Seafarers' Section
Maritime Safety Committee

27.05.2022

Safety dynamics of ship's energy sources

The transport industry is focusing on alternative energy sources due to a rise in public willingness and the need to partake in global efforts to reduce harmful emissions. The United Nations Sustainable Development Goals (UN SDGs) have driven political pressure across all sectors including maritime. The International Maritime Organization (IMO), the technical agency under the UN developing safety and security standards for the maritime industry, has also pledged its commitment to decarbonise shipping in an effort to contribute to this united worldwide endeavour.

For decades, the maritime industry has dealt with widely available carbon-based fuels which are operated under normal temperature and pressure.

For the maritime industry, the visions and strategies for environmental protection have been developed and include the use of alternative energy sources. Taking into account the fact that there is more than one type of energy source on a ship for safeguarding propulsion and manoeuvring, especially during emergency operations, it is an urgent safety matter to have a clear understanding of the differences amongst energy sources used. This is a historic transition where numerous uncertainties and risk may emerge.

These developments require further consideration for the safety of the human element who are involved and affected across the whole sector in this transition. The need for safety assurances, proper training, and familiarisation must be recognised and implemented to guarantee that all personnel are able to return back home safe.

Seafarers, firefighting personnel, search and rescue personnel, pilots, dockers, bunkering handling personnel and tugboat personnel are directly and indirectly affected and involved in on-the-job operations throughout this transition.

Companies, authorities, suppliers, protection and indemnity insurance providers, and recognised organisations including unions are to ensure the safety of those mentioned above.

Maritime education and training institutes, medical practitioners, and security enforcing bodies are to ensure safety and security culture is firmly embedded in the whole system.

For all stakeholders, appropriate competencies and establishing a safety culture are essential for health and safety for both the human element and the environment.

Introducing a new type of energy source encompasses the entire life cycle from manufacturing, transporting, bunkering, storage, and energy processing onboard.

To protect human lives in this transition, it is necessary to have a clear vision of the safety dynamics associated with each energy source. This can be accomplished by acquiring the correct knowledge about the energy sources being used and obtaining the proper competencies necessary for the whole operation, including emergency circumstances. Competencies must therefore include knowledge of operations that may include, inter alia, extreme temperatures and pressures, toxicity, corrosiveness and high voltage, all of which can inflict harm and/or accidents.

The purpose of this document is to highlight the imminent need to put in place measures for those involved in direct on-the-job operations and provide recommendations to close the safety and competency gaps that may exist.

When introducing alternative energy sources, the following are crucial:

- **A robust training scheme that guarantees the highest level of safety culture;**
- **appropriate training that covers communication, risk analysis, operation and emergency situations;**
- **knowledge about construction and design and relevant regulations;**
- **adequate fire detection and fire-fighting equipment;**
- **availability of proper lifesaving appliances; and**
- **provisions of adequate personal protection equipment for all personnel.**

Part II

A table who according to the ITF MSC SG TOR

- *Identify technical characteristics of fuels and energy sources which produce less emissions;*
- *Identify hazards related to safety and health and operation, including bunkering and storage;*
- *Identify safety and health issues for lives and cargo on board related to construction and design of a ship; and*
- *Recommendations to close the safety gap.*

Attachments

a) The Scrubber

b) The Fuel Cell

Part II

Safety dynamics of ship's energy sources

Energy	**Characteristics**	**Construction & Design**	**Environmental Effectiveness**	**Fire and explosion risks**	**Health and safety issues**	**Recommendation**
Hydrogen	Storage temperature -253°C Storage pressure 700 Bar boiling point -252.8°C Flash point -252.8°C Energy density 142.0 MJ/kg Energy density table	6 to 10 times more storage space, few bunkering ports Stores tank and Fuel cell shall be on top deck CH2 tank bundle(s), Isolated lines. pressure-relief system artificial ventilation to provide continuous air changes to the tank hold space Pressure regulating unit(s). Fire protection system. H2 detection system.	Virtually zero exhaust emissions But to produce 1 kg hydrogen 48 kWh is needed And Transport using carbon fuel is a challenge	Low density, low ignition energy, wide flammability range, and potential explo siveness. Structural fire protection (insulation towards neighbouring spaces). Safety systems (fire detection, firefighting system, emergency shutdown system).	Bunkering possesses Extreme high pressure Extreme low Temperatures If hydrogen is inhaled in small concentrations it can cause symptoms like headache, nausea, irritation in skin and eye, convulsions. Inhalation of high concentration of hydrogen can cause asphyxiation.	Amendment to IGF Code crew training /competency requirements and amendments to STCW Focus on Ships specific training and Familisation First aid competence Amendments to engine certification requirements, such as NOx Code and MARPOL VI depending on possible local emissions from hydrogen fueled engines. *Five lessons to learn on hydrogen as ship fuel*

Energy	Characteristics	Construction & Design	Environmental Effectiveness	Fire and explosion risks	Health and safety issues	Recommendation
Ammonia	Storage temperature -30 °C Vapour pressure (45°C) 18 Bar boiling point - 33,4 °C Flash point 132°C Energy density 22.5 MJ/kg	4 X more storage space, few bunkering ports Must be stored in a tightly closed container in a well-ventilated place, protected from heat sources, separately from oxidizing agents, fixtures and fittings in copper and brass must not be used in storage rooms and containers. Use explosion-proof electrical equipment. Provide proper storage and packaging to prevent environmental pollution. Install gas detector (s) that provide early warning of leakage.	The energy input required to synthesize ammonia from fossil fuels is given as 7.8, 10.6, and 11.7 MWh/ton ammonia for feedstocks of natural gas (SMR), coal, and fuel oil respectively, or roughly 8-12 MWh/ton ammonia	Explosive limits 15,0–33,6% Fire hazard: Ammonia gas mixed with air can ignite! Containers may explode on heating due to overpressure. At fire or high temperature, nitrous gases (NOx) are formed. Fire-fighting measures: Do not try to extinguish fire in burning gas. Try to stop the gas leak if this can be done without risk - IF THIS IS NOT POSSIBLE, LET THE GAS BURN! Extinguish ambient fire with carbon dioxide (CO2), powder, sand or foam. Do not use a combined water jet. Keep unauthorized persons away from the danger area. Ventilate well.	Corrosive and Toxic.established routines for all handling of ammonia and use of personal protective equipment. Personal protective equipment selected in collaboration with the supplier of such equipment. Have emergency preparedness for handling minor injuries, equipment and routines for first aid. Emergency / eye showers must be available. 100% overview of where the gas will / can go in the event of a possible leak / discharge Well-marked escape routes.	crew training/competency requirements and amendments to STCW Focus on Ships specific training and Familisation First aid competence Amendments to engine certification requirements, such as NOx Code and MARPOL VI depending on possible local emissions from hydrogen fueled engines. *Harnessing ammonia as ship fuel*

Energy	**Characteristics**	**Construction & Design**	**Environmental Effectiveness**	**Fire and explosion risks**	**Health and safety issues**	**Recommendation**
Low Sulphur Heavy Fuel oil (LSHFO)	Room temperature Atmospheric pressure Flash point 61°C Energy density 41 MJ/kg	*As it, but chemical tank and pumps must be extra security and ventilated* *IMO 2020 – A Deeper Study on VLSFO Issues & Challenge*	Reduce Sulphur oxides (SOx) But increase toxid Chemicals and plastic *IMO 2020 – cutting sulphur oxide emissions*	Sulfur removal requires toxic chemical additives that are in themselves harmful to both machinery and humans, as well as requiring more maintenance	The oil is toxic to humans as one of its major components will be a mixture (as much as 30-50%) aromatic polyaromatic hydrocarbons (PAHS) of various sorts, all of which are highly acutely and chronically toxic to people and marine life. If not removed from the marine environment, any remaining oil will take a long time to break down and become small sources of long-term chronic ecotoxicity. *Why Toxic VLSFO 'Frankenstein Fuel' Is Such A Danger For The Planet*	Accurate data sheets - Protective equipment Mandatory measures to enhance the safety whit use of fuel oil, and avoid criminalization's Reporting confirmed cases to IMO Actions against oil fuel suppliers that have been found to deliver oil fuel that does not comply with minimum flashpoint requirements Documentation of the flashpoint of the actual fuel batch when bunkering SOLAS requirements on flashpoint. Guidelines for ships to address situations where they have indicative test results with flashpoint requirements Measures related to oil fuel parameters other than flashpoint

Energy	Characteristics	Construction & Design	Environmental Effectiveness	Fire and explosion risks	Health and safety issues	Recommendation
Marine Gasoline Oil (MGO)	Room temperature Atmospheric pressure Flash point 65°C Energy density 45.3 MJ/kg	Determination of differences in fuel properties between biofuels and fossil fuel equivalents, plus necessary changes to fuel storage and handling arrangements and engines.	Toxic to aquatic life with long lasting effects. Be aware of toxic chemical additives	Upper/Lower Flammable Limits UEL: 7.0 LEL: 0.6	May be fatal if swallowed and enters airways. Causes skin irritation. Harmful if inhaled. Suspected of causing cancer. May cause damage to organs through prolonged or repeated exposure. Toxic to aquatic life with long lasting effects.	Protective equipment Safety Data Sheet
Biofuel	Room temperature Atmospheric pressure Flash point 150°C Energy density 38 MJ/kg	Same as MGO *Use of Biofuels in Shipping*	Burn cleaner than fossil fuels, do not produce sulfur or aromatics, but still emit greenhouse gases such as carbon dioxide, According to a report from the National Renewable Energy Laboratory biodiesel produces 78.5 percent fewer carbon dioxide	Same as MGO	Same as MGO and does not meet the applicable criteria for PBT (Persistent, Bioaccumulative and Toxic) or vPvB (very Persistent and very Bioaccumulative).	Protective equipment Safety Data Sheet Be aware of toxic chemical additives

			emissions than petroleum diesel. In addition, biofuels act as carbon washers as they grow - they capture carbon. When you take into account both the reduced emissions and the carbon capture factor, this fuel is environmentally friendly if it can be used clean and looks away from the fact that food is used in production.			
						

Energy	**Characteristics**	**Construction & Design**	**Environmental Effectiveness**	**Fire and explosion risks**	**Health and safety issues**	**Recommendation**
LIQUEFIED **N**ATURAL **G**AS	Storage temperature -162°C Atmospheric pressure Vapour pressure 0.01bar Flash point -188°C Energy density 55.0 MJ/kg **LNG** is a colourless and odourless liquid that contains 85-95% methane with trace amounts of ethane, propane, butane and nitrogen.	LNG bunkering infrastructure is continually improving, with fuel already available in most major shipping hubs. Storage tanks on deck Evacuation valve with pipe high above the ship's highest point Gas tight rooms Sniffers Double pipes Enclosed engine room Special isolated tanks	Complete removal of Sox, 30% less CO2 than fuel oil, reduces nitrogen oxide emissions, does not emit soot, dust or fumes, and produces insignificant amounts of sulfur dioxide, mercury, and other particulates compared to other fuels. But release methane, which is the dominant component in natural gas, and is 20% danger GHG. In addition methane reacts in the atmosphere and forms, among other things, tropospheric ozone which is harmful to both health and the environment.	LNG is highly flammable and explosive substance with ignition point of 595 °C, rapid flame propagation, large mass burning rate about 2 times more than gasoline, high flame temperature, so the burning is of strong radiant heat, easy to form large area of fire, with characteristics of recrudescence, re-explosion and difficult to stamp out. Structural fire protection (insulation towards neighbouring spaces). Safety systems (fire detection, firefighting system, emergency shutdown system).	Bunkering prosses is very danger Roll over The main hazards handling LNG are fire and explosion, cryogenic freeze burns, embrittlement of metals and plastics, and confined spaces hazards.	Use IGF Code On hands training Simulator training **Familiarization** Protective equipment First aid competence Guidance on LNG Bunkering

Energy	**Characteristics**	**Construction & Design**	**Environmental Effectiveness**	**Fire and explosion risks**	**Health and safety issues**	**Recommendation**
Liquefied Petroleum Gas	Storage temperature -42°C Atmospheric pressure Vapour pressure (27°C) 6.4 bar Flash point -104°C Energy density 47.2 MJ/kg The biggest difference between LPG vs natural gas is that they are different gases, as LPG is propane ($C3H8$) vs natural gas, which is methane ($CH4$). LPG-propane is not natural gas. LPG-propane is a product of natural gas processing, as it is refined from the raw natural gas that comes out of the well and is also referred to as one of the natural gas liquids – NGL.	LPG is colourless and its density as a liquid is approximately half that of water. If LPG is spilt on water, it will float on the surface before vaporising. The liquid has approximately 1 /250th of the gas volume. The gas or vapour is at least 1.5 times as dense as air and does not disperse easily. It will end to sink to the lowest possible level and may accumulate in cellars, pits, drains or other depressions	Reduces sulphur oxide emissions by 97% compared with HFO or ULSFO and lowers nitrous oxide emissions by around 20%. LPG is nontoxic, not only making it safer and easier to handle, but also protecting soil and water from harmful toxins, in case of accidental leaks or accidents at sea. could LPG be the marine fuel for the future?	LPG forms flammable mixtures with air in concentrations of between approximately1.8% and 9.5%. It is a fire and explosion hazard if stored or used incorrectly. If LPG escapes into a confined space and is ignited, an explosion could result. If an LPG vessel is involved in a fire, it may overheat and rupture violently giving an intensely hotfireball and may project pieces of the vessel over considerable distances. Structural fire protection Safety systems (fire detection, firefighting system, emergency shutdown system).	Eye: irritation from vapour. Irritation and freezing if liquidenters Skin: Liquid can cause irritation and frostburn if in contact. Inhaled: May cause irritation to respiratory tract. Moderate exposure may cause headaches or dizziness. Elevated exposure may cause unconsciousness and respiratory arrest by diluting the oxygen concentration in air below the level necessary to support life; it can act as an asphyxiant. May affect the heart and nervous system.	Use IGF Code On hands training Simulator training **Familiarization** Protective equipment First aid competence *Guide for LPG Marine Fuel Supply*

Energy	**Characteristics**	**Construction & Design**	**Environmental Effectiveness**	**Fire and explosion risks**	**Health and safety issues**	**Recommendation**
Liquefied Ethylene Gas	Atmospheric pressure Flash point -136,6 °C Energy density 20 MJ/kg autoignition temp: 490°C	Same as LNG/LPG	Ethane as a marine fuel has similar environmental benefits to LNG	Same as LNG/LPG flammable limits LEL 2.7 % UEL 36 %	Same as LNG/LPG	Same as LNG/LPG
Ethanol	Room temperature Atmospheric pressure Flash point 14°C Energy density 19.9 MJ/kg	2,5 X more storage space, few bunkering ports Methanol and ethanol are both colourless, flammable liquids. Methanol is the simplest of alcohols and is widely used in the chemical industry. It can be produced from many different feedstocks, both fossil and renewable, with the majority produced from natural gas.	Clean-burning, no sulphur, can be produced from renewable feedstocks. Emissions of both methanol and ethanol from combustion in diesel engines are low compared to conventional fuel oils with no aftertreatment. Particulate emissions very low, nitrogen oxide emissions lower than with conventional fuels, depend on the combustion concept and temperature. Very small amount of sulphur oxide emissions depend of the pilot fuel.	Extremely flammable liquid and vapor. Ethanol is a flammable colorless liquid; a polar solvent that is completely miscible in water. It is heavier than air, and has a wider flammable range than gasoline, with a Lower Explosive Limit (LEL) to an Upper Explosive Limit (UEL) range of 3.3% to 19%. . Ethanol is still considered a flammable liquid in solutions as dilute as 20%. with a flash point of 36°C. At colder temperatures (below about 10°C), the vapor pressure of ethanol is outside the flammable range.	fatal if swallowed and enters airways Suspected of causing blood cancer if repeated over-exposure by inhalation and/or skin contact occurs. May cause damage to liver, kidneys and nervous system by repeated or prolonged inhalation or skin contact. Causes eye irritation. Can be absorbed through skin. Repeated or prolonged skin contact can cause irritation and dermatitis	Safety Data Sheet Protective equipment Amendment to IGF Code crew training /competency requirements and amendments to STCW Focus on Ships specific training and Familisation First aid competence

Energy	**Characteristics**	**Construction & Design**	**Environmental Effectiveness**	**Fire and explosion risks**	**Health and safety issues**	**Recommendation**
Methanol	Room temperature Atmospheric pressure Flash point 12.8°C Energy density 31.1 MJ/kg	2,5 X more storage space, few bunkering ports Extreme danger of starting fire	Both methanol and ethanol dissolve readily in water, are biodegradable, and do not bioaccumulate. They are not rated as toxic to aquatic organisms. Study on the use of ethyl and methyl alcohol as alternative fuels in shipping	Whether in liquid or gaseous form, methanol is highly flammable. Gaseous methanol molecules can travel quite a distance. This could potentially spread fires in other places. Methanol containers can explode if they're not sufficiently insulated or protected. When in contact with a platinum-blank catalyst, methanol can also ignite. Structural fire protection (insulation towards neighbouring spaces). Safety systems (fire detection, firefighting system, emergency shutdown system).	Toxid Methanol may cause birth defects of the central nervous system in humans. Chronic poisoning from repeated exposure to methanol vapor may produce inflammation of the eye (conjunctivitis), recurrent headaches, giddiness, insomnia, stomach disturbances, and visual failure.	Safety Data Sheet Protective equipment Amendment to IGF Code crew training /competency requirements and amendments to STCW Focus on Ships specific training and Familisation First aid competence

Energy	Characteristics	Construction & Design	Environmental Effectiveness	Fire and explosion risks	Health and safety issues	Recommendation
Lithium - ion Battery	Room temperature Atmospheric pressure Energy density 0.5 MJ/kg	-100% for ship emissions for a pure battery powered ship. For hybrid packages the reduction will be dependent upon the power system design and voyage profile and may vary between a major reduction for ships with large batteries on short sea voyages to minimal reduction for large ships making transoceanic voyages.	The design of the battery compartment must take into account the maritime environment with regard to a number of factors: moisture, salt, vibration, electromagnetic radiation and high voltage systems, cooling and ventilation during normal and abnormal operation. Furthermore, barriers are needed other dangerous cargo / storage and the effect of high temperatures in case of fire taken into account (may be steel melting). These safety requirements also apply to retrofit solutions.	Extremely high Fire temperature which can melt steel Extremely explosive gasses (see gas table below) Lithium-ion batteries can spontaneously ventilate a lot of gas, and self-ignite,	High Voltage Hydrofluoric acid (Hydrogen fluoride - HF) the gas evolved by fire in Lithium-ion is very dangerous: Skin hazard Absorbed through skin. Causes nerve, bone and organ damage. Can be fatal. Eye hazard High risk of blindness. Inhalation hazard Toxic, lethal concentrations> 200ppm, non-lethal doses may cause pulmonary edema. Ingestion toxid fatal Given this risk, one should keep a good distance and not go into areas where one can stay exposed to hydrofluoric acid. Furthermore, be aware that filter	Good maintenance procedures. • Keep the battery compartment dry and clean. • Maintain air filters in the room. • Check the ventilation system in the battery and battery compartment routinely. • Exercise regularly for manual shutdown in various abnormal conditions such as one natural part of emergency drills. • Use access restriction and perform secure job analysis (SJA) for maintenance work in the battery compartment. • The operator must have knowledge of parameters that are indications of a course to thermal runaway. Examples are rising battery temperature, high voltage and current, and gas evolution. • The operators must have knowledge of the

Name			
Carbon Monoxide	x	x	
Carbon Dioxide		x	
Oxygen			
Hydrogen	x		
Methane	x		
Ethylene	x		
Ethane	x		
Propane	x		
Benzene	x		
Ethanol	x		
Methanol	x		
Nitrogen Dioxide		x	
Ethyl Fluoride	x		
Hydrogen Sulfide	x	x	x
Hydrogen Fluoride		x	x
Hydrogen Cyanide		x	
Hydrogen Chloride		x	x
Phosphoryl Fluoride		x	x
Ethyl Carbonate			
Dimethyl Carbonate	x		
1,4 Dioxane	x	x	

			It is crucial that the battery cells are of classified quality and that Energy Management System (EMS) and Battery Management System (BMS) have been tested against communication, surveillance and security systems.	without warning «Thermal Runaway» the temperature from the flames can be above 1000 °C and melt steel! Leave the battery compartment, close and monitor the situation outside the compartment. Disconnect the battery system and make sure the battery cooling system is activated, release extinguishing system use of salt water should be avoided in the battery compartment and directly on batteries Do not re-enter the battery compartment until the exhaust gas has been vented Notify internally and send out an emergency message to relevant emergency agencies Monitor other auxiliary systems such as video surveillance, gas or temperature sensors and exhaust system / gas ventilation from	masks and ordinary fire clothing does not provide protection against this acid - and glass in masks and instruments will break when exposed to hydrofluoric acid. Only chemical suits will provide protection against hydrofluoric acid.	prerequisites for safe operation of the battery system. This can be: restrictions on power take-off and characteristics of connected equipment quantity and type of coolant - ventilation inlets and outlets and dedicated ventilation from battery cabinets In the event of modifications, the risk analysis for the battery system must be reviewed in order to ensure that the assumptions and results are still valid. • Do not leave the battery compartment doors open longer than necessary. • Do not store equipment in the battery compartment that could create sparks, burns or generate a lot of heat. • Consider lifting restrictions above and near battery compartments

				the battery compartment. Make sure that flue gases are not ventilated to areas where people are Avoid adding oxygen, Use high voltage and chemical protective equipment Do not enter the battery compartment until you have a complete overview of the gas concentration in the compartment. Always wear complete protective equipment Never touching batteries as these are conductive Short circuits in the battery installation can occur even when using fresh water		

Energy	Characteristics	Construction & Design	Environmental Effectiveness	Fire and explosion risks	Health and safety issues	Recommendation
Fusion Energy – Thorium Molten salt Reactor	Reactor temperature 700°C Vapour pressure boiling point 4787°C melting point 1750°C density (20°C)11.72 g.cm-3 Energy density 79,420,000 MJ/kg	Placed in engine room, double Cooling systems, molten salt reactor is capture with 1 meter's thick concrete shell, the weight and size will mathematically on a 68220-dwt tanker release around 6,500 total dwt on top of that the benefits of no need for HFO store tanks! And "bunkering" is not needed but the Th-"stone" with size of an golf ball must be changed every 10 year!	ZERO	a "freeze plug" where a reactor drain-plug is actively cooled to keep the fuel in and the reactor running. If anything goes wrong, the reactor fuel is safely drained, and the reactor stops. The molten salt intrinsically slows the reaction if it becomes overheated because of its negative temperature coefficient of reactivity. The operational temperature of MSRs is 600-700°C, while the boiling point of the molten salt is ~1,400°C 8 leaving a very large safety margin which makes the MSR inherently safe against overheating.	Normally none	Use SOLAS CONVENTION CHAPTER VIII – NUCLEAR SHIPS with updated additions STCW Competence certificate is needed crew training /competency requirements and amendments to STCW Focus on Ships specific training and Familisation First aid competence Thorium as an energy source Thorium-based Molten-Salt Reactors can enable low-carbon deep-sea shipping

Fuel cell	A fuel cell consists of basic elements for electrodes and electrolyte. See annex 1	Heavy Must be placed on deck	Potentially -100% depending upon fuel used and means of producing fuel.	Extremely explosive		Have in mind the construction and design in connection whit Fire, gasses and evacuations situations
Exhaust Scrubbers	Carbon Capture See annex 2	Heavy	Potentially -100% depending upon fuel used	Daily maintenance		This is the best solutions for large existing ships

This document does not contain renewable energy sources, such as solar and wind power.

Be aware on a ship there will always be several types of energy sources that require different competence and fire extinguishing equipment

Energy efficiency:

Fuel cell is around 60 %

Combustion engine is about 35 %

Steam turbine is about 50 %

Thorium Molten salt Reactor is about 50 %

Definition of flash point: The lowest temperature at which vapors above a volatile combustible substance ignite in air when exposed to flame

* Differences between liquid and gas and terms used, such as storage temperature and vapor temperature

ITF: WHAT IS THE IGF CODE AND HOW DOES IT AFFECT ME? Alternative ship fuels – status and outlook

ITF MSC suggest a change/ amendment in STCW as following in **Reg. I/1.1.15 Definitions and Clarifications**

Propulsion power means the total maximum continuous rated output power for propulsion **and manoeuvring,** in kilowatts, of all the ship's ~~main propulsion~~ machinery **regardless of energy source** which appears on the ship's certificate of registry or other official document

a) The Scrubber/Exhaust Gas Cleaning System (EGCS)

There are 3 types of *wet* scrubbers: open-loop, closed loop or compact/ hybrid using both open/closed loop *adopted by the maritime industry for removal of sulphur oxides (SOx) and particulate matter in the exhaust air*.

The closed loop: is equipped with a storage tank that is holding the remaining exhaust "mud" (sludge) and released ashore when available to convenient port facilities

Open loop: *is equipped with a sludge tank and a washwater treatment tank that dilutes the washwater before it is drained out at the bottom of the scrubber*, while the clean gas continues through the packing via the demister unit, before it is released into the atmosphere.

The result is an efficient and well tested cleaning process with no moving parts.

Process: Sodium Hydroxide NaOH (Caustic Soda as alkaline) + seawater (including any type of seawater; low alkaline and saline water) sprayed inside the chamber of the scrubber right after combustion in 3 sequences: seawater – NaOH - seawater.

System used natural seawater in both open and closed-loop operation and could boost with alkali to reach pH>6 at outlet.

All exhaust sources on board can be connected to only one common EGCS unit, or individual scrubbers for each exhaust source (ME, AE, boiler)

KEY FEATURES

No back pressure

- No fuel penalty
- AE's can start connected to EGC unit(s)
- No restrictions running AE's in part load – no impact on engine parameters (EIAPP)
- Boilers connected

Closed loop/open loop operation

- Open loop 0,5% Sulphur – sea water only when Sulphur < 3,5%
- Open loop 0,1% Sulphur – sea water + NaOH dosing; can transit any water – no alkalinity restrictions
- Closed loop – sea water + NaOH dosing; only required where zero discharge is called for pH
- Open loop 0,5% Sulphur – process water + cooling water + dilution device
- Open loop 0,1% Sulphur plus NaOH (pH 6,5 at 4m or pH 6 at overboard)

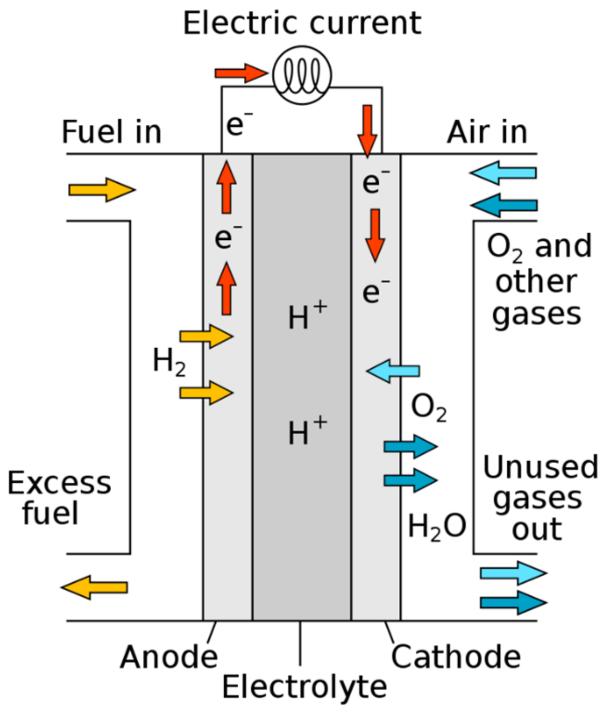
b) The Fuel Cell

A fuel cell is an electrochemical cell that converts the chemical energy of a fuel (often hydrogen) and an oxidizing agent (often oxygen into electricity through a pair of redox reactions.

Fuel cells are different from most batteries in requiring a continuous source of fuel and oxygen (usually from air) to sustain the chemical reaction, whereas in a battery the chemical energy usually comes from metals and their ions or oxides that are commonly already present in the battery, except in flow batteries. Fuel cells can produce electricity continuously for as long as fuel and oxygen are supplied.

The first commercial use of hydrogen–oxygen fuel cell was in 1932. The alkaline fuel cell, also known as the Bacon fuel cell after its inventor, has been used in NASA space programs since the mid-1960s to generate power for satellites and space capsules. Since then, fuel cells have been used in many other applications. Fuel cells are used for primary and backup power for commercial, industrial and residential buildings and in remote or inaccessible areas. They are also used to power fuel cell vehicles, including forklifts, automobiles, buses, trains, boats, motorcycles and submarines.

There are many types of fuel cells, but they all consist of an anode, a cathode, and an electrolyte that allows ions, often positively charged hydrogen ions (protons), to move between the two sides of the fuel cell. At the anode a catalyst causes the fuel to undergo oxidation reactions that generate ions (often positively charged hydrogen ions) and electrons. The ions move from the anode to the cathode through the electrolyte. At the same time, electrons flow from the anode to the cathode through an external circuit, producing direct current electricity. At the cathode, another catalyst causes ions, electrons, and oxygen to react, forming water and possibly other products. Fuel cells are classified by the type of electrolyte they use and by the difference in startup time ranging from 1 second for proton-exchange membrane fuel cells (PEM fuel cells, or PEMFC) to 10 minutes for solid oxide fuel cells (SOFC). A related technology is flow batteries, in which the fuel can be regenerated by recharging. Individual fuel cells produce relatively small electrical potentials, about 0.7 volts, so cells are "stacked", or placed in series, to create sufficient voltage to meet an application's requirements. In addition to electricity, fuel cells produce water, heat and, depending on the fuel source, very small amounts of nitrogen dioxide and other emissions. The energy efficiency of a fuel cell is generally between 40 and 60%; however, if waste heat is captured in a cogeneration scheme, efficiencies of up to 85% can be obtained.



From Wikipedia