Clean LNG fuel for Black Sea-Danube-Rhine corridor

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Abstract: - International regulations on emissions have forced the shipping industry to rethink its options. IMO introduced emission controls, which will increasingly affect the international shipping in the next decade. The introduction of emission control areas (emission control areas, ECAs) in Europe, USA and Canada's territorial waters have forced owners to take into account and alternative fuel sources besides the traditional ones. It promotes more companies that uses LNG, because ships are more efficient and environmentally friendly. There is a strong need to modernize the inland waters vessels fleet in order to improve environmental and economic performance LNG as fuel will significantly reduce vessel emissions (-20% CO2, -80 to 90% NOx, almost zero PM & SOx) and will increase the competitiveness of Danube transport (fuel cost savings relate into lower transport costs of est. up to 15%) Further CO2 reduction possible by blending with BIO-LNG. LNG as cargo will increase transport volumes and will offer energy (cost) savings to many industries in the entire region.The author aims to analyze a technical solution regarding an import and distribution facility consisting in converting an LNG carrier into a floating storage and regasification unit (FSRU) located in Constanta port.

Key-Words: - LNG, conversion, storage capacity, FSRU, loading arms, regasification, cryogenic

1 Introduction

Compared to the world oil market, the world LNG market is quite small. Total LNG demand is around 242 [MMTPA](million metric tones per annum)[1, 2]. That means that a single Qatari megatrain amounts to more than three percent of the world market; a project like Qatargas II is almost seven percent of world demand[3]. By way of comparison with oil, a major 250,000 [b/d] refinery is less than one-quarter of one percent of world oil demand. Every liquefaction plant is an important element of the world market. The cost of liquefaction plants varies tremendously depending on location; less than half of the cost is usually the liquefaction plant itself. Most major LNG export projects have been located near remote gas reserves; often ports, and even new cities, must be built. In addition, the capacity for building major LNG projects is limited by the availability of engineering and skilled labor. The cost of liquefaction plants tended to fall steadily from the 1980s until the early 2000s, but a large number of new projects and shortages of labor and specialized fabrication facilities have caused prices to skyrocket.

The market is not large enough for a buyer to be able to count on purchasing needed volumes whenever required. Even large volumes of oil are always available at some price, but in some situations there may be almost no uncommitted volumes of LNG. Similarly, the seller has a limited number of possible buyers, since the number of LNG import terminals around the world is quite limited. In addition, most of the supply contracts in the world today include destination controls. That means that the seller generally cannot resell LNG that they buy to some other country, or reassign their contract. This is an attempt by sellers to control the market. LNG carriers typically cost around US$200 million. The typical LNG tanker holds around 145,000 [m^3], equivalent to about 62,000 [t] of LNG; but there are now vessels of up to 266,000 [m^3] (nearly 120,000 [t] of LNG). The larger ships are too big to access many ports, and deliver such large volumes that they exceed the storage capacity of some smaller buyers.

LNG storage and regasification facilities are nowhere near as costly as liquefaction plants, but they can still be quite costly—from US$100 million to about US$2 billion for larger terminals. Much of this depends on the size of the facility, but often a large share of the cost is for constructing new port facilities.

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FSUs (Floating Storage Units) and FSRUs (Floating Storage and Regasification Units) are essentially converted LNG tankers or dedicated structures permanently moored, and supplied by other LNG tankers that deliver new cargoes. Not only are such options often cheaper than onshore storage and regasification, the setup time is far less—usually 12 months before first LNG delivery, as opposed to 3-5 years for the traditional option.

2 Marine facilities

The project consists in building a LNG import terminal in Constanta, harbor from where the merchandise (LNG in this situation) can easily be delivered on Danube's basin and reach central European countries [4]. Up to now there was little or none import and use of LNG in countries like: Germany, Austria, Slovakia, Hungary, Serbia, Bulgaria, unlike other European countries that have over 20 Years of using LNG. The reason these countries didn't profit from the benefits of LNG usage is that there was little access to import LNG and if there was, it was very expensive. In order to deliver LNG to Austria a railway or truck transport should have been organized in special containers from the LNG terminal near a sea to Austria. Through the terminal built in Constanta specialized vessels could transport LNG at lower prices to all countries upstream Danube.

Constanta LNG terminal is the only one in the Black sea, and except the one in Greece, the only one in Central-Eastern Europe.

2.1 Location

Romania, Constanta County, Constanta-South Port, Agigea. The Port of Constanta is located on the Western Coast of the Black Sea, at 179 [Nm] from the Bosphorus Strait and 85 [Nm] from the Sulina Branch, through which the Danube flows into the sea [9]. It covers 3,926 ha of which 1,313 [ha] is land and the rest of 2,613 [ha] is water.

The two breakwaters located northwards and southwards shelter the port creating the safest conditions for port activities. The present length of the North breakwater is 8,344 [m] and the South breakwater is 5,560 [m]. Constanta Port has a handling capacity of 100 million tons per year and 156 berths, of which 140 berths are operational. The total quay length is 29.83 [km], and the depths range between 8 and 19 [m].

These characteristics are comparable with those offered by the most important European and international ports, allowing the accommodation of tankers with capacity of 165,000 [dwt] and bulk carriers of 220,000 [dwt]. Currently there are several projects in progress, in order to build new facilities for cargo handling and to improve the transport connections between Constanta Port and its hinterland. These projects are mainly located in the South part of the port. Port limits: as the commercial limits, the port of Constanta is confined by the North and South breakwaters.

2.2 Investment's beneficiary

National Company "Maritime Ports Administration" SpA. Constanta in partnership with private European natural gas production in decline but consumption generally predicted to increase over the following decades, Europe is expected to become even more dependent upon gas imports with LNG playing a very important role. LNG has proved to be a globally flexible, competitive and reliable source of energy, providing security of supply in the mix of gas import options.

The European Commission is looking at the harmonization of the gas quality specifications across European Union in order to create effective interoperability of gas networks and facilitating a free trade of gas by lifting local gas quality barriers.
Many other factors also need to be taken into account: fuel prices, bunker consumption ,investment costs and payback period, the age distribution of ships and the number of ships and trucks, current and future regulations and so on. Close examination of these aspects indicates that small scale LNG is commercially viable:

• The potential demand is substantial. Many companies identify international shipping as a growth market for gas, through using LNG as a bunker fuel for ferries, cargo ships and tankers. At the moment some 90.000 vessels are used in the world fleet, they use around 280 [MT/y] of petroleum fuels which represent a potential market for LNG as a shipping fuel of up to 315 million [t]. This is 1.25 times the amount of the LNG production capacity today.

• LNG prices are becoming attractive compared to other bunker fuels. Over the past 20 years price differentials between fuel oil, gasoil/diesel and LNG have changed significantly. In 1997 oil prices hovered around $20/ barrel(West Taxes Intermediate) and around $2.50/ MMBtu for Henry Hub natural gas in the US. Today, these are around $100/ barrel for oil and $5/ MMBtu for natural gas.

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2.3 Floating LNG terminal

An example of LNG tanker conversion work is presented below with emphasize on the scope of work for the shipyard:

-Detailed Engineering: major achievements include complete turret construction methodology brainstormed and worked out by the Yard's engineers such that there were no damages to the Inconel cladding of the turret bearings. In addition the nearly 2000 [t]. Re-gasification module T-16 was an engineering challenge to lift and install onboard. A Floating Storage and Regasification Unit (FSRU) is permanently moored close to the market (Figure 1)[1].

Fig.1. A view of FSRU

-Procurement: with restrictions to sourcing the material required for the various grades of piping, mainly Cuniferand Cryo and the stringent MED and 3.2 certification requirements Procurement was never something less than an on going challenge.

-Construction: the Project can well boast of carrying out routine complex works as part of the scope related to Topside such as the fabrication and installation of the 600 [t], 25 [m] high external turret and turret mooring system, installation of the prototype four loading arms 75 [MT] each, lifting, installation and tie-ins for the 2100 [MT] regasificationT-16 and the 400 [MT] T-20 be index modules. Installation and tie-ins for the two10000 [kW] STGs and installation of the unique articulated-type vent tower are other significant firsts. In all 97,272 [inch] diameter of piping, including exotic material for cryogenic piping and over 320 [km] of cable pulling was completed for the Project.

Extensive piping fabrication works including stainless steel piping for handling of LNG cargo at minus 163 [°C] and insulating with PUF type material was carried out. Major Vessel and Topside works carried out were chain table replacement for the turret mooring system, side by side berthing mooring system installation, modification of cargo pump tower internal structure and installation of retractable cargo pumps, installation of the pipe rack module, product sea water systems piping with diameters up to 52 [inch].Total steel tonnage fabricated and installed for vessel conversion was 4,400 [t] and was compliant with the highest quality standards in the maritime industry.

-Marine facilities; offshore gas unloading jetty, mooring dolphins and breasting dolphins.

-FSRU – permanently moored alongside the jetty.

-Export gas pipeline (approximately 2.2[km]) running on the jetty to the onshore gas distribution network including a gas metering station owned by Romanian client.

-LNG carriers will moor alongside the FSRU and unload LNG into the unit for storage prior to regasification and export to the onshore gas distribution pipeline.

-Mooring system comprises of:

-installing 18 off 150 [t] chain stoppers;

-12 quick release double hooks with electrical warping drums;

-frame reinforcement.

Water depth in Agigea south basin N of breakwater is approx. 16-17 [m].

2.4 LNG transport Barge Articulated Tug

Pre-Commissioning and Assistance to Final Commissioning:

-Final commission in of newly installed HVAC system was completed by the yard and their sub-contractors. In addition the yard has provided support to the client for other commissioning works such as cool down of cryogenic piping, Boiler flash up, performance trial run of power generators, harbor acceptance test of aft thruster and leak test of the natural gas piping.

What is commendable is that all of the above was completed consuming 9.57 million man hours with only three LTIs. It is expected that a total of 9.59 million man hours would be consumed by the time of project completion [3].

3. Technical specifications in Constanta LNG project

-FSRU will be placed offshore, 4 [km] from the shore.

-Storage capacity: 135.000 [m.

-FSRU specifications:

-Length-289[m];
-Beam-moulded breadth=48 [m];
-Deadweight 82100 [t];
-Draft 12.5 [m];
-Gross tonnage 115000 [t];
-Net tonnage- 34550 [t].
-Minimum depth for offshore mooring an FSRU is 15 [m].
-Minimum depth for pier side or jetty mooring is > 14 meters.
-Designed for benign waters. Agigea waters are considered very suitable.
-Design lifetime: 30 years at location.
-Re-gas send-out requirements: minimum rate 50 [t/h]; maximum rate 250 [t/h].
-Vaporizers: with propane and sea water.
-Steam from existing ship boilers used for re-gas.
-Fuel consumption 50 [t] LNG per day/100 % re-gas capacity.
-DNV class notation: REGAS-1.

The FSRU is supplied with LNG by shuttle tankers berthing side by side to it, through 4 loading arms at a flow rate of 8000 [m^3/h], this means that max 20 [h] are required to download a vessel of 135 000 [m^3]capacity at max discharging rate including mooring and de-mooring time. The terminal is designed to perform 3-4 discharging operations/month. The loading lines are kept in refrigerated (cold) condition between 2 discharging through a small recirculation of LNG so as to shorten the cool-down phase and therefore reduce the overall duration of unloading operation. The FSRU is equipped with 3 Tri-Ex type units using large quantities of seawater as a heating medium.

Operational condition: Limit for LNGC unmooring and loading arm disconnection. Max. Wind speed 27 [knot]/approx 44 [m/s]; Max sea state Heights 2.5 [m]; Max surface current 2 [knots]/1[m/s].

3.1 Technical specifications for the regasification system. Moss regasification system

The process of liquefying the natural gas involves compression and cooling of the gas to cryogenic temperatures (e.g. -160° Celsius). Prior to liquefaction the gas is first treated to remove contaminants, such as carbon dioxide, water and sulphur to avoid them freezing and damaging equipment when the gas is cooled. At this destination, the LNG is offloaded to special tanks onshore, before it is either transported by road or rail on LNG carrying vehicles or re-evaporated and transported by e.g. pipelines. In many instances more advantageous to re-evaporate the natural gas aboard the seagoing carrier before the gas is off-loaded into onshore pipelines.

LNG is sent from the tanks to the regasification skid situated forward. The regasification skid essentially comprises booster pumps and steam heated vaporizers. The booster pumps will increase the pressure to about 90 [bar], before the high pressure LNG is evaporate after which the gas passes through a fiscal metering unit and is sent to the sub sea pipeline via the gas swivel and flexible risers. An LNG carrier approaches the FSRU to bring a new cargo. The FSRU is compatible with the world LNG carrier fleet:

a) Typically, LNGCs of 80,000 to 170,000 [m^3] will be used;

b) Both Moss and Membrane type LNGCs are compatible[5].

This project offers full feasibility to discharge LNG from the FSRU to LNG bunker vessels and short-sea LNG shipping or road trucks.

3.2 LNG transfer

The LNG is transferred from the LNG carrier to the FSRU. LNG transfer can be done “ship-to-ship” or across a berth with flexible hoses(Figure 2),[1] or articulated cryogenic chicksan loading arms(Figure 3), [3].

Fig. 2. Flexible hoses.

Fig. 3. Cryogenic loading arms.

FSRU continuously re-gasifies the LNG and send the high-pressure natural gas to shore. Onboard regasification of LNG has multiple seawater pumps which provide the heat to warm the LNG; steam heat may replace or supplement the seawater heating; a modular and skid-based design; proven systems and components(Figure 4), [5].

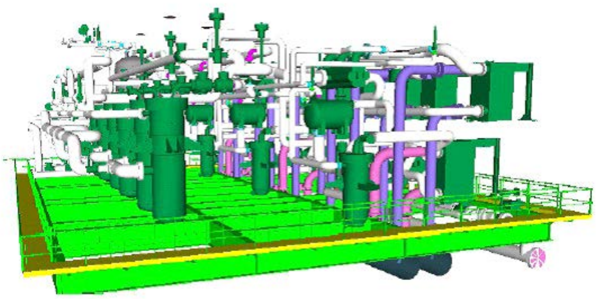

Fig. 4. Regas skids. [4]

4. Results

LNG terminal offers many good results:

a) Cost reduction for European transport sector;

b) Maritime access in Constanta port;

c) Strategic location Constanta port via Black Sea –Danube channel - inland waterway access.

The project components costs are estimated to reach a total amount of 175.525.000 euro, but can vary depending on the capacities and structure of the investment. After the elaboration of the feasibility study a more accurate cost will be provided (Table 1).

Table 1. The costs of Romania LNG project[1]

Component	**Value(euro)**	**Value (roni)**
Fesability study	875 000	3 816 850
FSRU	132 000 000	575 678 400
Marine facilities	25 000 000	109 030 000
Pipes network	10 000 000	43 612 000
LNG transport carrier	8 000 000	34 889 600
Total costs	**175 875 000**	**767 026 050**

The cargo is taken from the LNG carriers and stores in special tanks and from here is load to smaller vessels for transport upstream Danube, or it can load through the LNG pipe networks to deliver LNG via road/rail way, or pushes LNG into the regasification unit and than through the pipeline in the national gas network.

During the development of LNG carriers there have been different tank designs [6]. The main purpose of the cargo containment system is to keep the gas below its boiling point and maintaining the adequate insulation. For this purpose it is important to select the appropriate containment system which is also determined by taking into consideration the tank's capability to withstand sloshing loads. The tank designs can be divided into two main categories; the membrane or the independent tanks. The membrane category consists of two tank design types used for LNG, namely the membrane tanks and the semi-membrane tanks. Even though the tank types have different designs, some characteristic elements are present in all of the tanks. The double bottom and the secondary barrier are very important in case of leakages of the LNG to prevent pollution of the ocean. These elements are shown in Figure 5, [5].

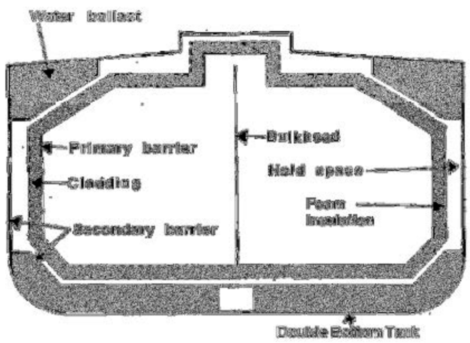

Fig.5. Definition of element.

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The membrane tank system consists of a very thin primary layer (membrane) supported by insulation. The system is directly supported by the ship's inner hull. The membrane containment systems must always have a secondary barrier in case of a leakage in the primary barrier(Figure 6, [7], [8]).

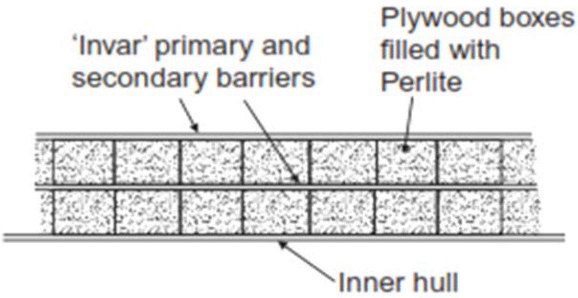

Fig.6. Gas transport system.[7]

5. Conclusions

This project is of European importance and helps develop not only one but many other countries because Central and Eastern Europe does not have access to LNG import, or has limited access to very expensive LNG due to a long chain of intermediaries and limited transport capacities that hold back the possibility of developing this industry [9]. LNG is a much cleaner form of fuel that can power industries, transports and also can be converted into natural gas for domestic consumption. LNG is a much cleaner form of fuel that can power industries, transports and also can be converted into natural gas for domestic consumption

• LNG is less expensive than conventional fuels, half the price of diesel.

• Central and eastern Europe does not have acces to LNG import, or has limited access to very expensive LNG due to a long chain of intermediaries and limited transport capacities that hold back the possibility of developing this industry.

• By building an LNG Terminal in Constanta, Romania, LNG can be delivered upstream Danube to Linz or even Nuremberg. Constanta is the door for large scale imports (from the sea) to Central Europe.

• By using LNG instead of traditional fuels economies of scale can be created from a micro perspective (lower utilities invoices) to a macro scale perspective (environmental quality improvement and lower operation prices in industries and transports).

References:

[1] Sagau, M., LNG import facility consisting of existing LNG Moss type vessel into floating terminal with regasification unit, *Journal of Sustainable Energy,*, Vol.4, No.1-2, 2013, pp. 123-129.

[2] http://www.definition-of.com

[3] http://www.hnei.hawaii.edu

[4] ***LNG Import Terminal in Constanta, Project, RomAir, Bucharest, 2013.

[5] Kristiansen, H., *Hoegh LNG FSRU*, Terima Kasih Publishing House, 2013.

[6] http://www.isgintt.org/files/Chapter_33en_isgintt_062010.pdf, International Safety Guide for Inland Navigation Tank-barges and Terminals, chapter 33.

[7] Eyres, D. J., *Ship Construction* , Butterworth-Heinemann Publish House, 12/2006.

[8] Jonas Ringsberg Hale Saglam - Ulrikke Brandt - Britta Wodecki, *Marine structural engineering*, LNG carriers,MMA167, 2012.

[9] http://www.portofconstantza.com/apmc/. National Company "Maritime Ports Administration" SpA Constanta, *Official Documents*, 2013.