DNV GL Perspective - Regulations, Codes and Standards

H2@Ports Workshop

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ABOUT DNV GL - Leading the surge towards the future

MARITIME

- **Maritime** is our core industry
- **11,678 ships & mobile offshore units** in DNV GL class, 280.6 mGT
- **Strong presence** in all ship segments
- **Dedicated ship type expert teams** support our clients worldwide
- **Among top performing class societies** in Port State Control statistics
- **200 Maritime offices** across the world

24% Market share (measured in GT)  
3,600 Maritime staff worldwide

OIL & GAS

12,500 employees groupwide

ENERGY

5% revenue invested in R&D activities

DIGITAL SOLUTIONS

564x105 to 189x183

431x292 to 546x387

576x298 to 689x399

20x493

Total number of ships (in operation and on order)

- **Bulk carriers**: 1252, 42
- **Container ships**: 774, 38, 45
- **Crude oil tankers**: 533, 31
- **Oil/Chemical tankers**: 478, 42, 28
- **Cruise ships**: 229, 33, 17
- **Ro-Ro cargo ships**: 163, 9
- **Gas tankers**: 94, 17
- **General cargo ships**: 86, 17
- **RoPax**: 81, 21
- **Car carriers**: 56
- **Car/passenger ferries**: 53, 175
- **Other activities**: 20, 50
- **Fishing vessels**: 18
- **Other offshore vessels**: 1
- **Offshore supply ships**: 37, 52
- **Tugs**: 17

- **Total**: 3756
Number of ships with batteries by ship type

- In operation
- Under construction
- Unknown
Towards zero emissions in shipping

- **HYDROGEN – FUEL CELLS**
  - Next generation
  - Increased range
  - Reduced weight possible
  - More flexible charging/bunkering
Zero/V - Hydrogen Fuel-Cell Coastal Research Vessel

Sandia partnered with the Scripps Institution of Oceanography, the naval architect firm Glosten and the class society DNV GL to assess the technical, regulatory and economic feasibility of a hydrogen fuel-cell coastal research vessel.

Regulatory situation – a main barrier

- The IGF Code entered into force Jan 1st 2017
- Governs the use of low flashpoint liquids and gaseous fuels

- DNV GL Class Rules for fuel cells and the class notations FC(Safety) and FC(Power)
  - Section 3 – Fuel cell installations – FC
    - Sets requirements FC power systems, design principles for FC spaces, fire safety, control and monitoring systems

- No fuel specific requirements (hydrogen)
- No prescriptive hydrogen requirements available
- The applicable part of the IGF Code (Part A) requires that an “Alternative design” approach is followed
Regulation overview - status

Maritime Fuel Cell Systems

Requirements for on board energy generation systems

Fuel specific requirements

IGF code entered into force Jan. 1st 2017

Contains detail requirements for natural gas as fuel only, and internal combustion engines, boilers and gas turbines

Work started on technical provisions for methyl /ethyl alcohols as fuel and fuel cells

Alternative Design Approach

Most classification societies have established Rules covering fuel cells and to some extent low flashpoint liquids
Currently, for Fuel Cells and Hydrogen

- IGF codes provides the possibility for alternative design process

- The equivalence of the alternative design shall be demonstrated by a risk-based approach 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

Preliminary Analysis
- Identification of rule deviations
- Hazard Identification
- Scenarios, methods and assumptions for quantification

Quantitative Analysis
- Quantification of selected scenarios
- Comparison to conventional design

Report of Assessment
- Documentation
- Presentation to flag
Regulation overview - DNVGL Fuel Cell Rules

- DNVGL Rules for Classification – Ships
  - Part 6 Chapter 2 Section 3 – Fuel Cell Installations – FC
  - The Rules offer two class notations:
    - **FC(Power)**
      - Given to ships that fulfils design requirements in the Rules, where the FCs are used for essential-, important- or emergency services.
    - **FC(Safety)**
      - Given to ships that fulfils the environmental- and safety requirements in the Rules, where the FCs are not used for essential-, important- or emergency services.
Hydrogen Safety - Experiments and simulations

• Major Hazards Research and Testing Facility (Spadeadam)
• Enables us to understand hazards and to develop and validate models
Explosion Risk Analysis (ERA) approach

**CONSEQUENCE ANALYSIS WITH FLACS**

- CFD Converting geometry
- CFD Ventilation
- CFD Dispersion
- CFD Explosion

**FREQUENCY AND SYSTEM ANALYSIS**

- Response surfaces
- Leak frequency
- Flow conditions and ESD segments
- Ventilation
- Gas detection
- Ignition sources

Risk analysis:
- DNV program EXPRESS
- Response surfaces
- JIP Ignition model
- Monte Carlo simulations

**Improve design**

- Design effects and recommendations
- Explosion DAL
Ventilation example

- Horizontal cut
- Vertical cut
Gas leak dispersion example hydrogen
### Technology overview- Fuel Cells types

<table>
<thead>
<tr>
<th>Type</th>
<th>Maturity and Relevance</th>
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<tbody>
<tr>
<td>Electro-galvanic fuel cell (EgFC)</td>
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<td>Enzymatic Biofuel Cells (EnzFC)</td>
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<td>Magnesium-Air Fuel Cell (Mg-AFC)</td>
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<td>Metal hydride fuel cell (MHFC)</td>
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<td>Protonic ceramic fuel cell (PCFC)</td>
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<td>Microbial fuel cell (MFC)</td>
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<td>Alkaline fuel cell (AFC)</td>
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<td>Direct borohydride fuel cell (DBFC)</td>
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<td>Direct carbon fuel cell (DCFC)</td>
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<td>Direct formic acid fuel cell (DFAFC)</td>
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<td>Molten carbonate fuel cell (MCFC)</td>
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<td>Phosphoric acid fuel cell (PAFC)</td>
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<td>Solid oxide fuel cell (SOFC)</td>
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<td>PEMFC</td>
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<td>High Temperature PEM</td>
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<td>Reformed methanol FC (R-MFC)</td>
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<td>Regenerative fuel cell (RegFC)</td>
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<td>RFC – Redox</td>
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<td>Solid acid fuel cell (SAFC)</td>
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<td>Upflow microbial fuel cell (UMFC)</td>
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<td>Zinc-air battery</td>
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<thead>
<tr>
<th>Solid Oxide Fuel Cell</th>
<th>Molten Carbonate FC</th>
<th>Phosphoric Acid FC</th>
<th>HT PEM fuel cell</th>
<th>Alkaline fuel cell</th>
<th>PEM fuel cell</th>
<th>Direct Methanol FC</th>
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<tbody>
<tr>
<td>Tolerance for cycling</td>
<td>Lifetime</td>
<td>Efficiency</td>
<td>Safety aspects</td>
<td>Physical size</td>
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<td>Technological maturity</td>
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<tr>
<td>Efficiency</td>
<td>Emissions</td>
<td>Relative cost</td>
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<td>Technology overview</td>
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<tr>
<td>Relative cost</td>
<td>Modular power levels (kW)</td>
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<td>Sensitivity for fuel impurities</td>
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Maritime Fuel Cell Product Certification/Type Approval – under development

- DNVGL has initiated the development of a class program CP for Fuel Cell Power Installations, describing the procedures and technical requirements for the approval and certification of such systems (similar to the DNV GL CP-0418 for Lithium Batteries [https://rules.dnvgl.com/docs/pdf/DNVGL/CP/2015-12/DNVGL-CP-0418.pdf](https://rules.dnvgl.com/docs/pdf/DNVGL/CP/2015-12/DNVGL-CP-0418.pdf)).

- Technical basis will be e.g. the draft of the IGF-Code for fuel cells, the DNVGL CG-0339 'Environmental test specification for electrical, electronic and programmable equipment and systems' [https://rules.dnvgl.com/docs/pdf/DNVGL/CG/2015-11/DNVGL-CG-0339.pdf](https://rules.dnvgl.com/docs/pdf/DNVGL/CG/2015-11/DNVGL-CG-0339.pdf) and the IEC 62282 'Fuel Cell Technologies'.

- Since the technical requirements for fuel cell power installations are equivalent for case-by-case or type approval (only the procedure is different) and due to the very different kinds of fuel cells (PEM, HTPEM, HTFC etc.) the procedures and the technical requirements for approval and certification of such systems will be developed together with manufacturer and class until the above mentioned Class Program is available.
DNV GL initiative – MARHYSAFE: Maritime Hydrogen Safety Joint Development Project

Goal:
- Remove regulatory and approval barriers
- Develop the knowledge required for safe and reliable onboard hydrogen storage, bunkering and use of hydrogen in shipping

Indication of partners:
- Public: Norwegian Maritime Authority, Norwegian Public Roads Administration, Norwegian Defence Material Agency (Navy, NDMA)
- Private: Equinor, Scandlines, RCCL, Air Liquide, HySeas Energy, Redrock (Canada), UMOE, Hexagon, Standards Council of Canada

R&D partners:
- University of South-Eastern Norway (USN)

Status:
- Currently discussing with potential partners
- Open for more partners
- Planning to start the project soon (2019)
# DNV GL’s services on Fuel Cell / Hydrogen

| **R&D** | • Applied research and development including *experimental* setups  
|         | • Explosion and fire experiments and research |
| **Innovation & demonstration** | • Realization of *demonstration* projects  
|         | • Techno-economic *road mapping* for technology or solutions  
|         | • System integration with renewables/electricity/.. |
| **Implementation support** | • Technology qualification  
|         | • Explosion and fire safe design analysis  
|         | • *Recommended practice* and standards development  
|         | • Guideline for HRS user interface improvement process |
| **Realisation support** | • Consortium initiation/execution  
|         | • *Safety assessments* (HAZOP, HAZID, QRA, RRR, CFD modeling) |
| **Operational excellence** | • Custody transfer  
|         | • Performance validation  
|         | • Process optimization  
|         | • H2 Incident and accident database (HIAD) |

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**Safer, Smarter, Greener...**

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