Outcome of the 108th Session of IMO's Maritime Safety Committee (MSC 108)

In summary, MSC 108:

1) Adopted amendments to the SOLAS Convention (MPRA Committee).
2) Adopted a revised roadmap for the development of a code to regulate autonomous ships (Maritime Autonomous Surface Ships – MASS) (MASS Committee).
3) Adopted revised Guidelines on maritime cyber risk management (Security Committee).
4) Progressed the development of a safety regulatory framework to support the reduction of GHG emissions from ships using new technologies and alternative fuels, and endorsed the agreement to proceed with the development of training provisions for seafarers on ships using alternative fuels (MPRA Committee).
5) Adopted new training requirements on prevention and responding to violence and harassment in the maritime sector, including sexual harassment, bullying and sexual assault – amendments to the STCW Code adopted (MPRA Committee).
6) Adopted a Resolution on maritime security in the Red Sea area (Security Committee).
7) Noted IMCA's submission on training of DP Personnel (M117).

1 Adoption of Amendments to Mandatory Instruments

Contracting Governments to the 1974 SOLAS Convention adopt proposed amendments to:

A SOLAS chapter II-1

B SOLAS chapters II-2 and V

C The International Code of Safety for Ships Using Gases or Other Low Flashpoint Fuels (IGF Code)

D The International Life-Saving Appliance Code (LSA Code)

E Resolution MSC.215(82) – Performance standard for protective coatings for dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers

F Resolution MSC.402(96) – Requirements for maintenance, thorough examination, operational testing, overhaul and repair of lifeboats and rescue boats, launching appliances and release gear

G Resolution MSC.81(70) – Revised recommendation on testing of Life-Saving Appliances (LSAs)

as further elaborated below.

A Amendments to SOLAS Chapter II-1 Construction – Structure, Subdivision and Stability, Machinery and Electrical Installations

Paragraph II-1 3.6

At its last session the MSC had approved draft amendments to SOLAS regulation II-1/3-4 in relation to new requirements for all new ships other than tankers of not less than 20,000 GT to be fitted with emergency towing arrangements, for adoption at MSC 108 and entry into force on 1 January 2028 (MSC 108/WP.4, Annex 1).

Date of entry into force of the proposed amendments

The draft amendments proposed for adoption at MSC 108 should be deemed to have been accepted on 1 July 2027 and enter into force on 1 January 2028.

B Amendments To SOLAS Chapter II-2 Construction – Fire Protection, Fire Detection and Fire Extinction and Chapter V – Safety of Navigation (Regulation 31 Danger Messages)

At its last session the MSC had approved amendments to SOLAS chapter II-2 in relation to fixed fire detection and alarm systems in control stations and cargo control rooms for adoption at MSC 108 and entry into force on 1 January 2026 (MSC 108/WP.4, Annex 2). Subsequently, the IMO has revised MSC.1 Circular 1456 to incorporate revised unified interpretations of SOLAS Chapter II-2 and the International Code for Fire Safety Systems (FSS Code) and the International Code for Application of Fire Test Procedures (FTP Code). See MSC.1/Circ.1456/Rev.1 attached.

Date of entry into force of the proposed amendments

The draft amendments proposed for adoption at MSC 108 should be deemed to have been accepted on 1 July 2025 and enter into force on 1 January 2026.

C Amendments to the International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels (IGF CODE)

At its last session the MSC had approved draft amendments to the IGF Code for adoption at MSC 108 on provisions for portable dry chemical powder fire-extinguishers (MSC 108/WP.4, Annex 3).

Date Of Entry Into Force Of The Proposed Amendments

The draft amendments proposed for adoption at MSC 108 should be deemed to have been accepted on 1 July 2025 and enter into force on 1 January 2026.

D Draft Amendments to the International Life-Saving Appliance (LSA) Code

At its last session the MSC had approved draft amendments to chapters II, IV and VI of the LSA Code concerning the in-water performance of lifejackets, single fall and hook systems, and lowering speed of survival craft and rescue boats, for adoption at MSC 108 (MSC 108/WP.4, Annex 6).

Date of entry into force of the proposed amendments

The draft amendments proposed for adoption at MSC 108 should be deemed to have been accepted on 1 July 2025 and enter into force on 1 January 2026.

E Draft Amendments to Resolutions MSC.215(82)

At its last session the MSC had approved, as a minor correction, draft amendments to the performance standard for protective coatings for dedicated seawater ballast tanks in all types of ships concerning replacement of the references to "NACE Coating Inspector Level 2" in paragraph 6.1.1 with "AMPP Certified Coatings Inspector" following the change of name of NACE International to Association for Materials Protection and Performance Inc. (AMPP) (MSC 108/WP.4, Annex 9).

Date of entry into force of the proposed amendments

The draft amendments proposed for adoption at MSC 108 should be deemed to have been accepted on 1 July 2025 and enter into force on 1 January 2026.

F Draft Amendments to Resolution MSC.402(96)

At its last session the MSC had approved draft amendments to paragraph 6.2.3 of the 'Requirements for maintenance, thorough examination, operational testing, overhaul and repair of lifeboats and rescue boats, launching appliances and release gear' (resolution MSC.402(96)) emanating from the new ventilation requirements for totally enclosed lifeboats adopted through resolution MSC.535(107), for adoption at MSC 108 (MSC 108/WP.4, Annex 11).

Date of entry into force of the proposed amendments

The draft amendments proposed for adoption at MSC 108 should be deemed to have been accepted on 1 July 2025 and enter into force on 1 January 2026.

ADOPTION OF AMENDMENTS TO NON-MANDATORY INSTRUMENTS

G Draft Amendments to the Revised Recommendation on Testing of Life-Saving Appliances (LSAs) (Resolution MSC.81(70))

At its last session the MSC had approved, in principle, consequential draft amendments to the *Revised recommendation on testing of life-saving appliances* (resolution MSC.81(70)) emanating from the draft amendments to the LSA Code concerning the in-water performance of lifejackets and lowering speed of survival craft and rescue boats, with a view to adoption at this session, in conjunction with the adoption of the associated draft amendments to chapters II and VI of the LSA Code (MSC 108/WP.4, Annex 15).

2 Development of a Goal-Based Instrument for Maritime Autonomous Surface Ships (MASS)

1) Belgium, Liberia and Republic of Korea proposed an oversight mechanism for MASS and associated ROC(s) by introducing the concept of Remote Operation Management (ROM), with associated certification provisions for MASS and ROC.

2) IACS outlined the work it has undertaken to assess, consolidate and standardise the vocabulary relevant to MASS to support the verification and validation of MASS systems.

3) IMarEST and ITF highlighted the need to address properly the human element, and proposed revisions to chapter 7 (Human Element) of part 2 of the draft MASS Code.

4) France and Spain proposed to include provisions in the MASS Code that address how steering and sailing rules of COLREGs would be applied to MASS, in light of the risks associated with the remote operator not being on board the MASS.

5) France proposed a number of matters to be considered in further development of the MASS Code, such as

   a) applicability of STCW Convention requirements for MASS master and crew, and

   b) ILO addressing matters pertaining to remote operators, using a suitable vehicle, such as the Joint ILO/IMO Tripartite Working Group, cybersecurity and connectivity.

6) Germany and Norway proposed to clearly define and to delineate from each other any new terminology that has not been used in IMO instruments before, including Autonomous Navigation System (ANS).

7) IMRF outlined the capabilities and requirements to ensure that MASS meet their obligations under SOLAS and other relevant conventions. It was stressed that it was imperative to provide an effective and reliable emergency response to persons in distress at sea. Consequently, IMRF proposed procedural and technical requirements and functions, both at sea and ashore.

8) France identified the main regulatory, human, technological and organisational recommendations to consider cybersecurity and safe operation of maritime drones in the context of autonomous ships.

9) ISO provided information on the development of a standardisation roadmap and international standards for smart shipping by the Ships and Marine Technology Technical Committee of ISO (ISO/TC 8).

In the ensuing discussion, the following views were noted:

1) The role of the master, including the overriding authority and responsibility for the ship, required further consideration, in particular, in connection with the ROC and responsibility of the Flag State.

2) The goal-based approach to be followed for the Code necessitated clearer functional requirements and should be supplemented with criteria, which could be used to assess compliance, i.e. expected performance in a quantitative manner, where possible and practicable.

3) Hazard identification tables should be provided for the functional requirements, so as to enable an understanding of the rationale of the latter and to be able to revise them in the future.

4) With respect to the establishment of a regulatory framework for ROC operations, as proposed in document MSC 108/4/2, the proposed ROM oversight mechanism was a means to address the Flag State obligation under UNCLOS and to ensure safe MASS operation, although further elements needed to be addressed (e.g. responsibility division between ISM and ROM companies,

ROC minimum manning and maximum number of ships operated by a single operator/ROC); and having the ROC company separate from the IMO company would be difficult to implement.

2.1 Finalisation and Adoption of the MASS Code

1) Finalisation and adoption of the non-mandatory MASS Code is planned for 2028, followed by an experience-building phase.
2) It will not be possible to achieve the 2026 adoption deadline for a mandatory Code. Therefore, the earliest possible entry into force would be on 1 January 2032.

3 Adoption of Revised Guidelines on Maritime Cyber Risk Management

The Committee approved the draft revised Guidelines on maritime cyber risk management (MSC-FAL.1/Circ.3/Rev.3 (MSC 108/WP.10, annex 1) which have been forwarded to the Facilitation Committee for its approval.

4 Outcome of the Working Group on Development of a Safety Regulatory Framework to Support the Reduction of GHG Emissions from Ships Using New Technologies and Alternative Fuels

IMCA attended the Working Group which was requested to:

1) further develop and update the list of alternative fuels and new technologies to support the reduction of GHG emissions from ships (see Table 1 below)
2) continue the assessment for each identified fuel and new technology
3) identify and record safety obstacles and gaps in the current IMO instruments that may impede the use of the alternative fuels or new technologies, and
4) initiate discussions on challenges or difficulties encountered in connection to ship design, shipbuilding, structural adaption in existing ships, and fuel supplying to accommodate new technologies and alternative fuels.

In terms of training, it was agreed that the introduction of alternative fuels and new technologies would automatically add new complexities to the onboard ship systems. Therefore, further consideration should be given to the human element, and the crew training and ship-specific familiarisation. It was agreed that crew members should be required to have ship-specific training when joining a ship, to ensure a safe operation, and that they are aware of the challenges, risks and complexities that these new and emerging technologies and fuels present in normal and emergency situations.

The MPRA Committee will continue to monitor developments of a safety regulatory framework and keep members informed.

Table 1 below shows what fuels/efficiency measures were discussed.

Table 1 – Types of fuels and efficiency measures

Liquid Fuels	Liquefied & Compressed Gaseous Fuels	Power Conversion Systems	Fuel/Energy Storage (storage also addressed within fuel categories)	Improved Efficiency	Emissions Control & Reduction
Fatty-acid methyl ester (FAME)	Ammonia	Fuel Cell Power Installations	Lithium-Ion Batteries	Wind Assisted Power	Ammonia Abatement
Hydrothermal liquefaction (HTL) fuel	Dimethyl Ether (DME)	Fuel Reforming	Supercapacitor energy storage technology	Air Lubrication	CO_2 Abatement – onboard carbon capture and storage (OCCS, OCCU)
Pyrolysis fuel	Ethane	Nuclear Power	Other Battery Technologies	Foils / Hydrodynamic Energy Saving Devices	Methane Abatement
Methyl/ethyl alcohol fuels	Hydrogen – (compressed, liquid, metal hydride)	Solar Power	High-Pressure Composite Cylinders	Low-Friction Antifouling Paints	N_2O Abatement
Hydrotreated vegetable oil (HVO)	Methane/Natural Gas (compressed/CNG, liquefied/LNG)	Wind propulsion	Metal Hydrides	Hull Form Optimisation	Onshore Power Supply
Fischer-Tropsch (FT) diesel	Propane/Butane (LPG)		Liquid Organic Hydrogen Carrier (LOHC)	Optimal Routing	
	Fuel Blends/Mixtures (e.g. hydrogen – natural gas)			Propeller Optimisation and Propulsion Improving Devices	
				Advanced Waste Heat Recovery	

4.1 Liquid Fuels

Liquid fuels include:

- fatty-acid methyl ester (FAME)
- hydrothermal liquefaction (HTL) fuel
- pyrolysis fuel
- methyl/ethyl alcohol fuel
- hydrotreated vegetable oil (HVO)
- Fischer-Tropsch (FT) diesel.

4.1.1 Fatty-Acid Methyl Ester (FAME)

Fatty acid methyl ester is the most common type of biodiesel (mainly used in the road-transport sector). It is produced from bio-oil (triglycerides) and methanol or ethanol, using a transesterification (chemical-conversion) process.

The biomass feedstocks most commonly used to produce FAME in Europe are rapeseed oil, palm oil and used cooking oil. Other feedstocks include soybean (common in the U.S. and South America), corn and coconut (common in the Pacific Islands). Animal-based greases and fats, such as tallow and poultry litter, also are used. Algae, a widely available potential feedstock, can be used to produce FAME through a transesterification process, but the lipids would need to be removed from the algal biomass beforehand.

For diesel engines, FAME is a more suitable fuel than straight vegetable oil. It can be used as a replacement fuel for marine diesel oil and MGO in diesel engines, but this may require engine modifications and approval from the engine manufacturer.

FAME can be considered a drop-in biofuel which can replace up to a certain percentage of fossil fuel oils. FAME has been used in blends with fossil fuel oil, requiring little or no engine modifications.

4.1.2 Hydrothermal Liquefaction (HTL) Fuel

HTL biocrude is a crude-like bio-oil that is produced from biomass using hydrothermal liquefaction technology. The production process uses temperatures between 250 °C and 550 °C, with pressures of 5-25 MPa for 20 to 60 minutes. Catalysts are used to maximise production yields. The water becomes either subcritical or supercritical and acts as a solvent, reactant, and catalyst during the process. The oxygen in the biomass is removed through dehydration or decarboxylation

Unlike the pyrolysis process, HTL can process wet biomass. Non-processed agricultural residues and lignocellulosic biomass are ideal feedstocks because they offer a mix of carbohydrates and low-lignin content to reduce the risk of charring. Algae also can be used as a feedstock.

HTL biocrude has poor compatibility with existing marine engines and is not considered a drop-in fuel. But it may be used in engines in blends with residual fuels. Alternatively, HTL biocrude can be further upgraded, most likely via hydroprocessing, to produce a drop-in MGO or MDO.

4.1.3 Pyrolysis Fuel

Pyrolysis oil is a bio-oil or biocrude made through a pyrolysis process. In the process, biomass feedstock is heated at high temperature (typically between 300 and 650 °C) for a few seconds, in the absence of oxygen. Instead of being combusted, the feedstock decomposes into combustible gases and charcoal. Some gases condense to form pyrolysis oil. There are different processes, which produce different combinations of gases, pyrolysis oil and charcoal. The share of pyrolysis oil is typically 60 to 70%.

Two main types of production processes are slow pyrolysis and fast pyrolysis. In slow pyrolysis, low heating rates and temperatures of 500 to 600 °C lead to a high yield of char and a lower production volume of bio-oil (10 to 15 weight % [wt%]). In fast pyrolysis, biomass is rapidly heated to 400 to 600 °C in an inert atmosphere with a high nitrogen content at ambient pressure. In this type of process, the bio-oil yield is much higher, with a liquid product yield of about 70 wt%, a water content of 15 to 30 wt%, and an oxygen content of 35 to 40 wt%. Fast pyrolysis also can be achieved by using a catalyst (catalytic fast pyrolysis), which improves the quality of the pyrolysis oil, or in the presence of pure hydrogen at higher pressure (hydropyrolysis), which enhances dehydration of the bio-oil and reduces carbon loss and coke formation.

The common feedstocks for producing pyrolysis oil are lignocellulosic and other energy crops. The biomass fed into the reactor must be milled and have a moisture content below 10%, which may require pre-treatment.

The physical and chemical properties of pyrolysis oil depend to a large degree on the used biomass feedstock and process conditions, notably temperature, pressure, heating rate and residence time. The elemental composition resembles that of used biomass.

Pyrolysis oil therefore has a poor compatibility with existing marine engines (ICCT, 2020). It is not a drop-in fuel, and its use would require marine engines and fuel systems to be modified or replaced. Pyrolysis oil has different characteristics than vegetable or petroleum oils; it is acidic and corrosive. Because the viscosity of pyrolysis oil increases during storage (which may lead to incomplete combustion and the particle deposits, causing engine damage), it should not be stored for more than a few months. Also, the water content increases over time, which leads to phase separation phenomena. Marine engines are often equipped with heaters and coolers to perform online control of the viscosity of the fuel, and this system also can be used for pyrolysis oil. Pyrolysis oil is expected to have a lower calorific value than MDO (due to the high oxygen content of 35 to 50 wt%), so the fuel-oil supply system, which includes pumps, pipes, fuel boosters and fuel injectors, needs to be expanded to a higher capacity.

Pyrolysis oil has a high polarity, which makes it immiscible with fossil oils. However, it can be blended with emulsion biofuels to increase thermal efficiency and reduce the output of particulate matter from engines. But given its problematic features, such as high viscosity and corrosiveness, pyrolysis oil should be processed further to make it suitable for use in fuel engines. For example, a catalytic-upgrading process can improve its fuel characteristics and stability enough to produce a drop-in fuel. This process involves hydrogenation (often called "hydroprocessing") and produces a 'hydrogenated pyrolysis oil' that may be suitable for diesel engines.

4.1.4 Methyl/Ethyl Alcohol Fuel

Bio-alcohols

Bio-alcohols are a group of liquid biofuels that can be produced from a range of feedstocks and production pathways. The most relevant bio-alcohols to the marine sector are bio-methanol and bioethanol, both of which can be used to replace distillates. It is acknowledged that methanol or bio-methanol produced from natural gas or biomass, respectively, requires marine engines that are specifically designed or converted to operate on methanol, as well as the relevant fuel-storage tanks and fuel-supply systems.

Bio-ethanol

Bio-ethanol is produced by fermenting sugar and starch crops (glucose-based feedstocks) such as wheat, sugar cane and maize or algae. This type of bioethanol is often referred to as "first-generation" bioethanol. First generation refers to biofuels from food crops, but also to the conversion pathway. The term "conventional bioethanol" is used as well. As the different meanings of these definitions are often used, it is recommended to mention both the fuel and the feedstock.

The three main steps used to produce bioethanol through cellulosic ethanol conversion of lignocellulosic biomass are pre-treatment, hydrolysis and fermentation. Pre-treatment extracts the carbohydrates from the biomass.

Hydrolysis of cellulose and hemi-cellulose produces sugars, which are then fermented. There are different types of hydrolysis (including enzymatic hydrolysis, the use of acids and treatment with hot water or steam) each with their own advantages and disadvantages.

In the hydrolysis process, lignin is a residual product that can be used in gasification or solvolysis to produce another biofuel, such as solvolysis oil.

Bio-ethanol also can be produced from lignocellulosic and algal biomass, using innovative production technologies Bioethanol from lignocellulosic and algal biomass is often referred to as "second generation" or "advanced" bioethanol, as these new production pathways that came after the pathways for bioethanol from sugars and starches. In EU policy "advanced" refers to the feedstocks, but sometimes it also refers to the more advanced conversion technology.

Bio-ethanol could be used as a drop-in fuel for maritime shipping, but as with bio-methanol (in the following section), it will require that the engine, the fuel-containment and fuel-supply systems are designed to operate on ethanol. Although 2-stroke and 4-stroke marine engines operating on methanol are currently in service, there is insufficient information available about the use of ethanol on marine engines.

Bio-methanol

Bio-methanol is produced through the gasification of biomass and a synthesis of the resulting syngas to methanol. In the synthesis step, syngas is pressurised and converted to methanol in the presence of a metal catalyst, followed by the removal of water and impurities. The methanol conversion is done at high pressure and low temperatures (50-100 bar and 220-275 °C, in the catalyst of copper and zinc oxides on alumina).

Lignocellulosic biomass can be used as a feedstock in combination with thermal gasification; wet biomass can be used as a feedstock in combination with supercritical water gasification.

Alternatively, bio-methanol may be produced from bio-methane via reforming, with or without the addition of low-carbon hydrogen.

A limited amount of bio-methanol can be blended with marine diesel for use in marine engines. It also could be used at higher percentages in adapted or multi-fuel engines, or as a 100% methanol fuel in direct-methanol fuel cells.

Large bore 2-stroke or 4-stroke engines using methanol and equipped with separate injection systems for fuel oil and methanol, i.e. dual-fuel (DF) engines, can typically burn methanol containing a percentage of water. It is possible to burn a fuel solution using more than 50% water in some of these engine designs.

However, using a water-in-methanol solution will result in a fuel penalty during combustion, as it costs energy to heat up the water. Furthermore, the energy used to supply or produce the freshwater on board – by freshwater generators, for example – needs to be considered. Further, it should be considered that diluting methanol with water further decreases the calorific value of methanol, which is already low. The calorific value of methanol per unit weight is roughly half the calorific value of conventional marine fuels.

Bio-methanol can be used as a hydrogen carrier (natural hydrogen content) and can be reformed into hydrogen at low temperatures to supply fuel cell power system.

Note: Methyl/ethyl alcohol fuels can also be produced from other feedstocks of hydrogen and carbon.

4.1.5 Hydrotreated Vegetable Oil (HVO)

HVO, is also known as renewable diesel or hydrotreated esters and fatty acids. To produce HVO, feedstocks undergo a process of hydrotreatment and refining, usually in the presence of a catalyst where it is compared to FAME production. In the two-stage hydrotreatment process, hydrogen is first deoxygenated and the double bonds in the hydrogen molecules are saturated to form alkanes. In the second stage, the alkanes are isomerised and cracked.

HVO can be produced from vegetable oils used for cooking oil (UCO) and animal fats (AF), or from the algal lipids extracted from algae.

UCO and AF supply chains operate in accordance with the principles of the circular economy, allowing waste and by-products otherwise destined for disposal to be converted into products with high added value.

Due to hydrotreatment during production, a process similar to fossil-refinery practices, the fuel oils are more similar to petroleum diesel than to FAME. This results in higher quality of fuel that is typically produced meeting diesel fuel standards.

Pure HVO is considered a drop-in fuel and can replace fossil diesel oil in most of the available marine engines.

Can be used as drop-in, mixed with other hydrocarbon-only diesels such as MGO and can be mixed with FAME.

4.1.6 Fisher-Tropsch (FT) Diesel

FT diesel is produced by means of applying Fischer-Tröpsch synthesis to synthesis gas. Routes to manufacture synthesis gas from biomass comprise biomass gasification, currently touted as the most economical route, reforming of bio-methane, and reverse water-gas shift (reacting hydrogen with CO_2).

In gasification, biomass processing produces a synthesis gas (syngas), which is mainly a combination of hydrogen and carbon monoxide. The process takes place at a high temperature (around 900 °C) and pressure, and with a low proportion of oxygen and/or steam-to-gas. It decomposes the biomass into its basic components (CO, H_2 and CO_2). The gas is then cleaned to remove soot and tar. In the FT synthesis process, the syngas reacts over a catalyst and forms carbon chains (CC) of various lengths.

Various biomass feedstocks can be used, including agricultural residues and lignocellulosic (woody) biomass. Types of lignocellulosic biomass include forestry residues, quick-growing woody crops such as miscanthus and willow, and agricultural residues such as corn stover and wheat straw.

FT diesel is a drop-in fuel that can be used 'neat' (i.e. it can fully replace fossil diesel), or can be blended with fossil diesel up to a high percentage without engine modifications.

4.2 Liquefied & Compressed Gaseous Fuels

Liquefied & compressed gaseous fuels include:

- ammonia
- dimethyl ether (DME)
- ethane
- hydrogen (compressed, liquid, metal hydride)
- methane/natural gas (compressed/CNG, liquefied/LNG)
- propane/butane (LPG)
- fuel blends/mixtures (e.g. hydrogen – natural gas).

4.2.1 Ammonia

Ammonia may be used as fuel for fuel cells, internal combustion engines, gas turbines or boilers, with different technology readiness levels. Ammonia is gaseous at the atmospheric pressure and temperature above -33.3 °C, and, according to the literature, the equilibrium points between gas and liquid occur at:

- 10.25 bar at 25 °C
- 11.67 bar at 30 °C
- 15.56 bar at 40 °C
- 20.34 bar at 50 °C.

Therefore, practically ammonia may be stored in a liquified form, either by cooling, pressurisation, or a combination of both. Gaseous ammonia is much lighter than air (0.696 g/m^3 vs 1.225 kg/m^3).

Ammonia is soluble in water (340 g/l at 25 °C) and creates an alkaline solution (pH 11.3 for 1M solution corresponding to about 17 g ammonia per litre of water). It is highly toxic to humans and, according to the National Institute for Occupational Safety and Health (NIOSH), the Recommended Exposure Limit (REL) for ammonia is 25 ppm (averaged over an 8-hour workday), with a maximum allowable Short Term Exposure

Level (STEL) of 35 ppm during any 15-minute period in the day, and an Immediately Dangerous to Life and Health (IDLH) value of 300 ppm.

Ammonia is hard to ignite (minimum ignition energy is generally estimated to be in the range of 12-50 mJ, vs. hydrogen with only 0.016 mJ), has low flame speed (0.07 m/s), and low flame temperature. Such properties, together with the possible dependence of the flashpoint on the method used to determine it (e.g. ISO 1523, ISO 2719, ISO 2592, ISO 3679, ISO 13736), have introduced uncertainty in determining its flashpoint (reported with different values between 11 °C and 650 °C). However, being a combustible gas at standard conditions, most of the methods and definitions for flashpoint are not applicable.

Irrespective of the above, it is consolidated knowledge that ammonia may create explosive atmosphere when its concentration in the air is between 15% (LEL) and 28% (UEL). Therefore, it appears that, regardless of the definition of low flashpoint fuel given in SOLAS regulation II-1/2.30, precautions should be taken in respect of the possible formation of both toxic and explosive atmosphere for its safe use as a fuel. Ammonia is corrosive to some materials, especially copper and its alloys.

For certain situations ammonia vapour may form clouds denser than air. The most common situation which is also of most concern is for releases of pressurised warm liquid ammonia. Here immediate boiling of ammonia will take place when pressure drops from ambient temperature storage pressure to atmospheric. This will lead to flash-boiling in which the expanding ammonia bubbles break the liquid release into a denser-than-air mixture of gas and mist. For situations with sufficient access to air, e.g. releases outdoors, most of the released ammonia may remain airborne and only smaller fractions will rain out, forming a pool on the ground. The ammonia fog evaporation process will cool the air with entrained fog towards -70 °C when all ammonia in the air has evaporated, and for larger releases such dense plumes of ammonia may remain near the ground for kilometres.

4.2.2 Dimethyl Ether (DME)

DME can be produced by the gasification of biomass, followed by catalytic-fuel synthesis. During the gasification process, biomass is broken down into syngas, which can be used to produce DME directly, or the gas can be first converted to methanol as an intermediate product, followed by methanol dehydration.

Thanks to gasification technology, virtually all types of biomass feedstock can be used; lignocellulosic biomass via thermal gasification and wet biomass feedstocks via super-critical water gasification (see the description on liquefied biomethane).

DME can be used as part of a blend with MGO or MDO after limited engine modifications, although the percentage blend is understood to be rather low and is thus self-limiting in terms of CO_2 reduction when considered as a drop-in fuel. However, DME may be used with LPG where it can be considered a drop-in fuel, though blending percentages above 30% still need to be verified and additional storage tanks and fuel-supply systems will be needed. To use DME as a 'neat' fuel requires dedicated engines.

DME may be used as a fuel for internal combustion engines, gas turbines or boilers with varying technology readiness levels.

In the case of DME, the high oxygen content, together with the absence of C–C bonds in the molecules, causes a practically smokeless combustion, which is one of the most important advantages of DME. DME is not affected by hazardous contaminants like sulphur and vanadium. Major benefits from this fuel are the large reduction of CO_2 and NOX emissions and the absence of SOX emissions.

4.2.3 Hydrogen

Hydrogen may be used as fuel for fuel cells, reciprocating internal combustion engines, gas turbines or boilers, but these technologies are still under development. Hydrogen is gaseous at atmospheric pressure and at temperature above -253 °C. Hydrogen may be liquified only at temperature below its critical temperature (about -240 °C). Gaseous hydrogen at ambient conditions is much lighter than air (0.08988 g/m^3 vs. 1.225 kg/m^3).

Hydrogen is very easy to ignite (minimum ignition energy of only 0.016 mJ) and shows the unusual property that the expansion is exothermal (hydrogen is heated by expansion). The flammability/explosivity range of hydrogen in the air is very wide, between 4% (LEL) and 74% (UEL). Hydrogen is typically stored as a compressed gas, or in a liquified form by cooling, or may be stored in metal hydrides at ambient temperature and little pressure (values depending on the specific metal).

Hydrogen, in contact with certain metals, may cause their embrittlement. In the case of some steels operating at elevated temperatures (typically above 400 °C) in a hydrogen rich atmosphere, a phenomenon named High Temperature Hydrogen Attack (HTHA) needs to be taken into consideration as well.

As most materials (metals and polymers) are permeable to hydrogen, hydrogen diffusion in metallic materials is difficult to grasp, owing to the non-uniform compositions and material structures; further research would be necessary to enable safe application of hydrogen in future ship propulsion as well as energy storage and conversion machinery.

In the case of liquefied hydrogen, the low temperatures may cause condensation of air on exposed parts of the containment system, with a possibility of localised oxygen enrichment due to condensation from the atmosphere.

4.2.4 Methane/Natural Gas

Methane may be used as marine fuel both in compressed form or, most commonly, in liquid state. To keep methane liquified at ambient pressure, the storage temperature must be kept below -161.5 °C.

Methane has a high calorific value per unit weight: ~50 MJ/kg, higher than conventional marine fuels (typically 35-40 MJ/kg).

The most common source of methane is natural gas, from which a methane-rich gas can be obtained after purification. This is a fossil methane source. Albeit a fossil fuel, the methane molecule contains four hydrogen atoms and methane is considered an attractive fuel in the interim because its combustion produces less CO_2 per unit energy released than conventional marine fuels.

Alternatively, methane can be extracted from the product of anaerobic digestion of decomposable waste (biogas) and landfill gas (renewable natural gas) or it can be manufactured by reacting CO_2 with low-carbon hydrogen (e-methane).

4.2.5 Propane/Butane (LPG)

LPG may be used as a fuel for internal combustion engine, gas turbines or boilers with varying technology readiness level. LPG is considered to be a clean, energy efficient and portable fuel at an affordable price and possess the advantage of being readily available worldwide.

LPG is a mixture of propane and butane, meaning that in case of leakage, vapours will accumulate in the lower portion of the surrounding area. LPG is a preferred fuel choice of LPG carriers.

LPG is portable and easy to handle; it can be stored in pressurised tanks; it is easily accessible across all terminals in the world, and is more environmentally friendly than other fossil fuels. LPG can offer shorter payback periods, lower investment costs, and lower sensitivity to fuel price scenarios.

The LPG quality is particularly jeopardised during the trans-shipment processes, when this fuel may be exposed to contamination by other substances like water and sulphur compounds. The contaminants present in LPG may cause the corrosion of structural materials in contact with this fuel. The solid products of the corrosion process are mechanical contaminants, which may cause damage to system components.

4.2.6 Fuel Mixtures

A regulatory framework should be developed for mixing fuels to address the safety risks of any fuel mixture. This could take the form of a risk assessment where the properties of each individual component of the mixture would have to be considered in addition to the risks associated with the mixture.

4.3 Power Conversion Systems

Power conversion systems include:

- fuel cell power installations
- fuel reforming
- nuclear power
- solar power
- wind propulsion.

4.3.1 Fuel Cell Power Installations

Fuel cell technologies may take until the late-2030s to reach full commercial maturity. Hydrogen fuel cells are already being piloted and commercial operations are expected in the late 2020s, at least for smaller vessels. The key challenges are scaling up the power output, ensuring reliability for sustained operation, fuel storage/handling and regulatory maturity.

Liquid organic hydrogen carrier (LOHC) technology provides higher density hydrogen storage. Though more recently developed, it is also forecast to commercialise over similar timescales as hydrogen fuel cells, i.e. forecast to be used in commercial operations later this decade.

Methane and methanol fuel cells are forecast to begin commercial operation around 2030 and take a decade to fully mature. Methanol and methane can either be used directly in some fuel cells or reformed on board to produce hydrogen first. Development of both technologies is forecast to be similar. Vessels using methane/methanol for propulsion with engines may provide an opportunity to accelerate commercialisation of methane/methanol fuel cells through use for auxiliary power.

The first vessels to pilot using ammonia directly in fuel cells are expected in the late 2020s. Onboard cracking of ammonia into hydrogen is forecast to commercialise earlier, however. Cracking into hydrogen allows a wider choice of fuel cell types but adds complexity. The full commercialisation of ammonia fuel cell technologies for propulsion is unclear because it depends on how its efficiency, cost, and robustness compares with ammonia engines.

Main fuel cell technologies foreseen for marine applications:

- Low Temperature Proton Exchange Membrane Fuel Cell (LT-PEM)
- High Temperature Proton Exchange Membrane Fuel cells (HT-PEM)
- Solid Oxide Fuel Cell (SOFC).

4.3.2 Fuel Reforming

Fuel reforming is the technology where the primary fuel stored onboard is reformed into a new fuel and by-products in a processor such as a fuel reformer or fuel cracker. The fuel reformer often uses a catalyst and temperature to decompose the fuel, but other technologies are also relevant. Examples of relevant applications are:

- Cracking to decompose ammonia into hydrogen and nitrogen molecules, with the hydrogen fed into a fuel cell or used as pilot fuel in an ammonia engine. Cracking into ammonia to hydrogen allows a wider choice of fuel cell types but adds complexity. Used as pilot fuel, it allows dual-fuel ammonia engines to run without CO_2 emissions.
- Reforming of LOHC to release hydrogen to be used in a fuel cell or hydrogen engine. See fuel-specific LOHC for information on the technical process details.
- Reforming of methanol to hydrogen and CO_2, with the hydrogen used in a fuel cell or hydrogen engine and the pure CO_2 possibly captured in an onboard carbon capture and storage (OCCS) system.

Fuel reforming is included in MSC.1/Circ.1647 as part of the introduction and definitions:

- Certain fuel cell power installations use a *process of fuel reforming* to develop a reformed fuel for use in the fuel cell.
- *Fuel reformer* is the arrangement of all related fuel-reforming equipment for processing gaseous or liquid primary fuels to reformed fuel for use in the fuel cells.

- *Fuel cell power system* is the group of components which may contain fuel or hazardous vapours, fuel cell(s), *fuel reformers*, if fitted, and associated piping systems.
- *Reformed fuel* is hydrogen or hydrogen-rich gas generated in the fuel reformer.
- *Primary fuel* is fuel supplied to the fuel cell power system.

Fuel reformer is expected to be a part of onboard power systems for some coming ship designs. This is due to the lower risk potential when using LOHC or higher energy density and power potential of ammonia storage and ammonia engines.

4.3.3 Nuclear Power

Nuclear energy is the only energy source which is released without combustion, and nuclear reactors, therefore, do not emit greenhouse gases when operating. Nuclear energy provides a clean and reliable energy source and is a significant part of the world energy mix.

The use of nuclear power generation in the shipping industry since the middle of the 20th century, including merchant shipping and Navy, has shown a very high safety standard. No fatalities and few injuries have been recorded from radioactive releases in ocean-going vessels. Classification Societies are working to write new class rules and standards for nuclear-powered ships and the marine and nuclear insurance industries will come together to create a commercial insurance framework for new nuclear maritime solutions.

The nuclear industry has benefited from more than 70 years of operational experience which has been used to provide continuous improvements and enhancements to the safety aspects of nuclear reactors.

New reactor designs are now being built. Molten Salt Reactors combine the fuel and coolant as a liquid, making a meltdown impossible. Gas-cooled and liquid-metal-cooled reactors, where water is replaced as a coolant, avoid the risk of a hydrogen explosion in the event of a meltdown. All these new designs are based on the fundamental "defence in depth" principle for the prevention and mitigation of potential initiating events and applying inherently passive safety systems providing further safety enhancement. The application of new reactor technology to maritime is expected to play a major part towards net zero goals.

4.3.4 Solar Power

Solar power, a fully mature technology on land, has been demonstrated on-board and is expected to develop commercially later this decade. However, its use is expected to be limited by practical constraints, so the extent of possible commercialisation is unclear.

4.3.5 Wind Propulsion

The propelling of a ship through the direct harnessing of wind energy via a 'wind engine' or other device/design aspect.

Definitions:

- *Primary wind-powered ship*: a ship which is designed to maintain service speed most of the time using wind propulsion only [a ship which is designed to use primarily the wind propulsion and the engine as a complementary propulsion].
- *Wind-assisted ship*: a motor ship which is adapted such that in favourable wind conditions, the propulsive power to maintain service speed is reduced from using wind-powered technology [a motor vessel equipped with a wind-powered technology as a complementary propulsion].
- *Wind-powered ship*: Primary Wind-Powered Ships and Wind-Assisted Ships [a ship without engine]

4.4 Fuel/Energy Storage

Fuel/energy storage includes:

- lithium-ion batteries
- supercapacitor energy storage technology
- other battery technologies
- high-pressure composite cylinders
- metal hydrides
- liquid organic hydrogen carrier (LOHC).

4.4.1 Lithium-Ion Batteries

Battery Energy Storage System (BESS) is a rechargeable battery with internal storage specifically designed to store and deliver electric energy into the grid, which includes battery modules, packs, electrical interconnections, means of isolation, cooling system (as appropriate), battery management system and other safety features. Lithium-ion battery technology with electrolyte is the most widespread technology in use for transport applications including maritime.

4.4.2 Supercapacitor Energy Storage Technology

Supercapacitor, also known as electrochemical capacitor, is a type of high-performance energy storage technology, different from traditional capacitors or rechargeable batteries. Supercapacitor features super-fast charging, which allows achievement of rated capacitance by a few minutes of charging.

4.4.3 High-Pressure Composite Cylinders

Composite cylinders such as those used in multi-element gas containers (MEGCs). They usually consist of spirally wound fiberglass cylinders with or without plastic or metal liner.

4.4.4 Metal Hydrides

Thanks to metal bonds, metal hydrides can store hydrogen in metal powder. The absorption of hydrogen by hydrides is an exothermic process, which releases heat. The desorption of hydrogen from hydrides is an endothermic process that requires energy. The thermal management is a key parameter in the process. Reversibility of these processes allows the reuse of metal powder for hydrogen storage almost indefinitely. The hydrogen atoms occupy the interstitial sites of the metallic lattice, which enables a good volumetric density. Metal hydrides are stored at low and constant pressures that increase safety.

Main advantages are:

- high volumetric density
- good safety properties
- long lifetime, no degradation
- density corresponds to compressed hydrogen at approximately 1000 bar(g)
- flow rates can be controlled with temperature
- hazardous area to be considered only on flanges and connections.

Main disadvantages are:

- low mass density.

4.4.5 Liquid Organic Hydrogen Carrier (LOHC)

Liquid organic hydrogen carrier (LOHC) technology provides higher-density hydrogen storage when hydrogen is released onboard from the LOHC to be used as fuel.

4.5 Improved Efficiency

Improved efficiency includes:

- wind-assisted power
- air lubrication
- foils / hydrodynamic energy-saving devices
- low-friction anti-fouling paints
- hull form optimisation
- optimal routing
- propeller optimisation and propulsion improving devices
- advanced waste heat recovery.

4.5.1 Wind-Assisted Power (WAP)

Flettner rotors, which are now in use providing wind assistance on several vessels operating commercially, with commercial development expected to accelerate into the 2030s.

Towing kites and rigid sails have achieved pilot demonstrations, and commercial operation is expected by 2025.

However, not all wind assistance technologies are suited to all vessel types, so until their practicality and effectiveness have been more widely demonstrated, their commercialisation paths are unclear. (Wind propulsion assistance technologies are considered as energy reduction technologies to reduce demand on using fuel for propulsion.)

4.5.2 Air Lubrication

Air lubrication also serves to reduce hull friction. Air lubrication consists of a number of nozzles or mixing chambers that inject air through the hull, creating an air cushion under the bottom and along the sides. The system, in its simplest form, consists of a series of nozzles in the forepart of the vessel and a number of small compressors to provide air. In this form, the drawback is that the air bubbles cannot follow the hull when the vessel is rolling.

4.5.3 Foils / Hydrodynamic Energy Saving Devices

Foils are hull appendages that improve the hydrodynamics of a vessel. Foils may be active or passive and may be retractable. Foils can improve a vessel's hydrodynamics by reducing the wetted surface area, reducing wave motions in a seaway or optimising trim.

The use of foils to improve energy efficiency is experiencing a resurgence – particularly in smaller commercial vessels. Fully lifted hydrofoils are relevant where high speeds are necessary, and ships are light:

- Drag of a foil is directly related to its surface, and surface is linked to the lift that must be created. The heavier a ship, the greater the drag.
- Drag and lift is also related to the square of the speed: a fast ship will need less surface than a slower ship.

Bow foils on larger vessels improve sea-keeping and reduce wave-added resistance through the thrust force generated by the foil as the vessel heaves and pitches. Bow foils may experience large loads and are limited to ships about 50m long, up to now.

4.5.4 Low-Friction Antifouling Paints

Friction-reducing advanced hull coatings are already applied in commercial operation and are expected to reach full maturity before 2030.

Low-friction paints have no biocide and rely on very smooth surface aspect so that marine life cannot adhere. Negative effects on the environment are limited and since friction is lower, energy consumption is lower as well.

Low-friction paints are in general mainly composed of silicone.

4.5.5 Hull Form Optimisation

For a given ship (displacement, arrangement, metacentric height (GM), propeller diameter), a variety of hull shapes can be created. The main goal of hull form optimisation is to find one of the best designs leading to the lowest energy consumption.

Two main areas can easily be optimised: bow and stern.

Depending on the ship use (speed, manoeuvring capabilities, etc), a bulb or a straight bow can be selected. Shape of the stern will also have a strong impact on inflow to the propeller.

Using CFD and optimisation algorithms, it is possible to generate hundreds of hull shapes and to evaluate their performances without spending time and money in towing tanks. Most recent algorithms are able to dig in to the most promising designs and to refine them. Hull optimisation can also be performed on retrofitted vessels: a route change, a speed change or a draught change may have significant impacts on the performances, and a hull optimisation for one set of parameters may not be adapted to another set of parameters.

4.5.6 Optimal Routing

Performance studies performed by the naval architect generally consider calm water conditions. However, depending on the weather conditions and ship characteristics (length, speed), various phenomena may occur, leading to added resistance: slamming, drift, added resistance in wave, windage, excessive heeling.

Weather routing is an essential part of route planning to save energy since software can predict energy consumption for a variety of environmental conditions and is able to consider ETAs.

Most shipping companies use weather routing.

4.5.7 Propeller Optimisation and Propulsion Improving Devices

Propeller optimisation measures include propeller design, propeller polishing, propeller retrofitting.

Propulsion improving devices seek to improve the hydrodynamic efficiency of the propeller or the interaction of the propeller with the hull or the rudder. This may be achieved by adding pre-rotation to the propeller inflow, improving propeller inflow, alleviating flow separation, decreasing eddies or decreasing cavitation caused by propeller-rudder interaction.

Examples of propulsion improving devices include stern ducts, wake equalising ducts (WEDs), pre-swirl ducts (PSDs), pre-swirl stators (PSS), vortex generator fins (VGFs), propeller boss cap fins (PBCFs), and rudder bulbs in combination with propeller caps, twisted rudders, etc.

4.5.8 Advanced Waste Heat Recovery

Advanced waste heat recovery systems recover useful energy from low-grade waste engine (or high-temperature fuel cell) heat. Although relatively recently developed for maritime use, they are starting to be used in commercial operation.

Organic Rankine Cycle (ORC) has been a mature land-based application for decades and changing it to marine application is uncomplicated.

4.6 Emissions Control and Reduction

Emissions control & reduction includes:

- ammonia abatement
- CO_2 abatement – onboard carbon capture and storage (OCCS)
- methane abatement
- N_2O abatement
- onshore power supply / cold ironing.

4.6.1 Ammonia Abatement

Text to be developed.

4.6.2 CO_2 Abatement

Onboard carbon capture and storage (OCCS) is a technology, by which carbon dioxide is separated, either pre-combustion or from the combustion exhaust stream, and temporarily stored on board. The separation process may use a variety of technologies, including absorption/adsorption, membrane gas separation, and others.

The temporary storage of captured carbon can be done as follows but may include other processes:

- as liquefied CO_2 by compression and cooling and stored in low-temperature thermal containers / tanks
- as solid state (calcium carbonate, etc.) and stored in containers / tanks
- as liquid by dissolving CO_2 carbon dioxide in amine solution by means of a CO_2 scrubber.

4.6.3 Methane Abatement

Text to be developed.

4.6.4 N_2O Abatement

Text to be developed.

4.6.5 Onshore Power Supply / Cold Ironing

Shore power is transitioning from commercial operation to commercial development for larger vessels, with international standards in place. However, its high capital costs have been difficult to justify without firm demand, with unclear financial benefit to vessel operators or ports. Favourable policies are starting to be adopted and so it could be widely used (i.e. full maturity) within a decade.

5 Proposed Amendments to the STCW Code

At its last session the MSC had approved draft amendments to section A-VI/1 of the STCW Code to prevent and respond to bullying and harassment, including sexual assault and sexual harassment (SASH), with a view to adoption at this session (MSC 108/WP.4, Annex 12).

Date of Entry into Force of the Proposed Amendments

The draft amendments proposed for adoption at this session should be deemed to have been accepted on 1 July 2025 and enter into force on 1 January 2026.

6 Adoption of a Resolution on Maritime Security in the Red Sea Area

MSC 108 considered document MSC 108/7/2 (co-sponsored by the Industry, including IMCA) providing information on:

1) the impact of the ongoing security situation in the Red Sea and Gulf of Aden on industry
2) the actions taken by the international community, and
3) the proposed actions, including the development of an MSC resolution, condemning the attacks and the promotion of best practice guidance for ships and seafarers preparing to transit, or transiting, the region.

In introducing the document, the Industry stated that since 19 November 2023, merchant ships had been subjected to unprecedented attacks from Houthi forces in Yemen. This endangers the lives of seafarers almost daily, and has resulted in the sinking of the MV Rubymar, the tragic loss of life onboard the MV True Confidence, and the 25 crew members of the MV Galaxy Leader remaining captives of the Houthis.

The Committee condoned the unacceptable unprovoked attacks on seafarers and noted that several IMO Member States are deploying military assets to protect seafarers and maintain freedom of navigation, in particular Operation PROSPERITY GUARDIAN and Operation ASPIDES.

In response to the discussion MSC 108 adopted a draft MSC resolution on the Security situation in the Red Sea and Gulf of Aden resulting from Houthi attacks on commercial ships and seafarers (attached MSC 108/WP.10, Annex 2).

7 IMCA's Code of Practice for the Training and Experience of Key DP Personnel

The Committee noted IMCA's submission document MSC 108/INF.5 providing information on its updated *Code of Practice for the Training and Experience of Key DP Personnel* (IMCA M117), Rev. 3.1, issued in August 2023, which provides a more detailed, comprehensive and up-to-date approach to the training and competence of DP personnel, incorporating advancements in technology, changes in industry practices, and a heightened focus on safety, efficiency and continuous professional development.

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