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LNG AS SHIP FUEL

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THE FUTURE – TODAY

LNG READY SERVICE

ENGINES FOR GAS-FUELLED SHIPS

RECOMMENDED PRACTICE ON BUNKERING

GLOBAL LNG SOLUTIONS

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THE NEW REFERENCE FOR LNG PROPULSION

Development of emission reductions from 4,200 TEU to present 18,800 TEU ships of UASC with LNG as fuel on Asia to Europe trading route

Fuel consumption is the major cost driver in shipping. Only the most fuel efficient ships will survive in tomorrows' markets! This thesis has become the challenge for UASC – United Arab Shipping Company with their German Consultant and Ship Designer TECHNOLOG Services GmbH from Hamburg. The TECHNOLOG Consultants have been engaged by UASC with design optimisations of their earlier UASC new-building series since 1997, which have grown steadily in capacity over the years from the initial Panmax size of 4,100 TEU (A4) via 7,200 TEU (A7) to 13,500 TEU (A13) ships in 2010, with last ship delivery of the series in 2012.

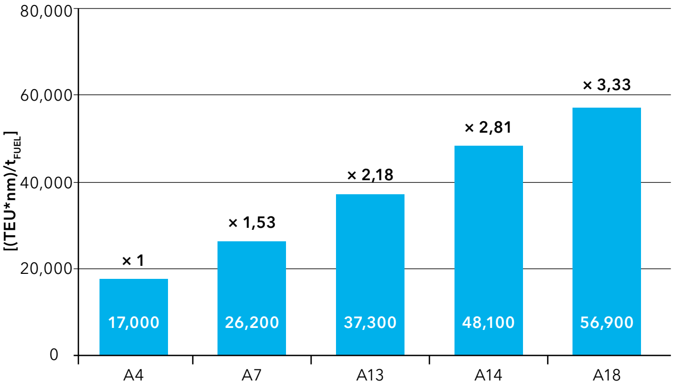
UASC will now double its fleet capacity with eleven 14,500 TEU (A14) and six 18,800 TEU (A18) new super-efficient and environmentally friendly container vessels. High efficiency and low fuel consumption generally also means fewer emissions These seventeen ships have been ordered from Hyundai Heavy Industries and Hyundai Samho Heavy Industries and will be under DNV GL Classification. The ships will come into service between the end of 2014 and autumn 2016. This article will demonstrate the efficiency gains and reductions in emissions by UASC over recent years until the intended application of LNG as ship fuel. At the end of the article, an outlook/summary on the emission reduction potential through the use of LNG as fuel in these vessels is given. It should be noted that LNG will only become competitive, and therefore commercial feasible, if it can be offered below the HFO price, or if the 0.5% S regulations come into force in 2020.

UASC is the major Middle East liner company serving AEC8 ports between Shanghai and Hamburg with their Asia to Europe service. The string of 10 number 4,100 TEU (A4 class) ships operated on this route between 1999 and 2008. These were powered with MAN B&W 10L80MC Mk.V engines with an NCR of 29,200 kW and a daily average fuel consumption of 46.4 ton. The yearly fuel consumption of these 10 ships was 167,000 ton of HFO with a CO_2 output per year of 0.5 million ton. The transport cost per TEU/nm according to UASC profile is 3.85 Cent with a CO_2 output per TEU/nm of 162.1 gram.

In 2008, these A4 class vessels were replaced by the new larger 8 (+1) numbers 7,100 TEU (A7 Class) vessels on this route. These ships were propelled by Wärtsilä 11 RT-flex 96C engines with an NCR power of 56,628 kW. They were designed for a speed of 25.5 knots on design draught with related fuel consumptions on average of 59.8 ton per day. The yearly fuel consumption of these 9 ships was 194,000 ton of HFO with a CO_2 output per year of 0.62 million ton. The transport cost per TEU/nm, according to UASC profile, is 2.81 Cent, with a CO_2 output per TEU/nm of 129.6 gram.

From 2011, the 9 number 13,500 TEU (A13 class) vessels were introduced, powered by MAN B&W 12K98 ME7 type main engines, also utilizing a Waste Heat Recovery System and PTO/PTI facilities in the upper speed range. These ships dispose of a NCR power of 64,593 kW for 25 knots on design draught, with an operational average daily fuel oil consumption of 70.7 ton. The yearly fuel consumption of these 9 ships was 229,000 ton of HFO, with a CO_2 output per year of 0.73 million ton. The transport cost per TEU/nm according to UASC profile is 1.98 Cent, with a CO_2 output per TEU/nm of 81.3 gram.

TRANSPORT EFFICIENCY - CONTAINERMILES WITH 1t OF FUEL



While the previous vessels were all standard shipyard designs that only underwent limited optimisation and were trimmed for the common high operational speeds at that time, the new vessels of 14,500 TEU (A14 class) and 18,800 TEU (A18 class) were developed for economy and best fuel consumption by UASC with their consultant TECHNOLOG and the tendering shipyards, later the selected builders HHI, in successful partnership. These newbuilds have the following particulars:

Main Particulars	A14	A18
Length, overall: abt.	368.00 m	400.00 m max.
Length, betw. Perp.:	352.00 m	383.00 m
Breadth, moulded:	51.00 m	58.60 m
Design draught:	14.50 m	14.50 m
Scantling draught:	15.50 m	16.00 m
Flag:	Marshall Islands	Malta
Class: DNV + 1A1, Container Carrier, DG-P, BIS, TMON, BWM-T, E0, NAUT-OC, Recyclable, CLEAN, NAUTICUS(Newbuilding) further extended by LNG preparation and hull stress monitoring		

Both vessel types follow an identical design and outfitting strategy. All of them have been designed and equipped for fuel economy with hull form optimization to UASC's intended operating profile. With all the vessels having their keel laying dates before end 2015, they are IMO Tier II compliant concerning NO_X emissions.

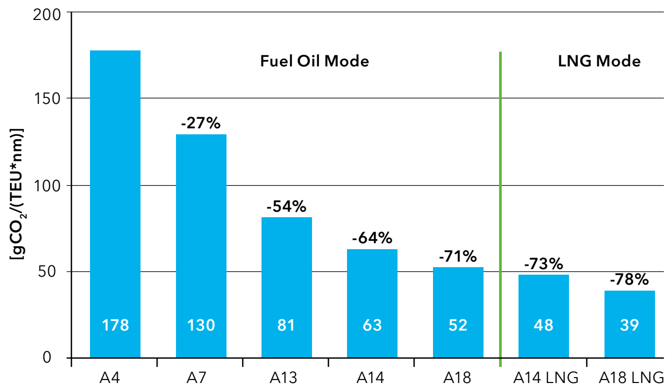
The 11 number A14 class will be propelled by long stroke MAN 9S90ME-C10.2 with an NCR of 32,625 kW, supported by a low load WHRS with PTO/PTI. The average daily fuel oil consumption will be 62.8 ton. The yearly fuel consumption of these11 ships will be 248,000 ton of HFO with a CO_2 output per year of 0.80 million ton. The transport cost per TEU/nm according to UASC profile is 1.53 Cent, with a CO_2 output per TEU/nm of 63.2 gram. This is again a reduction in CO_2 footprint of 22% compared to the A13 vessels.

The 6 new number A18s will operate in alliance with 5 new CSCL vessels in partnership, therefore only the 6 UASC vessels have been evaluated. These will be propelled by long stroke MAN 10S90ME-C10.2 with an NCR of 37,500 kW supported by a low load WHRS with PTO/PTI. The average daily fuel oil consumption will be 71.6 ton. The yearly CO_2 output of these 6 ships will be 0.50 million ton. The transport cost per TEU/nm according to UASC profile is 1.29 Cent, with a CO_2 output per TEU/nm of 52.3 gram, which is 36% below the CO_2 footprint of the A13 vessels.

When the ships are eventually retro-fitted to LNG as fuel, there will be a CO_2 reduction of 25%, a NO_X reduction for these IMO Tier II vessels of 25%, a SO_X reduction of 97% and a Diesel particle reduction of 95%.

The use of LNG as fuel will significantly reduce all emissions to the atmosphere, which may cause harm to people or contribute to the global warming effect. The CO_2 emissions per slot show the following achievements for the global service:

CO_2 EMISSION PER SLOT



The vast reductions, even when comparing to the recent A13 Class vessels, are based on the following essential achievements:

- Hull Form Optimisation by CFD based on UASC operational profile with respect to draughts and speeds
- CFD evaluation and investigations of trim angles
- Extensive Model testing of operating draughts and speeds
- Application of twisted leading edge high performance rudder with rudder bulb
- Use of Becker Twisted Fin Pre-Swirl energy saver
- High performance large diameter slow RPM 5-bladed propeller
- Low resistance high performance underwater paint, e.g. (Jotun X200)
- Resistance and Propulsion has been optimised for minimum fuel consumption
- Waste Heat Recovery System (WHRS) developed especially for low load also
- Shaft Generator/Motor (PTO/PTI)
- AMP-Container (shore connection-cold ironing)
- Energy consumers have been optimised for lowest consumption: Pumps, Fans, LED-Lighting, Air Conditioning, regenerative power of windlasses
- Container intake was optimised according to UASC cargo profile / container mix
- Most extensive Energy Management and Ship Performance Monitoring with transmission of data via satellite to shore base
- Ballast Draught Sea Trials at Delivery of each vessel, Loaded Sea Trials on Design Draught during Maiden Voyage of type-vessel

Challenges related to the application of LNG as fuel compared to existing applications

These new vessels must be most competitive when put into service compared to (still) conventional ships and, moreover, the most competitive in the years to come, while complying with the increasing environmental demands of IMO MARPOL VI concerning emissions of SO_x, NO_x, diesel particles, and CO_2. With the increasing environmental consciousness of global warming by coastal countries, Emission Controlled Areas will certainly extend. UASC has opted for LNG as a fuel rather than investing in scrubbers and SCR's, and with this decision has accepted the role as market leader for LNG as a ship fuel with mega box container carriers and large scale bunkering.

Challenges are related to pragmatic decisions for navigation in ECA only zones or globally, endurance ,suitable LNG tank size, tank construction type and costs, the location of the tank in the ship and economy of retro-fitting, the selection of fuel gas supply system (F.G.S.S.), as well as the position of bunker stations and vent mast for the least loss of precious container stowage space. The further development of efficient bunkering logistics along the trading routes with the availability of adequate LNG bunker quantities and refueling without lost idle time is also a demand.

Technical concept of UASC for A14 and A18 Class vessels

From the retro-fit perspective, it became obvious that the cargo hold directly in front of the engine room would be the most suitable location, with short piping routes to the LNG tank. Further, a type 'B' tank will have a greatest stowage density compared to several smaller cylindrical type 'C' tanks, and thereby have far fewer container slot losses. The Approval in Principle (AIP) for the LNG plant design was obtained from DNV GL through technical cooperation between the UASC Newbuilding Team with HHI shipbuilders, Hyundai Engine & Machinery Division (HHI-EMD) and Japan Marine United Corporation (JMU) for the Self-supporting Prismatic-shape IMO type-B LNG Tank (IHI-SPB Tank). This was officially presented to HHI and UASC during the SMM exhibition in Hamburg in September 2014.

The retrofit concept is based on the fact that the tank will be positioned between the longitudinal hold bulkheads with a safety distance between the outside insulation of the tank to shell being B/10. The tank connection space, the Fuel Gas Supply System rooms and the LNG Bunker Stations are located above the tank. All the requirements follow the latest version of the IMO IGF-Code.

LNG as ship fuel

LNG as a fuel appears commercially most attractive when comparing the expected prices from 2020 of low sulphur heavy fuel oil (LSHFO) or Marine Gas Oil (MGO), and the extensive long term availability of natural gas. For Europe, we compared similar prices between LNG and HFO until 2020, but from 2020 onwards (if not delayed until 2025) we will have to compare the attractive LNG prices with those for higher cost distillates or blends. The still sizeable investment costs for LNG retrofit will achieve very fast pay-back times once the fuel price differences become visible.

LNG is the most environmentally friendly ship fuel. The Table below gives the CO_2 footprint of the different scenarios for the A14 vessel. From Jan. 2015 onwards, the vessels have to run on MGO within the ECA area in Europe and will run on HFO outside the ECA zones. This reference scenario (NO 1) gives the 100% reference with regard to CO_2 emissions. 6.2% of the emissions are related to the ECA operation and 93.8% to the operation outside of the ECA.

Scenario	Fuel consumption until 2020 (0.1% S in ECAs)					Fuel consumption after 2020 (0.5% S world wide)				
	MGO	HFO	LSFO	LNG	Sum	MGO	HFO	LSFO	LNG	Sum
1. Oil fuel alternative (baseline)	6.2	93.8			**100.0**	6.2		93.3		**99.6**
2. HFO only		104.4			**104.4**		104.4			**104.4**
3. LNG @ HFO & HFO - LNG below HFO price	0.3	33.2		52.1	**85.6**	0.3	0.5		74.4	**75.2**

% CO_2 (Case 1. = 100%)

LNG as fuel – the overall CO_2 emissions

1. Vessel runs on MGO in ECAs and on HFO outside of ECAs (6% ECA exposure).
2. Theoretical case that the vessel runs on HFO only.
3. Vessel runs on LNG as much as possible:
   – Until 2020: because LNG is below HFO price but only available in Rotterdam.
   – After 2020: because LNG is cheaper than the 0.5% S fuel oil; LNG is available in Europe and Asia

Until 2020, LNG will most likely be available only at a commercially feasible price. Operation on LNG outside of ECA is only commercially feasible if the LNG is cheaper than HFO, which is unlikely for LNG in Asia. The vessels cannot run the complete round voyage on LNG with one tank filling. Therefore the CO_2 reduction until 2020 is 14.4% compared to the reference scenario (85.6% instead of 100%). Beyond 2020, scenario no. 3 assumes that LNG is available at a price below HFO also in Asia or that the 0.5% S worldwide limit will lead to costs of ship fuel above LNG prices. In this case, HFO and MGO are only used as pilot fuels and the CO_2 emissions are reduced by 24.8% (to 75.2% of the reference case). These calculations consider the effect of the methane slip, which is very low for the high pressure MAN engines.

Total CO_2 emissions include CH4 slip of 12.92 g/MJ (assumption for four-stroke engines with IPCC factor 25)

COMPARISON OF EMISSIONS FROM DIFFERENT FUELS						
	CO_2 equivalent [g/MJ] (Tab 3, DNV-2012-0719)				% CO_2 (HFO=100%)	
Data from DNV No 2011-1449, rev 1 (Tab 16 mainly); DNV NO 2012-0719	% CO_2 compared to HFO (from composition)	Well To Tank CO_2 emissions (WTT)	Tank To Propeller CO_2 emissions (TTP)	Total CO_2 emissions	% Total	% Tank To Propeller (TTP)
Oil fuel (HFO)	100.00	9.80	77.70	87.50	100.00	100.00
Oil fuel (MGO)	96.49	12.70	74.40	87.10	99.54	95.75
LNG (from Qatar used in Europe)	73.93	10.70	69.50	80.20	91.66	89.45
LNG (from Qatar used in Qatar)		7.70	69.50	77.20	88.23	89.45

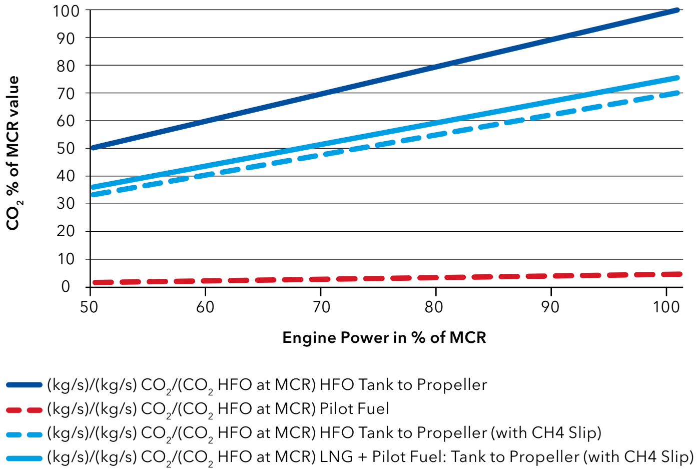
- Main part of emissions result from the combustion in the engine (TTP=Tank To Propeller)
- CO_2 emissions from production are in the same range for oil fuel and LNG (WTT=Well To Tank)
- CO_2 emissions are between 8 to 25% below HFO emission

High pressure two-stroke engines have very low CH4 slip (0.2 g/kWh 1.39 g/MJ CO_2 equivalent with IPCC factor 25 for CH4 effect; Source: MAN in Diesel facts 3/2011, p1 and 2)

It is often claimed that the positive CO_2 effect for methane is reduced if the production of methane is considered. In 2012, DNV performed evaluations of the total CO_2 emissions from a number of fuels, including LNG used in Qatar without transport emissions to the end user and LNG from Qatar and used in Europe. The table above gives the related values and also the values for HFO and MGO. The so called "Well to Tank" emissions (WTT) are related to the production of the fuel while the "Tank to Propeller" emissions are related to the burning process and methane slip effect on board of the ship.

The values in the table demonstrate that the WTT emissions are similar for all fuels and small compared to the TTP emissions. The table also shows that the CO_2 emissions are reduced even if a relatively high methane slip is assumed.

The methane slip is very low for the MAN high pressure two-stroke engines and therefore the CO_2 reduction is higher than given in the table above. The values are given in the figure below as a function of power output. More than 20% of the CO_2 emissions can be saved even if the pilot oil consumption is considered. At low loads, the emission reduction is still approx. 12 %.



- Efficiency of engine: 49%
- CH4 slip: 0.20 g/kWh (2-stroke)
- CO_2 Tank to Propeller, with slip and pilot oil
- Maximum value: 74% of HFO value
- Tank To Propeller CO_2 emissions are dominating
- Well to Tank CO_2 emissions are approx. 10% of Tank To propeller CO_2 emissions
- Maximum reduction in CO_2 with CH4 slip: 26% (74% of HFO value) ▮