Marine Environment Protection: A Review of Current Technologies for Ships

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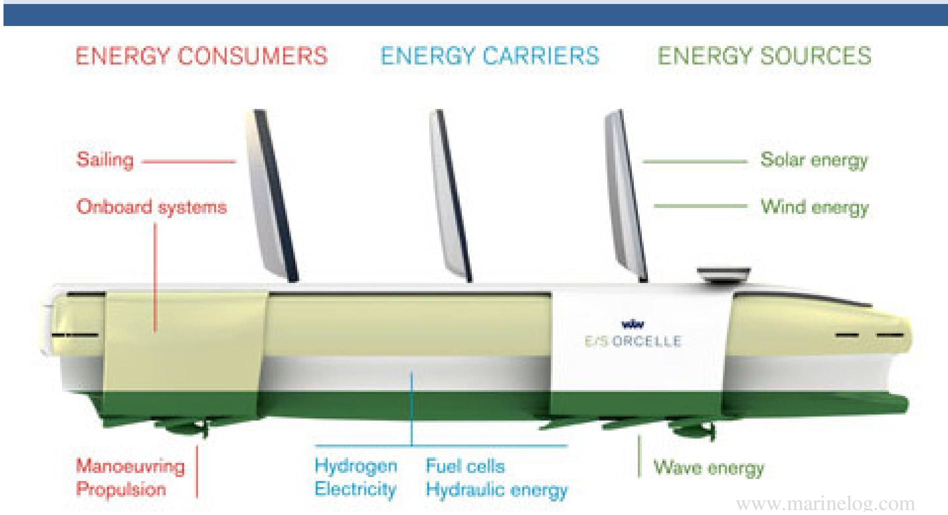

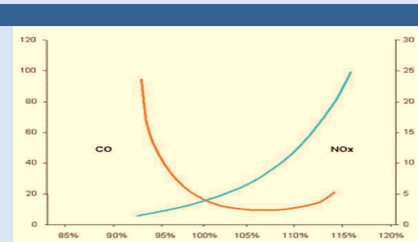

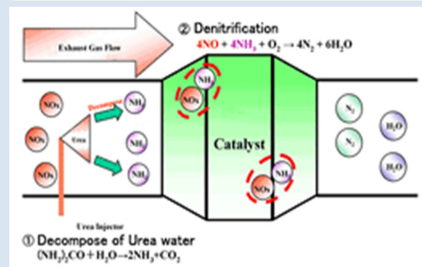

Shipping, the lifeblood of global economy comes with attendant ecological threats from invasive species in ballast water and hulls, harmful compounds in anti-fouling systems, emissions and discharge of harmful substances. This paper reviews the technological requirements among the regulatory, design, construction and management measures by IMO to address the threats.

KEY WORDS
Marine environment, environment protection, MARPOL, anti-fouling, ballast water, emission control, ship technology

INTRODUCTION

Shipping – sustained by over 50,000 merchant ships registered in over 150 nations – is the life blood of the global economy. Seaborne trade continues to expand, bringing benefits for consumers across the world. Estimated at 57 thousand billion tonne-miles in 2017, seaborne trade estimates have quadrupled, from just over 8 thousand billion tonne-miles in 1968 to over 32 thousand billion tonne-miles in 2008. However, expanding trade and increased traffic volumes come with attendant consequences.

The spread of invasive species through ships ballast water is now recognized as one of the greatest threats to the ecological and the economic well-being of the planet. Biofouling of ships hulls is also a significant vector of invasive species. At the same time anti-fouling systems that slowly leach into the sea water, killing barnacles and other marine life that may have attached to the ship persist in the water, killing sea life, harming the environment and possibly entering the food chain. Tributyltin has been described as the most toxic substance ever deliberately introduced into the marine environment. If left unregulated, shipping could be responsible for 17% of global CO_2 emissions in 2050 and represent a major challenge to meeting future target for emissions required to achieve stabilization in global temperatures. Oil pollution, the oldest of concerns, remains one of the most conspicuous forms of damage to the marine environment. Some 2,900 million tonnes of crude oil and oil products is transported every year around the world by sea and of the estimated one million tonnes of oil entering the marine environment annually, at least 45% is believed to come from shipping.

Given the range of ecological threats posed by shipping and its share of more than 90% in the global trade volumes, international shipping forms an essential component of the programme for future sustainable economic growth. Ocean goal, SDG 14 is integral to the United Nations 2030 Agenda for Sustainable Development and central to the International Maritime Organisation (IMO), a specialized agency of the United Nations. Regulatory, design, construction and management measures being adopted by the IMO are playing a key role in preventing and controlling pollution caused by ships and in mitigating the effects of any damage that may occur as a result of maritime operations and accidents.

The canvas of current technological requirements emanating from the IMO regulatory framework for environment protection includes those under the remit of SOLAS Convention, MARPOL Convention and its six annexes for prevention and control of marine pollution, AFS Convention for control of harmful anti-fouling systems on ships, and the BWM Convention for prevention of the potentially devastating effects of the spread of invasive harmful aquatic organisms carried by ships' ballast water.

This review of technological measures adopted by the IMO to prevent pollution from international shipping is by no means exhaustive but purely intended to serve as a broad reference and overview for seafarers and academicians alike.

MINIMIZING TRANSFER OF INVASIVE AQUATIC SPECIES THROUGH SHIPS' BALLAST WATER AND SEDIMENTS

Ballast water is the water specifically taken on board a ship to control trim, list, draught, stability or stresses of the ship. Ballast water from ships is a significant pathway for introduction of non-indigenous species to new environments in many areas of the world, with devastating effects of bio-invasions continuing to increase significantly with expanding trade volumes. Management of ballast water involves a mechanical, physical, chemical or biological process, used either singularly or in combination to remove, render harmless or avoid the uptake or discharge of harmful aquatic organisms and pathogens within ballast water and sediments.

Sediment management is integral to any form of ballast water management. Aquatic organisms can settle out of ballast water and continue to exist in sediments that accumulate in ballast water tanks, surviving for long periods after the ballast water is discharged. Their subsequent discharge in another port or area is likely to cause harm or damage to the environment. Therefore, the ships design and construction should minimize the uptake and undesirable entrapment of sediments, facilitate removal of sediments and provide safe access to allow for sediment removal and sampling. The internal structure of ballast water tanks is to be designed to avoid the accumulation of sediments. (IMO 2012)

Exchange and treatment are the two options available for management of ballast water onboard ships and governed by the D1 and D2 performance standards specified in the Ballast Water Management Convention (IMO 2004).

Ballast Water Exchange

Ballast water exchange (BWE) is currently considered the single-most practical method for ballast water management. Three methods of BWE are detailed in the *Guidelines for ballast water exchange* (G6) (IMO 2017). In the sequential method, a ballast tank is first emptied and then refilled with replacement ballast water to achieve at least a 95% volumetric exchange. In flow-through method, replacement water is pumped into ballast tank allowing water to flow through overflow or other arrangements whereas in dilution method, replacement ballast water is pumped through the top of the ballast tank and simultaneously discharged from the bottom at the same flow rate, maintaining a constant level in the tank throughout the ballast exchange operation. At least three times the tank volume would be required to be pumped through each tank to meet the ballast water exchange performance standard as per regulation D-1 in both, flow-through and dilution method.

Ballast Water Treatment

Treatment methods and technologies have developed rapidly and current options include mechanical treatment (e.g. filtration, separation or destruction), physical treatment (e.g. ultraviolet light, heat treatment, deoxygenation), chemical and electrochemical treatment (i.e. using Active Substances) and combinations thereof (IMO 2016). The biological performance standards of ballast water management systems (BWMS) are specified in regulation D-2 of the Ballast water Convention and summarized in *Table 1*.

Table 1. Performance standards (regulation D-2)

Organism category	Performance standard
Organism, size = 50 µm [(a)]	< 10 viable organisms/ml
Organism, size = 10 & < 50 µm [(a)]	< 10 viable organisms/ml
Toxicogenic *Vibrio cholerae*	< 1 cfu [(b)] /100 ml
Escherichia coli	< 250 cfu [(b)] /100 ml
Intestinal Enterococci	< 100 cfu [(b)] /100 ml

(a) Minimum dimension; (b) cfu: Colony-forming unit

Mechanical treatment. Mechanical treatment is achieved at intake by filtration, cyclonic separation or electro-mechanical separation. Screen and disk filters used at intake reduce sediment and organisms. The smaller the mesh size of the filter screens the more will be the filtration. 50µm or less mesh size is commonly applied in BWMS to achieve the regulatory standard. Most filters are self-cleaning with back flushing cycles. Waste water from the back flush is discharged directly overboard. Together with the resistance of the filter this self-cleaning procedure will form pressure drops and affect the flow rate negatively. Cyclonic separation uses centrifugal forces to separate solid particles from water. However, this is only possible with particles having a specific gravity higher than that of water. Electro-mechanical separation works with a flocculent injection that attaches to the sediment and organisms. Solid particles are then removed by filtration and magnetic separation. Mechanical treatment is often used in conjunction with physical and/ or chemical treatment methods.

Physical treatment. Physical treatment is accomplished by ultraviolet (UV) irradiation, de-oxygenation, cavitation, ultrasound, etc.

UV irradiation is used to eliminate or damage organisms (phytoplankton, zooplankton, human pathogens and bacteria) to such extent that they are not able to reproduce. The effectiveness is dependent on the turbidity and the transmittance rate in water. Most ballast water management systems that use UV irradiation combine it with prior mechanical treatment. Often UV treatment is performed at intake and discharge of ballast water.

De-oxygenation or, removing dissolved oxygen in ballast water affects aerobic organisms (i.e. those that require oxygen). Oxygen is replaced by inert gases (often nitrogen). Although de-oxygenation can be positive in order to prevent corrosion, it is important to use inert gas, which does not react chemically, to avoid any oxidative or hydrolytic effects. De-oxygenation requires longer tank holding time and may not be suitable for ships employed on short voyages.

Cavitation method damages membranes of organisms, ensuring that they are not able to reproduce when discharged into the environment but, is normally avoided in shipping owing to its negative effect on materials. It may be used in controlled manner taking care to protect against the possible effects of hydrodynamic forces and ultrasonic oscillations on materials and the environment, including humans. Cavitation can be applied regardless of voyage length and is often combined with another physical treatment method.

Chemical treatment. Ballast water can be chemically treated by administering Active Substances or Preparations, or by producing Active Substances on board. Commonly used Active Substances are sodium hypochlorite, ozone and hydrogen peroxide, which are expressed as TRO. Sodium hypochlorite can also be generated on board by using an electrolytic cell and having enough salinity in the ballast water. Active Substances should be depleted or be neutralized before discharging into the environment. The Maximum Allowable Discharge Concentration (MADC) of the Active Substances and neutralizing agents is specified in the Type Approval Certificate. Further, installation requires adherence to strict guidelines to prevent the risk of explosion from the accumulation of hydrogen gas, which is a by-product of certain systems, and to avoid exposure to ozone gas.

Combination of treatment techniques. Treatment technologies can be combined and differ in rate of application, holding time, power consumption and effects on other ship equipment or structures. A combination of different treatments can reduce the limitations of an individual technology. Therefore, many ballast water management systems (BWMS) use a combination of two or more technologies, e.g. filtration combined with UV, filtration combined with chemical injection/ electro-chlorination, etc.

Type approval. The Ballast Water Management system is required to be approved by the IMO and the current list of approved equipment is available at BWM.2/Circ.34/Rev.6.

Towards a ballast-free future. Ships of the future are headed to be ballast-free. A hybrid design by *Nobu Su* has retractable duct propellers for low-speed ballast voyages that carry about one tenth of the ballast water typically required. DNV GL has developed two designs, ballast-free *Triality* for VLCCs and low-ballast *Quantum* concept for 6,200teu container ships partially achieved through a wide beam which eliminates need for ballast water for most loading conditions. Shipbuilding Research Centre, Japan has similarly designed a Minimal Ballast Water Ship, *MIBS* and Non-Ballast Water Ship or *NOBS*, also with breadth far wider than conventional ships. Wallenius Wilhelmsen Logistics car carrier design, *Orcelle*, does not require ballast water and does not release any emissions into the atmosphere or into the ocean. The idea combines fuel cells, wind, solar and wave power to propel the vessel. University of Michigan Variable Buoyancy Ship concept for a seaway-sized bulk carrier has three longitudinal trunks per side, in a deepened hull, to provide safe operating drafts whereas the system developed by Yokohama National University employs buoyancy control compartments with exit valves at the bottom. The automatic ballast exchange system for VLCCs, *Aubalex* developed by Vela Marine attaches directly to the ship's existing ballast system at the forward end of the ballast pipeline allowing water into the system at the bow's stem through an access opening in the central pipeline system which is discharged overboard at the tank top within 500 miles of uptake. (Laursen 2016)

PREVENTING NEGATIVE IMPACTS OF BIOCIDALLY ACTIVE SUBSTANCES USED IN ANTI-FOULING SUBSTANCES ON SHIPS

Biofouling is the accumulation of aquatic organisms such as micro-organisms, plants, and animals on surfaces and structures immersed in or exposed to the aquatic environment. Biofouling can include microfouling and macrofouling. Macrofouling involves large, distinct multicellular organisms visible to the human eye such as barnacles, tubeworms, or fronds of algae and microfouling involves microscopic organisms such as bacteria and diatoms and the slimy substances that they produce.

Anti-fouling coating system means the combination of all component coatings, surface treatments (including primer, sealer, binder, anti-corrosive and anti-fouling coatings) or other surface treatments, used on a ship to control or prevent attachment of unwanted aquatic organisms. Anti-fouling system means a coating, paint, surface treatment, surface, or device that is used on a ship to control or prevent attachment of unwanted organisms.

The Guidelines for the control and management of ship's bio-fouling (IMO 2011) identifies niche areas of ships that require an anti-fouling coating system of adequate thickness for optimal effectiveness which are as follows:-

(a) inlet grates and the internal surfaces of sea chests;
(b) housings/ recesses, and retractable fittings such as stabilizers and thruster bodies of bow and stern thrusters;
(c) exposed edges on the hull, such as around bilge keels and scoops, and weld joints;
(d) recesses within rudder hinges and behind stabilizer fins, rudders, rudder fittings and the hull areas around them;
(e) propellers and immersed propeller shafts;

(f) exposed sections of stern tube seal assemblies and the internal surfaces of rope guards;
(g) hull surface under the cathodic protection anode and the anode strap;
(h) housing of retractable pitot tubes; and
(i) inside the pipe opening and accessible internal areas of sea inlet pipes and overboard discharges.

Initial ship design and construction features to minimize ship biofouling risks include excluding, as far as practical, small niches and sheltered areas; rounding and/ or bevelling of corners, gratings and protrusions; providing the capacity to blank off the sea chest and other areas, such as moon pools, floodable docks and other free flood spaces; and keeping of bends, kinks and flanges in seawater piping to the minimum.

Four main types of Marine Growth Prevention Systems (MGPS) are used on board ships in internal seawater cooling systems, sea chests, etc. along with anti-fouling paints – electrolytic system, chemical dosing, ultrasonic system and electro-chlorination. (Anish 2017)

ISO 13073-1.2012 specifies risk assessment method for protecting the marine environment from the potential negative impacts of biocidally active substances used in the anti-fouling system applied to ships. It does not, however, provide a specific test method for evaluating the hazard and toxicity or, usage restrictions of certain substances or, an efficacy-evaluation method for a specific substance. (ISO 2012)

ADDRESSING EXHAUST GAS EMISSIONS FROM SHIPS[1]

A ship should ideally resemble the near-zero emission concept cargo ship designed by Wallenius Wilhelmsen. In fact, it is desirable that every company implements Maximum Technologically Feasible Reduction (MTFR)[2] to achieve its environmental objective. This will considerably decrease the pollutants compared with the baseline, though not eliminate them altogether.[3] Regulations 12-15 of Marpol 73/78 govern the emissions of Ozone Depleting Substances (ODS), Nitrogen Oxides (NOx), Sulphhur Oxides (SOx), and Volatile Organic Compounds (VOCs) from ships. An overview of the available means for reducing the various exhaust emissions from ships ensues.

Carbon Dioxide

CO_2 emission is proportional to the carbon content in the fuel. In a stoichiometric burning, carbon is turned to CO_2 three times its volume and CO due inefficiency of process. Thus, the only effective method to reduce CO_2 emissions is to reduce fuel consumption by applying higher efficiency engines and/ or propulsors. Multiple engines such as the Volvo Penta partnered Concept Ecoship utilising ten diesel engines which drive generators, ensure peak running efficiency at all times.[4] Propulsors consisting of a mechanical Azipull thruster with pulling propeller result in a power saving of about 20%. A bulbous bow typically reduces the required propulsion power between 8% and 15%.

Nitrogen Oxides

Exhaust gas NOx builds up in three ways[5] of which thermal NOx is decisive for total emission. NOx is also related to the engine type[6] owing to its dependence on the burning process. Thus, NOx reduction can be achieved by either altering the engine design factors[7] or by using special devices such as selective catalytic reduction (SCR), exhaust gas recirculation (EGR), emulsion fuel injection, and so on. The most proven techniques – ranked in order of their NOx reduction potential – are SCR,[8] EGR, fuel-water emulsification, timing tuning, and fuel valve and nozzle optimisation.

The NOx/ fuel inverse proportionality[9] poses a challenge. A downstream SCR system resolves the dilemma in diesel engines. Being relatively simple to install even in an existing vessel[10] a detailed description ensues.

[1] An earlier version was published as an article under the title, "Tackling exhaust emissions from ships" in Bluewaters Jul 2012, Volume XIII, Issue 2, pp. 18-21

[2] The US EPA control standards for air toxics refer to it as the MACT i.e. Maximum Achievable Control Technology and subject the major source to the MACT standard under section 112 of the Clean Air Act.

[3] According to the European Commission's Clean Air for Europe impact assessment MTFR will result in an improvement by 2020. For VOC the improvement is limited to 15% whereas, the additional reduction for SOx, NOx and PM will be 17, 8 and 18% respectively.

[4] A comparative study between a combined gas and steam turbine (COGES) plant and a diesel plant on a Panamax-size cruise ship proved that CO emissions are lower for COGES than with the diesel configuration. This is due to the operational profile of the ship and the use of steam in fresh water production.

[5] The three ways in which NOx builds up are by reaction between nitrogen and oxygen of combustion air (**thermal NOx**), reaction between exhaust gas hydrocarbon and combustion air oxygen (**prompt NOx**), and by reaction between thermal bindings in fuel (**fuel NOx**).

[6] A low speed engine with slow burning process and high fuel/ air ratio has the highest emission due to the long time the oxygen has to react with nitrogen.

[7] There have been investigations into NOx reduction by modification of engine design factors viz. verified number of injection holes of fuel atomisers, retarded fuel injection timing, increase of compression ratio and charged air pressure, reduced overlap period of exhaust and inlet valve openings, retarded inlet valve closing timing and adoption of retarded fuel injection timing in low loads.

[8] In addition to NOx reduction, reduction of N_2O and HC is also possible by using SCR system.

[9] Increased fuel consumption also entails increased CO_2 emission.

[10] The investment cost, however, is approximately 25% higher than fitting during new building.

In an SCR (*Figure 1*), NOx is converted to pure nitrogen and water-vapour with no by-products by injecting small amounts of urea solution in water directly into the exhaust gases upstream of the catalytic converter. The urea is vaporised and mixed with the exhaust gases which pass through channels in the catalysts, which are mounted in a specially designed reactor. An oxidation catalyst used in combination with a suitably dimensioned SCR catalyst adsorbs any un-reacted reagent, oxidizes any eventual slip of NH_3 and any residual HC not already oxidised by the SCR catalyser.

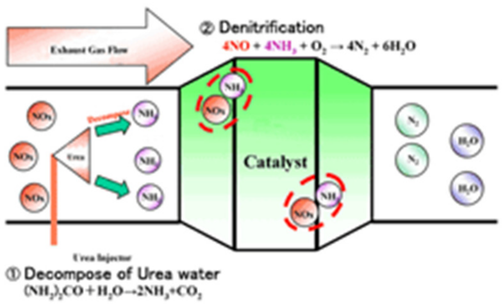

Figure 1. Principle of SCR

An SCR catalytic converter achieves NOx reduction in the range 91–96%,11 depending on loading conditions. A water based system such as direct water injection to cylinder or water fuel emulsion suits a reduction target of 50%. Gas turbines could be equipped with low NOx burners. Even with SCR, bigger engines and low engine number gives lower cost than high number of engines at the same power level.

Sulphur Oxides

All the Sulphur in the fuel remains in the exhaust gases. One feasible method to reduce SOx emission is to use low Sulphur HFO. MDO is a suitable alternative for a green ship.[12] 75% SOx reduction is achieved together with reduced fuel consumption and maintenance requirements by operating on MDO containing less than 1% Sulphur.

Volatile Organic Compounds

These light-end hydrocarbon gas emissions produced when loading tankers constitute methane itself (5-30%) and those that do not contain methane (NMVOCs). Three methods are available to reduce these emissions altogether, viz. absorption into the crude being loaded, liquefaction and subsequent discharge or use as fuel onboard and sequential transfers of tank atmospheres during loading and discharge.

Particulate Matter

Common Rail Injection. Approximately 10-20% of the engine particulate emissions are composed of soot. These emissions are significantly higher during transient engine operations. Load dependant optimisation of injection intensity by means of a common rail injection system and an improved air supply in the lower part load range with a corresponding Engine Management System reduces visible soot peak in the transient range.

High Frequency Induction Heating. PM and NOx are in a trade-off relationship.[13] A potential solution is to install an exhaust gas filter on the exhaust pipe. Conventional re-heating is futile due excessive heating of the filter by heat transfer. High-frequency induction heating burns off PM at 1273 deg K.

Waste Heat Recovery

A waste heat recovery plant significantly reduces the overall level of exhaust emissions. Electrical power about the equivalent of 11% of engine shaft power is recovered and can be employed in either the shaft motor generator or in supplying shipboard services.

ENERGY EFFICIENCY MEASURES

Energy Efficiency Design Index

The Energy Efficiency Design Index (EEDI) is mandatory for new ships and the Ship Energy Efficiency Management Plan (SEEMP) for all ships with effect 1 January 2013 (IMO 2011). The basic idea of the EEDI is to give each and every new vessel a calculable figure that will denote its emissions of CO_2 in relation to the amount of tonne-mile of cargo carried.

To state the EEDI formula in simple terms, the CO_2 emission represents the total CO_2 emission from the combustion of fuel, including propulsion and auxiliary engine sea load, taking into account the carbon content of the fuels in question. If innovative energy-efficient technologies are incorporated on a ship, their effects are deducted from the total CO_2 emission. The energy saved by the use of renewable sources of energy e.g. wind or solar energy is also deducted from CO_2 emissions based on actual efficiency of the systems. The transport work is calculated by multiplying the ship's capacity (deadweight), as designed, by the ship's design speed measured at the maximum design deadweight condition and at 75% of the rated installed main propulsion engines. Denoted in grams of CO emitted per tonne nautical mile (the emissions from taking a tonne of cargo one nautical mile) the figure should be below a relevant benchmark for the specific ship type and size. The bench mark is established from the corresponding average figures of existing ships of specific type and size. (Bose 2012)

Vessels that exceed this benchmark figure and are therefore heavier polluters will not be certified to operate. The figure for the benchmark will then be lowered over time as new technology provides the capabilities for more energy efficient ships to be built. The first iteration of the EEDI is developed for the largest and most energy-intensive segments of the world merchant fleet, embracing 72% of emissions from new ships

[11] Additionally, HC is reduced 83-93% and when integrated with a silencer section, noise is reduced 25-35 dB.

[12] 30-40% savings are accrued in scheduled maintenance cost by burning MDO instead of HFO. Choice of smaller diameter engines for MDO ship than HFO ship benefits lower first cost.

[13] While NOx was reduced, PM increased in studies on reduction of combustion temperature.

and covering oil and gas tankers, bulk carriers, general cargo ships, refrigerated cargo carriers and containerships. The mechanism is non-prescriptive and leaves the choice of technologies in a ship design to the stakeholders, as long as the required energy-efficiency level is attained, enabling the most cost efficient solutions to be used.

The measures encompass improvement of all factors which influence the design and fuel efficiency of a ship such as the use of non-fossil fuels as well as improved propulsive, engine, hull and thermal efficiencies to achieve substantial reduction in fuel consumption and resulting CO_2 emissions on a capacity basis (tonne-mile) (Dingley 2012). Table 2 elucidates a few examples.

Table 2. Technologies for EEDI reduction

EEDI reduction measure	Remark
Optimised hull dimensions and form	Ship design for efficiency via choice of main dimensions(port and canal restrictions) and hull forms
Light weight construction	New lightweight ship construction material
Hull coating	Use of advanced hull coatings/paints
Hull air lubrication system	Air cavity via injection of air under/around the hull to reduce wet surface and thereby ship resistance.
Optimisation of propeller-hull interface and flow devices	Propeller-hull-rudder design optimisation plus relevant changes to ship's aft body.
Contra-rotating propeller	Two propellers in series; rotating at different direction.
Engine efficiency improvement	De-rating, long-stroke, electronic injection, variable geometry turbo charging, etc.
Waster heat recovery	Main and auxiliary engines exhaust gas waste heat recovery and conversion to electric power
Gas fuelled (LNG)	Natural gas fuel and dual fuel engines
Hybrid electric power and propulsion concepts	For some ships, the use of electric or hybrid would be more efficient.
Reducing on-board power demand (auxiliary system)	Maximum heat recovery and minimizing required electrical loads flexible power solutions and power management.
Variable speed drive for pumps, fans etc.	Use of variable speed electric motors for control of rotating flow machinery leads to significant reduction in their energy use.
Wind power (sail, wind engine, etc.)	Sails, fletnner rotor, kites, etc. These are considered as emerging technologies.
Solar power	Solar photovoltaic cells.
Design speed reduction (newbuilds)	Reducing design speed via choice of lower power or de-rated engines.

Computer model to appraise energy efficiency

A variety of emission-reduction solutions are available such as propeller polishing, water flow optimization and hull cleaning, with energy savings far exceeding the upfront capital costs. The provision of information about the effects of these energy efficiency measures improves confidence, in their utilization by international shipping.

IMO has developed a computer-based tool through DNV GL to appraise technical and operational energy efficiency measures for ships. The MS Excel based tool, in its advanced mode, permits the user to define inputs to the appraisal model including costs to identify the optimal energy efficiency (overall net benefit) through adoption of one or more of the specified energy efficiency measures. As the tool supports preliminary investigation and initial assessment of the impacts of technical and operational energy efficiency measures, it could potentially serve as a provisional decision-making tool. The tool can be accessed at **Appraisal Tool** at IMO website http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/.

PREVENTION OF POLLUTION BY OIL, NLS, SEWAGE AND GARBAGE

Several technological measures have been implemented over time for prevention of oil pollution from ships. Tanks are provided exclusively for sludge, segregated ballast and slop. The slop tank is provided with an oil/ water interface detector for rapid and accurate determination of the interface. Cargo tanks are governed by limitations on size and arrangement and fitted with tank cleaning system using crude oil washing. Machinery spaces are equipped with an oil filtering equipment whose discharge does not bear an oil content exceeding 15ppm. Tankers are additionally equipped with an oil discharge monitoring and control system. Accidental discharge in the event of a collision or grounding is protected by a double hull besides a double bottom in the pump room. Further, ships are designed to comply with specified accidental and hypothetical oil outflow performance and, intact and damage stability criteria.

A stripping arrangement in ships designed to carry chemicals and noxious liquid substances (NLS) in bulk ensures that the residue in any tank does not exceed 75 liters.

A sewage treatment plant ensures prevention of pollution by sewage. Alternately, ships are equipped with a sewage comminuting and discharge system or a holding tank for subsequent discharge to facility ashore. A standard discharge connection as specified in the regulations facilitates discharge ashore.

A comminuter or grinder for food wastes and other garbage including paper products, rags, glass, metal, bottles, crockery and other similar refuse comminutes or grounds garbage to size below 25mm.

CONCLUSION

A class notation such as the DNV CLEAN DESIGN,[14] RINA GREEN STAR DESIGN[15] or GL EP[16] together with the Green Award is a reflection of the ship's environmental standards and the company's commitment to the protection of the environment.

[14]The DNV class notations CLEAN and CLEAN DESIGN comprise 3 main areas: emissions to air, operational discharges to sea, and accidental discharges to sea. Accidental discharges are only covered in CLEAN DESIGN, which is a stricter notation.

[15] The GREEN STAR DESIGN notation is awarded to ships which meet requirements of both additional class notations CLEAN SEA & CLEAN AIR which are based on MARPOL Annex I, IV, V, VI requirements.

[16] The EP or Environmental Passport focuses on the following environmental characteristics: engine and incinerator emissions, vapour emission control systems, refrigeration systems, fire-fighting, pollution by oil and noxious liquid substances, pollution by sewage or garbage, ballast water management, anti-fouling systems.

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