help to reduce the emission of harmful pollutants.

Natural gas is an extremely important source of energy for reducing pollution and maintaining a clean and healthy environment. In addition to being a domestically abundant and secure source of energy, the use of natural gas also offers a number of environmental benefits over other sources of energy, particularly other fossil fuels. Natural gas can be used in the transportation sector to cut down on these high levels of pollution from gasoline and diesel powered cars, trucks, buses and ships. According to the EPA, compared to traditional Ships, Ships operating on Liquefied natural gas have reductions in carbon monoxide emissions of 90 to 97 percent, and reductions in carbon dioxide emissions of 25 percent. Nitrogen oxide emissions can be reduced by 35 to 60 percent, and other non-methane hydrocarbon emissions could be reduced by as much as 50 to 75 percent. In addition, because of the relatively simple makeup of natural gas in comparison to traditional marine fuels, there are fewer toxic and carcinogenic emissions from natural gas propelled ships, and virtually no particulate emissions.

Thus the environmentally friendly attributes of natural gas may be used in the marine transportation sector to reduce air pollution.

In 2009 CLNG, a multinational company specialising in this field, commissioned a report performed by Pace Global Energy Services comparing the overall lifecycle greenhouse gas emissions of LNG production, processing and transportation, to those of coal. The study shows that existing domestic coal power plants produce two-and-a-half times more emissions on a lifecycle basis than LNG. Even the cleanest coal technologies were found to produce 70% more lifecycle emissions than LNG. Increased use of renewable fuel sources such as wind and solar will not stop the need for clean natural gas. Due to the intermittent nature of renewable energy sources such as wind and solar, natural gas, supplementation by LNG, will serve as a critical and environmentally-friendly energy supply and ensure energy reliability to consumers.

References

[1] *Chemical Entities of Biological Interest*. UK: European Bioinformatics Institute. 17 October 2009. Main. Retrieved 10 October 2011. Carbon Dioxide, Methane Rise Sharply in 2007

[2] Clayton B. Cornell (April 29, 2008). "Natural Gas Cars: CNG Fuel Almost Free in Some Parts of the Country"

[3] David A. Hensher, Kenneth J. Button (2003). Handbook of transport and the environment. Emerald Group Publishing. p. 168. ISBN 0080441033

[4] Energy Information Administration - www.eia.gov

[5] MARPOL Annex VI – www.imo.org

[6] Shindell, D. T.; Faluvegi, G.; Koch, D. M.; Schmidt, G. A.; Unger, N.; Bauer, S. E. (2009). "Improved Attribution of Climate Forcing to Emissions". Science 326 (5953): 716–718

[7] "Technical summary". Climate Change 2001. United Nations Environment Programme.

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