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APPLICATION OF LIQUEFIED NATURAL GAS

PRIMENA TEČNOG PRIRODNOG GASA

Originalni naučni rad / Original scientific paper
UDK /UDC:

Rad primljen / Paper received: 7.3.2022

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Keywords
- liquefied natural gas (LNG)
- cryogenic tanks
- transport
- energy system

Abstract

The use of liquefied natural gas (LNG) has obvious following advantages: production of cheap energy and cheap raw materials (natural gas methane); provides environmental energy sources; applicable in almost all sectors of the economy, making it a significant environmental factor; can be easily transported; it is applicable to different types of transportation units; requires the development of a gas pipeline and increases the lifetime of the car. Natural gas is characterised in that it is extremely cumbersome and cannot be transported across oceans in the natural state through pipelines; even where transport over long distances is technically possible, gas losses are unavoidable, as is associated with the so-called cost of disposal. In liquid form, however, natural gas is much more compact and occupies only 1/600 of its original volume. This fact coupled with the need to transport gas over long distances, literally 'beyond the seas and oceans,' serves as the basis of development of LNG industry. LNG is a very fast-growing industry of the world energy system. Fuel for vehicles and agricultural machines, new design cryogenic tanks, or pressure vessels, can also use this inexpensive fuel in a liquid state.

Ključne reči
- tečni prirodni gas (TPG)
- niskotemperaturni rezervoari
- transport
- energetski sistem

Izvod

Primenom tečnog prirodnog gasa (TPG) očigledne su njegove sledeće prednosti: dobija se proizvodnja jeftine energije i jeftinih sirovina (prirodni gas metan); obezbeđeni su ekološki izvori energije, primenljivi u gotovo svim sektorima privrede, što ga čini značajnim činiocem zaštite životne sredine; lako se transportuje; primenljiv je za različite vrste transporta; ne zahteva izradu gasovoda i povećava životni vek automobila. Prirodni gas je okarakterisan time što je izuzetno kabast i ne može se transportovati preko okeana u prirodnom stanju kroz cevovode, čak i tamo gde je to tehnički moguće; prevoz na dugim relacijama povezan je sa velikim troškovima kao i sa tzv. troškovima odlaganja. U tečnom stanju, međutim, prirodni gas je mnogo kompaktniji i zauzima samo 1/600 od prvobitne zapremine. Ova činjenica, zajedno sa potrebom za transport gasa na velike udaljenosti, bukvalno 'preko mora i okeana', poslužila je kao osnova razvoja industrije TPG. TPG je vrlo brzo postala rastuća industrija u svetu energetskih sistema. Goriva za vozila i poljoprivredne mašine, novi dizajn kriogenih rezervoara, ili posuda pod pritiskom, omogućava korišćenje ovog jeftinog goriva u tečnom stanju.

INTRODUCTION

Natural gas is characterised by the fact that it is extremely cumbersome and cannot be transported across the oceans in its natural state by pipeline. Even where transport over long distances is technically possible, gas, oil, and coal has losses, and it involves so-called costs of remoteness. In liquefied form, however, natural gas is much more compact and takes only 1/600 part of its original volume. This fact, coupled with the need to transport gas over long distances, literally 'across oceans and seas,' forms the basis of the development of the industry. LNG production is a very fast-growing industry in the world energy system /1/. In this paper the application of LNG is presented, with basic data needed for future investigation in respect to structural integrity issues related to it. The main issue is with highly loaded pressure vessels used for transport and/or storage of the LNG, as analysed in a number of papers, /2-6/.

CRYOGENIC TECHNOLOGY

Figure 1 presents the pressure generator for gas supply to the consumer. The principle of operation of the generator is based on filling high pressure seamless cylinders and tubeless components heated to the temperature for creating the required pressure. When the liquid evaporates it forms a vapour state of natural gas. Opening the shut-off valves (2), the LNG pump under pressure of steam enters the gasifier (1). To avoid the formation of frost and ice on the outer surface of the gasifier (1), with warming of the water – the gasifier (1) has thermal insulation. In each gasifier a heating element is introduced (3). Power of the heating element (3) depends on the size of the gasifier, providing the necessary speed and temperature of the LNG flow (2). The temperature of the heating element (3) is automatically adjusted at the pressure set point (4).

USING CNG IN THE TRANSPORT SECTOR

Major driving forces in the implementation of gas fuel for cars is a noticeably lower price of natural gas compared to gasoline and diesel fuel, and a significant reduction in harmful emissions of internal combustion engines, /7-9/.

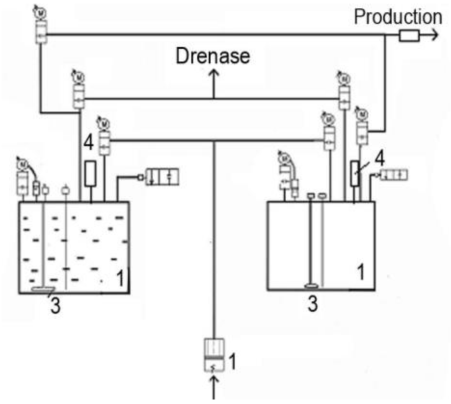

Figure 1. The generator for the gasification of liquefied natural gas and filling gasiform product to the consumer.

The motives of gasification of vehicles are as follows: a sharp increase in motor vehicles operated by the negative impact on the environment and human health; rising prices of motor fuels in the continued growth of the car park; the need to reduce dependency on oil, especially in the transport sector; growth of consumption of petroleum products.

Essentially, natural gas on cars can be used in two forms:
– compressed natural gas (CNG) with working pressure of p_w = 25.0 MPa at environmental temperature. 1 lit. of CNG is energetically equivalent to 0.22 lit. of petrol;
– liquefied natural gas with a maximal working pressure of p_w = 1.6 MPa, at -164 °C. One litre of LNG is equivalent in energy to 0.65 lit. of petrol.

Curbing the widespread use of CNG in road transport is caused by the following factors:
– necessity of application of pressure vessels;
– significant increase in the weight of fuel system engine;
– declining range of mileage on one re-fuelling (power reserve of a middle class car at 90 km/h on gasoline is 500 km, and the CNG – a total of 180 km);
– poorly developed infrastructure of NGV filling stations-CNG (the existing regulatory framework for safe operation requires the fulfilment of conditions of placement of CNG stations at a distance of not less than 60 m from other structures and objects).

The main advantage of LNG before CNG for use on vehicles is considerably lower overall weight and dimensions specification of necessary equipment and improved mileage without refuelling. Much of these advantages especially manifest themselves when using natural gas in cargo-passenger vehicles with engine capacity above 198 kW.

LNG is almost 2 times lighter than gasoline, nontoxic, chemically inactive and with octane number of 105-107, which is 13-15% higher than that of gasoline. Its combustion products contain less carbon monoxide and nitrogen oxides than compressed natural gas due to the better cleaning process.

Using LNG as a fuel gas for cars also has a beneficial effect on engines, resulting in the following:
– increases engine life 3 times and reduces the consumption of oil by 2 times;
– reduction of specific fuel mass flow rate (higher calorific value);
– decreases near to zero the content of harmful gases in the exhaust of engines;
– softer operating mode.

Compared to similar systems for CNG, the large-scale production of LNG unit investment on production is 25-30 % cheaper, LNG production 40% and total given the cost of 'production-distribution' for LNG is cheaper 10-30%. Figure 2 shows the KAMAZ, equipped with a cryogenic tank.

Figure 2. KAMAZ truck, equipped with cryogenic LNG tank of fuel capacity 300 lit.

The economic effect of transition to LNG in the freight segment is estimated between 15-25%. Currently there are three technologies LNG-engines used for sea-going vessels:
– engine with spark ignition at the lean fuel-air mixture;
– flexible fuel engine with diesel fuel and ignition working on gas at low pressure;
– flexible fuel engine with diesel fuel and ignition working at gas pressure.

Spark-ignition engines operate on natural gas only, while dual fuel diesel-gas engines can operate on diesel, LNG, and oil. To date, there are 3 main manufacturers in this market: Wärtsila, Rolls-Royce and Mitsubishi Heavy Ind.

Talking about the development of engines for the automotive sector, it is worth mentioning the American company Cummins Westport that has developed a line of LNG-engines intended for heavy trucks. In Europe, Volvo has launched production of the new 13-litre engine 'Volvo FM Methane Diesel,' running on diesel and LNG. Notable innovative solutions in the field of LNG-engines can be attributed with compact engines with compression ignition (Compact Compression Ignition (CCI) engine), developed by Motiv Engines. Referring to US fuel prices, you can calculate that the work truck with a diesel engine costs 0.17 USD per horsepower per hour, and the traditional LNG engine - 0.14 USD, and the CCI-engine-as low as 0.07 USD.

CRYOGENIC TANKS

When transferring vehicles to LNG, the problem of high cost of fuel system is raised, defined in the main cost to manufacture cryogenic tanks, traditionally made with multi-layer screen-vacuum insulation (Table 1). Screen-vacuum insulated cryogenic tanks are 3-4 times more expensive than automotive composite (plastic) tanks with polyurethane insulation, /10-12/.

Table 1. Compared fuel system cost.

Volume (m^3)	Mass (kg)	Dimensions		Price (USD)
		Length (mm)	Diameter (mm)	
250	110	1950	600	2500
100	65	1100	450	1400
50	40	850	340	1000

The main requirement for large cryogenic tanks of fuel storage-capacity at 99 K (-164 °C) for up to 5 days 24 h at relatively high pressure, can reach 0.5 MPa in normal operation. In normal operation, the vapour pressure of gas in the tank does not exceed allowable and are dumped into the atmosphere only freelance and in emergencies through an emergency drainage system.

The use of LNG filling stations based on cryogenic gas machines (CGM) Stirling makes it possible to use instead of the cheaper types of vacuum thermal insulation. In this case, the transport needs to be refilled every day before leaving it in operation. Currently being developed are cryogenic tanks specially designed for public and freight transport, municipal, as well as for cars. They performed ‘layer cake’ represents layers of polyurethane foam insulation and composite material of low thermal conductivity and high durability, /13/. Cryogenic tanks are 3-6 times cheaper than tanks on similar vehicles made of multilayer screen-vacuum insulation, the LNG storage tubeless ranges from 1 to 5 days. In Figs. 3 and 4 cryogenic tank testing is shown, developed at Perm National Research Polytechnic University (PNRPU).

Figure 3. Stand for testing.

Figure 4. Composite cryogenic tank with sticky sensors.

MARITIME TRANSPORT

In this case the LNG is favourable due to the reduction of maximum permissible sulphur content in fuels. The legislation would affect about half of 10000 ships engaged in the transport of goods within EU. In addition, since January 1 2020, new world rules would go into effect aimed at reducing fuel sulphur limits from 3.5 to 0.5 %. Along with the environmental pillar, the use of LNG as fuel for maritime transport will bring significant economic benefits, /14-15/.

According to 2012 LNG prices in the EU ranged from 300 to 410 EUR per tonne, while the price of fuel oil used as fuel by the majority of vessels, amounted to 480 EUR per tonne. Starting from 2015 onwards, vessels are obliged to use ultralow sulphur gasoil, at 730 EUR per tonne. It becomes apparent that LNG has a huge potential, and in the coming years it has become an effective alternative to traditional petroleum fuels used in maritime transport.

DECENTRALIZED ENERGY SUPPLY USING LNG

Considerable advantages of LNG are made if it is used as thermal power station and boiler fuel. Table 2 presents fuel properties. As an example, consider heating the cottage village, in which a setting of the boiler of capacity 2 MW, provides warm accommodation to 20 thousand m^2. The heating season is 5760 h. There are two options for solving the problem: make a pipeline trail 8 km of diameter 160-200 mm or provide boiler installation of imported fuel. If it is imported fuel oil, it is advisable to consider LNG, natural gas (NG), liquefied petroleum gas (LPG), and diesel (DT). Comparison of 1 Gcal of heat is shown in Table 3.

Table 2. Comparative characteristics of fuels.

Type of fuel	Lower calorific value (kcal/kg)	Efficiency of thermal installations (%)	Reduced prod. costs 1 Gcal (%)
LNG	11500	91-93	100
Coal	4200	65-70	127-174
Fuel oil	9700	85-88	143-176
Diesel	10180	88-90	396-428

Table 3. Cost of 1 Gcal of heat when using different fuels.

	Type of cost	Cost, in 1000 USD			
		NG	DT	LPG	LNG
Capital investment	Boiler ‘ZIOSAB – 2000’	21.5	15.0	21.5	21.5
	Laying gas pipeline 13 km	1000.0	-	-	-
	The supply system DT	-	25.0	-	-
	LPG supply system	-	-	38.0	-
	LNG supply system	-	-	-	111.0
	Reserve fuel tank	9.0	9.0	9.0	9.0
	Total equipment	1030.5	49.0	68.5	141.5
	Construction-Assembly	17.0	23.0	34.0	56.0
	Total capital investments	1047.5	72.0	102.5	197.5
Operational costs	The cost of fuel oil	32.7	260.4	224.0	120.3
	Maintenance costs	7.0	7.0	7.0	7.0
	Depreciation for pipeline life 30 y. Equipment 15 y.	39.0	5.8	8.7	14.4
	Total operating costs	78.7	273.2	239.7	141.7
	Cost of 1 Gcal	0.008	0.028	0.024	0.014
	Investment payback, in years	9	-	-	6

From the indicative calculation of capital investment, operating costs and cost of heat shows that the highest capital investment for the organisation of heating account for natural gas and pipeline relates to a length of 8 km. Despite the fact that the amount of capital investment in the organisation of work of the boiler on diesel fuel, the cost is much less than 1 Gcal of heat energy generated at 65% more than the asking price. Application of DT and LPG as heating fuel to a consumer is not beneficial, /7-9/.

At a cost of 1 Gcal, calculated using LNG, is 75 % more than using a natural gas pipeline, but capital investment to support the operation of the boiler by natural gas pipeline laid on by 530 % more than is needed to turn the boiler on LNG. Thus, the estimated payback of capital investments in the work of the boiler of LNG is 1.5 times less than natural gas, which turns out to be the determining factor when choosing a carrier. When calculating the cost price of 1 Gcal, obtained with the use of LNG delivery of 1 t price is adopted equal to 100 USD.

So, for the Moscow region, while domestic use of gas with central heating and water supply costs 0.11 USD for 1 m^3/person (norm 12 m^3 per person per month). As an example, cryogenic tanks are shown in Fig. 5.

Figure 5. Cryogenic tanks, 40 m^3, for LNG storage and regasification for subsequent gas supply boiler room.

LNG can also be used as a motor fuel in diesel-generators to get low-cost electricity. As a result of exhaust heat utilization can simultaneously receive high-grade heat for heating and hot water, /16/. For example, if you install a diesel generator that runs on gas, with a capacity of 1500 kW, annually you receive over 13000 MWh of electricity and about 10000 Gcal of thermal energy for heating and hot water. The investment payback period for the purchase of diesel-generator is 3-3.5 years. Therefore, an alternative to the traditional dependence of consumers on major suppliers of electrical and thermal energy are stand-alone objects with the minimum energy using LNG.

CONCLUSION

Cryogenic technology provides:

- heat and hot water modular boiler-gas or gas-fired hot water boilers of different capacity that provide cheaper heating for homes and businesses;
- centralized gas supply homes and businesses-township system solves the problem of pipeline gas supply for domestic, industrial furnaces, and other equipment;
- cheap electricity-gas power plant provides electricity to villages without having to extend the power line;
- free cold-simple quick-freezing and refrigeration with freezing temperatures at -20 °C/-150 °C, working through cold evaporation will satisfy the needs of LNG in storage products, and save electricity;
- fuel for vehicles and agricultural equipment - cryogenic tanks, new construction or high-pressure cylinders will use this inexpensive fuel in a liquefied state.

ACKNOWLEDGEMENTS

This study is supported by the Ministry of Education, Science and Technologilac Development of the Republic of Serbia, through project grants TR 32036 and TR 35038.

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