

MARITIME

Maritime Fuel Cell Applications

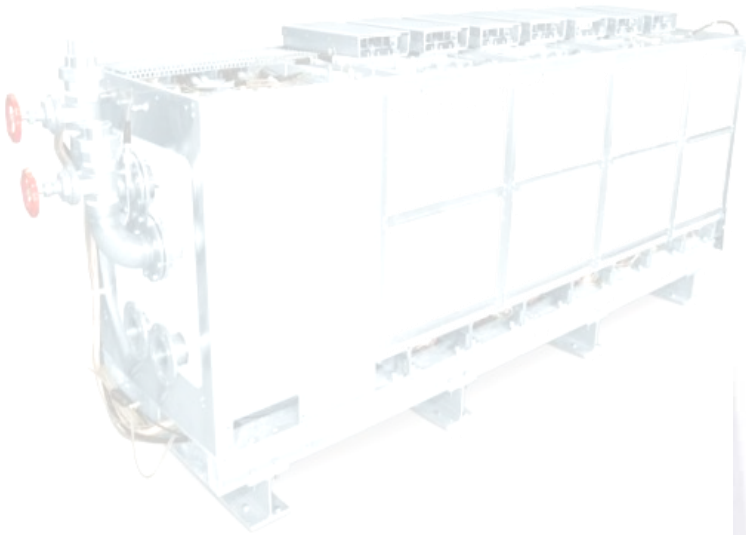
Regulations, Codes and Standards

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Valencia, 15th of June 2017

Regulations, Codes and Standards - Content

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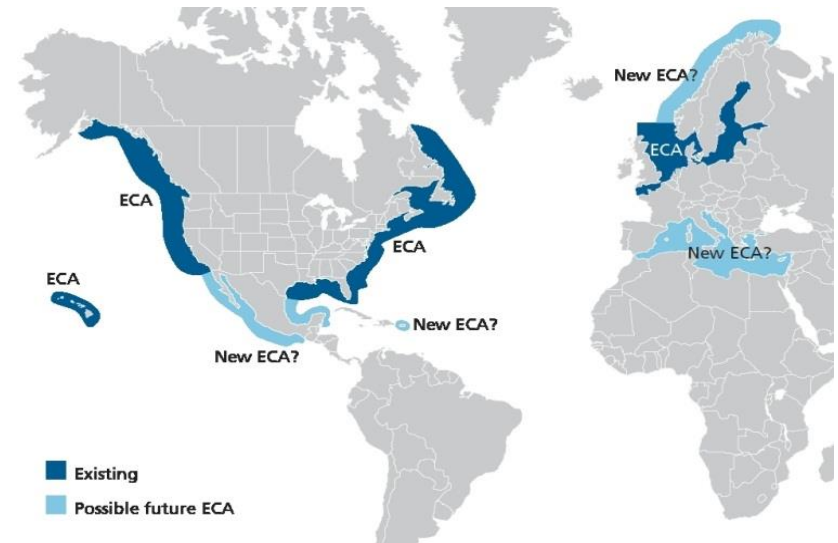
Introduction

Motivation

- Improvement of Ship Energy Efficiency
- Reduction of emissions to air
- Reaching insignificant noise and vibration level

Driver

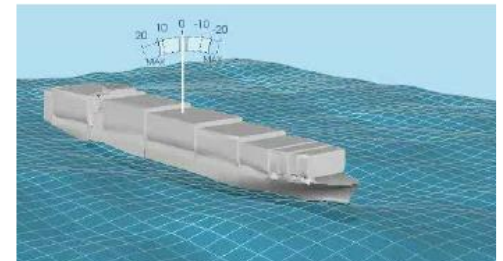
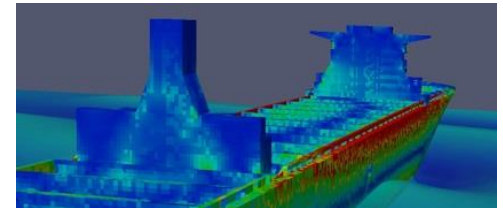
- Environmental regulations and initiatives to
 - Increase efficiency of ship operation
 - Reduce NO_x , SO_x , CO_2 and particle (PM) emissions



Introduction

Challenges, seagoing vessels

- Maritime Environment
 - ship motions
 - vibrations
 - humidity till 60 %
 - salty air
 - temperatures:
 - Full load capacity and efficiency till 45 °C
 - Full response for electrical equipment till 55°C
- Design requirements
 - testing criteria (different to land-based application)
 - reliability and availability
 - fuel storage, transport, processing onboard



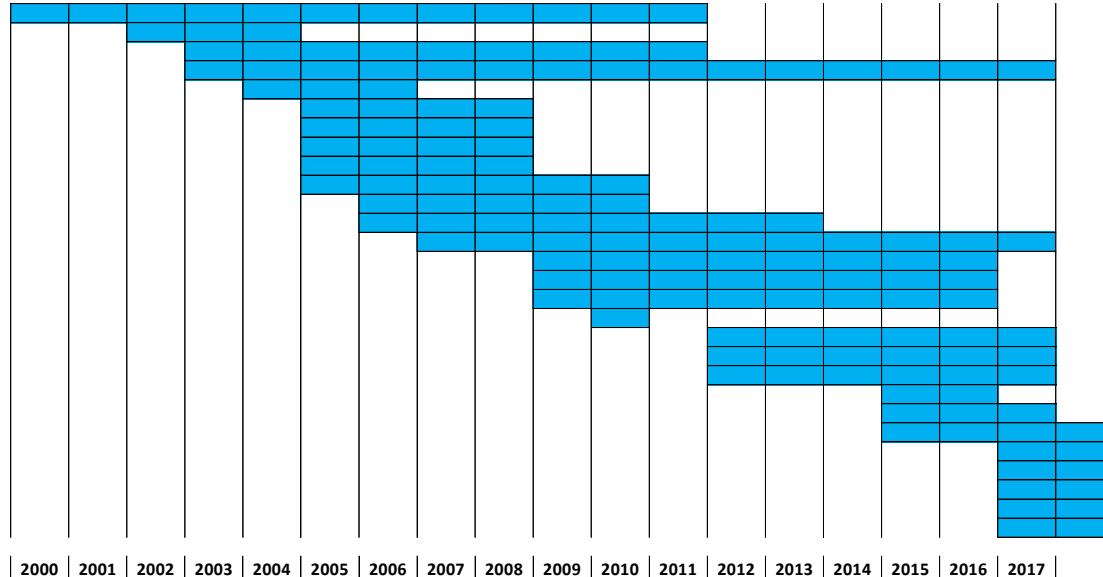
Introduction

Developments

- The maritime industry started with first Fuel Cell applications in the early 2000
- Most of the studies and projects were performed in the US and Europe due to development programmes
- Technology readiness was proven: SOFC and PEMFC Technology are most promising for maritime
- Recent development projects focusing on a **common rule frame work for maritime Fuel Cells**



Maritime Fuel Cell Project Time table



Current Status – Overview Rules and Regulations



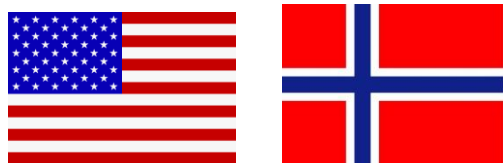
International Maritime
Regulations



Class Rules

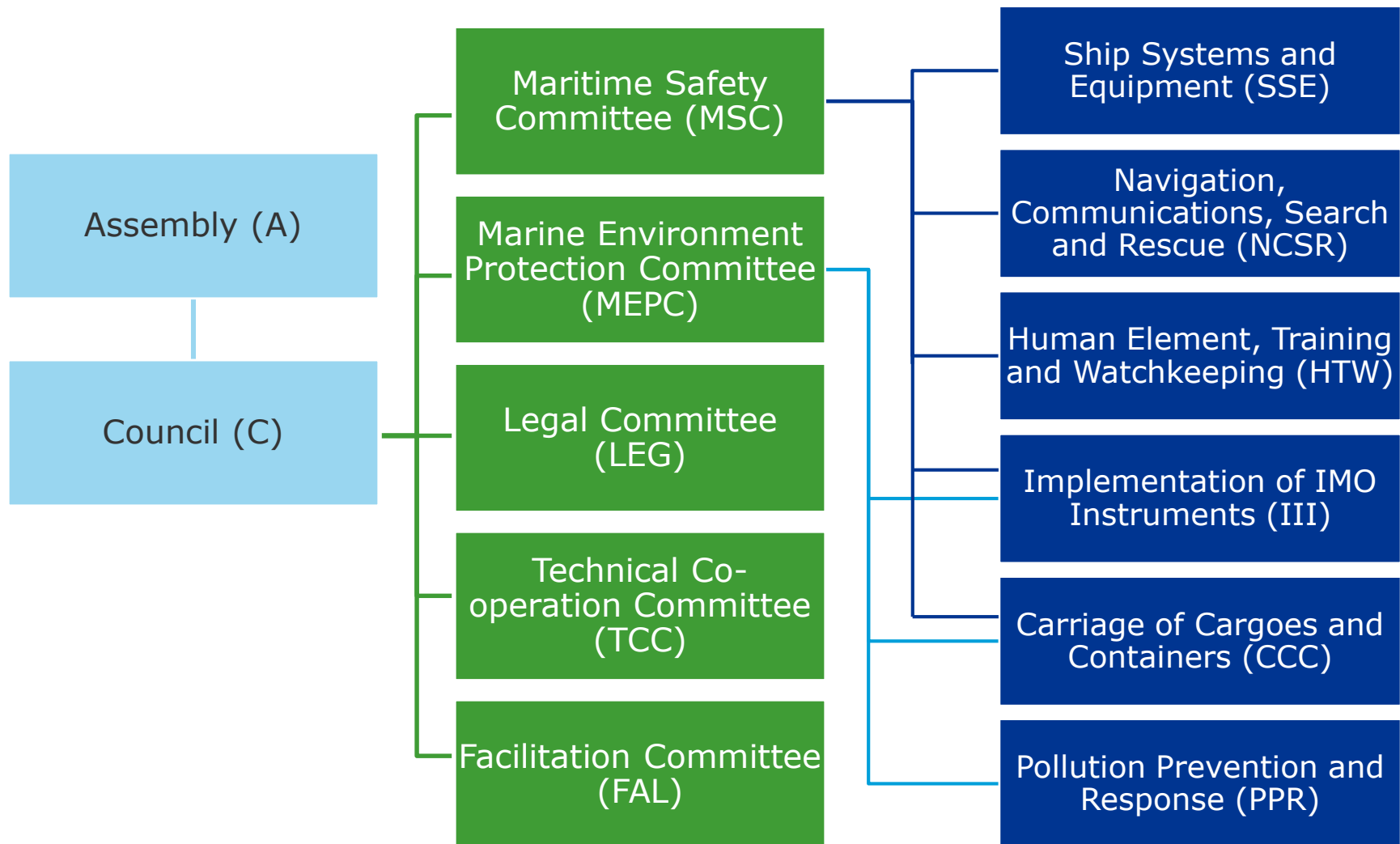


International Standards

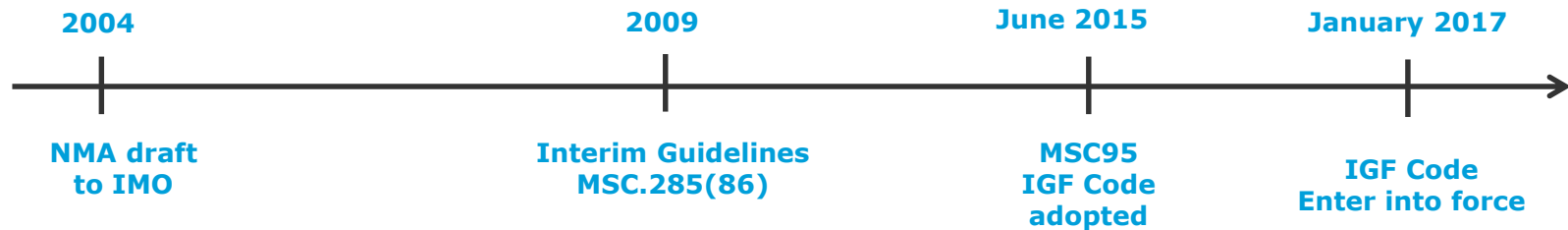


National Regulations

Committees and Sub-committees of IMO



Current Status – Statutory requirements

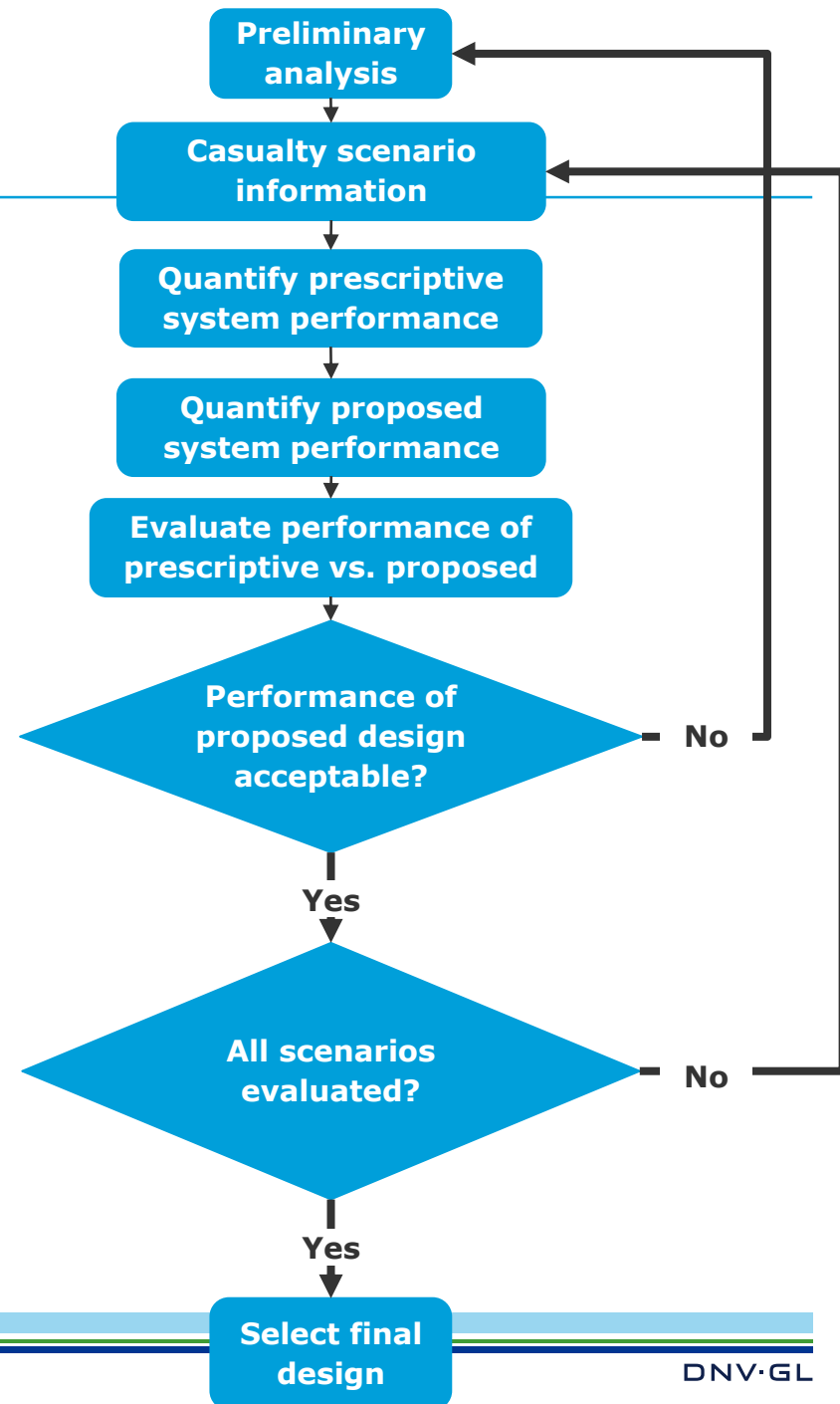


- The process for development of an International Code for gas fuelled ships in IMO was initiated by the Norwegian Maritime Authority (NMA) in 2004
- Interim guidelines on safety for natural gas- fuelled engine installations in ships, Resolution MSC.285(86) in place from 2009. Voluntary guidelines.
- **IGF Code** - Code of Safety for Ships using Gases or other Low flashpoint Fuels, adopted by IMO June 2015, replaced the interim guidelines by January 2017
- The IGF Code will provide mandatory provisions for the arrangement, installation, control and monitoring of machinery, equipment and systems using low-flashpoint fuels, to minimize the risk to the ship, its crew and the environment
- The code opens for the use of low flashpoint fuels in general, but only contains detailed requirements to natural gas as fuel. The use of other low flashpoint fuels including **hydrogen can be approved based on alternative design.**

Current Status - Alternative Design

Currently, for Fuel Cells and Hydrogen

- Chapter 2.3 of the IGF codes provides the possibility for the approval of hydrogen and fuel cell applications by an alternative design process
- The *equivalence* of the alternative design shall be demonstrated as specified in SOLAS [regulation II-1/55](#) and approved by the Administration
- The “Guidelines on Alternative Design and Arrangements for SOLAS Chapters II-1 and III (MSC.1 / Circ. 1212)” providing guidance to perform the *Alternative Design Process*



Current Status – Class Rules

Most of the maritime fuel cell process chain covered by Class rules and recommended practices

- **Gas-fuelled ships**

- Pt.6 Ch.2 Sec.5 GAS FUELLED SHIP INSTALLATIONS – GAS FUELLED
- The requirements cover all aspects of the gas fuel installation, from the ship's gas fuel bunkering connection all the way up to and including all gas consumers

- **Low flashpoint fuels**

- Pt.6 Ch.2 Sec.6 LOW FLASHPOINT LIQUID FUELLED ENGINES – LFL FUELLED

- **Fuel Cells**

- Pt.6 Ch.2 Sec.3 FUEL CELL INSTALLATION – FC

- **Batteries**

- Pt.6 Ch.2 Sec.1 BATTERY POWER

- **Bunker vessels**

- Pt.6 Ch.5 Sec.14 GAS BUNKER VESSELS – GAS BUNKER
- Focus on **equipment and arrangements for safe transfer** and operation

Current Status - Main principles relevant DNV GL Rules

Segregation

Protect gas fuel installation from external events

Double barriers

Protect the ship against leakages

Leakage detection

Give warning and enable automatic safety actions

Emergency shutdown

Reduce consequences of a leakage

Current Status - Bunkering



From road trucks

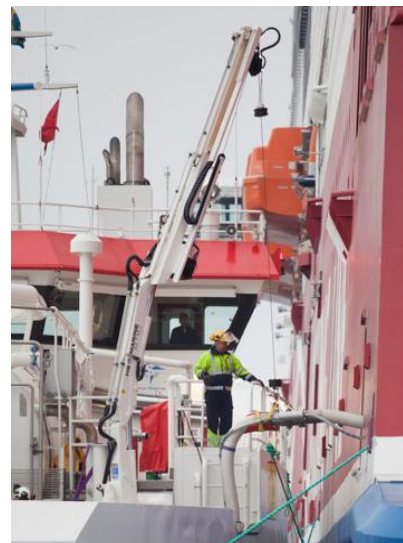


Shore storage tank



Portable Gas fuel tank

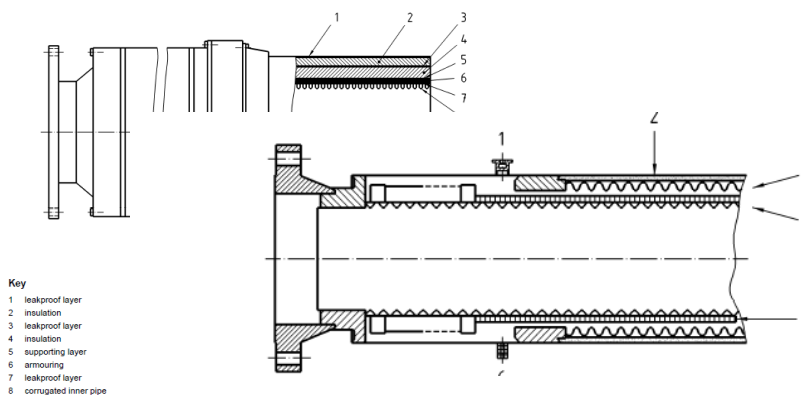
Ship to ship transfer



Current Status - Bunkering

Flexible hoses

- Proven solution for STS ops
- Good safety record
- Require hose handling cranes
- Become bulky at higher transfer rates



Rigid arms

- Well developed standards
- Allow reduced manning
- Sensitive to sea/weather conditions

Figure 1 —

- Key
- 1 pumping port
 - 2 armouring
 - 3 corrugated outer pipe
 - 4 corrugated inner pipe
 - 5 super insulation vacuum
 - 6 vacuum supervision leak

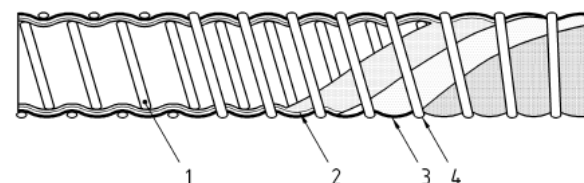
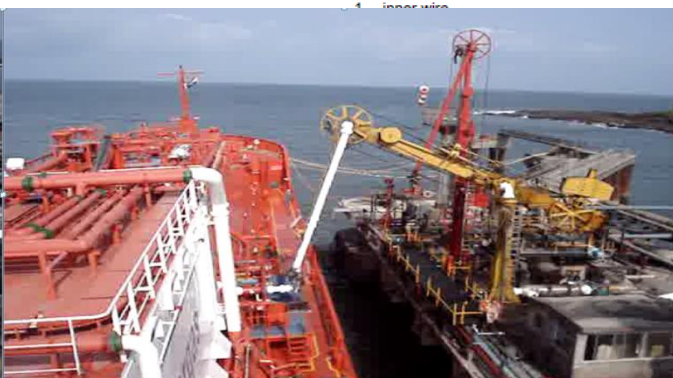


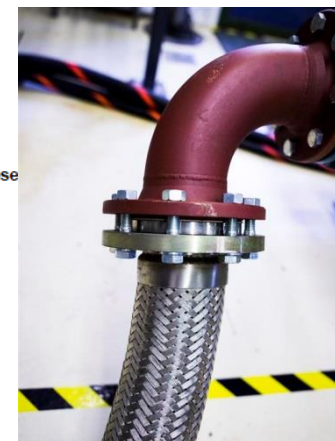
Figure 2 — Typical I

Key

1 inner wire



typical hose

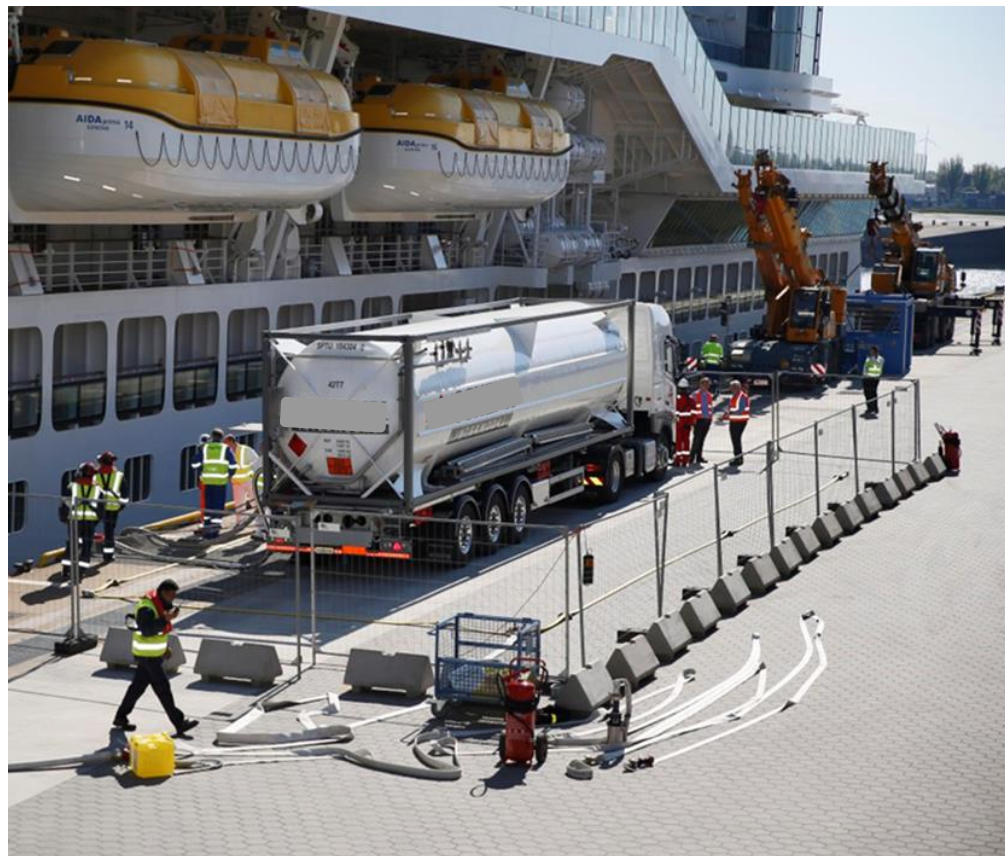


Current Status - Bunkering

Requirements in ISO / TS 18683 (for Natural Gas only)

- Perform Risk Assessment
- Establish Safety Zone
- Establish Security Zone
- Use suitable standards for equipment and processes

EN 1474-1	Installation and equipment for liquefied natural gas. Design and testing of marine transfer systems. Part 1: Design and testing of transfer arms
EN 1474-2	Installation and equipment for liquefied natural gas. Design and testing of marine transfer systems. Part 2: Design and testing of transfer hoses
EN ISO 28460	Petroleum and natural gas industries. Installation and equipment for liquefied natural gas. Ship-to-shore interface and port operations
ISO TS 18683	Guidelines for systems and installations for supply of LNG as fuel to ships
ISO 17357	Floating pneumatic rubber fenders
OCIMF	Design and construction specification for marine loading arms
OCIMF	Mooring equipment guidelines
OCIMF	Information paper marine breakaway couplings
SIGTTO	ESD arrangements & linked ship/shore systems for liquefied gas carriers
DNVGL-RP-0006:	Development and operation of liquefied natural gas bunkering facilities



- Consider SIMOPS (Simultaneous Operations)

Ongoing developments

Today's most promising project

- **e4Ships** – German funded Lighthouse project for maritime Fuel Cell application
- **Aim** – Development of Fuel Cell auxiliary power generator capable for serial production and capable for type approval. Provide input for Rule development (e.g. IGF Code)
- Developments are in line with the objectives of the German "*mobility and fuel strategy*":
 - Introduction of *alternative and regenerative fuels*
 - Development of *innovative power technologies*
 - Aiming a big share of Hydrogen and Fuel Cell application for all modes of transport in a long-term view



A project of



Funded by



Coordinated by



Ongoing developments

- **IGF Code** – further work (MSC96): The IMO correspondence group will continue to work on requirements for fuel cells, methyl-/ethyl- alcohols and low flashpoint diesel installations for future inclusion in the IGF Code. E4ships2 will provide input accordingly
- **Class Rules**: Are continuously updated in the context of IGF Code development
- **Bunkering**: Bunkering of hydrogen and other low flashpoint fuels then Natural Gas are not addressed at the moment

Summary

- Major Class Societies published rules for maritime fuel cell applications
- Low flashpoint fuels (natural gas, methanol, ethanol, low flashpoint diesel and hydrogen) are seen as future maritime fuels
- Requirements for maritime low flashpoint fuels and fuel cell installation will be covered by the IGF Code
- In the meanwhile the „Alternative Design Assessments“ is door-opener for new design solutions as e.g. Fuel Cells and Hydrogen as fuel
- Harmonization with land based standards is done by considering relevant ISO and IEC standards
- Main GAP: Bunkering of low flashpoint fuels other than Natural Gas are not regulated
- ISO / TS 18683 for Natural Gas could give guidance



“water will one day be employed as fuel, that hydrogen and oxygen which constitute it, used singly or together, will furnish an inexhaustible source of heat and light, of an intensity of which coal is not capable”

Jule Verne, the mysterious island, 1874



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SAFER, SMARTER, GREENER

Risk Assessments

Fuel System
(onboard)

Relevance

- Flag state
- Class

Transfer System
(ship / shore)

Relevance

- Port Administration
- Flag state (if applicable)

Simultaneous
Operations (SIMOPS)
during transfer

Relevance

- Port Administration
- Flag state (if applicable)

Ongoing Developments



SchlBZ



German funded lighthouse project “e4ships”

- Framework project “Toplaterne”
 - ▶ *Focus on safety and rule development*
- Fuel cell systems on board of a Passenger Vessel (Cruise and Yacht)
 - ▶ *Focus on integration in ship design, ship safety (SOLAS) and overall efficiency*
- High Temperature Fuel Cell systems on board of Passenger and Special Vessels
 - ▶ *Focus on application of diesel fuel oil and hybrid design (FC – Battery Buffer)*
- Fuel Cell systems on board of an inland navigation Vessels
 - ▶ *Hybrid system design (just started)*
(Diesel, Fuel Cell, Energy Buffer)

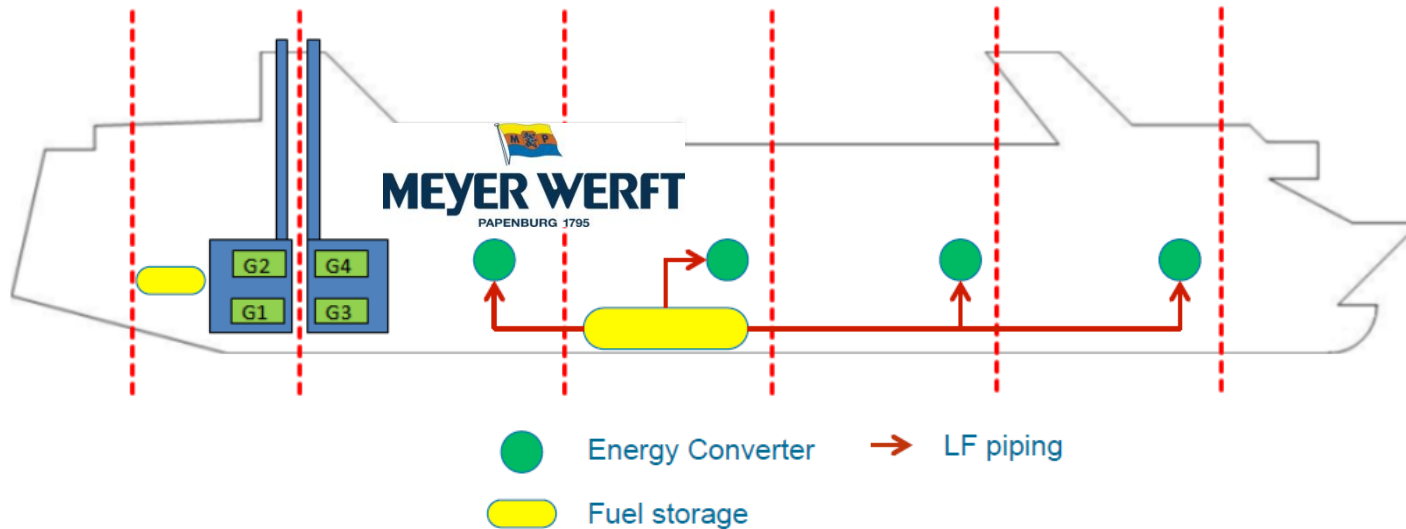
Ongoing Developments

e4Ships partner



Ongoing Developments

Pa-X-ell: Distributed Energy Conversion and Integration



- Fuel cells in different fire zones ► SOLAS
- Safe supply of fuel cells ► IGF piping for low-flashpoint fuels
- Thermal integration of Fuel cells ► increased fuel efficiency
- Electrical integration of Fuel cells ► development of control, energy buffer

Ongoing Developments

Pa-X-ell: Actual achievements

- Modularized FC system concept
- 120 kW Fuel Cell Container – Methanol Fuel Cell Rack with auxiliary equipment
- Risk Assessment performed for Fuel Cell and Methanol system
- In operations since May 2014 for long term trials
- Second generation of FC module developed (higher efficiency, reduced invest. Cost)




MEYER WERFT
PAPENBURG 1795

Ongoing Developments

SchIBZ – application of Solid Oxide Fuel Cells



- 100 kWel high-temperature fuel cell for seagoing vessels has been developed and manufactured
- SOFC is fuelled with diesel oil
- Use of diesel fuel for SOFC system successful tested
- Practical testing planned for end of 2015 / 2016

Ongoing Developments

SchIBZ: Actual achievements

- **Diesel reforming:**
proof of concept over more than 3200h with 10ppmS diesel fuel with the result of a clean fuel gas
- **SOFC Module:**
construction of a 27kW SOFC module for ship borne use, test with minimal degradation over more than 1000h, electrical efficiency 50+%
- **System:**
Risk Assessment performed for SOFC systems and intended onboard integration



Summary & Outlook

- FC technology is available from land-based applications
- Principal maritime suitability was proven by demonstration projects
- **e4Ships** is currently the most promising project worldwide developing and testing **marketable maritime FC Systems** until end of 2016
- Developments by Pa-X-ell and SchIBZ aiming significant **reductions of investment costs and increase of lifetime** of maritime FC systems
- Resulting from Toplaterne requirements will be implemented in the IGF Code building international **regulatory baselines for FC applications**
- For all projects within e4Ships a second phase is in development for further practical testing of maritime FC technology until 2022
- Developments are strongly supported by the Federal Ministry of Transport and Digital Infrastructure



e4ships
Brennstoffzellen im maritimen Einsatz



Bundesministerium
für Verkehr und
digitale Infrastruktur