E

MARINE ENVIRONMENT PROTECTION COMMITTEE
66th session
Agenda item 4

MEPC 66/INF.4
1 November 2013
ENGLISH ONLY

AIR POLLUTION AND ENERGY EFFICIENCY

Information about the application status of Tier III compliant technologies

Submitted by EUROMOT

SUMMARY

Executive summary:	The approval process at MEPC 65 of amending the effective date of NO_x Tier III emission requirements demonstrated that questions about the maturity of Tier III compliant technologies remain. The objective of this document is to inform the Committee about the status of three major technologies: Selective Catalytic Reduction, Exhaust Gas Recirculation and the use of Liquefied Natural Gas, as identified by the correspondence group in its submission MEPC 65/4/7 as Tier III compliant.
Strategic direction:	7.3
High-level action:	7.3.1
Planned output:	7.3.1.1
Action to be taken:	Paragraph 42
Related documents:	MEPC 66/6/3; MEPC 65/4/27, MEPC 65/4/7, MEPC 65/INF.10 and MSC.285(26)

Introduction

1 The correspondence group identified in document MEPC 65/4/7 three technologies that have the potential to meet Tier III NO_x limits, which are sufficiently mature to be utilized from the beginning of 2016. These technologies are: Selective Catalytic Reduction (SCR), Exhaust Gas Recirculation (EGR) and use of Liquefied Natural Gas (LNG) as a marine fuel. In this respect, EUROMOT agrees with the conclusion of the correspondence group as reflected in document MEPC 65/4/7.

2 Regardless of the outcome of the correspondence group and based on document MEPC 65/4/27, the Marine Environment Protection Committee (MEPC) approved at its sixth-fifth session an amendment of regulation 13 of MARPOL Annex VI to postpone the implementation date for Tier III limits to 1 January 2021. With its decision, MEPC 65 counteracted the demand of industry for a dependable legal framework and for granting

reasonable lead time for the implementation of new technologies. Recent discussions between stakeholders foster EUROMOT's concern that IMO's primacy could suffer and national or local regulatory patchworks might replace global regulations.

3 The objective of this EUROMOT document is to present the current technical status and some critical aspects of Tier III technologies. This document also provides comments on the arguments for a delay of Tier III brought forward by the Russian Federation in document MEPC 65/4/27.

Selective Catalytic Reduction (SCR)

4 SCR technology has been used to reduce NO_x from exhaust gas for many decades. SCR was initially installed to stationary applications and has been implemented to large bore marine diesel engines since the early 1990's. The demand for marine SCR systems remained at a comparatively low level before the year 2000, but has been growing considerably during recent years. The main drivers for installation of SCR prior to the IMO Tier III requirements have been the Norwegian NO_x Fund, various local harbour dues, and fairway fees for NO_x emissions. Also attaining a "green" image has played a considerable role for some ship operators. There are already today hundreds of ships sailing with SCR installed. Actually, SCR technology has largely demonstrated its capabilities.

5 The recent main development areas have been on optimizing SCR use with high sulphur marine fuel oils, and on improvements aimed at creating a compact, cost-efficient, robust and reliable design. Based on the experience, the use of SCR and high sulphur marine fuels along with combinations with exhaust scrubbers and boilers is not technically limited, provided that the design of all components, from the engine through to the whole SCR after treatment system, is integrated accordingly.

SCR system and process overview

6 The SCR system consists of a reducing agent storage tank, a reducing agent feeding and dosing unit, injector and mixer, a reactor with catalyst elements and a control system. The reducing agent used is often a water solution of urea ($CO(NH_2)_2$). Ammonia (NH_3) can also be directly used, but its safety requirements make it less preferable. In the marine sector, the ISO standard for the marine urea solution (40%) is under consideration and is expected to be finalized in 2013-2014.

7 The liquid urea solution is injected into the exhaust duct upstream of the SCR reactor. The main reactions of the process can be seen below; the urea is evaporated and decomposed into isocyanic acid (HNCO), carbon dioxide (CO_2) and ammonia (reaction 1). The isocyanic acid is further decomposed into ammonia and carbon dioxide (reaction 2). The nitrogen oxides of the exhaust are reduced to N_2 and H_2O by the reaction with the ammonia (reactions 3 and 4). Reactions 1 and 2 take place before the SCR reactor, reactions 3 and 4 inside the SCR reactor on the surface of the catalyst elements.

(1) $CO(NH_2)_2 \rightarrow NH_3 + HNCO$
(2) $HNCO + H_2O \rightarrow NH_3 + CO_2$
(3) $4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$
(4) $6NO_2 + 8NH_3 \rightarrow 7N_2 + 12H_2O$

SCR main components

8 The SCR reactor works as a housing for the catalyst elements. As a default, one SCR reactor is installed per engine and exhaust gas pipe. The reactor is a steel casing consisting of an inlet and an outlet cone, catalyst layers, a steel structure for supporting the catalyst layers and typically a soot blowing system in large marine engine installations (figure 1). Compressed air connections for cleaning the catalysts (soot blowing) are installed commonly at each layer. The reactor is generally equipped with a differential pressure transmitter for monitoring the condition of the catalyst elements and a temperature transmitter for monitoring the exhaust gas temperature. The reactor is also equipped with maintenance doors for inspection and servicing/replacement of the catalyst elements. The reactor can be installed either vertically or horizontally on board the ship. With 2-stroke engines the reactor is typically installed before the turbocharger turbine and with 4-stroke engines after turbine.

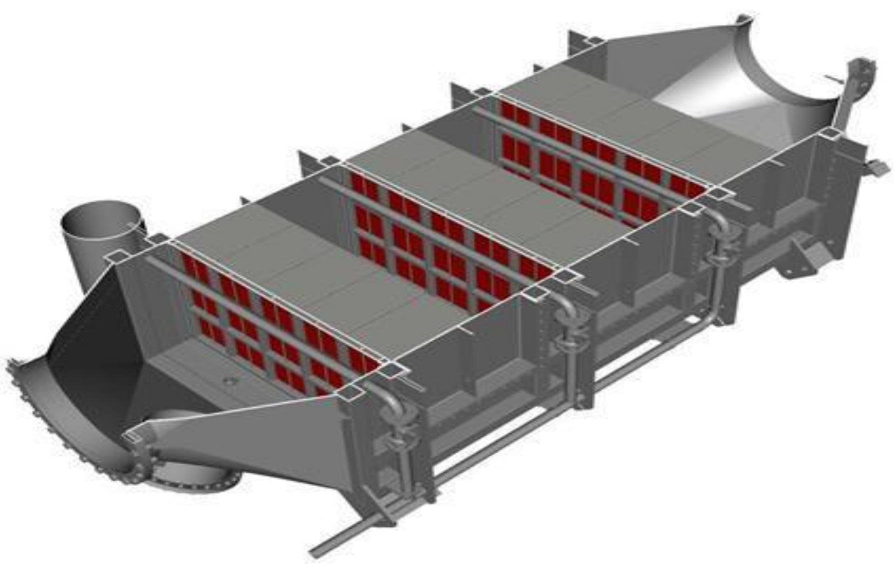

Figure 1: Sectional view of a SCR-catalyst chamber showing the elements in multiple layers

9 The chemical reactions that reduce NO_x occur on the surface of the porous structure of the catalyst elements by means of an active catalyst substance and ammonia, which originates from the injected urea. The catalyst elements are located in steel frame packages within the SCR reactor. The brick-shaped catalyst elements have a honeycomb structure to increase the catalytic surface area. Commercial SCR catalysts are most often titanium dioxide TiO_2-supported vanadium pentoxide V_2O_5 catalysts that contain some tungsten trioxide WO_3 as a promoter. The catalyst can be either coated with catalytically active material or extruded to have a homogenous mixture of the active compound in the catalyst element. The vanadium based SCR catalysts have been largely used in marine and stationary applications due to their high activity within the typical engine exhaust gas temperature window, and their tolerance against sulphur.

10 Although the catalyst is, by definition, basically not consumed, some deactivation of the catalyst elements always occurs. The lifetime of the elements is therefore not endless. Deactivation may be caused by an aging phenomenon, such as a gradual change in the surface crystal structure. Typically, the sintering process is accelerated at abnormally high temperatures. Deactivation can also be caused by the deposit of a foreign material on the

active sites of the catalyst surface. Use of improper lubricating oil containing some deactivating chemicals could cause some irreversible deactivation.

11 The catalyst elements for typical marine fuel applications are normally dimensioned according to the need to meet the expected catalyst lifetime of 3 to 6 years or 12,000 to 24,000 running hours. In addition to the fuel type and initial dimensioning and design, the lifetime depends on the actual operational conditions.

12 Control of the SCR system can be based on a feedforward, feedback, emission modelling control method, or on a combination of these. The control unit can be connected to the engine control system, enabling automatic adjustment of the urea injection based on the operation of the engine. In this case, the SCR unit receives the engine load and speed signal and adjusts the urea dosing accordingly. Alternatively, SCR-control systems including feedback control are under development. This requires that the system be equipped with a NO_x sensor or an analyser system. Moreover, the dosed urea amount can be controlled as well by an emission-model-based control system, taking into account the engine and ambient air conditions.

13 The urea injection is automatically activated when the engine is started and the correct temperature for the urea injection is reached. Correspondingly, when the exhaust gas temperature drops under the design limit, the urea injection is shut off.

14 Mixing of the reducing agent and exhaust gas flow is essential to the performance of the catalyst elements. The mixing duct is installed between the urea injection unit and the SCR reactor and provides time for the urea to transform into ammonia, stir homogeneously before the mixture enters the SCR reactor and reaches the catalyst elements.

15 The urea tank provides storage for the urea (figure 2). Urea is not defined as a hazardous material, but as it has corrosive effects, the tank must be made of a suitable material. The temperature of the tank shall be kept within a correct window between +5°C and +35°C in order to avoid freezing or evaporation.

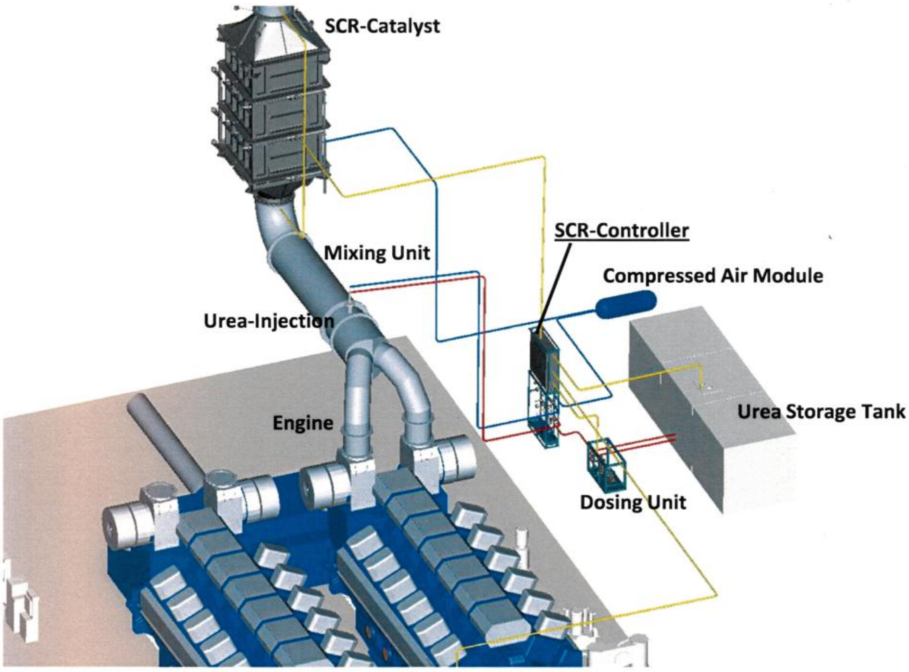

Figure 2: Scheme of a SCR-arrangement on board

Correct exhaust gas temperature window for SCR

16 The temperature window of the SCR process is generally 250 to 500°C. However, the optimum temperature is limited to a narrower window by certain factors.

17 In order to reach a sufficient reaction rate, and to avoid deactivation and fouling due to formation and condensation of some hydrocarbon, ammonium sulphate and bisulphate components, the minimum temperature is typically between 280°C and 340°C. The minimum temperature level is a function of the fuel sulphur content – lower temperature with low sulphur content and higher with high sulphur. Maintaining an adequate temperature window prevents condensation with negative side effects, such as an increasing exhaust back pressure.

18 The upper temperature limit is 400 to 450°C. If the upper limit is exceeded, a higher consumption of the reducing agent can be expected as the ammonia will start to burn, the catalyst lifetime becomes shorter, and at temperatures above 500°C the catalytic material may be damaged. Undesired side reactions also start to occur at higher temperatures.

19 The reaction of SO_2 to SO_3, which is stimulated at higher exhaust temperatures, has to be limited as well. As the SO_3 is a visible aerosol, it results in a blue plume at the stack. This visibility is dependent on, e.g. concentration, light conditions, and background colour. A higher vanadium content of the catalytic material supports this reaction.

20 To summarize, the minimum exhaust gas temperature for urea injection is critical to the SCR system, operating on typical marine fuel sulphur contents, in order to avoid the condensation of ammonia salts and hydrocarbons on the catalyst elements. The maximum exhaust gas temperature is critical to the high sulphur SCR system in order to minimize oxidation of the SO_2 to SO_3 over the SCR reactor.

21 The IMO Tier III NO_x limits are measured on the EIAPP test cycle (paragraph 3.2 of NO_x Technical Code 2008, as amended) and SCR operation is required to be tested on the test bed at 25%, 50%, 75% and 100% engine load points. This means that the engine shall be able to deliver the appropriate exhaust gas temperature in order to allow the injection of urea within this entire load range. It can be achieved by engine modification and tuning. The exhaust inlet temperature to the catalyst is continuously monitored and this signal is processed in the SCR-controller for maintaining the actual temperature within the required range. Variable values, like sulphur content of the fuel and disturbances from ambient conditions can be compensated.

SCR integration to the entire exhaust gas line

22 The SCR must be operated within the correct exhaust gas temperature window. Accordingly, it is therefore necessary to install the SCR before the exhaust boiler and SO_x-scrubber. The temperature interchange in the SCR reactor is negligible and thus does not affect the boiler and scrubber design. However, the system has to be designed in a way that the maximum by engine allowed backpressure for the total exhaust gas line is not exceeded.

Conclusions and comments for SCR to concerns expressed in document MEPC 65/4/27

23 SCR is a feasible and mature technology by which the IMO Tier III NO_x level can be achieved already today. The following can be concluded:

.1 From the chemical reactions the use of urea increases CO_2 from the engine by less than 1% as typical urea consumption is about 6.5 g/kWh (as 100% urea concentration) resulting in about 4.8 kg CO_2/MWh and the diesel engine typical CO_2 emissions are 600 to 650 kg CO_2/MWh.

.2 A properly designed reactor with a soot blowing system has overcome the risk of deterioration caused by fouling of unburned fuel and lubricating oil. Soot blowing is also removing dust and deposits from the catalyst layers. The soot blowing should be periodically activated at all times while the engine is running i.e. the catalysts should be kept clean also when the urea injection is turned off.

.3 The challenge with deterioration caused by sulphur in the fuel has been solved by using catalyst elements that are tolerant against sulphur i.e. no deactivation occurs due to sulphur.

.4 A proper control strategy along with a properly designed urea injector/mixing system has overcome the risk of increased ammonia slip. To achieve the approximate 75% NO_x reduction, that is required for meeting IMO Tier III NOx limits, a feedforward and/or modelling control strategy is suitable. For higher NO_x reduction levels (90 to 95%) a feedback control strategy would be needed.

.5 The challenge of addressing the narrow exhaust gas temperature window has been solved for the entire load range between 25% to 100% of engine-MCR by modification and tuning of the engine.

.6 As the catalyst element exchange interval is long i.e. typically 3 to 5 years, the need for special reception facilities in harbours for used elements are very limited. Used SCR elements are treated as hazardous material and have to be handled in line with the local disposal laws.

.7 SCR investment cost for big marine engines is typically 30 to 100 EUR/kW (40 to 135 USD/kW) and operation cost, while operating inside a NO_x Emission Control Area, represent typically about 7 to 10% of the fuel costs.

Exhaust Gas Recirculation (EGR)

24 EGR technology has been used to reduce NO_x from exhaust gas for decades. Initially developed for the automotive industry and integrated in a vast number of automotive engines, EGR was first considered for marine-2-stroke-development in the early 1980s. Figure 3 indicates milestones in the EGR-history for one engine design.

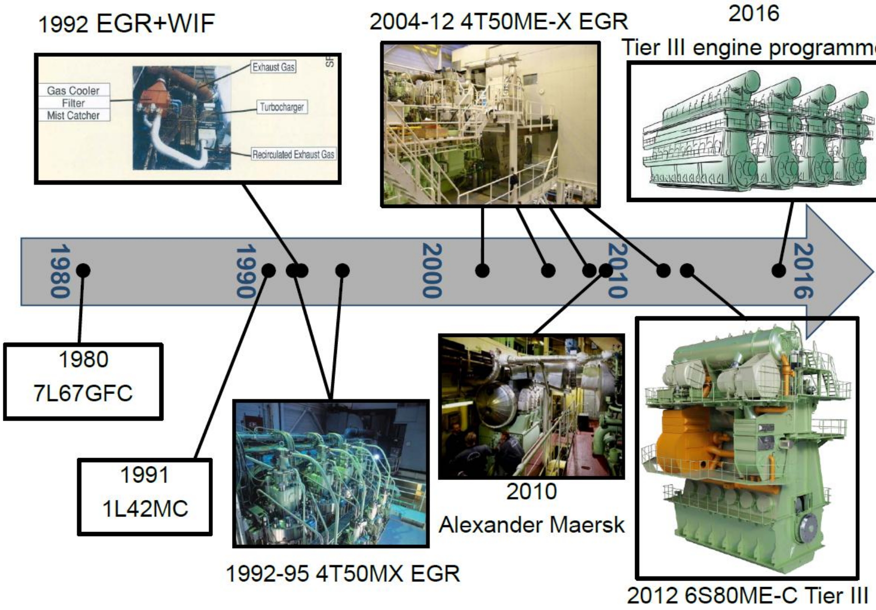

Figure 3: Example of EGR development milestones

25 The stipulated implementation of the Tier III limits boosted the development of the EGR-technology. The required 75% NO_x-reduction was achieved even under use of high sulphur fuel. Further optimization of the process leads to a cost-efficient, robust and reliable design, and compactness permits the integration of the EGR to the engine.

Figure 4: 23 MW low-speed engine with Tier III EGR at Hyundai Heavy Industries test bed 2012

26 Use of EGR and high sulphur marine fuels in combination with exhaust scrubbers and boilers is not technically limited. Consumables used for the EGR scrubbing process can be saved in the SO_x scrubber process as the sulphur only needs to be removed once, as well as certain synergy opportunities on water treatment systems exist.

EGR system and process overview

27 The EGR system of a typical large engine consists of a range of engine integrated components as well as an EGR scrubber water cleaning system with storage tanks for caustic soda (NaOH) and sludge. The main purpose of the water treatment system is to clean the water for a continuous reuse in the EGR scrubber, allowing a controlled dosage of NaOH for neutralization of the fuel sulphur and to clean surplus water to IMO SO_x scrubber criteria. Excess water originated from intake air humidity and from combustion of the hydrogen content in the fuel is removed as liquid in the water mist catcher and drains.

28 The main part of NO_x emissions from a diesel engine is the result of the reaction between oxygen and nitrogen from the intake air, and occurs at high temperatures caused by the combustion. When EGR is utilized, part of the fresh air for combustion is exchanged with the combustion products CO_2 and water vapour. This results in lowered amounts of available oxygen as well as in an increased heat capacity of the combustion air charge. Lower oxygen levels and higher heat capacity, both result in decreased combustion temperatures which reduce the NO_x formation. As marine engines operate on a range of fuels with altering compositions, combustion products with varying qualities and detrimental to the combustion chamber parts, are formed. Cleaning of the exhaust gas before recirculating is therefore mandatory.

EGR main components

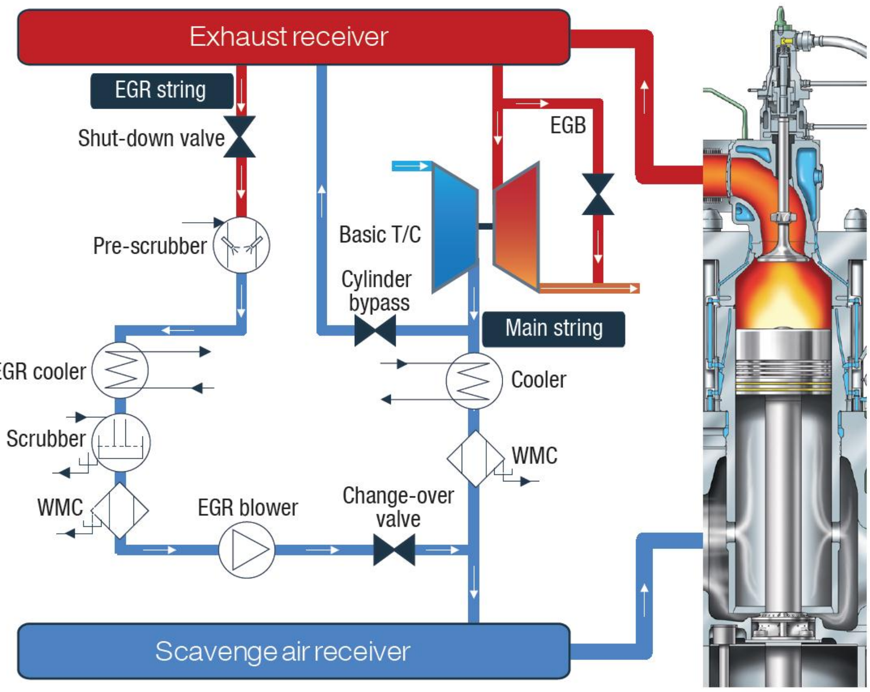

Figure 5: Typical EGR configuration for a low speed engine

29 EGR consists of a range of components new to the engine design. The majority of these components may be integrated into the base engine design. The cleaning of the exhaust is performed in the pre-scrubber and scrubber modules. The recirculated gas is cooled in the EGR cooler. A high-efficiency EGR blower is required to boost the pressure from exhaust receiver pressure to scavenge receiver pressure and to overcome the pressure difference in the EGR line. Turbochargers and water mist catchers perform the same operation as in standard Tier II engines: to boost intake air pressure and to remove condensed water from the air stream. A range of control valves are incorporated to assure safe operation and to enable different engine modes as Tier II with no EGR and Tier III with EGR. Optional low EGR fuel optimized Tier II modes can be realized with this setup.

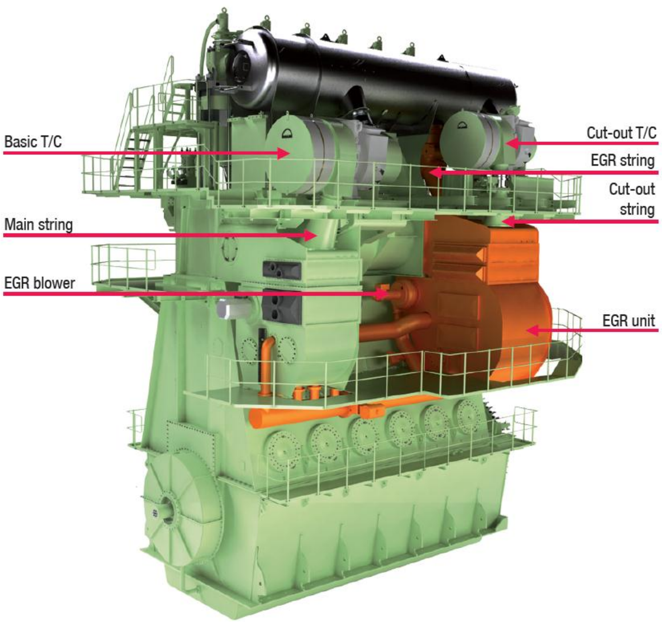

Figure 6: Engine integrated components on a low speed engine with two turbochargers

Conclusions and comments for EGR to concerns expressed in document MEPC 65/4/27

30 EGR is a feasible and mature technology by which the IMO Tier III NO_x level can be achieved already today. The following can be concluded:

.1 EGR is available for all sizes of low speed engines used for ship propulsion. The engine types available cover the vast majority of main propulsion engines used for large ocean going vessels subject to Tier III regulation.

.2 EGR engines are available from more than 20 engine manufacturers[1], many of these among the largest global marine engine manufacturers.

.3 EGR is a well-known technology with many automotive references. In the maritime sector, two EGR engines are in operation as main propulsion

1 Internet: http://www.mandieselturbo.com/0000054/Company/Licensees.html

engine for large container ships[2] operating on HFO and more are under construction[3].

.4 Several engine designers and engine manufacturers have published information on development of EGR technology for marine application[4].

.5 EGR investment cost is typically 45-60 EUR/kW and operating cost, while operating inside a NO_x Emission Control Area, represent typically about 4 to 6% of the fuel costs.

Use of Liquefied Natural Gas (LNG) as a marine fuel

31 Starting with the use of boil-off gas on LNG cargo ships, natural gas has been safely used as a fuel for vessels for almost 50 years. However, it was not before the year 2000 that the first ship (MF Glutra, a car/passenger ferry operating on the Norwegian west coast close to Molde) running solely on LNG as fuel, entered into service. Currently, there are more than 25 ships in operation with roughly 50% of them being car/passenger ferries on duty. Taking the confirmed orders for 2013 into account, there is not only an increase in the total number to as much as 50 vessels but also the range of use expands to applications such as roll-on/roll-off ships and platform supply vessels[5,6].

---

2 Internet:http:/Marine-Power/Low-Speed/MAN-Diesel-and-Turbo-Engine-Clinches-World-Emissions First.html

3 Internet: http://mandieselturbo.com/1017726/Press/Press-Releases/Trade-Press-Releases/Marine-Power/Low-Speed/G-type-Tier-III-Compliant-Engines.html

4 A few examples: Wärtsilä: http://www.annualreport2011.wartsila.com/en/inside-stories/ship- power/tier-iii
Mitsubishi: www.mhi.co.jp/technology/review/pdf/e501/e501055.pdf
MTU:http://www.mtuonsiteenergy.com/fileadmin/fm-dam/mtu_onsite_energy/5_press/technical articles/en/MTU_White_Paper_Exhaust_Gas_Recirculation.pdf

5 P. M. Einang, Gas fuelled ships, CIMAC Paper No. 261, CIMAC Congress 2007, Vienna

6 G.-M. Würsig; LNG for ships – some key elements; DNV technical drop-in seminars at Nor-Shipping 2013, 05.06.2013, Oslo
http://mandieselturbo.com/1018022/Press/Press-Releases/Trade-Press-Releases/Marine-Power/Low-Speed/ME-GI-Order-Kickstarts-andnbsp%3b-New-Era-of-Propulsion.html
http://mandieselturbo.com/1018133/Press/Press-Releases/Trade-Press-Releases/Marine-Power/Low-Speed/ME-GI-Scores-Further-Success%3b-Forward-Looking-Customers-Acknowledge-ME-GI-Benefits.html

Figure 7: Examples of different ship types operating on LNG

MF Glutra – Car/passenger ferry (top left); MS Island Contender – Platform supply vessel (top right); Bit Viking – Tanker (bottom left); MS Stavangerfjord – Cruise ferry (bottom right)

32 The examples given in figure 7 show the trend or pattern for the use of LNG fuelled ships in short sea shipping and vessels used for LNG trading as well as in the oil and gas industry. The reasons can be found not only in the LNG infrastructure but also in the existence of the most stringent emission standards and/or local emission incentive schemes, like the Norwegian NO_x fund, in these waterways. Especially the latter ones have provided remarkably good starting conditions for LNG fuelled engines as their two main characteristics, very low initial emission level and high efficiency (see figure 8), are perfectly addressed thereby.

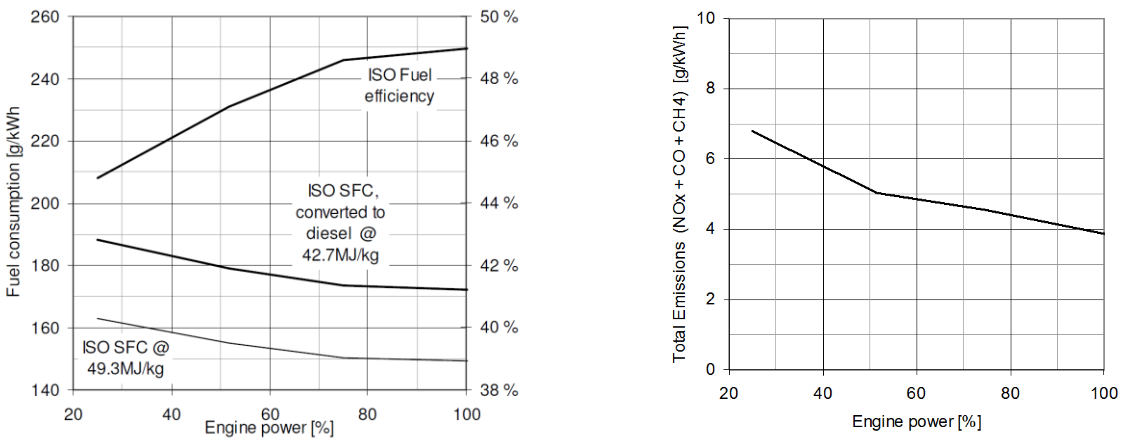

Figure 8: Performance and emission data of a Bergen Engines B3540V12PG engine[7]

[7] E. Vaktskjold et al., The New Bergen B35:40 Lean Burn Marine Gas Engine Series and Practical experiences of SI lean burn gas engines for marine mechanical drive, CIMAC Paper No. 413; CIMAC Congress 2013, Shanghai.

33 As natural gas-fired engines have originally been developed for stationary applications such as power generation, they are most commonly used as generator sets onboard of ships. However, there is also an increasing number of applications using variable speed mechanical drive propulsion engines. In addition, both single/mono and dual fuel gas-fired engines are available in a wide range of makes as two- and four-stroke low-,medium- and high-speed engines with output powers from around 500 kW up to over 35 MW and from manufacturers such as Caterpillar/MaK, MAN, Mitsubishi, Rolls-Royce Bergen Engines and Wärtsilä[8].

Operation mode and design of marine gas engines

34 Reciprocating internal combustion engines using gaseous fuels can be distinguished according to their operation mode into Diesel and Otto engines, the latter one allowing for a further differentiation into spark ignited single or mono fuel gas engines and dual fuel gas engines using a micro pilot diesel flame as ignition source. As the Otto cycle types are more often in marine applications, this paper will focus on these in the subsequent parts and descriptions. Figure 9 shows the principle of operation of a lean burn spark ignited gas engine as well as the typical operating range at air excess ratios (lambda values) of 1.8 and higher, resulting in an increased power and efficiency as well as reduced NO_x emissions.

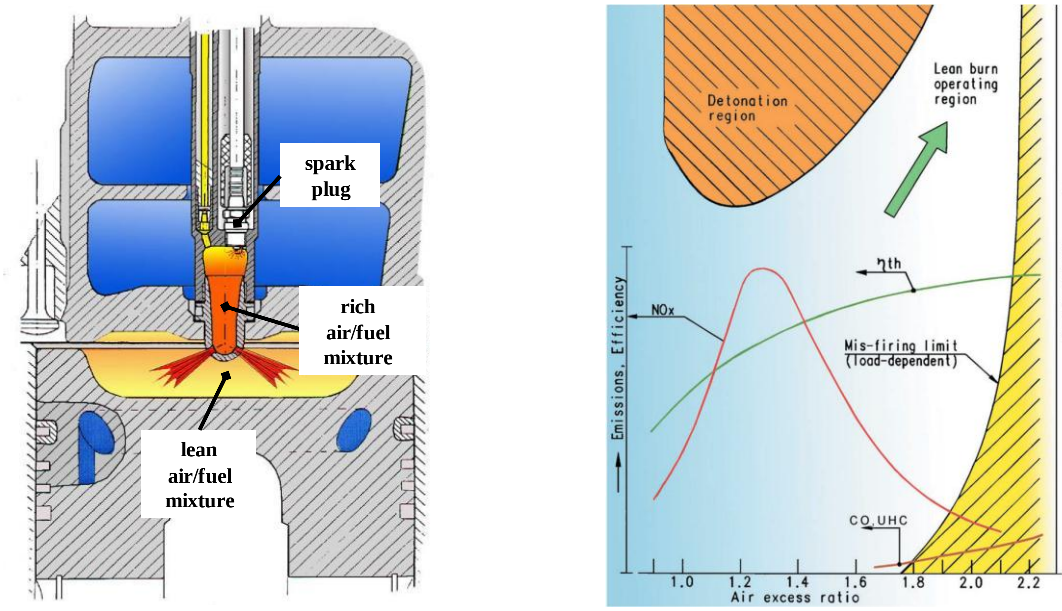

Figure 9: Principle (left) and range (right) of operation of a lean burn spark ignited gas engine

35 The general engine and combustion process of a dual and mono fuel gas engines is almost identical, differing only in the ignition of the lean air fuel mixture in the combustion chamber by either a pilot diesel injection or by a spark ignited rich air/fuel mixture inside a precombustion chamber. Compared to marine diesel engines, gas-fuelled engines are typically equipped with an advanced electronic engine management system ensuring that the operating parameters of the engine are adjusted and optimized to each other. This includes amongst others and if applicable the gas pressures, the air-/fuel ratio (AFR), the fuel rack and air throttle position as well as the ignition timing. The alarm and monitoring part of such a system features typically built-in safety functions to combine safe operation with high availability, engine protection and failure signaling. It includes a misfiring detection system

8 CIMAC WG 17 Position Paper, Information concerning the application of gas engines in the marine industry, July 2013.

based on the analysis of different operational parameters as well as a detection system for knocking combustion, all taking place on an individual cylinder level to keep both, the particular cylinder unit as well as the entire engine, within an ideal and safe operating range.

36 In order to conform to the classification rules for gas-fuelled ships, the engine design has to comply with the requirements for inherently gas safe machinery space or emergency shutdown (ESD) protected machinery space. The first one can be achieved by a design using double walled fuel gas piping in which the annulus between inner (primary barrier) and outer (secondary barrier) pipe is continuously ventilated, with minimum 30 air exchanges per hour, passing the vent air through gas detectors for gas leakage detection. The ESD approach, placing the engine with additional equipment into a gas-tight container with ventilation, monitoring and gas detection capability, can be a viable alternative for small engines. The main advantage with the inherently gas safe approach lies in the absence of any additional requirements compared to the use of traditional bunker fuels. At present, there are no general and mandatory safety regulations available for marine gas-fuelled engines. However, IMO is working on an International Gas Fuel Code (IGF) which is based on the Interim Guidelines MSC.285(86) of 2009 and which is planned for implementation in 2015. Until then, the acceptance has to be obtained from the respective flag States via complying with the specific rules of the approved classification society/societies[9].

Technical considerations for the use of marine gas engines

Safety

37 Stored LNG is natural gas in its liquid form and thus, neither flammable nor explosive. The main challenge here is the right choice of material as normal ship steel becomes brittle in the presence of cold jets of natural gas (roughly -163^{o}C). In order to cause an explosion by leaking natural gas, the temperatures have to be at or above 600^{o}C (w/o the presence of an ignition source) and the mixture with air must be within the flammability limits of 5% to 15% by volume. By contrast, the lower and upper explosion limits for heavy fuel oil are between approximately 0.5% to 5% and the auto-ignition temperature is at about 250^{o}C showing that natural gas does not pose an extra explosion risk. In addition, other risks can be overcome and safety factors been added by good design as well as granting training to the crew. According to the Classification Society DNV[10], there have been no major events, for example, fire and explosion by LNG fuelled engines or ancillaries on any of their classed vessels. In addition, there are also no reports on significant LNG releases in more than 50,000 bunkering operations. Rolls-Royce Bergen Engines has several lean burn gas engines in operation on ferries since 2007. These engines have more than 40,000 operating hours accumulated and do around 35 port calls per day. No reports about safety problems or safety-related stoppages have been received[11].

---

9 Marintek MT22 A12-091, NO_x abatement in marine sector – review of new techniques and their potential, September 2012.

10 G.-M. Würsig; LNG for ships – some key elements; DNV technical drop-in seminars at Nor- Shipping 2013, 05.06.2013, Oslo Winter Graugaard, Green Ship of the future low emission RO PAX, 35th Motorship Conference, 25.04.2013, Copenhagen.

11 Marintek MT22 A12-172, NO_x Fund supported NO_x abatement from 2008 to 2011 User experience, September 2012.

Costs

38 Regarding the costs accompanying the installation of a gas-fuelled engine on a vessel, it has to be strongly distinguished between the capital or investment costs and the operating or running costs. The investment costs are mostly influenced by the ship type, size and LNG storage capacity. Compared to conventional diesel fuelled engines there is a surcharge, which can be assigned to the main functional units as follows: 2% to 4% for the gas engine, 3% to 5% for additional balance of plant items such as gas preparation, piping or controls and the bigger part with 7% to 15% for the LNG storage system. The total costs from roughly 900 to 1300 € per kW (1200 to 1750 USD per kW) installed power as of today are expected to be reduced by 40% to 50% as soon as the design change from vacuum to conventional insulated pressure tanks can be undertaken. From an operational point of view, the use of gas-fuelled LNG-engines is, due to the lower fuel consumption (up to 20%), maintenance requirement and price of LNG compared to HFO already on a competitive level. In emission control areas (ECAs) or regions with emission incentive schemes (like the Norwegian NO_x fund), the payback time can be at or below 2 years (being dependent on such factors as the share of operation inside ECA and MDO-HFO fuel price spread). Thus, the total costs of ownership for operating a gas-fuelled vessel inside an ECA (NO_x and/or SO_x) can be considered to be competitive on a long-term perspective compared to diesel- or HFO-engines with exhaust aftertreatment[12].

LNG infrastructure/bunkering

39 There are several options for ships operating on natural gas to be refuelled, either directly from the LNG terminal, via truck-to-, jetty-to- or ship-to-ship bunker, or by using LNG storage containers. All technology is proven and available and the number of LNG terminals has increased in the course of the growing LNG market world-wide. However, these terminals are not necessarily suitable as bunkering stations and the situation as such is not comparable to that of marine diesel bunkering. Even though there is no established LNG infrastructure, especially in the Baltic Sea, the experience from the operation of gas-fuelled ships on the Norwegian coasts shows that it is possible. The model is based upon a delivery system using trucks to supply small tank farms at the bunkering port or to directly refuel the vessel from the truck[13].

Conclusions and comments for LNG to concerns expressed in document MEPC 65/4/27

40 The use of LNG-fuelled engines on board ships is proven technology. At the time being more than 25 ships with gas technology on board are in operation and about the same amount on order in 2013. The following can be concluded:

.1 Adoption of LNG – supply and – storage on board, including the essential safety equipment, result in higher initial capital costs. Taking into account the lower operation expenses and especially competitive gas fuel prices, the investment can pay off within a few years of operation.

.2 IMOs Sub-Committee CCC is developing the IGF-Code which could enter into force very soon. This will close the regulatory gap and shall give certainty to the stakeholders when improving gas-technology on board ships.

12 C. Winter Graugaard, Green Ship of the future low emission RO PAX, 35th Motorship Conference, 25.04.2013, Copenhagen.

13 G. Høybe, The NO_x fund – outlook and results so far, NO_x-fondseminar 2012; Trondheim.

.3 Several LNG-terminals in the Baltic Sea and North Sea are planned to start-up within the upcoming years, reducing the infrastructural shortcoming. The practice shows that alternative methods exist for supplying vessels, e.g. bunker barges, gas storage containers, trucks etc.

.4 The conclusion of the report on the "Conceptual designs for the conversion of the U.S. Great Lakes Steam Bulk carriers to LNG fueled propulsion" summarizes the situation precisely as follows[14]: "While the use of LNG involves new, higher technology and additional safety considerations, the use of LNG as a marine fuel for non-LNG cargo vessels is now a normal and successful part of marine practice in Norway following the introduction of the ferry **MV Glutra** 12 years ago."

Conclusion

41 Selective Catalytic Reduction, Exhaust Gas Recirculation as well as the use of Liquefied Natural Gas on board ships as a marine fuel are mature technologies. Engine manufacturers are continuing in their efforts to enhance all three techniques by reducing installation expenses and operation costs simultaneously. Several ships are already equipped with Tier III compliant installations. This document provides EUROMOT's clear message to the Committee that Tier III compliant technology is mature for use on board ships, which we kindly request the Committee to note when considering for adoption the approved amendments to regulation 13 of MARPOL Annex VI.

Action requested of the Committee

42 The Committee is invited to note the information provided.

References

Figures 1 and 2 by courtesy of Wärtsilä Vaasa, Finland Oy
Figures 3, 4, 5 and 6 by courtesy of MAN Diesel & Turbo Copenhagen, Denmark
Figures 7, 8 and 9 by courtesy of Rolls Royce Marine AS Bergen, Norway

___

[14] M. G. Parsons, Conceptual designs for the conversion of the U.S. Great Lakes Steam Bulk carriers to LNG fueled propulsion, 30.01.2013.