HYDROGEN IN THE MARINE INDUSTRY
SAFETY IN THE HYDROGEN SHIP / SUBMARINES

63° Congreso Internacional
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e Industria Marítima

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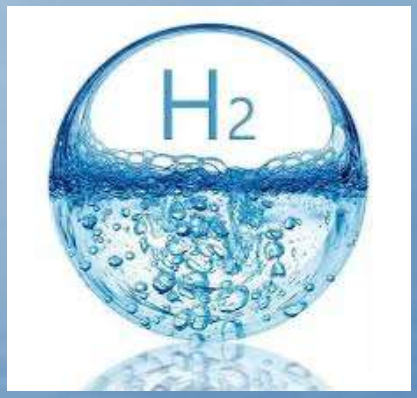
TRANSFORMANDO
LOS OCÉANOS:
INNOVACIÓN e ingeniería naval para
un mundo **CONECTADO** y **SOSTENIBLE**

H2 SAFETY

SAFETY CRITICAL

Demand for hydrogen has been increasing across all energy sectors as the world seeks to achieve its net zero emissions goals. The **design of safe and optimized hydrogen** ships is an important factor in the marine industry



SAFETY IMPACT

- **CREW**
- **EQUIPMENT /SHIP**
- **ENVIRONMENT**

Safety concept must go beyond compliance with legal obligations and maritime regulations. It is also necessary to consider the experienced use of advanced tools for the identification, evaluation, and management of safety risks, as support for administration and decision making

It is essential to **achieve high levels of safety in green hydrogen** ships: both in design and engineering, as well as in their operation and maintenance, so that we ensure the continuity of operation and business

REGULATIONS, CODES AND STANDARS FOR HYDROGEN AS MARINE FUEL

The safety challenges are underestimated or the connection between specific risk factors and the resulting operational hazards is not sufficiently appreciated with the actual regulations and standards

COMBINED APPROACH

It is necessary to develop a combined approach between prescriptive approach and risk-based approach

IMO: INTERNATIONAL MARITIME ORGANIZATION

When specific prescriptive rules and regulations are not yet in place, **SOLAS II-I** Regulation 55 and guidelines referenced by footnote **MSC.1/Circ.1212**, or associated guidelines found in **MSC.1/ Circ.1455**

PROPOUSE:

Structured design process based on safety risk assessments in cases where a ship is deviating from prescribed rules

PURPOSE:

Prove that the chosen solution is providing an equivalent safety level to the one required in SOLAS

'Alternative Design based on the risk-based approach

REGULATIONS, CODES AND STANDARS FOR HYDROGEN AS MARINE FUEL

CLASS RULES IN THE CLASSIFICATION SOCIETY

- **ABS:** The ABS criteria to be applied to gas or other **low flashpoint fueled ships is detailed in Part 5C, Chapter 13 of the ABS Rules for Building and Classing Marine Vessels** (Marine Vessel Rules. For supplemental information on hydrogen as a marine fuel, refer to the **ABS Sustainability Whitepaper Hydrogen as Marine Fuel**, and the **ABS Requirements for Fuel Cell Power Systems for Marine and Offshore Applications**

- **DNV:** DNV's Rules for Ships, **Pt.6 Ch.2 Sec.3 (DNV GL FC Rules**) The DNV rules for FC installations provide requirements aiming to ensure safe and reliable operation of the FC power installation. **DNV Class Rules, Pt.4 Ch. 1 on machinery systems** is relevant for required environmental conditions

- **BV:** BV has the **Rules for hydrogen-fuelled ships (NR678)**. The rules outline technical requirements for the safe bunkering, storage, preparation, distribution, and use of hydrogen as fuel for power generation on board. Monitoring and control systems are also covered, addressing specific safety challenges relating to the transport and use of hydrogen on ships

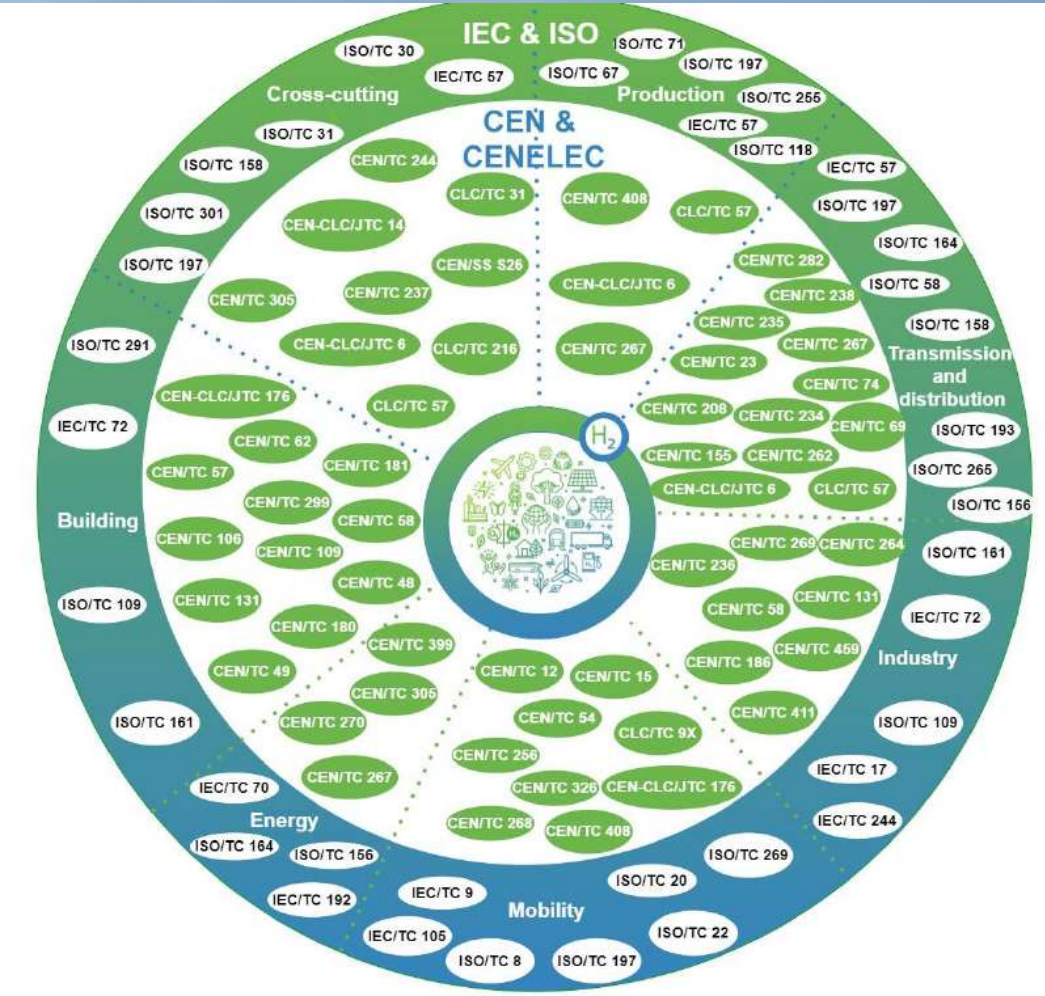
- **LR:** Lloyd's Register has issued **"Appendix LR3" component of the Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels**. They provide both general and specific hydrogen fuel rules ships using H2…

REGULATIONS, CODES AND STANDARDS FOR HYDROGEN AS MARINE FUEL

INTERNATIONAL HYDROGEN STANDARDS

Standards from the American Society of Mechanical Engineers (ASME) and the American Petroleum Institute (API) are the most used for maritime applications in general

Other standards are used depending on geography; for example, EU directives and standards may be used in the EU area. ISO and IEC standards are also relevant for introducing hydrogen as ship fuel



HYDROGEN SAFETY RISK ANALYSIS IN THE MARINE INDUSTRY

As shipping moves forward in the transition from existing energy sources, the industry must proactively develop standard safeguards and control measures for the deployment of future fuels, and it is necessary develop **safety risk analysis** to support the safety issues that can appear in novel designs

The purpose is to quantify the effect of different design solutions and safety systems and compare risks and use the comparison actively to decide how the **safety can be improved to an acceptable level**

Document safety solutions and use to obtain final approval with the **Alternative Design process**

In the meantime, and before good designs and rules are available, the innovative process **involving risk safety assessments** can be used to find safety and cost optimal solutions that provide equivalent or better safety at affordable cost

HYDROGEN SAFETY RISK ANALYSIS IN THE MARINE INDUSTRY

Risk analysis techniques for Hydrogen Ships

Hydrogen Ship Roadmap

LESSONS LEARNED FROM INDUSTRIES:
Hydrogen Accidents Data

SAFETY ANALYSIS:
Qualitative & Quantitative Safety Analysis

MODELING AND TESTING

USE SOLUTIONS TO DEVELOP STANDARDS

These steps can be used for each new/converted hydrogen-fuelled ship where the risk is identified by qualitative safety analysis and quantified through a Quantitative Risk Analysis (QRA) and compared with conventional ship risks to achieve approval in an iterative process. The last step can be undertaken when the technology is mature enough and enough experience is gained from earlier projects and QRAs so that safe and robust standards can be developed

HYDROGEN SAFETY RISK ANALYSIS IN THE MARINE INDUSTRY

Risk analysis techniques for Hydrogen Ships

Hydrogen Ship Risk-based Flow

Starts with qualitative hazard identification and assessments, moving forward with quantitative analysis, and based on this, selecting more detailed explosion and/or fire risk analysis

FIRST STEP

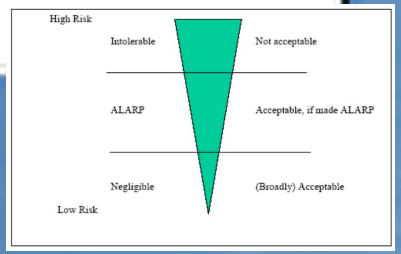
- Hazard Identification
- Safety Workshop
- Identify possible solutions
- Qualitative Assessesment

SECOND STEP

- Explosion / Fire Risk Assessment (ERA / FRA)
- Quantitative FTA for the H2-Fuelled Ship Safety Funtions
- Assess and select optimal solutions
- Decide safety control measures

THIRD STEP

- Quantitative Risk Analysis (QRA)
- Consider all risks
- Calculate overall risk (FN Curve)
- ALARP



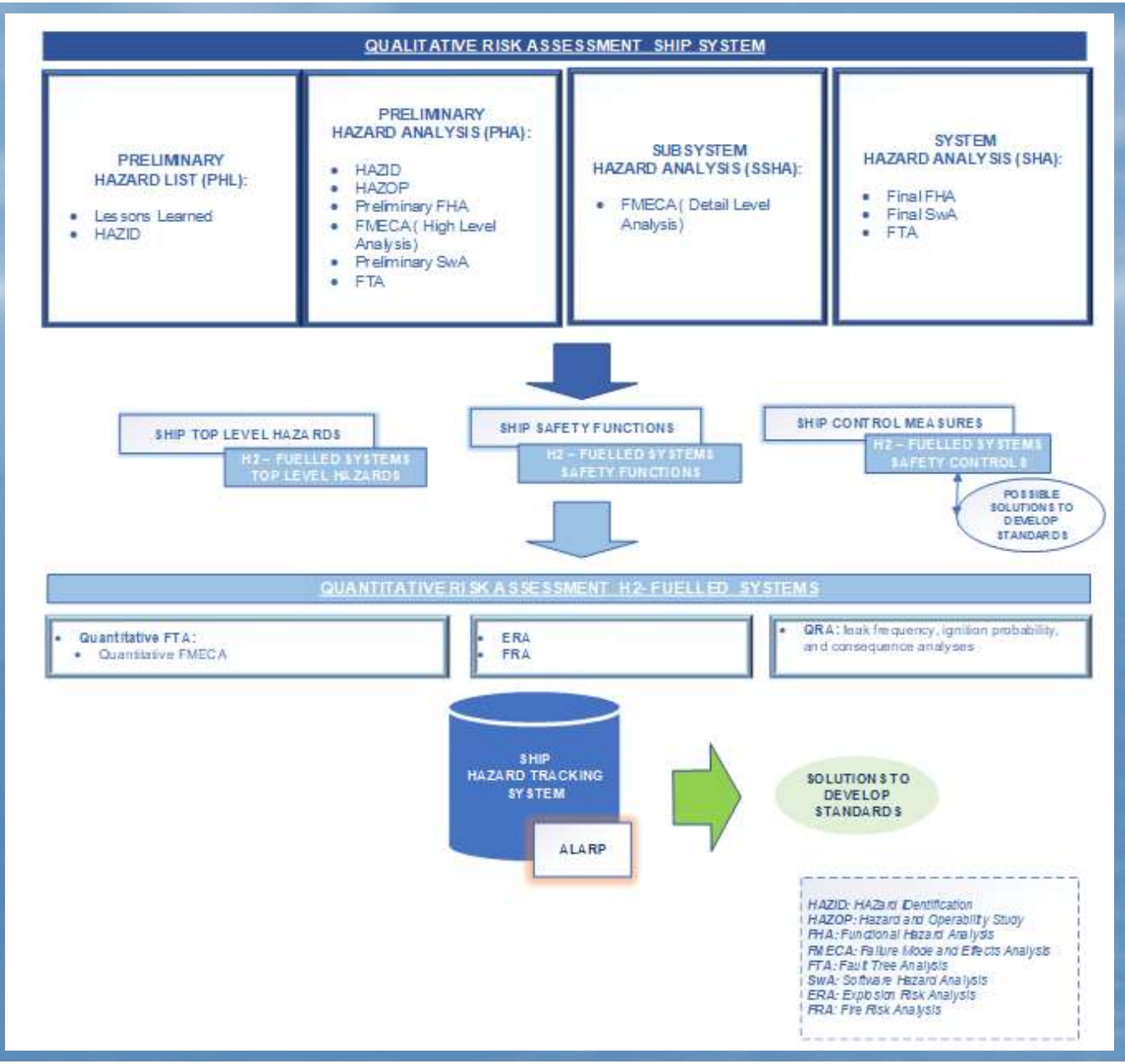
The first step is based in hazard identification and assessment with qualitative safety techniques and the second and third step is developed with a quantitative safety technique used for the specific hazards identified in step 1 for the H2- fuelled systems. These systems due to their safety criticality needs a more accurate analysis that can quantified the safety risks and ensure that all of them are eliminate or control to an ALARP level

HYDROGEN SAFETY RISK ANALYSIS IN THE MARINE INDUSTRY

Risk analysis techniques for Hydrogen Ships

Safety Analysis

- To prove that the chosen design solution is providing an equivalent safety level to the one required in the prescriptive rules that are not available due to the novel products
- To ensure that all safety aspects of the design are considered
- To provide a safe design through a IMO safety formal process, the Formal Safety Assessment (FSA), that permit to us to provide a robust Safety Case for the products that ensures that all the safety considerations are in place



HYDROGEN SAFETY RISK ANALYSIS IN THE MARINE INDUSTRY

Possible Safety Controls: Preventive and Mitigative Controls

- **Safety Design:**

Storage of high-pressure hydrogen tanks in the open, above deck can be advantageous since leaks can be dispersed in the open air, reducing cloud size, and the lack of confining walls will reduce the explosion severity.

With hydrogen storage and FC rooms under deck, segregation from manned and critical areas by distance and/or strong walls and decks should be considered.

Hydrogen spaces for storage and FCs should be placed with at least one wall or deck bordering an area without people and critical equipment.

Pressurized hydrogen tanks and other equipment need to be segregated to limit the amount of gas that can leak.

Single failure criteria: this means that the FC system shall be designed in such way, that no single failure can lead in a hazardous situation…

- **Detection and alarms:** Gas detection can be provided with point gas detectors that detect gas concentrations and give an alarm or a signal for automatic shutdown at a pre-set gas concentration
- **Ignition control:** Ignition control is to shut down possible ignition sources on gas detection
- **Isolation and shutdown:** Hydrogen flowing from or to a tank is isolated with isolation valves upon gas detection
- **Vents and pressure-relief systems / masts:** the vent system handles controlled releases of gas, such as blowdown releases and planned releases during maintenance etc
- **Ventilation**: In case of a hydrogen leakage into an enclosed volume, ventilation may be needed both for hydrogen dilution and extraction purposes
- **Storage system leak control:** gas storage systems can be safety critical since they contain enough gas to cause a critical explosion if a leak releases the stored hydrogen
- **Fire control and fire protection:** The main goal of the fire strategy should be to prevent escalation of the incident to other parts of the ship or fuel systems that can lead to yet more escalation

CONCLUSIONS

The hydrogen use as fuel on ships shall be doing **safely**

Hydrogen Safety

It is necessary to analyze **all its possible impacts on the safety of the own ship, its crew, and the environment.** The applicable safety concept must go beyond compliance with legal obligations and maritime regulations, more of them, are in development, increasing the necessity of safety analysis in this H2 industry

It is essential to consider the **use of advanced tools for the identification, evaluation, and management of safety risks**, as support for administration and decision making to develop H2 safety systems

We use qualitative and quantitative risk assessments, starting with the qualitative approach for the vessel and the quantitative approach for the most critical effects that generate risks for the H2 systems to be aware of the total impact on the safety of the H2 vessel

We should use the H2 systems **safety risk approach to provide a strong argument about the safety impacts that could appear and how we can eliminate or reduce them to an ALARP level that minimizes the safety effects on the ship, personnel and the environment**. Through this evaluation we **will be able to improve the established regulations**, understanding the dangers of H2 and the necessary control measures that we must implement in H2 vessels

✓ *The European Maritime Safety Agency (EMSA), is developing a Study on the safety of hydrogen as fuel for ships*

ALARP™

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