European Maritime Safety Agency

Study investigating the safety of hydrogen as fuel on ships

FINAL REPORT

DELIVERABLE D.6 – PART 1, 2 AND 3

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Abstract

This report is developed as part of the project “EMSA study investigating the safety of hydrogen as fuel on ships”. The overall objective of the project is to conduct a structured set of safety assessments and reliability analyses, resulting in a Guidance document which addresses ships using hydrogen as fuel. The purpose is to support regulators and the industry in navigating towards a safe and harmonised deployment of hydrogen as a fuel, which could demonstrate an important step towards decarbonising the sector.

This final report provides the executive summary of the project, the results obtained in the previous tasks, as well as the Guidance for ships using hydrogen as fuel and recommendations as appropriate.

Executive Summary

The project's overall objective is to carry out a structured set of safety assessments and reliability analyses, delivering a Guidance document addressing ships using hydrogen as fuel. The purpose is to support regulators and the industry in navigating towards a safe and harmonised deployment of hydrogen as fuel, which could demonstrate an important step towards decarbonisation of the sector. This report is the result of the sixth and final task of the study investigating the safety of hydrogen as fuel on ships.

The International Maritime Organization (IMO) updated its greenhouse gas (GHG) strategy in 2023 with a goal of achieving net-zero emissions by 2050. Together with new EU regulations, this will be critical for decarbonising international shipping. Energy efficiency measures can lower GHG emissions from ships, but they will not bring the industry to net-zero emissions by 2050 without a change to zero-GHG fuels and potentially other technologies.

Most potential zero-carbon fuels, such as hydrogen, have properties that pose different safety challenges compared to conventional fuel oils. This requires the development of IMO regulations and classification rules for safe design and use onboard ships, in parallel with the technological progress needed for their uptake. It is important to take a systematic approach to ensure that the upcoming regulatory framework addresses all hazards associated with using hydrogen as fuel on ships.

What we did

The project has applied the IMO goal-based approach outlined in IMO's Generic guidelines for the development of goal-based standards (IMO, 2019), and draws upon comprehensive risk assessment and reliability analysis as documented in the following tasks:

- Task 1: Mapped hydrogen-specific safety hazards, threats, and risks; reviewed existing regulations and standards; validated modelling tools; and drafted preliminary guidance.
- Task 2: Analysed reliability of hydrogen equipment and safety-critical systems; developed a generic risk model for hydrogen-fuelled ships.
- Task 3.1: Performed HAZID workshops for generic hydrogen fuel systems (compressed and liquefied hydrogen) and hydrogen consumers; identified hazards and preventive measures.
- Task 3.2 & 4: Conducted risk analyses for two generic fuel system concepts and two specific ship types (Platform Supply Vessel with compressed hydrogen fuel system and Service Operation Vessel with liquefied hydrogen fuel system).
- Task 5: Developed the EMSA Guidance for ships using hydrogen as fuel, including gap analysis against IGF Code, alignment with draft IMO Interim Guidelines, and stakeholder consultation.

What we found

Hydrogen presents unique safety challenges compared to natural gas:

  - A wider flammability range, lower ignition energy, and higher burning velocity lead to increased risk of fire and explosion.
  - Cryogenic properties and vacuum insulation failures pose structural and operational hazards.
  - Hydrogen embrittlement and components prone to leaks raise reliability concerns.

Existing IGF Code provisions for natural gas are insufficient for hydrogen; additional measures are required:

- It should be assumed that there is a probability of ignition in a hydrogen leakage scenario even after measures such as installing certified-safe electrical equipment have been implemented.
- Design for significant leaks and include secondary enclosures around leak points (with inert gas for gaseous hydrogen piping, vacuum for liquefied hydrogen piping).

Reliability analysis revealed significant uncertainty in leak frequency and ignition probability due to the limited availability of hydrogen-specific data; heat exchangers, compressors, and valves are identified as particular risk drivers.

HAZID and risk analyses confirmed that:

- Open-deck storage reduces the risk of gas accumulation but complicates leak detection for single-walled piping.
- Inerting spaces to prevent explosions is complex and not entirely reliable; complete secondary enclosures around all hydrogen piping are preferable.
- Bunkering in semi-enclosed spaces significantly increases the risk of explosion.

Occupational hazards include asphyxiation, cryogenic burns, and high-pressure leaks; robust training and safety culture are vital.

The Guidance document (Appendix A) outlines goals, functional requirements, and prescriptive measures consistent with the IMO Interim Guidelines. It provides recommendations for system design, operational practices, and emergency preparedness. The Guidance differs from the draft IMO Interim Guidelines for the Safety of Ships Using Hydrogen as Fuel (CCC 11/WP.4 Annex 2) in several areas, as detailed in Appendix B. Notably, the Guidance recommends that all potential hydrogen leak sources be protected within secondary enclosures, both in enclosed spaces and on open deck. This approach introduces variations in the safety barriers compared to those outlined in the IMO draft.

The lack of bunkering guidance on the shore-side is a significant safety gap that requires closing. Appendix C includes a high-level list of subjects that would need to be developed to guide relevant stakeholders on what is required to perform a safe bunkering operation.

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List of Abbreviations

CCC	The IMO Sub-Committee on Carriage of Cargoes and Containers
CCPS	Center for Chemical Process Safety
CFD	Computational Fluid Dynamics
CH2	Compressed hydrogen
EMSA	The European Maritime Safety Agency
ESD	Emergency Shut-Down
EU	European Union
FSHS	Fuel Storage Hold Space
GHG	Greenhouse gas
GOALDS	GOAL based Damage Stability project
H2	Hydrogen
HAZID	Hazard Identification
HCRD	Hydrocarbon Release Database
HIAD	Hydrogen Incident and Accident Database
HRA	Human Reliability Analysis
IGC Code	The International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
HyRAM	Hydrogen Risk Assessment Models
IGF Code	The International Code of Safety for Ships using Gases or other Low-flashpoint Fuels
IMO	The International Maritime Organization
ISO	The international Organization for Standardization
LH2	Liquefied hydrogen
MSC	The IMO Maritime Safety Committee
NASA	National Aeronautics and Space Administration
NPRD	Nonelectronic Parts Reliability Data
OREDA	Offshore and Onshore Reliability Data
PDS	Product Data Syndication
PRV	Pressure Relief Valve
PSV	Platform Support Vessel
QRA	Quantitative risk assessment
SIL	Safety Integrity Level
SOLAS	The International Convention for the Safety of Life at Sea
SOV	Service Operation Vessel
TCE	Tank Connection Enclosure
TCS	Tank Connection Space
TPRD	Thermal Pressure Relief Devices

1. Introduction

EMSA has contracted DNV to conduct a study on the safety of hydrogen as a fuel for ships. The project's overall objective is to conduct a structured series of safety assessments and reliability analyses, resulting in a guidance document for ships using hydrogen as fuel. The purpose is to assist the industry and regulators in achieving a safe and harmonised deployment of this key technology, which could demonstrate an important step towards decarbonisation of the sector. This report presents the findings of Task 6 of the study.

The purpose of this task – the final report – is to provide an executive summary of the project, including the results from previous tasks, as well as presenting the Guidance for ships using hydrogen as fuel and corresponding recommendations as appropriate.

The International Maritime Organization (IMO) updated its greenhouse gas (GHG) strategy in 2023, with the goal of achieving net-zero emissions by 2050. Together with new EU environmental regulations, this will be a critical driver for decarbonizing international shipping. Energy efficiency measures can lower GHG emissions from ships but will not bring the industry to net-zero emissions by 2050 without a change to zero-GHG fuels and potentially other technologies.

Most potential zero-carbon fuels, such as hydrogen, present safety challenges that differ from those of conventional fuel oils. This requires the development of IMO regulations and classification rules for safe design and use on board ships, in parallel with the technological progress needed for their uptake.

To ensure that all hazards related to the use of hydrogen as fuel on ships are covered in the regulatory framework under development, it is necessary to use a systematic approach, such as the IMO goal-based approach provided in MSC.1/Circ.1394 (IMO, 2019), and to build on extensive risk assessment and reliability analysis.

This project has delivered a series of reports summarising findings from each task. This report (Deliverable D.6) relates to Task 6. An overview of all study tasks and deliverables is provided in Figure 1-1.

Figure 1-1 Study tasks and deliverables. This report presents the result of the sixth task (Task 6).

This final report presents the results of the sixth task and provides a summary of previous work. It has the following structure:

- Chapter 2 (Part 1) provides the results of Tasks 1 and 2.
- Chapter 3 (Part 2) provides the results of Tasks 3 and 4.
- Chapter 4 (Part 3) outlines the approach and foundation for developing the Guidance for ships using hydrogen as fuel in Task 5.
- Chapter 5 provides the main conclusions and recommendations.
- Appendix A presents the draft Guidance for ships using hydrogen as fuel.
- Appendix B provides a paragraph-by-paragraph comparison between the draft Guidance for ships using hydrogen as fuel and the IMO draft interim guidelines for the safety of ships using hydrogen as fuel.
- Appendix C includes a proposed structure of a Guidance addressing the bunkering process.

2. PART 1 – Summary of Tasks 1 and 2

This part presents the findings from Tasks 1 and 2 of the study, documented in (EMSA, 2024a) and (EMSA, 2024b) respectively.

2.1 Task 1 – Mapping safety risks for hydrogen fuelled ships

The first project task focused on analysing hydrogen's main characteristics to identify the safety hazards, system threats, and associated risks when hydrogen is used as a marine fuel. Natural gas, governed by the IGF Code and its established safety barriers, served as a benchmark. The review also included mitigation principles, lessons from past hydrogen incidents, and validation of modelling tools. Relevant statutory regulations, classification rules, standards, and best practices were examined to determine the extent to which hazards and risks are addressed by existing frameworks.

Based on the above, preliminary goals and functional requirements for a guidance document for ships using hydrogen as fuel were defined, and an initial table of contents was drafted. The following sub-sections summarize the primary outcomes from Task 1.

2.1.1 Hydrogen safety hazards, threats, and risks

The primary safety hazard associated with using hydrogen as a fuel on a ship is related to the high flammability properties, which exceed those of natural gas. Hydrogen has: (i) a much wider flammability range, (ii) a significantly lower minimum ignition energy, and (iii) a higher burning velocity. This means that explosions caused by hydrogen can be more severe than those caused by natural gas and may even transition into detonation. The low boiling point of hydrogen poses additional safety concerns for storage and distribution. This includes managing boil-off gas and preventing the condensation and solidification of gases with higher boiling points. Air contamination in a liquefied hydrogen (LH2) system will solidify as nitrogen, oxygen, and frozen water. These contaminants can cause blockages in pipes or instruments, leading to equipment failure and posing a potential risk of explosion when systems are heated, and the oxygen-enriched air evaporates.

Due to its low density, hydrogen gas will tend to rise and disperse in an open environment. Directional effects of high-pressure releases and releases of cryogenic hydrogen may complicate this picture. In confined spaces, hydrogen can accumulate in high spots and reach ignition sources, such as ceiling lights. Accounting for the density of any released gas is important for the proper design of many safety barriers. Examples include the placement of gas detectors, the layout of ventilation systems, and the shape of spaces where gas leaks might occur, all of which must consider the density of the leaking gas.

Damage to fuel containment systems and, to a lesser extent, piping systems has the potential to release all the hydrogen stored onboard, which would be a catastrophic event. Consequently, it is of the utmost importance that storage and distribution systems for hydrogen fuel are sufficiently protected against external events that could potentially damage them.

When hydrogen is compressed to high storage pressures (250-700 bar), it gains significant potential energy like any other gas. Releasing this energy can cause strong pressure effects depending on the release rate, even without combustion. Sudden releases of hydrogen from high-pressure hydrogen systems are also known to ignite spontaneously without any apparent ignition source.

Hydrogen releases in confined spaces are particularly dangerous because the explosion pressure rapidly increases after ignition, causing potential structural damage, a higher risk of further hydrogen leaks, and the destruction of safety barriers. Leakages of LH2 in enclosed spaces will cause significant cooling effects, potentially affecting the integrity of gas-tight systems and the operation of safety equipment inside.

When vacuum insulation fails or when large amounts of cold gas are vented, the outside surfaces of the LH2 containment and vent piping could become cold enough to liquefy the oxygen and nitrogen in the air. Condensed air reaching ship steel and cooling confined spaces could quickly cause structural damage due to low-temperature embrittlement. During condensation, oxygen liquefies faster than nitrogen. Oxygen-enriched liquefied air raises the flammability of materials it contacts.

Hydrogen can significantly degrade the mechanical properties of metals, a phenomenon known as hydrogen embrittlement.

Significant hydrogen leakages can cause asphyxiation due to oxygen depletion. Additionally, low surface temperatures and reduced flame visibility are risk factors that must be mitigated to prevent frostbite and burn injuries.

2.1.2 Established principles for mitigation and control of hydrogen hazards

Eliminating hazards is always the best option, but it may not always be feasible. In such cases, it's essential to implement a range of risk controls to lower the risks to an acceptable level. The “Hierarchy of risk control measures" shown in Figure 2-1 highlights the importance of recognising that technical measures are generally more effective than operational measures in managing risks. The most effective risk control contributions and the foundation for safe operations can be incorporated during the design phase by using control measures from the top of the hierarchy. However, proper training and operational procedures are essential to ensure the safe operation of a ship throughout its lifespan. Ultimately, the design intent must be maintained throughout the full life cycle: safety measures should not degrade over time.

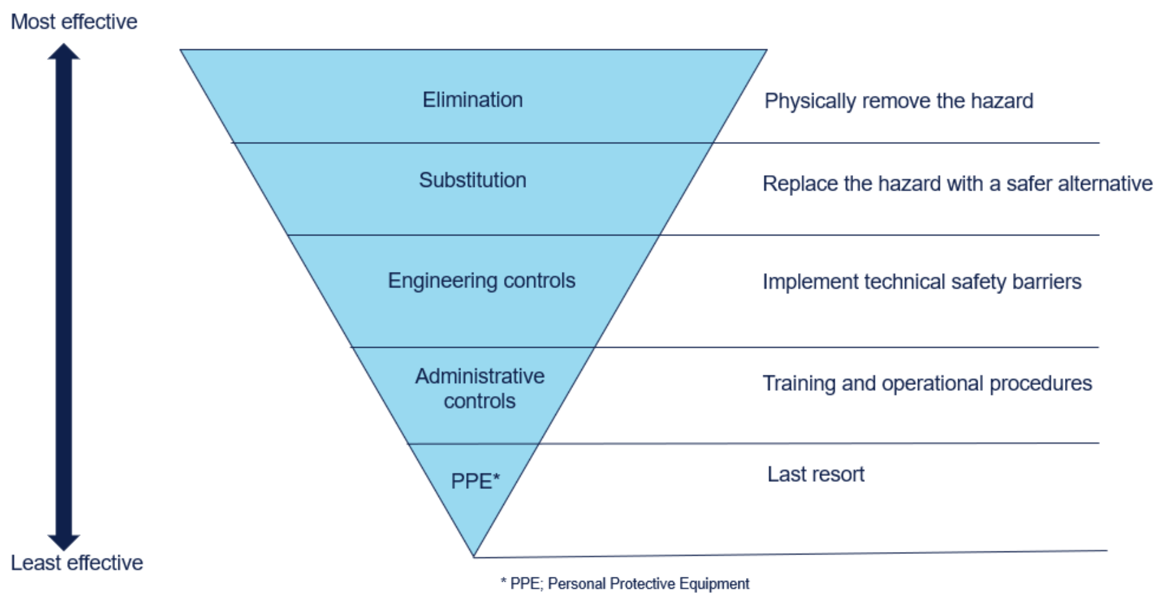

Figure 2-1 The Hierarchy of Risk Control Measures (Source: DNV).

The general principles, guidelines, and recommended practices derived from knowledge gained in other industries are essential for safely managing hydrogen. According to (ISO, 2015) and (NASA, 1997), regulators are advised to assume an ignition source is present even when compliance with acceptable standards for certified electrical equipment is maintained. This suggests that the ignition of hydrogen in a release scenario should be presumed, and additional measures (e.g., secondary barriers) should be implemented to prevent ignition unless the ignition event falls within the ship's design capabilities.

The MarHySafe project (MarHySafe, 2021) concludes that extreme explosions are more likely to happen with hydrogen than with natural gas. The project notes that defining relatively small credible leak sizes in risk assessments for shore-based hydrogen applications is a common practice. This often leads to a focus on hydrogen fires, as significant explosion events are not considered feasible due to the combination of leakage rates and safety barriers. MarHySafe recommends considering more severe leak scenarios for maritime systems due to the new and more critical application area. It is also noted that several Classification Societies have included requirements for considering leakages up to full-bore rupture in their current class rules.

Determining the size of hydrogen leakages that a hydrogen-fuelled ship is designed to withstand is crucial for assessing its overall safety. The IGF Code for natural gas refers to a “maximum probable leakage,” which can be interpreted in various ways. Another key decision that will greatly influence the ship's design is whether to assume there is a probability of ignition even after measures like installing certified-safe electrical equipment have been implemented.

There are key differences to consider when hydrogen technologies are transferred from land to ships. These include factors such as the autonomy of ships operating in open seas, space limitations, and environmental conditions. Consequently, not all land-based solutions and safety principles, such as separation distances and keeping all leakage sources in the open air, are applicable to ships using hydrogen as fuel.

2.1.3 Lessons learned from hydrogen-related accidents

Reviewing accident databases shows that hydrogen-related accidents occur. Out of the 575 accidents analysed in the HIAD 2.0 database, the main causes of hydrogen-related accidents are categorised as system design errors and failures, and human errors. A combination of these factors has also led to severe incidents. The largest proportion of cases was associated with safety management system factors (49%). The second most common cause was errors in materials or manufacturing (35%). Many incidents were caused by individual human errors (29%) and system design errors (27%). Nearly half of the incidents in the HIAD 2.0 database involved human and organisational errors. Therefore, training operating personnel and increasing their understanding of hydrogen hazards will be vital to preventing future hydrogen-related incidents. Likewise, safety management systems must adequately address hydrogen hazards in operational procedures, inspection plans, and emergency response procedures.

2.1.4 Validation of modelling techniques and tools

In evaluating consequence scenarios involving gas leaks, ventilation, dispersion, and explosions, commercial CFD models are used to simulate these phenomena with sufficient precision. Specifically, these models can effectively capture the behaviour of hydrogen up to the point of deflagration. However, it is important to note that there is usually less validation available for hydrogen than for natural gas or methane, and some consequence types have not been validated. Nonetheless, this does not inherently make the tools unusable. Careful consideration must be given to the execution of the analysis where validation is limited or absent. While hydrogen-specific models exist for calculating leak frequency and ignition probabilities, failure data and validation are lacking to ensure their accuracy in quantitative risk analysis. Therefore, this area often contains the highest uncertainty in the risk models.

2.1.5 Review of existing regulations and standards

We found that the existing safety barriers in the IGF Code for natural gas do not account for hydrogen's higher flammability. In (EMSA, 2023) and in (DNV, 2022) the need for additional safety measures is confirmed. As of 2024, the IMO draft guidelines and various classification rules for hydrogen-fuelled vessels largely adopted the IGF Code safety concept for natural gas with added risk assessment. Key hydrogen specific topics identified in classification rules included:

- Extensive guidance on risk assessment scope.
- Accumulation of released hydrogen (confined areas, enclosed, semi-enclosed spaces).
- Formation of liquefied or solidified air and water.
- Loss of vacuum insulation.
- Vent mast arrangements.
- Materials suitable for hydrogen service (hydrogen permeation and embrittlement).
- Definition of leakage sizes for various piping system components, including full-bore rupture.
- Location, design, and construction of hydrogen storage tanks.
- Arrangement of secondary enclosures for hydrogen piping (vacuum, helium, nitrogen).
- Arrangement of spaces containing hydrogen systems (vacuum, helium).
- Fire safety.
- Hazardous area classification, including electrical equipment.
- Personnel safety and PPE.

2.1.6 Drawing up a preliminary Guidance

Sections 2.1.1 through 2.1.5 indicate that the following functional requirements are critical to achieving a safety standard equivalent to that of a conventional oil-fuelled vessel:

- A substantial leakage from fuel piping systems should be considered in the design of safety barriers for a hydrogen-fuelled ship.

- The ship design should be based on the assumption that there is a probability of ignition even after measures like installing certified-safe electrical equipment have been taken.

- Hydrogen leakages should be prevented from reaching areas where combustion could be supported.

The above formed the basis for the first draft Guidance including preliminary goals and functional requirements.

2.2 Task 2 – Reliability analysis for hydrogen systems

The second project task reviewed three key areas: reliability of hydrogen equipment, reliability of safety-critical systems, and safety analysis of hydrogen-fuelled ships. The study assessed failure data sources for equipment reliability, identified critical components based on current design concepts, and evaluated the performance of safety-critical systems within generic hydrogen fuel configurations. These analyses provide a foundation for hazard identification and risk assessment and inform the development of a generic risk model for hydrogen ships, based on the findings from Task 1 (EMSA, 2024a). The following sub-sections present a summary of the key findings from Task 2.

2.2.1 Reliability analysis of hydrogen equipment

Leak frequencies have always been a major source of uncertainty in risk analysis. Currently, the absence of hydrogen-specific failure data and uncertainties about their suitability for ship applications lead to a high level of uncertainty in leak frequency analysis in QRAs for hydrogen fuel system installations.

Due to limited experience with hydrogen-fuelled ships and the absence of an industry-specific leak database for the maritime sector, we have found that using the generic HCRD and/or HyRAM+ databases to be the most suitable alternative when establishing leak frequencies for hydrogen-fuelled ships.

The reason for selecting HCRD was its extensive, high-quality dataset, its widespread use in QRAs, and its consideration of various parameters, including equipment operation in offshore environments. The choice of HyRAM+ was due to this toolkit forming the basis for carrying out QRAs and modelling the consequences for hydrogen infrastructure and transportation systems. Although the leak data in HyRAM+ originates from various industries and contains limited hydrogen-specific information, it is currently the only dataset specifically designed for hydrogen applications. It is also worth noting that HyRAM+ is a research software actively under development, so the models and data may evolve over time.

Although the HCRD and HyRAM+ databases are considered the most applicable and have the highest quality, they do not account for maritime-specific factors. Additional uncertainty arises from the differences in the properties and behaviour of hydrogen compared to the media on which the Oil & Gas databases are based. Hydrogen is prone to leaking due to its low density and small molecular size. It's not clear how much these characteristics, in combination with the specific environmental conditions onboard a ship, will impact the reliability of data sources in accurately predicting leak frequencies. Additionally, hydrogen installations typically feature smaller equipment sizes compared to industrial plants and offshore installations. Inspection, certification regimes, and maintenance intervals also significantly influence the frequency of leaks in process equipment and can vary between the oil and gas, process, and shipping sectors.

For safety and control equipment, it is important to address uncertainty on a case-by-case basis in quantitative risk analysis. The data collected from the oil and gas sector is based on an industry that requires demonstrating Safety Integrity Level (SIL), which is not a requirement in maritime. Hardware and software from reputable manufacturers, who also supply SIL-certified components to the oil and gas sector, are likely to meet higher standards and have less uncertainty. There is no clear preference for failure-on-demand probabilities of safety and control equipment; instead, multiple sources have been referenced. The failure data from the PDS Handbook, OREDA, CCPS Guideline, and NPRD have all been reviewed and cited in this study.

2.2.2 Reliability analysis of safety-critical systems

To effectively evaluate the performance of safety-critical systems, it is essential to consider them within their specific context. This involves outlining some fundamental design assumptions. The two primary parameters that define the ship's arrangement and consequently influence the risk level for hydrogen-fuelled ships are:

- **Storage condition** of fuel onboard: Liquefied hydrogen (LH2) or compressed hydrogen gas (CH2).
- **Storage location** of fuel onboard: On deck (unconfined area) or below deck in a confined space.

The analysis was performed for two different fuel containment systems and storage locations, in addition to one bunkering configuration:

Compressed hydrogen storage on deck – Leak detection and fuel supply shutdown system

One challenge with storing compressed hydrogen on deck is the difficulty in arranging hydrogen piping with secondary enclosures due to the large number of pipes and the small dimensions. For portable tanks, there is the additional complication of non-permanent connections, which must be operated at every refuelling operation. A single-walled hydrogen system on deck will rely on leakage detection located in open air to identify and stop a hydrogen leak. In Case 1, we investigated this design feature to understand better how the reliability of leakage detection impacts the vessel's overall safety.

Liquid hydrogen storage below deck – Inert Gas System

In Task 1 (EMSA, 2024a), we found that dilution ventilation may not be an effective method for reducing the impact of significant hydrogen releases in enclosed spaces. Case 2 examined an alternative to a ventilated TCS, which involves maintaining a constantly inerted atmosphere inside the TCS to prevent ignition, fire, and explosion. The analysis focused on the likelihood of having a sufficiently inert atmosphere in the TCS on demand. We also discussed other challenges associated with using inerting as a key safety measure.

Bunkering of liquefied hydrogen – Safe hydrogen bunkering

To mitigate risks related to refuelling, a bunkering location on an unrestricted open deck provides the best boundary conditions for safely bunkering hydrogen. In Case 3, we examined the bunkering of liquefied hydrogen on a vessel where the general arrangement prevents the installation of the bunkering manifold on the open deck. We examined the consequences of a potential leak in a semi-enclosed bunkering station, similar to those typically used for LNG-fuelled ships. The intention was not to quantify reliability as in the previous two cases but instead to discuss important challenges and lessons learned from recent studies.

2.2.3 Safety analysis of hydrogen-fuelled ships

The goal of this sub-task was to develop a framework for a generic risk model for hydrogen-fuelled ships, based on the hazards, threats, and risks identified in (EMSA, 2024a). Findings from the reliability analysis of hydrogen equipment and safety-critical systems were also crucial inputs to the model (EMSA, 2024b).

The model contributes to risk quantification and also visualizes potential consequence outcomes following an initiating event, thereby enhancing the understanding of major accident risks in complex scenarios. Highlighting the potential consequences of hydrogen releases underscores the importance of stopping the event as early as possible in the chain of events, ideally by preventing any release in the first place.

As with any quantitative risk model, it is important to recognise that the framework developed in this study would need to be enriched with additional real-world scenarios. While it provides valuable insights and aids in understanding potential risks, it cannot capture every variable and nuance of actual events. It is a useful tool for risk assessment and decision-making, acknowledging the inherent uncertainties and limitations. The aim of the model was to create an event tree for risk analysis that can be applied to all hydrogen loss-of-containment events. The model is general and suitable for both liquid, gaseous, and two-phase hydrogen releases, whether they occur in enclosed spaces or on an open deck. While numerous event trees exist for loss of containment in the oil and gas industry, relating to hydrocarbon releases, the use of hydrogen as a fuel in shipping is a relatively new application. QRAs need to be developed from scratch to include new hazards and effects that are not always modelled in traditional QRAs.

We found that the main sources of uncertainty in the risk model are the leak frequency data and ignition probability. This aligns with findings from a DNV study on Hydrogen Risk Assessment methods from 2008, which also identified significant uncertainty in safety systems failure probabilities (DNV, 2008). These uncertainties stem from a limited availability of databases specifically focused on hydrogen equipment failures. Additionally, hydrogen ignition models are still under development. The ignition probabilities greatly affect the estimated risk level, resulting in significant uncertainty when using ignition probabilities for hydrogen. Studies have also identified a knowledge gap regarding the exact ignition mechanisms for hydrogen releases.

Furthermore, there is high uncertainty regarding whether the gas detector system can react quickly enough to prevent a critical gas cloud from forming. If leaks are in the range of 0.1 kg/s, an explosive atmosphere can be generated within a few seconds. Conventional point gas detectors are not fast enough, and the reliability of acoustic detectors is uncertain due to the potential for ultrasonic noise interference.

As with any quantitative risk analysis, there will be uncertainty associated with the final risk level calculated using this model framework. However, the method offers a structured approach to understanding risks, enabling decision-makers to make informed choices even with uncertain data. Additionally, the modelling can identify the most significant risk drivers and quantify the risk-reducing effects, aiding in the selection of effective preventive and mitigating measures.

3. PART 2 – Summary of Tasks 3 and 4

This part presents the findings from Tasks 3.1, 3.2 and 4 of the study documented in (EMSA, 2025a), (EMSA, 2025b) and (EMSA, 2025c) respectively.

3.1 Task 3.1 Hazard identification

A HAZID study was conducted on generic hydrogen fuel system concepts to identify key safety risks and potential mitigation measures. It covered the entire process from bunkering to exhaust, concentrating on leakage scenarios and related flammable and cryogenic effects. The study was conducted through a multidisciplinary workshop with sessions on compressed hydrogen systems, liquefied hydrogen systems, and hydrogen consumers. The findings support the development of safety improvements and guidance for hydrogen-fuelled ships. The following sub-sections summarise the results of Task 3.1.

3.1.1 Hazard identification of CH2 fuel systems

The HAZID work for CH2 systems was conducted across a variety of system configurations as follows:

- Portable CH2 fuel tanks in open swap containers.
- Portable CH2 fuel tanks in swap containers with naturally ventilated tank connection enclosures.

- Portable CH2 fuel tanks in swap containers with an inerted tank connection enclosure.
- Fixed CH2 fuel tanks with an inerted tank connection enclosure.
- Common hazards for CH2 fuel systems (valid for all configurations).

The key findings from hazard identification of CH2 fuel systems across the various configurations are outlined below.

The extensive use of pipe fittings and flexible hoses significantly increases the risk of leaks in the fuel piping associated with the portable tanks. Such leaks could generate a critical cloud that, if ignited, can cause severe damage. The primary challenges associated with this concept are:

  - Lack of control over the leak and its direction.
  - Significant uncertainty regarding the detection of leaks. A critical cloud is likely to form long before the leak is detected.
  - Insufficient protection of tanks and nearby containers against hydrogen-initiated jet fires and explosions.

Tank isolation valves, combined with restrictive flow orifices or excess flow valves, can help improve safety. While they can stop larger leaks, more minor leaks might remain unnoticed for a long time, as detecting gas leaks in an open environment is difficult.

Arranging a tank connection enclosure (TCE) around tank valves and the related piping system has certain advantages compared to open containers:

  - Improved control of leaks and detection capabilities.
  - Enhanced physical protection from jet fires and explosions.
  - Better protection against mechanical impacts.

However, a concept involving a naturally ventilated TCE may be at risk of severe explosions and potentially DDTs within the enclosure, even in the case of more minor leaks. The concept might also allow unignited gas to escape from the enclosure during a leak, potentially creating a large hydrogen cloud in the surrounding area.

Inerted TCEs can reduce the risk of ignition within the enclosure. However, for concepts applying portable tanks, the following are noted:

  - The lifting of containers may cause cracks and oxygen ingress as the container experiences torsion and bending.
  - When the container is not connected to the ship system (when the container is transported on shore, during lifting, and onboard before being connected to the ship system), the safety systems will not function. This is an inherent issue for all swappable containers.
  - When gas-freeing the enclosure for inspection or maintenance, the main safety barrier to prevent ignition will be removed.

Due to the above, the workshop participants considered that the inert concept for TCEs would be easier to implement on a fixed fuel tank installation.

Fixed CH2 fuel tanks with an inerted TCE avoid many of the challenges of portable storage systems, such as:

  - Dependence on non-permanent flexible hoses to connect tanks and ship systems.
  - Dependence on non-permanent connections of control and safety systems.
  - Difficulties in applying secondary enclosures.
  - Hazards of lifting tanks on/off the ship.
  - Dependence on non-permanent sea fastenings.

One of the major hazards associated with the CH2 fuel system is the risk of fire or explosion affecting fuel storage tanks. If a hydrogen fuel system is exposed to an external fire, it will heat up, potentially compromising its structural integrity. Thermal Pressure Relief Devices (TPRD) are currently used to prevent the rupture of pressure vessels in such fires. The TPRD operates differently from a typical safety valve, as it opens when a sensor detects high temperature, not pressure. Once open, it will remain open. Uncertainties still remain regarding:

- Can pressure vessels be subjected to jet fire impingement without activating the TPRD fuse?
- What should be the requirements for the placement of the TPRD sensor?
- If the TPRD sensor is located within the tank space or the TCE, it may take longer for the TPRD fuse to activate in the event of an external fire (i.e., when the device has responded to high temperatures).

3.1.2 Hazard identification of LH2 fuel systems

The primary focus of the HAZID for liquefied hydrogen systems was on scenarios involving hydrogen leakage within the fuel system and their potential to induce flammable and cryogenic effects. In the event of leaks from the piping inside the tank connection space (TCS), the hydrogen could ignite, leading to fire or explosion. Moreover, a hydrogen leak might result in overpressurisation of the space. Leaks of liquefied hydrogen would generate a rapid pressure increase as LH2 expands 850 times when transitioning from liquid to vapour. Additionally, the cooling effect inside the TCS would be substantial. Both scenarios pose risks of structural damage and loss of integrity of the TCS. The key findings from the hazard identification of LH2 fuel systems are outlined below.

Tank connection spaces

Three options for arranging the TCS for an LH2 fuel tank were discussed in the HAZID workshop:

- Mechanical ventilation.
- Inerting.
- Secondary enclosures for all liquefied and gaseous hydrogen piping.

As a safety measure, mechanical dilution ventilation could prevent small leakages from accumulating an ignitable hydrogen atmosphere in the TCS, but it would not prevent potential ignition and jet fires. For more substantial hydrogen releases in enclosed spaces, forced ventilation should not be considered a dependable safety measure. It is important to note that the primary safety barrier employed in other industries is to eliminate the risk of hydrogen leakages in enclosed spaces.

Preventing ignition by removing the oxidant is a sound principle; however, the complexity of the solution, the wide explosive range of hydrogen, and the unknowns make prescriptive regulatory guidance challenging for this concept. The following was noted:

- An inert atmosphere prevents access to the TCS during operation.
- It is unclear how a loss of tank vacuum and subsequent cooling of the TCS by cold tank surfaces will affect the primary safety barrier (nitrogen-filled TCS).
- Gas freeing after a leakage is a complex operation with the possibility of error.
- The main safety barrier is dependent on an active barrier (constant availability of nitrogen).

An LH2 fuel system, where the piping systems for liquefied and gaseous hydrogen are protected against leakages by secondary enclosures for the complete system, would be possible to make safe from a flammability point of view.

Bunkering station for LH2 bunkering

The liquefied hydrogen bunkering manifold should be situated on the open deck, avoiding areas where hydrogen gas may accumulate, as far as the ship's design permits.

In instances where semi-enclosed bunkering station configurations are necessary due to the ship's design, the effects of an ignited leak should be mitigated by reducing the volume of the bunkering station that could potentially be subject to significant leaks.

Common hazards for LH2 fuel systems

Liquefied hydrogen is stored at a temperature of -253°C, which is lower than the condensation temperature of the nitrogen and oxygen in the air. If the storage tank vacuum insulation is lost, the external surfaces of the tank may become cold enough to liquefy the surrounding atmosphere, and the heat input to the tank will increase rapidly. Condensed air reaching ship steel could rapidly result in structural damage from low-temperature embrittlement. Pressure relief systems must be able to handle the quick pressure increases and hydrogen boil-off to prevent overpressure and potential failures of the tank or piping system. When large volumes of cold gas are vented through the vent system and the vent mast, there is also a risk of cooling the venting system to a temperature below the condensation point of the air. The loss of tank vacuum insulation can lead to extremely low temperatures in the tank hold space, tank connection space, and in areas where the vent system is located. This could potentially compromise the structural integrity of these spaces and the systems within them.

3.1.3 Hazard identification of hydrogen fuel consumers

The key findings from the hazard identification of hydrogen fuel consumers, including fuel preparation and the engine room, are presented below:

H2 leakage in the fuel preparation room

- A fuel preparation room for hydrogen compressors and buffer tanks represents an immature concept.
- A higher tank pressure or lower fuel supply pressure might make a fuel preparation room unnecessary for low-pressure consumers.
- Fuel preparation rooms should be situated on the open deck.
- Mechanical ventilation of the fuel preparation room is excluded as an effective safety barrier due to the potential size of leaks from compressors and buffer tanks.
- Double-walled piping and inerting should be considered.

H2 leakage in the inner pipe of a double-walled piping system

- All fuel piping in enclosed spaces should be configured as double-walled piping.
- Inerting the outer pipe is regarded as the best option for low, medium, and high-pressure engines.
- The ESD-protected machinery space concept with single-walled piping in the engine room is unsuitable for hydrogen.

Gas fuel consumer in the engine room

- All hydrogen fuel piping on the engine should be arranged as double-walled piping.
- The engine's gas vent line, including the vent outlet, should be designed to withstand ignition and possible detonation.
- For engine knocking and crankcase explosion risks, the same basic principles as for LNG fuel should be applied, but the implications due to hydrogen properties must be considered.

3.2 Task 3.2 Risk analysis of generic hydrogen fuel systems

Several generic hydrogen fuel system concepts were identified during the HAZID study (EMSA, 2025a). Two were selected for prescriptive guidance development and risk analysis:

- **Compressed hydrogen (CH_2)** system with fixed tanks, inerted tank connection enclosure (TCE), and secondary enclosures for distribution piping.
- **Liquefied hydrogen (LH_2)** system with vacuum-insulated IMO Type C tanks, tank connection space (TCS), and secondary enclosures for distribution piping.

Both concepts were selected for their use of secondary enclosures, which facilitate quick leak detection, reduce ignition risk, and prevent gas accumulation. Systems lacking secondary enclosures were omitted because it is challenging to establish universally applicable safety barriers that fulfil the Guidance functional requirements. However, this choice does not exclude the possibility of safely developing other designs through further analysis.

For each concept, frequency analysis (using HyRAM+ leak data), qualitative consequence analysis, and bowtie-based barrier modelling were performed for loss-of-containment scenarios. The following sub-sections summarize Task 3.2 results.

3.2.1 Risk analysis of compressed hydrogen (CH2) fuel systems

The key findings from the risk analysis of CH2 fuel systems for the selected hazardous events are presented below.

Leakages inside tank connection enclosure

The frequency calculations indicate that leakage events from the TCE have a high likelihood. For a fuel storage system comprising four TCEs, the total leak frequency was estimated to be equivalent to one leak every 10 years. This is exacerbated by the high uncertainty in the generic failure values, suggesting that the actual frequency could be even higher than the calculated values.

If a leak is ignited inside the TCE, the consequence may be a jet fire if there is immediate ignition or a deflagration or detonation if there is delayed ignition. An explosion inside the TCE could cause its walls to blow out due to the pressure of the blast, potentially impacting nearby individuals and safety-critical systems. The initial effects of such an event could range from injuries to fatalities.

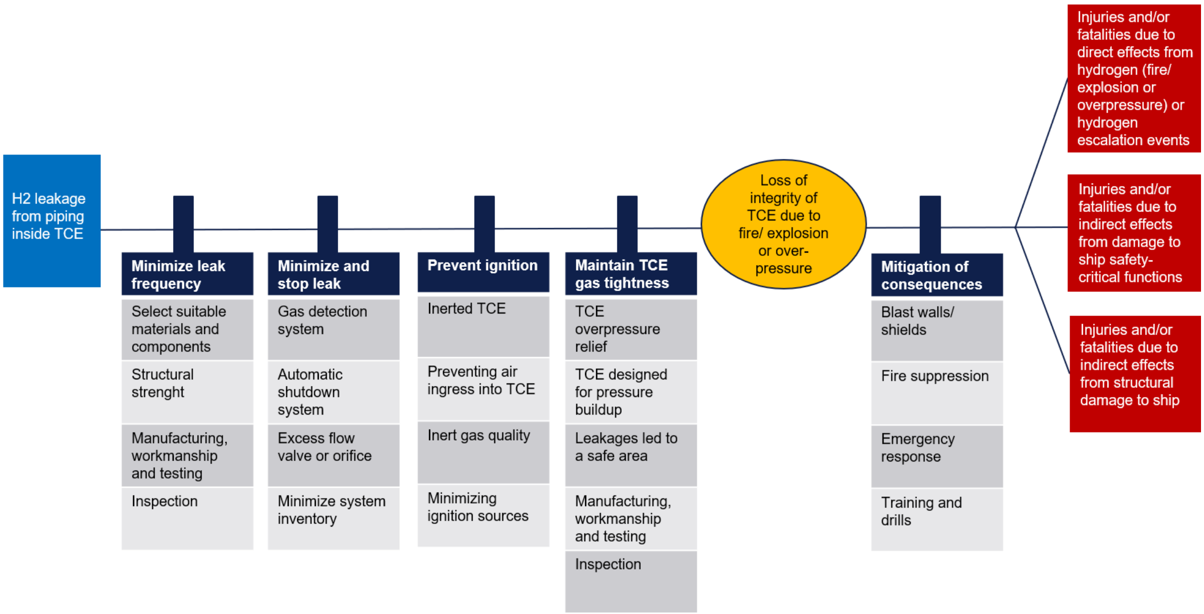

Figure 3-1 Bowtie for risk of leakages inside the tank connection enclosure. (Source: DNV).

The top event in Figure 3-1 is defined as loss of integrity of TCE due to fire/explosion or overpressure. This cause is H2 leakage from piping inside TCE. Such event may may endanger persons, the ship and/or safety-critical functions. Barrier functions designed to prevent the top event are listed in sequential order:

- Minimize leak frequency.
- Minimize and stop leak.
- Prevent ignition.
- Maintain TCE gas tightness.

Leakages in other parts of the ship's fuel supply piping

The frequency calculations indicate that leakage events from supply piping also have a relatively high likelihood. The total leak frequency was estimated to be equivalent to one leak every 23 years. The bowtie is fundamentally similar to the 'leakages inside tank connection enclosure'. However, for this risk analysis, the key difference is that releases from the inner piping goes into a secondary enclosure, commonly known as a double-walled pipe.

Fire/explosion affecting fuel storage tanks

The HAZID study determined that the potential fire or explosion risks to the fuel storage tanks and piping could either stem from hydrogen-initiated events (fire/explosion originating from hydrogen systems) or from non-hydrogen-initiated events related to ship systems/areas or external to the ship boundary. The frequency per ship year for non-hydrogen-initiated events involving fire/explosion was estimated to be 9.8E-4 (one event every 1,000 years), while the frequency for hydrogen-initiated events was estimated to be 1.8E-4 (one event every 5,600 years) due to the safety barrier of inert atmosphere in the TCE and double-walled supply piping.

A hydrogen fuel storage tank subjected to severe heat loads may experience a reduction in strength, potentially leading to rupture and subsequent explosion, deflagration, detonation, or fireball. Type IV pressure vessels are constructed from composite materials, which are more prone to heat damage than pressure vessels made of steel. Additionally, the fire may damage the safety systems needed to control the fuel system.

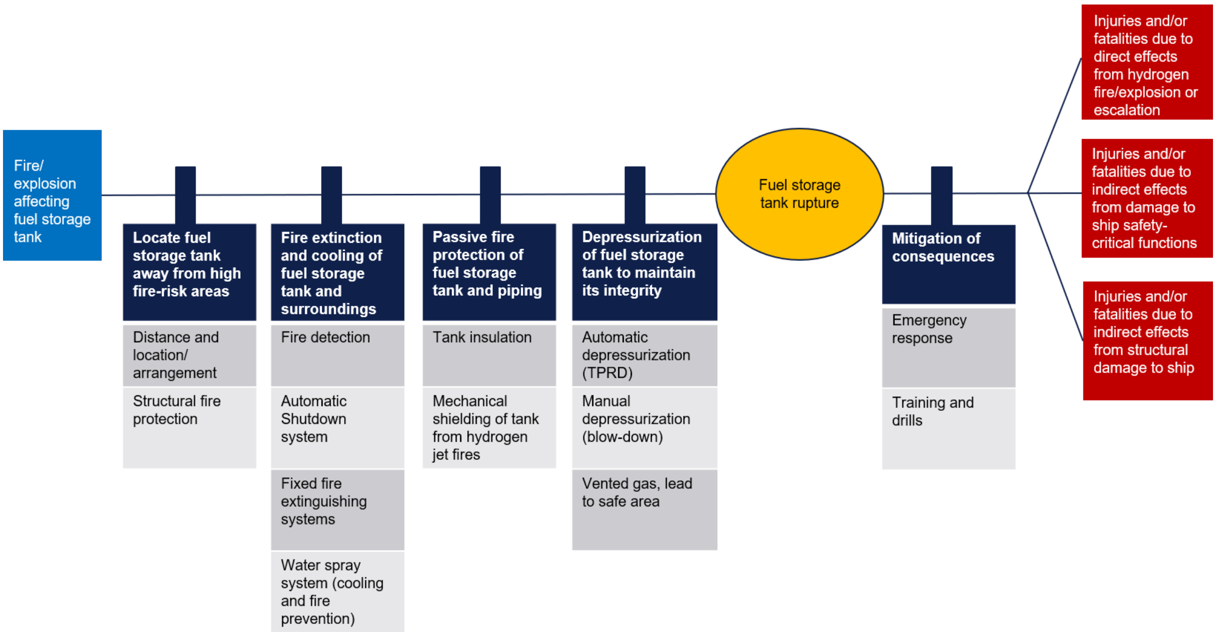

Figure 3-2 Bowtie for risk of fire/explosion affecting fuel storage tanks by heat ingress (Source: DNV).

The risk of fuel storage tank rupture due to heat ingress from fire was analysed in Figure 3-2. The barrier functions that protect against this top event are listed in sequential order:

- Locate fuel storage tank away from high fire-risk areas.
- Fire extinction and cooling of the fuel storage tank and surroundings.
- Passive fire protection of fuel storage tank and piping.
- Depressurization of the fuel storage tank to maintain tank integrity.

3.2.2 Risk analysis of liquefied hydrogen (LH2) fuel systems

The key findings from the risk analysis of LH2 fuel systems for the selected hazardous events are presented below:

Leakages inside the tank connection space

The frequency calculations indicate that leakage events from piping inside the TCS have a high likelihood of occurring. The total leak frequency was estimated to be 1.5 leaks per year. The major contributor to the leak frequency is the vaporiser.

If a leak is ignited inside the TCS, the consequence may be a jet fire if there is immediate ignition, or a deflagration or detonation if there is delayed ignition. A deflagration or detonation is a major concern due to its higher damage potential from overpressure effects. There is also a potential for escalation, which could initiate a domino effect, sequentially affecting several other tanks and hydrogen systems.

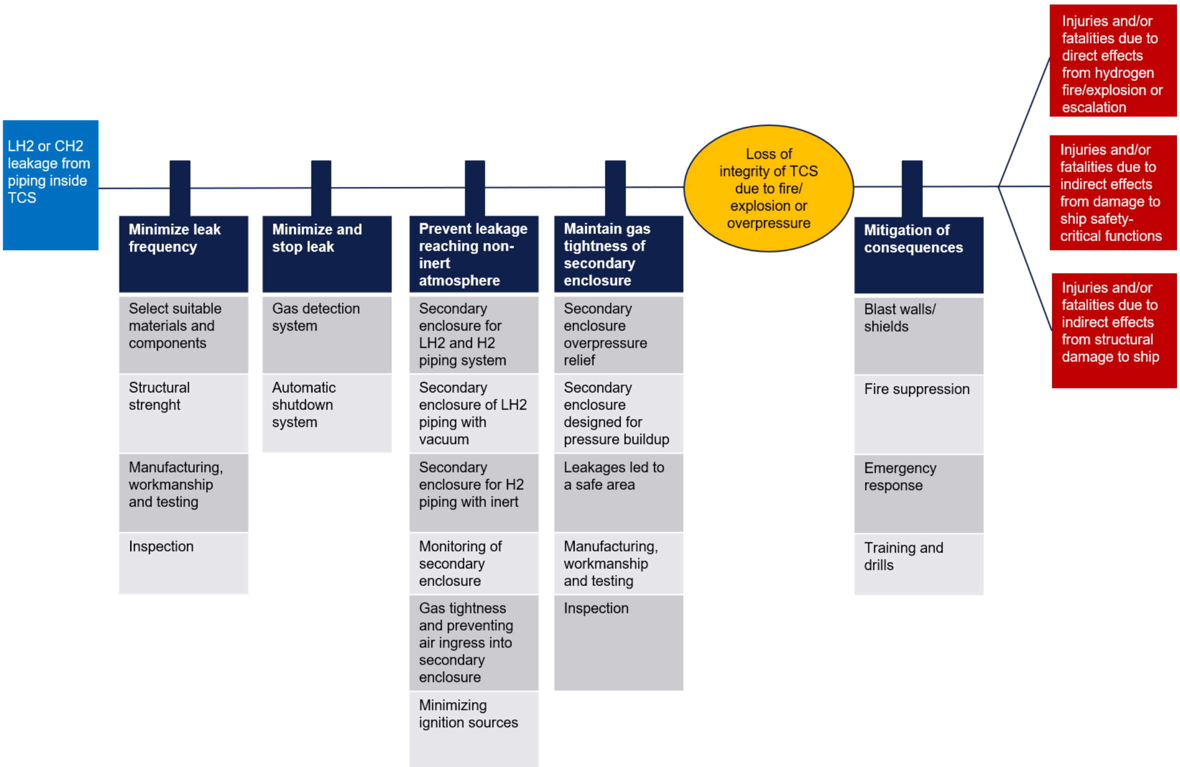

Figure 3-3 Bowtie for risk of leakages inside TCS in LH2 fuel system (Source: DNV).

The risk of leakages inside the TCS was analysed in Figure 3-3. The preventive barrier functions to protect against the loss of integrity of TCS due to fire, explosion or overpressure are listed in sequential order:

- Minimize leak frequency.
- Minimize and stop the leak.
- Prevent leakage reaching a non-inert atmosphere.
- Maintain gas-tightness in the secondary enclosure.

Loss of vacuum insulation for the tank

Currently, there are no available generic failure rates for vacuum loss in LH2 systems. To obtain a specific failure rate for this safety-critical system, suitable for quantitative risk analysis, a dedicated reliability analysis would be required.

There are several potential consequences if the top event in Figure 3-4 occurs, and these consequences may happen simultaneously:

- Loss of structural integrity of Fuel Storage Hold Space (FSHS) or TCS (and/or loss of safety functions due to cryogenic effects).
- Rapid pressure increase and excessive boil-off from the tank being discharged to open deck through the vent mast.

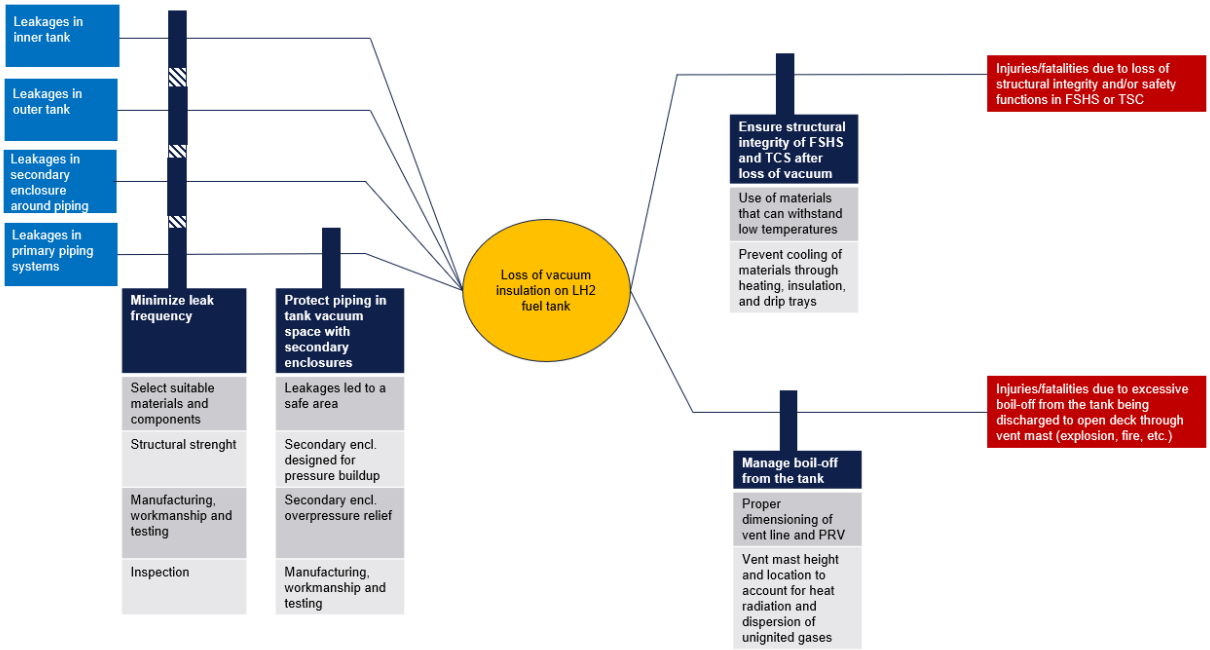

Figure 3-4 Bowtie for risk of loss of vacuum insulation on LH2 fuel tank (Source: DNV).

The preventive barrier function that protects against the top event is minimize leak frequency**.** When there is only one barrier function to prevent a top event, it means that there is a single line of protection against the occurrence of that event. However, the barrier function consists of several elements that collectively contribute to its effectiveness.

One additional barrier function is valid only for leakages in primary piping systems. This function protects against hydrogen leakages in the vacuum space by adding a secondary enclosure around the piping. The barrier function consists of the following barrier elements:

- Secondary enclosure overpressure relief.
- Secondary enclosure designed for pressure build-up.
- Leakages led to a safe area.
- Manufacturing, workmanship and testing.

Should all preventive measures fail and the vacuum insulation of the LH2 fuel tank be compromised, this critical event could result in a rapid and excessive boil-off from the tank, discharged onto the open deck via the vent mast. The barrier function designed to address this event is to manage boil-off from the tank, which primarily focuses on:

- Proper dimensioning of vent line and PRV.
- Vent mast height and location to account for heat radiation and dispersion of unignited gases.

A loss of tank vacuum may also compromise the structural integrity and safety functions of surrounding areas such as FSHS and TCS. Managing the resulting cooling of the surroundings should be within the ship's design capabilities. To address this risk, the mitigation barrier function ‘Ensure structural integrity of FSHS and TCS after loss of vacuum’ has been implemented. This barrier function comprises two key elements:

- Use of materials that can withstand low temperatures.
- Prevent cooling of materials through heating, insulation and drip trays.

3.3 Task 4 Risk analysis of two specific ship types

This risk analysis in Task 4 covered two ship types and fuel system configurations based on partner designs to support the development of the guidance document:

- **Platform Supply Vessel (PSV):** compressed hydrogen stored above deck.
- **Service Operation Vessel (SOV):** liquefied hydrogen stored below deck.

The analysis addresses ship-specific hazards: for the PSV, dropped objects on fuel containment and ignition of vented hydrogen; for the SOV, collision, grounding, and occupational hazards. For each case, frequency analysis, qualitative consequence analysis, and bowtie-based barrier modelling were applied to selected hazardous events. Given the conceptual nature of the designs, the focus is on methodology rather than precise frequency estimates.

Dropped objects onto fuel containment systems or piping

The risk analysis focused on dropped objects on fuel storage tanks or piping due to cargo lifting operations. This event is particularly relevant for the PSV design, considering the frequency of loading and offloading of cargo and equipment to offshore fields. Dropped object studies are a vital component of quantitative risk assessment for offshore oil and gas operations, evaluating the risks associated with potential dropped objects during crane operations. This evaluation is typically carried out as a "Dropped Object Study" and is specific to each vessel and offshore unit. In this task, explaining the methodology of frequency analysis has therefore been considered more appropriate than attempting to perform an exact analysis. This decision acknowledges the importance of accurate data and operational specificity.

A dropped object causing a tank puncture will lead to a massive release of hydrogen gas, likely resulting in immediate ignition and the potential for further escalation events. This scenario represents a worst-case situation for the PSV used as the basis for this analysis, due to the severe consequences of hydrogen ignition and its proximity to the accommodation and the bridge. Escalation events could trigger a domino effect, sequentially impacting other fuel tanks and piping systems. Escalation events could jeopardise the entire ship, increasing the risk of multiple fatalities.

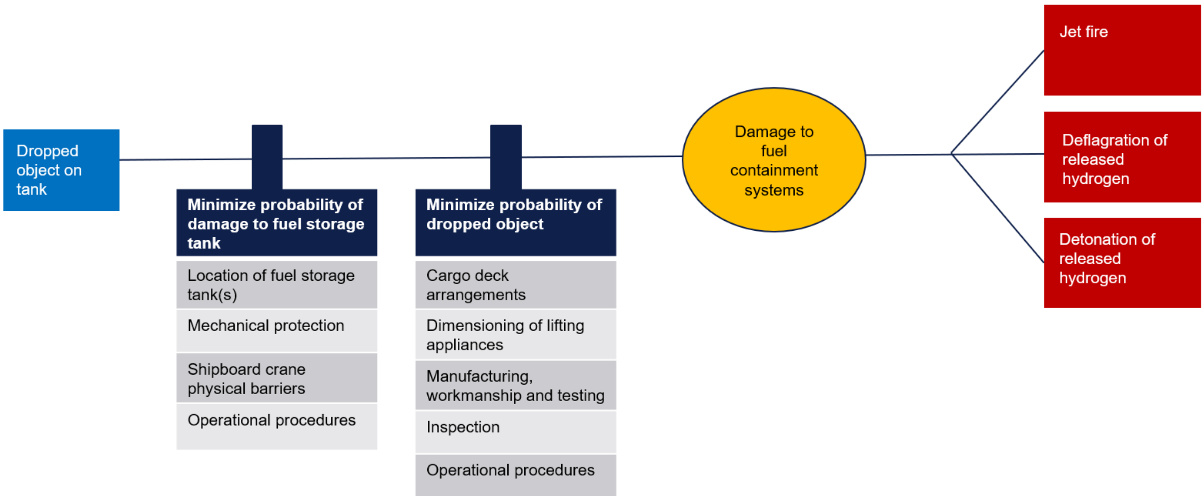

Figure 3-5 Bowtie for risk of tank puncture due to dropped object (Source: DNV).

The top event in Figure 3-5 is damage to fuel containment systems, resulting from the threat of dropped object. Such an event may endanger people, the ship and/or safety-critical functions. Preventive barrier functions designed to protect against the top event are listed in sequential order:

- Minimize probability of damage to fuel storage tank incl. tank location.
- Minimize probability of dropped object.

If all preventive barriers fail and a tank puncture occurs due to a dropped object, it is important to note that this scenario is not typically accounted for in the ship's design or regulatory standards. Consequently, no significant credit is given to the mitigation of consequences for this event, and it is therefore omitted in the bowtie.

Hydrogen release through the vent mast

A hydrogen fuel system subject to an external fire will heat up, and each fuel storage tank is therefore fitted with a tank discharge line designed to safely vent the contents through the vent mast in a fire scenario. While this prevents tank rupture, it introduces other potential risks that must be managed, such as ignition of hydrogen inside the vent mast or deflagration or detonation on deck.

Automatic or manual depressurization would only be necessary in the event of a major fire scenario, and the frequency analysis was included in the risk assessment for generic hydrogen fuel systems. A detailed frequency analysis for overpressurization during bunkering would require an assessment of the human element's contribution to system failure and was not performed for this study.

A discharge of hydrogen to the vent mast introduces the potential for ignition inside the vent mast, jet fire from the vent mast outlet, deflagration or detonation on the open deck. Further, hydrogen released through the vent mast may reach ventilation intakes or other openings into the ship where ignition is possible.

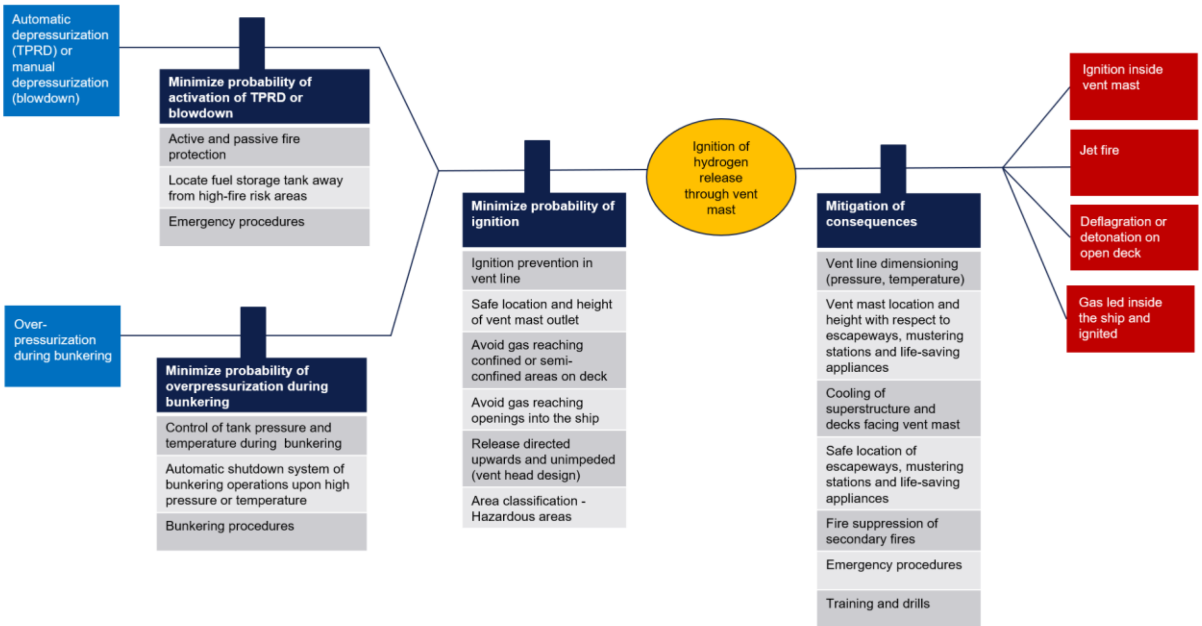

Figure 3-6 Bowtie for “ignition of hydrogen release through vent mast”. (Source: DNV).

The top event in Figure 3-6 is ignition of hydrogen release through vent mast, resulting from the threats of automatic depressurization (TPRD), manual depressurization (blowdown) and overpressurization during bunkering. Such event may endanger people, the ship and/or safety-critical functions. Preventive barrier functions designed to protect against the top event are listed below:

- Minimize the probability of activation of TPRD or blowdown
- Minimize the probability of overpressurization during bunkering.

- Minimize the probability of ignition.

Should all preventive measures fail and the hydrogen release through vent mast be ignited, the mitigation focuses on:

- Vent line dimensioning.
- Vent mast location and height with respect to escapeways, mustering stations and life-saving appliances.
- Emergency procedures.

Ship collision or grounding impacting fuel containment and piping systems

The frequency analysis presented focused on estimating the likelihood of puncturing a hydrogen fuel tank in the event of a collision. This method is based on an event tree structure derived from the 'GOAL based Damage Stability project' (GOALDS), as detailed in IMO information papers[2]. It also encompasses the calculation of the probability of tank penetration, contingent upon a hull breach, as outlined in SOLAS Chapter II-1. The consequence analysis and safety barrier modelling for this case are similar to the dropped object case and are not repeated here.

Occupational hazards

Studies indicate that the maritime industry suffers from significant underreporting of occupational accidents. Consequently, these statistics cannot be fully trusted for use in quantitative risk analysis, although they do provide valuable information for learning and improvements. An alternative approach is to model the risk and estimate the frequency of occurrence. This requires detailed descriptions of work tasks and their frequency. Methods such as Human Reliability Analysis (HRA) can be used to model these frequencies but were not performed in this study.

Occupational accidents related to hydrogen systems with the potential for injury or fatality include asphyxiation, cryogenic burns, high-pressure hydrogen release, jet fire, deflagration, or detonation of released hydrogen.

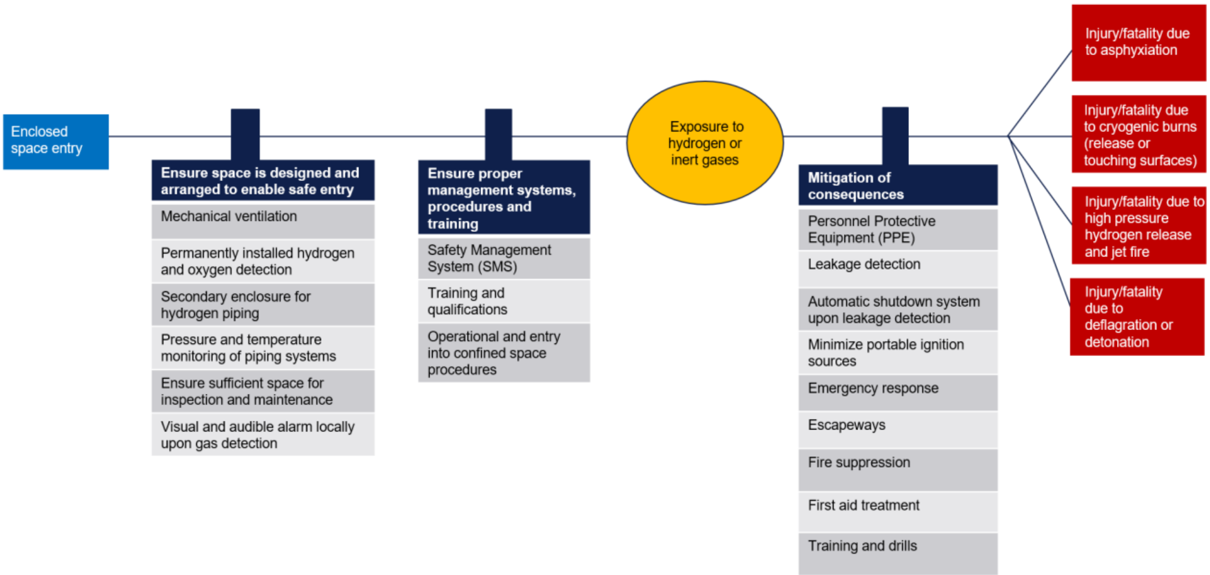

Figure 3-7 Bowtie for risk of exposure to hydrogen or inert gases due to entering enclosed spaces (Source: DNV).

The top event of Figure 3-7 is exposure to hydrogen or inert gases, resulting from the threat of enclosed space entry. Such an event may endanger people on board. Preventive barrier functions designed to protect against the top event are listed below:

[2] SLF 55/INF.7, SLF 55/INF.8, SLF 55/INF.9, etc.

- Ensure that the space is designed and arranged to enable safe entry.
- Ensure proper management systems, procedures and training.

Should all preventive measures fail, and the people onboard be exposed to hydrogen or inert gases, the mitigation focuses on:

- Personnel Protective Equipment.
- Emergency response.
- Escapeways.
- First aid treatment.
- Training and drills.

4. PART 3 – Summary of Task 5

This part provides a brief outline of the methodology used to develop the guidance for ships using hydrogen as fuel ("the Guidance"), which is included in Appendix A. The Guidance follows the IMO goal-based approach provided in MSC.1/Circ.1394 Rev.2 (IMO, 2019), specifying goals and functional requirements for each chapter.

As illustrated in Figure 4-1, the Guidance is developed based on, and in parallel with, the other tasks in the study. Furthermore, the currently available regulations and ongoing regulatory development within the IMO are considered through: (1) a gap analysis against the International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels (IGF Code), and (2) by closely following the ongoing IMO process for the development of interim guidelines for the safety of ships using hydrogen as fuel (IMO, 2025). The stepwise approach is briefly described in the following sections.

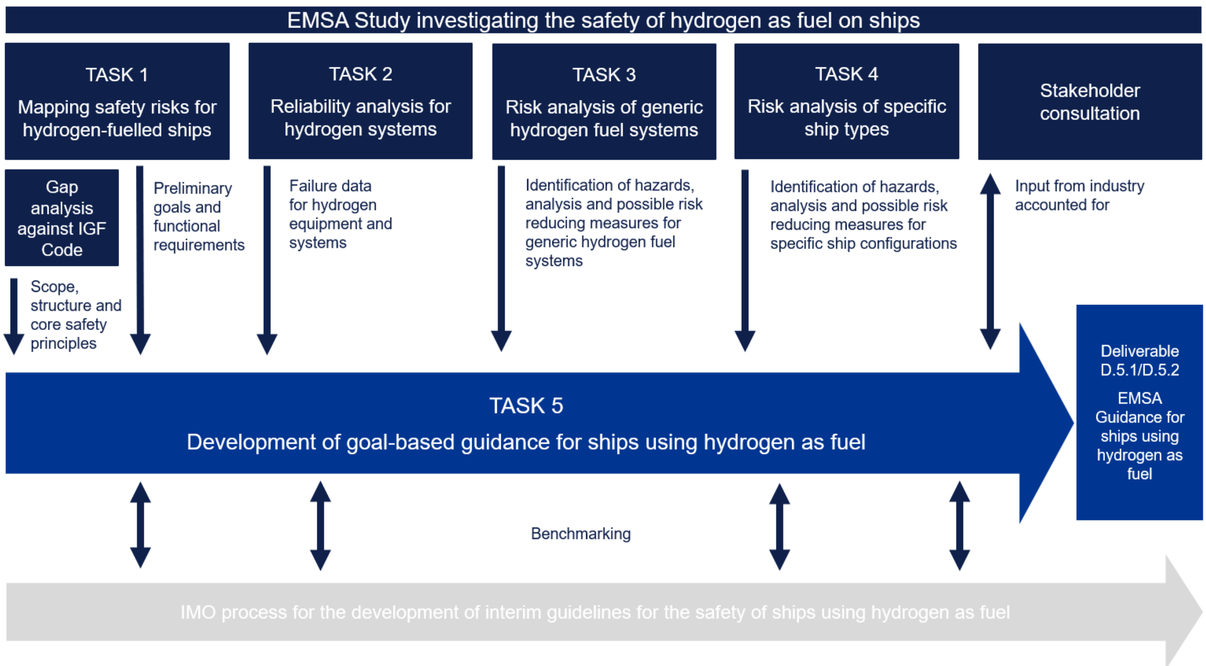

Figure 4-1 The stepwise approach for drawing up the Guidance for ships using hydrogen as fuel.

4.1 Gap analysis against the IGF Code

The IGF Code, which considers the IMO goal-based approach in its basic philosophy, provides internationally recognised regulations for LNG-fuelled ships. As shown in Figure 4-2, the safety principles embedded in the IGF Code for natural gas can broadly be divided into five categories: system integrity, double barriers, leakage detection, automatic isolation of leakages, and segregation. These core safety principles are equally important for hydrogen applications (EMSA, 2024a).

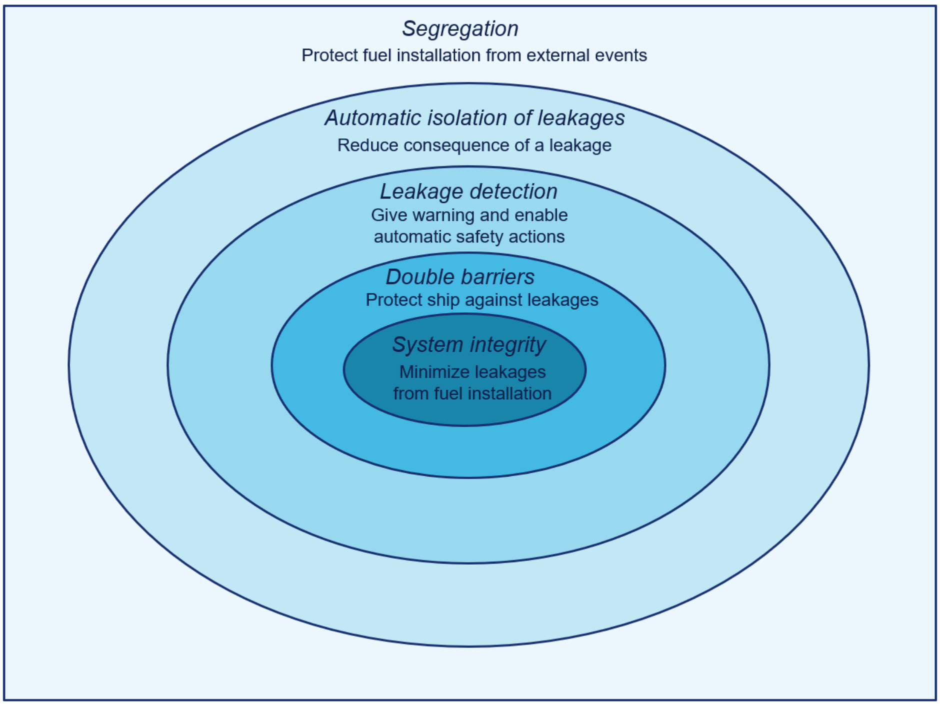

Figure 4-2 The safety concept of the current regulations in the IGF Code for natural gas (Source: DNV).

A gap analysis was conducted against the IGF Code to ensure consistency with the scope, structure, and core safety principles in the development of the Guidance. However, as summarised in Figure 4-3, hydrogen's unique properties – such as higher flammability and lower storage temperatures - necessitate additional safety measures and further regulatory development.

IGF can be used	IGF minor changes	IGF major changes	IGF questionable

	Segregation		System integrity		Double barriers				Leakage detection	Automatic isolation of leakages
	Mechanical damage	External fire	System design	Operational and emergency discharges	Piping	ESD machinery space	Double barrier spaces	Ventilation	LEL	ESD valves
Hydrogen			leakage, embrittlement, flammability	flammability	flammability	flammability	flammability	flammability	density, flammability range	flammability

LEL; Lower Explosion Limit, ESD; Emergency Shutdown

Figure 4-3 Suitability of using the safety concept of the current regulations in the IGF Code for natural gas also for hydrogen when used as fuel onboard (DNV, 2022).

The Guidance adopts the structural framework of the 19 chapters of the IGF Code. In addition, the Guidance includes a chapter 20 on personnel protection.

4.2 Input from Tasks 1 to 4

The development of the Guidance has drawn extensively on input from the other tasks in the study in the definition of hydrogen-specific safety measures:

- The high-level analysis of generic hydrogen hazards and risks, and comparison of rules and regulations performed in Task 1 resulted in a preliminary table of contents with preliminary goals and functional requirements (EMSA, 2024a).
- The reliability analysis performed in Task 2 provided failure data for equipment and systems for further consideration in the development of the Guidance (EMSA, 2024b).
- The risk analysis of generic hydrogen fuel systems performed in Task 3 resulted in the identification of hazards, analysis and possible risk-reducing measures for generic hydrogen fuel systems to be covered by functional and technical requirements (EMSA, 2025a) (EMSA, 2025b).
- The risk analysis of specific ship types performed in Task 4 resulted in the identification of hazards, analysis and possible risk-reducing measures for specific ship configurations to be covered by functional and technical requirements (EMSA, 2025c).

4.3 IMO process for the development of Interim Guidelines

The development of interim guidelines for the safety of ships using hydrogen as fuel was added to the work plan in 2021, and the first version was finalized at CCC 11 in September 2025, with expected formal approval and publication in 2026. The IMO process for the development of Interim Guidelines has been followed closely throughout the development of the Guidance. Appendix B provides a matrix comparison between the Guidance and the up-to-date version of the draft Interim Guidelines (IMO, 2025) with a justification column to indicate equivalence, differences and their justification.

4.4 Stakeholder consultation and workshop

The EU Survey online tool was used for the stakeholder consultation. The matrix format (as provided in Appendix B), which compares the draft Guidance and draft Interim Guidelines, was used for the hearing process. Industry stakeholders, including regulators, engine manufacturers and NGOs, provided valuable input that was considered in the completion of the Guidance.

A stakeholder workshop in the form of a presentation of the final Guidance at a DNV-hosted roundtable on safety for hydrogen-fuelled ships, with wide industry participation 3rd November 2025, marked the conclusion of the stakeholder consultation. The event brought together over 30 participants from across the maritime industry, including regulators, shipowners, charterers, engine and equipment manufacturers, fuel system and tank providers, and shipyards. The agenda included presentations and panel discussions aimed at reflecting on the outcomes of the IMO CCC 11 meeting and fostering collaboration on key safety challenges.

4.5 Addressing the bunkering process

Bunkering operations and associated facilities fall under regulatory frameworks different from those applying to ships, managed by national, local, and port authorities. These typically require site-specific risk assessments, including dispersion analyses. Harmonizing hydrogen bunkering safety standards at regional and international levels would streamline approval processes.

This study addressed bunkering issues relevant to the ship in the HAZID (EMSA, 2025a). The findings were incorporated into the functional requirements in Chapter 8 and supported by prescriptive guidance. Chapter 18.5 details operational requirements on the ship side (Appendix A).

Based on prior work on bunkering safety, including EMSA's biofuel bunkering study (EMSA, 2024c), Appendix C provides a high-level list of topics for developing comprehensive bunkering guidance for stakeholders.

5. Conclusions and recommendations

Our findings from the five Tasks of this study, summarised in the chapters 2 to 4, have provided insights into the safety hazards, system threats, and risks associated with using hydrogen as a marine fuel. While the safety principles embedded in the IGF Code for natural gas are equally important for hydrogen, the unique properties—such as higher flammability and lower storage temperatures—necessitate additional safety measures and further regulatory developments. In this regard, we present the following conclusions and recommendations based on our work.

1. The lack of hydrogen-specific failure data and uncertainties regarding suitability for ship applications lead to a high level of uncertainty in leak frequency analysis in QRAs for hydrogen fuel system installations. To compensate for this, uncertainty analyses should be performed to demonstrate, for example, how an increased leak frequency or rate might affect the overall risk level.

2. The likelihood of hydrogen leakages from piping systems cannot be excluded. The risks associated with hydrogen leakages are closely linked to the size of the leakage, and measures that may be effective for small leakages may not be effective in the event of a more significant system failure. Substantial leaks from the hydrogen fuel system should be accounted for in the design of hydrogen-fuelled ships.

3. It should be assumed that there is a probability of ignition in a hydrogen leakage scenario even after measures such as installing certified-safe electrical equipment have been implemented.

4. Detecting hydrogen leaks on an open deck quickly is challenging. Ignitable hydrogen clouds can form within seconds, much faster than those of other gases. Traditional gas detectors that rely on contact with leaked hydrogen to detect leaks will likely respond too slowly to prevent critical cloud accumulation.

5. Managing risks related to hydrogen leakages from single-walled piping systems in enclosed spaces is challenging when it is assumed that an ignition source will be present.

6. The likelihood of loss of tank vacuum insulation cannot be excluded, meaning that ships using liquefied hydrogen as fuel should be built to safely handle loss of tank vacuum insulation with respect to cooling of surrounding structures, condensation of air and increased boil-off.

7. While having a vent mast arranged to safely disperse any release of hydrogen from fuel storage tanks and piping systems is an important safety function, the risk of hydrogen ignition must be managed. This necessitates a case-by-case evaluation of the consequences of an ignition event. It must be ensured that the potential worst-case scenario regarding heat loads and pressure effects is acceptable in terms of the safety of the ship and the people on board.

8. The work activities related to the onboard hydrogen fuel system introduce new occupational hazards associated with direct exposure to hydrogen and its flammable and cryogenic properties, as well as asphyxiation effects. The crew must thoroughly understand the hazards associated with handling fuel and be aware of the integrated safety features, including their purpose, operation, and maintenance requirements. Therefore, it is vital to establish comprehensive training, operating procedures, and a robust safety culture to ensure the safe operation of the ship.

The 20 chapters of the Guidance document provided in Appendix A were developed based on the above. The Guidance differs from the draft IMO Interim Guidelines for the safety of ships using hydrogen as fuel (CCC 11/WP.4 Annex 2) in several areas. The main reason is that the Guidance recommends that all hydrogen leak sources be protected by secondary enclosures to prevent any leaks from spreading uncontrollably into enclosed spaces or areas on the open deck. This premise will particularly affect the provisions for Chapter 5: Ship design and arrangement, Chapter 12: Explosion prevention, Chapter 13: Ventilation, and Chapter 15: Control, monitoring and safety systems. Since the Guidance is a non-mandatory advisory document, it does not include references to the IMO's alternative design process for designs that deviate from the provisions, as opposed to the Interim Guidelines.

The lack of bunkering guidance on the shore-side is a significant safety gap that requires closing. Based on previous work on bunkering safety, including our work for EMSA on safe bunkering of biofuels (EMSA, 2024c), Appendix C includes a high-level list of subjects that would need to be developed to guide relevant stakeholders on what is required to perform a safe bunkering operation.

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Appendix A Draft Guidance for ships using hydrogen as fuel

1. INTRODUCTION

1.1 This Guidance for ships using hydrogen as fuel (the Guidance) is a non-mandatory and advisory document. Most potential zero-carbon fuels, such as hydrogen, have properties that present different safety challenges compared to conventional fuel oils. Implementing hydrogen fuel systems onboard ships requires the development of regulations for safe design and use in parallel with the technological progress necessary for their adoption. The purpose of this Guidance is to support the industry in this development by providing recommendations for practical design solutions based on a structured process, as outlined in the IMO goal-based approach in MSC.1/Circ.1394, and informed by extensive risk assessment and reliability analysis.

1.2 The Guidance is the result of a structured set of safety assessments and reliability analyses addressing ships using hydrogen as fuel, conducted in the EMSA Study investigating the safety of hydrogen as fuel on ships, and reported in the following publications available on the EMSA website:

1. Mapping safety risks for hydrogen-fuelled ships
2. Reliability and safety analysis
3. Hazard identification of generic hydrogen fuel systems
4. Risk analysis of generic hydrogen fuel systems
5. Risk analysis of two specific ship types using hydrogen as fuel

1.3 The Guidance follows the structural layout of the IGF Code. The first four chapters correspond with IGF Code Part A, which applies to all SOLAS ships using gaseous or low-flashpoint fuels. The subsequent chapter headings follow the IGF Code Parts A-1, B-1, C-1, and D structure, covering goals, functional requirements, and prescriptive regulations similar to those applicable to ships using natural gas as fuel. This is the same structure utilised by IMO in developing the Interim Guidelines for the safety of ships using hydrogen as fuel.

1.4 The Guidance differs from Interim Guidelines in several areas. The main reason is that the Guidance recommends that all hydrogen leak sources be protected by secondary enclosures to prevent any leaks from spreading uncontrollably into enclosed spaces or areas on the open deck. This premise will particularly affect the provisions for Chapter 5: Ship design and arrangement, Chapter 12: Explosion prevention, Chapter 13: Ventilation, and Chapter 15: Control, monitoring and safety systems.

1.5 Since the Guidance is a non-mandatory advisory document, it does not include references to the IMO’s alternative design process for designs that deviate from the provisions, as opposed to the Interim Guidelines.

1.6 For ease of reference, guidance provisions that are the same as in the draft IMO Interim Guidelines for the safety of ships using hydrogen as fuel (CCC 11/WP.4 Annex 2) (Interim Guidelines) are presented in *italics.*

2. GENERAL

2.1 Application

2.1.1 This Guidance applies to ships using liquified and/or compressed hydrogen as fuel to which Part G of SOLAS Chapter II-1 applies.

2.2 Definitions

2.2.1 For this Guidance, the terms used have the meanings defined in the following paragraphs. Terms not defined have the same meaning as in SOLAS Chapter II-2 and the IGF Code.

2.2.2 Bunkering systems refer to all piping systems used for the transfer of fuel from the bunkering connection to the fuel containment system.

2.2.3 *Cold hydrogen vapour means hydrogen vapour at a sufficiently low temperature to cause condensation of air, at or below -183°C.*

2.2.4 Compressed hydrogen means hydrogen in its gaseous state contained at any pressure above atmospheric pressure.

2.2.5 Condensed air refers to the phase change of the constituent gases within air into liquid or solid form when air is exposed to cryogenic temperatures.

2.2.6 Cryo-pumping refers to a situation in cryogenic systems where air or other gases unintentionally enter a vacuum-insulated space due to a leak, and are subsequently trapped or immobilized on extremely cold surfaces inside the system.

2.2.7 Fuel means hydrogen, either in its liquefied or gaseous state.

2.2.8 Fuel reformer is the arrangement of all related fuel-reforming equipment for processing gaseous or liquid primary fuels to reformed hydrogen for use as fuel.

2.2.9 Leak is a term used to describe the accidental discharge of gaseous or liquefied hydrogen due to a defect in the fuel piping system.

2.2.10 Non-inert refers to an atmosphere containing more than 3% oxygen.

2.2.11 Oxygen enrichment refers to the phenomenon of an increase in oxygen concentration above 23.5% by volume in air, caused by the exposure of air to cryogenic temperatures.

2.2.12 Permeability is a measure of how easily a material allows a substance (such as a fluid or gas) to pass through it without defect.

2.2.13 Permeation is the process by which a gas, liquid, or vapour passes through a solid material (like a membrane, liner, or insulation) on a molecular level.

2.2.14 Piping is a term that includes the following pipe components:

- pipes
- flanges with gaskets and bolts, and other pipe connections
- expansion elements
- valves, including hydraulic and pneumatic actuators, and fittings
- hangers and supports
- flexible hoses
- pump housings

2.2.15 Piping systems is a term that includes piping, as well as components in direct contact with the piping, such as pumps, compressors, heat exchangers, evaporators, independent tanks, etc., except for main components such as steam and gas turbines, diesel engines, reduction gears and boilers.

2.2.16 Primary fuel is the fuel supplied to the fuel reformer (e.g. ammonia, methanol, LNG, LOHC, etc.) that is reformed to hydrogen in the fuel reformer.

2.2.17 Reformed hydrogen is hydrogen or hydrogen-rich gas generated in the fuel reformer.

2.2.18 Secondary enclosure is an enclosure providing a gas and liquid-tight barrier for piping and equipment containing fuel. This includes, but is not limited to, double-wall pipes.

2.2.19 Self-ignition refers to ignition without the presence of any external ignition source.

3. GOAL AND FUNCTIONAL REQUIREMENTS

3.1 Goal

The goal of this Guidance is to provide for the safe and environmentally friendly design, construction, and operation of ships using hydrogen as fuel, in particular their installations of systems for propulsion machinery, auxiliary power generation machinery, and/or other purpose machinery.

3.2 Functional Requirements

3.2.1 The safety, reliability and dependability of the systems should be equivalent to that achieved with new and comparable conventional oil-fuelled main and auxiliary machinery.

3.2.2 The probability and consequences of fuel-related hazards should be limited to a minimum through arrangement and system design. In the event of gas leakage or failure of the risk-reducing measures, necessary safety actions should be initiated.

3.2.3 The design philosophy should ensure that risk-reducing measures and safety actions for the hydrogen fuel installation do not lead to an unacceptable loss of power.

3.2.4 Hazardous areas should be restricted, as far as practicable, to minimize the potential risks that might affect the safety of the ship, persons on board, and equipment.

3.2.5 The installation and use of equipment in hazardous areas should be minimized to that required for operational purposes and should be suitably and appropriately certified.

3.2.6 Unintended accumulation of explosive, flammable, or harmful gas concentrations should be prevented.

3.2.7 Fuel containment and fuel piping systems should be protected against external damage.

3.2.8 Sources of ignition in hazardous areas should be minimized to reduce the probability of explosions.

3.2.9 Safe and suitable fuel supply, storage and bunkering arrangements should be made, capable of receiving and containing the fuel in the required state without leakage. Other than when necessary for safety reasons, fuel supply, storage and bunkering arrangements should be designed to prevent venting under all normal operating conditions, including idle periods.

3.2.10 Piping systems, containment and over-pressure relief arrangements that are of suitable design, construction and installation for their intended application should be provided.

3.2.11 Machinery, systems and components should be designed, constructed, installed, operated, maintained and protected to ensure safe and reliable operation.

3.2.12 Suitable control, alarm, monitoring, and shutdown systems should be provided to ensure safe and reliable operation and limit the consequences of failures as far as possible.

3.2.13 Effective means of detecting a leakage, suitable for all spaces and areas concerned, should be arranged.

3.2.14 Fire detection, protection and extinction measures appropriate to the hazards concerned should be provided.

3.2.15 Commissioning, trials, and maintenance of fuel systems and gas utilization equipment should satisfy the goal in terms of safety, availability, and reliability.

3.2.16 The technical documentation should permit an assessment of the compliance of the system and its components with the applicable rules, guidelines, design standards used and the principles related to safety, availability, maintainability and reliability.

3.2.17 A single failure in a technical system or component should not lead to an unsafe or unreliable situation.

3.2.18 Measures should be taken to prevent the formation of oxygen-enriched or oxygen-depleted atmospheres, as well as the accumulation of solid air deposits or liquid air pools caused by low temperatures.

3.2.19 Sources of hydrogen leakages should be minimized to reduce the probability of explosions and exposure to humans and the environment.

3.2.20 Direct release of hydrogen into the atmosphere during normal operation and any foreseeable and controllable abnormal scenario should be minimized.

3.2.21 Measures to minimize the health hazards associated with exposure to hydrogen should be provided.

4. GENERAL REQUIREMENTS

4.1 Goal

The goal of this chapter is to ensure that the necessary assessments of the risks involved are carried out to eliminate or mitigate any adverse effects on the persons on board, the environment, or the ship.

4.2 **Risk assessment**

4.2.1 A holistic risk assessment should be conducted to ensure that risks arising from the use of hydrogen, affecting persons on board, the environment, the structural strength, or the integrity of the ship, are addressed. Consideration should be given to the hazards associated with the physical layout, operation, and maintenance following any reasonably foreseeable failure.

4.2.2 The risk assessment should specifically consider the hydrogen system integrity with focus on its ability to prevent and isolate leakages, and also evaluate potential ignition mechanisms and *consequences of ignition. Special consideration should be given, but not limited to, the following specific hydrogen-related hazards and topics:*

.1 For all systems:
.1 hydrogen embrittlement;
.2 natural permeability;
.3 detection of leaks;
.4 ignition sources and self-ignition mechanisms; and
.5 jet-fire, flashfire, deflagration, detonation and escalation;

.2 Additionally, for liquefied hydrogen fuel systems:
.1 effects of low temperatures;
.2 condensation of air and other gases;
.3 oxygen enrichment;
.4 cryo-pumping;

.3 Additionally, for pressurized or compressed hydrogen fuel systems:
.1 high-pressure leaks; and
.2 opening of pressure relief device;

.4 Additionally, for portable fuel containment systems:
.1 lifting operations;
.2 connection and disconnection;
.3 additional leak sources; and
.4 the purging and gas freeing, re-purging and gassing up of hydrogen systems after each portable tank connection and disconnection.

4.2.3 The risk assessment process should demonstrate that the goal in 3.1 and the functional requirements in 3.2 have been satisfied.

4.2.4 The risks should be analysed using acceptable and recognised risk analysis techniques. The analysis should ensure that risks are eliminated wherever possible. Risks which cannot be eliminated should be mitigated as necessary. Details of risks and the means by which they are mitigated should be documented.

4.3 Limitations of explosion and fire consequences

4.3.1 An explosion or fire due to a hydrogen leak or release should not:

.1 cause damage to or disrupt the proper functioning of equipment/systems located in any space other than that in which the incident occurs;

.2 damage the ship in such a way that flooding of water below the main deck or any progressive flooding occurs;

.3 damage work areas or accommodation in such a way that persons who stay in such areas under normal operating conditions are injured;

.4 disrupt the proper functioning of control stations and switchboard rooms necessary for power distribution;

.5 damage life-saving equipment or associated launching arrangements;

.6 disrupt the proper functioning of fire-fighting equipment located outside the fire- or explosion-damaged space;

.7 *affect other areas of the ship in such a way that chain reactions involving, inter alia, cargo, gas and bunker oil may arise; or*

.8 *prevent persons access to life-saving appliances or impede escape routes; or*

.9 *affect the fuel containment system;*

.10 lead to an unacceptable loss of power.

4.3.2 The guidance outlined in section 11.8 (Fire Risk Analysis) and section 12.3 (Explosion Risk Analysis) should be followed to verify that fire and explosion consequences remain within the limitations specified in 4.3.1.

This includes defining relevant operational and failure scenarios to be considered in the analyses, as well as determining the relevant leakage sizes.

5. SHIP DESIGN AND ARRANGEMENT

5.0 Hazards

5.0.1 Fuel containment systems and fuel piping systems may be damaged by external events, such as collisions, groundings, fire, explosions, cargo operations, ship operations, and environmental conditions, resulting in hydrogen releases.

5.0.2 Damage to fuel containment systems for liquefied hydrogen may result in a Boiling Liquid Expanding Vapour Explosion (BLEVE), releasing all the hydrogen in the tank.

5.0.3 Damage to fuel containment systems for compressed hydrogen may result in the sudden release of stored energy.

5.0.4 Hydrogen releases may ignite, resulting in a fire, deflagration, or detonation.

5.0.5 Liquefied hydrogen releases may cool down surrounding structures, causing embrittlement.

5.0.6 Cold surfaces may condense air, potentially cause embrittlement and create a fire hazard.

5.0.7 Cold surfaces may cool down surrounding structures, systems and equipment, causing structural damage or system malfunctions.

5.1 Goal

The goal of this chapter is to provide for safe location, space arrangements and mechanical protection of power generation equipment, fuel storage systems, fuel supply equipment and refuelling systems.

5.2 Functional Requirements

This chapter is related to functional requirements in **3.2.1** to **3.2.4**, **3.2.6** to **3.2.11**, **3.2.17** and **3.2.18.**

In particular, the following apply:

5.2.1 The fuel containment system(s) should be located and arranged in such a way as to minimize:

.1 *the probability of damage following a collision or grounding taking into account the safe operation of the ship and other hazards that may be relevant to the ship;*

.2 *the probability of mechanical damage from ship operations, cargo operations, and environmental conditions, either by locating the fuel tanks away from such hazards or by providing mechanical protection; and*

.3 the probability of mechanical damage from explosions, either by locating the fuel tanks away from areas of explosion risks, by providing mechanical protection, or by reducing the risk of explosions.

5.2.2 Fuel containment systems, fuel piping and other fuel sources of release should be so located and arranged that released hydrogen is led to a safe location in the open air, and on an open deck, not accumulating in confined or congested areas.

5.2.3 The access or other openings to spaces containing fuel sources of release should be so arranged that flammable or asphyxiating gas cannot escape to spaces that are not designed for the presence of such gases.

5.2.4 Fuel piping systems should be located and arranged to minimize:

.1 *the probability of damage following a collision or grounding, taking into account the safe operation of the ship and other hazards that may be relevant to the ship; and*

.2 the probability of mechanical damage from ship operations, cargo operations, and environmental conditions, either by locating the piping systems away from such hazards or by providing mechanical protection.

5.2.5 The propulsion, power-generating and fuel supply systems should be so designed that automatic safety actions after a fuel leakage or other fault conditions, as described in Chapter 15, do not lead to an unacceptable loss of power.

5.2.6 The probability of a hydrogen explosion in spaces containing hydrogen consumers or fuel piping systems should be minimized.

5.2.7 Spaces containing fuel piping systems should be arranged to prevent damage from pressure build-up caused by hydrogen leakage.

5.2.8 In spaces containing liquefied hydrogen, fuel leakage, loss or deterioration of vacuum insulation of tanks or piping systems should not compromise the integrity of structural materials; and

5.2.9 In spaces containing liquefied hydrogen, fuel leakage or a loss, or deterioration, of vacuum insulation of tanks or piping systems should not compromise the functionality of safety systems or components necessary for the ship's safety.

5.3 General Provisions

5.3.1 The requirements of sections 5.3.3 and 5.3.4 of the IGF Code, part A-1, should apply to ships using hydrogen as fuel.

5.3.2 Areas on open deck containing hydrogen sources of release, including bunkering stations and equipment for fuel preparation, should not allow accumulation of hydrogen gas and provide unobstructed dispersion of hydrogen.

5.3.3 Muster stations, life-saving appliances, and their access routes should not be located in hazardous areas.

5.4 Machinery space arrangement

5.4.1 Machinery spaces containing hydrogen systems and/or hydrogen fuelled machinery should be arranged such that the spaces may be considered gas-safe under all conditions, normal as well as abnormal conditions, i.e. inherently gas-safe.

5.4.2 In a gas-safe machinery space, a single failure should not lead to the release of fuel gas into the machinery space.

5.4.3 A gas safe machinery space may be arranged as a conventional machinery space.

5.4.4 All fuel piping within machinery space boundaries should be enclosed in a gas-tight secondary enclosure.

5.4.5 Access to machinery spaces should not be arranged from hazardous areas.

5.5 Fuel cell power installations

5.5.1 Fuel cell power installations should be arranged in accordance with the Interim guidelines for the safety of ships using fuel cell power installations (MSC.1/Circ.1647).

5.6 Location and protection of fuel piping

5.6.1 Fuel piping should not be located less than 800 mm from the side shell, which includes the aft end of the ship.

5.6.2 Fuel piping protected by secondary enclosures should not be led directly through accommodation spaces, service spaces, electrical equipment rooms or control stations as defined in the SOLAS Convention.

5.6.3 Fuel piping led through Ro-Ro spaces, special category spaces and on open decks should be particularly considered with respect to protection against mechanical damage.

5.7 Fuel preparation arrangements

5.7.1 The equipment for fuel preparation should be located in an area on the open deck providing natural ventilation and unobstructed relief of leakages.

5.7.2 Notwithstanding provision 5.7.1, vaporizers, heat exchangers, and motors for pumps submerged in tanks may also be located in tank connection spaces.

5.8 Tank connection spaces for liquefied hydrogen

5.8.1 Unless located on the open deck providing natural ventilation and unobstructed relief of leakages, fuel tank connections, flanges, and tank valves should be enclosed in a tank connection space arranged in accordance with these provisions.

5.8.2 All parts of the piping systems in tank connection spaces should be arranged with secondary enclosures designed to safely contain any leakage from the fuel system.

5.8.3 Tank connection space boundaries should be gas-tight towards other spaces in the ship.

5.8.4 The material of the bulkheads of the tank connection space should have a design temperature corresponding to the lowest temperature it can be subject to.

5.8.5 A loss of vacuum insulation in tanks or piping systems for liquid hydrogen should not render necessary safety functions in the tank connection space inoperable due to low temperatures.

5.8.6 Unless the tank connection space access is independent and direct from the open deck, it should be provided through a bolted hatch.

5.8.7 Tank connection spaces should not contain equipment for fuel preparation. As an exemption to this provision, vaporizers, heat exchangers, and motors for pumps submerged in tanks may also be located in tank connection spaces.

5.9 Tank connection enclosures for compressed hydrogen

5.9.1 Fuel tank connections, flanges, and tank valves should be placed in a tank connection enclosure in accordance with these provisions.

5.9.2 Tank connection enclosures should be designed to prevent ignition of leaked gas within the enclosure by maintaining an inert atmosphere at all times.

5.9.3 Tank connection enclosures should be arranged to minimize the volume as far as possible.

5.9.4 Tank connection enclosures should be gas-tight.

5.9.5 Tank connection enclosures should be able to withstand the highest pressure that may arise in a leakage scenario.

5.9.6 Tank connection enclosures should be arranged with continuous gas detection.

5.9.7 Tank connection enclosures should be arranged with a pressure relief device with a vent system that directs leaked gas to a safe location on the open deck.

5.10 Bilge Systems

5.10.1 Bilge systems installed in areas where hydrogen can be present should be segregated from the bilge system of spaces where hydrogen cannot be present.

5.10.2 The bilge system should have bilge well high-level alarms.

5.11 Protection against condensation of air

5.11.1 Drip trays or similar protection should be fitted where uninsulated components, or a loss of vacuum, may result in surface temperatures below the condensation temperature of air

Alternatively, components may be arranged with additional insulation to prevent surface temperatures falling below that required to condensate air.

5.11.2 The protection should be made of materials suitable for the collection of condensed air.

5.11.3 If drip trays are used for protection, they should be thermally insulated from the ship's structure so that the surrounding hull or deck structures are not exposed to unacceptable cooling.

5.11.4 Where relevant, drip trays should be fitted with a drain valve to enable rainwater to be drained over the ship's side.

5.11.5 Each tray should have a sufficient volume and thermal capacity to ensure that the maximum amount of potential air condensate, according to the risk assessment, can be handled. Active heating arrangements could also be considered.

5.11.6 Where capturing condensed air in drip trays, ensure through design that liquid hydrogen leaks cannot combine with condensed oxygen in any scenario.

5.12 Arrangement of entrances and other openings in enclosed spaces

5.12.1 Direct access should not be permitted from a non-hazardous area to a hazardous area. Where such openings are necessary for operational reasons, an airlock should be provided.

5.12.2 For inerted spaces, access arrangements should be designed to prevent unintended entry by personnel. If access to these spaces is not from an open deck, the arrangements should ensure that any leakage of inert gas to adjacent spaces is prevented.

5.13 Airlocks

5.13.1 Airlocks should be enclosed by gastight bulkheads with two substantially gastight doors spaced at least 1.5 m and not more than 2.5 m apart. Unless subject to the International Convention on Load Lines requirements, the door sill towards the hazardous side should not be less than 300 mm in height. The doors should be self-closing without any holding-back arrangements.

5.13.2 Airlocks should be mechanically ventilated at an overpressure relative to the adjacent hazardous area or space.

5.13.3 Airlocks should be designed to ensure that no gas can escape into safe areas during the most critical incidents occurring in gas-hazardous spaces separated by the airlock. These incidents should be assessed in the risk analysis as outlined in section 4.2.

5.13.4 Airlocks should be designed with a geometry that facilitates the removal of accumulated hydrogen.

5.13.5 Airlocks should allow free and easy passage for personnel and cover a deck area of no less than 1.5 m^2. They should not be used for other purposes, such as storage rooms.

5.13.6 An audible and visual alarm system should be provided to issue a warning on both sides of the airlock if more than one door is opened from the closed position.

5.13.7 Access to hazardous spaces below deck must be restricted if there is a loss of underpressure in the hazardous space.

Audible and visual alarms should be activated at a manned location to signal both the loss of pressure and the opening of the airlock doors when the pressure differential is lost between a hazardous and a non-hazardous space.

5.13.8 Where an airlock is arranged for access to small spaces serving as a staging area for the hatch to an inerted space, such as TCS, the space should be arranged with ventilation and oxygen deficiency detection.

5.14 Storage arrangements for compressed hydrogen

5.14.1 The fuel containment system and associated connections and equipment for compressed hydrogen should be located in an area on the open deck that provides natural ventilation and unobstructed relief for leakages.

5.15 Storage arrangements for liquified hydrogen

5.15.1 The fuel containment system and associated connections and equipment for liquefied hydrogen should be located in an area on the open deck, providing natural ventilation and unobstructed relief of leakages.

5.15.2 Vacuum-insulated type C tanks with tank connection spaces may be considered located in enclosed spaces, provided that:

- The possibility of hydrogen leakages into the tank connection space is eliminated by applying secondary enclosures around all tank connections, pipes and components.
- The fuel containment system is located in a dedicated fuel storage hold space in accordance with Part-A1 of the IGF Code.
- The dedicated fuel storage hold space is arranged to manage the cooling effects of loss of tank insulation safely.

6. FUEL CONTAINMENT SYSTEM

6.0 Hazards

6.0.1 Hydrogen released from the fuel containment system may ignite, resulting in a fire, deflagration or detonation.

6.0.2 Liquefied hydrogen released from the fuel containment system may cool down surrounding materials, causing embrittlement.

6.0.3 The loss of insulation properties for fuel containment systems for liquefied hydrogen, which increases the heat ingress to the fuel, may result in significant hydrogen releases.

6.0.4 Cold surfaces on the fuel containment system may condense air, causing embrittlement and a fire hazard due to oxygen enrichment.

6.0.5 Cold surfaces on the fuel containment system may cool down surrounding structures, systems and equipment, causing structural damage or system malfunctions.

6.0.6 The volume increase of liquefied hydrogen with increasing temperatures may result in a liquid-full containment system, corresponding over-pressurisation of the tank, and overflow of liquefied hydrogen through the vent system.

6.0.7 Hydrogen embrittlement of materials may lead to failure of the fuel containment system.

6.0.8 Thermal effects and ship movements may lead to fatigue and failure of the fuel containment system.

6.1 Goal

The goal of this chapter is to provide that hydrogen storage is adequate so as to minimize the risk to personnel, the ship and the environment to a level that is equivalent to a conventional oil-fuelled ship.

6.2 Functional Requirements

This chapter relates to functional requirements in **3.2.1** to **3.2.6**, **3.2.9** to **3.2.11** and **3.2.17** to **3.2.20**.

In particular, the following apply:

6.2.1 The fuel containment system should be so designed that a leak from the tank or its connections does not endanger the ship, persons on board or the environment. Potential risks to be avoided include:

.1 formation of ice from moisture in the air;

.2 formation of frozen or liquified air;

.3 exposure of ship materials to temperatures below acceptable limits;

.4 fuel leaking to form a flammable or explosive atmosphere;

.5 oxygen deficiency due to fuel and inert gases;

.6 flammable fuels spreading to locations with ignition sources;

.7 restriction of access to muster stations, escape routes and life-saving appliances (LSA); and

.8 reduction in availability of LSA.

6.2.2 Fuel containment systems should be designed to keep the fuel temperature and pressure within the design limits.

6.2.3 Fuel containment systems for liquefied hydrogen should be designed to minimize operational discharges by providing adequate insulation and/or through systems handling boil-off gas.

6.2.4 The fuel containment system should be designed to ensure that automatic safety actions after a fuel leakage or other fault conditions as described in chapter 15 do not lead to an unacceptable loss of power.

6.2.5 Fuel containment systems should be manufactured from materials suitable for hydrogen service.

6.2.6 Fuel containment systems for compressed hydrogen made of composite materials should be designed to provide an equivalent level of safety as fuel tank types defined by the IGF Code, including fire resistance, impact resistance, pressure relief arrangements and isolation of connected systems.

6.2.7 The fuel containment system should be arranged with a pressure relief system designed to safely discharge hydrogen in an open-air location.

6.2.8 Fuel containment systems should be capable of absorbing thermal expansion or contraction caused by extreme fuel temperatures, as well as movements of the fuel tank and hull structure, without developing substantial stresses.

6.2.9 Loss of vacuum should not lead to an unsafe condition.

6.3 General provisions

6.3.1 Piping between the tank and the first valve should have equivalent safety as the type C tank, with dynamic stress not exceeding the values given in 6.4.15.3.1.2 of the IGF Code Part A-1.

6.3.2 Means should be provided whereby the storage tanks can be safely emptied to shore.

6.4 Liquefied fuel containment

6.4.1 Unless expressly provided otherwise, the requirements of section 6.4 of the IGF Code should apply to ships using hydrogen as fuel.

6.4.2 The provisions for liquefied fuel containment in this Guidance are for vacuum-insulated type C tanks only. The requirements of section 6.4 of the IGF Code Part A-1 related to other tank types should not apply to ships using liquid hydrogen as fuel.

6.4.3 In addition to section 6.4.8 of the IGF Code, the following provisions regarding thermal insulation apply:

6.4.4 For vacuum-insulated tanks, the pressure relief valve capacity should be dimensioned for loss of vacuum and a fire scenario.

6.4.5 The vacuum jacket systems should be designed to accommodate the thermal flexibility of the inner boundary and allow for the jacket to follow its natural thermal displacement.

6.4.6 The fuel containment vacuum jacket systems should be separate from the piping vacuum jacket systems.

6.4.7 Piping connected to the tank should be protected by a secondary enclosure, including within the vacuum insulation space and up to the first valve.

6.4.8 It should be possible to empty, inert and gas-free fuel storage tanks and associated fuel piping systems. Instructions for carrying out these procedures should be available on board.

Inerting should be performed prior to venting with dry air to prevent the formation of an explosion hazardous atmosphere in tanks and fuel pipes.

6.4.9 General

The requirements in the IGF Code Part A-1 6.4.1 for Type C tanks should apply to ships using hydrogen as fuel.

6.4.10 Liquefied gas fuel containment safety principles

The requirements in the IGF Code Part A-1 6.4.2 for Type C tanks should apply to ships using hydrogen as fuel.

6.4.11 Secondary barriers in relation to tank types

The requirements in the IGF Code Part A-1 6.4.3 for Type C tanks should apply to ships using hydrogen as fuel.

6.4.12 Design of secondary barriers

The provisions for liquefied hydrogen fuel containment in this Guidance are for vacuum-insulated Type C tanks only.
Hence, the requirements in the IGF Code Part A-1 6.4.4 are not applicable for ships covered by these provisions.

6.4.13 Partial secondary barriers and primary barrier small leak protection system

The provisions for liquefied hydrogen fuel containment in this Guidance are for vacuum-insulated Type C tanks only.
Hence, the requirements in the IGF Code Part A-1 6.4.5 are not applicable for ships covered by these provisions.

6.4.14 Supporting arrangements

The requirements in the IGF Code Part A-1 6.4.6 for Type C tanks should apply to ships using hydrogen as fuel.

6.4.15 Associated structure and equipment

The requirements in the IGF Code Part A-1 6.4.7 for Type C tanks should apply to ships using hydrogen as fuel.

6.4.16 Thermal insulation

The requirements in the IGF Code Part A-1 6.4.8 for Type C tanks should apply to ships using hydrogen as fuel.

6.4.17 Design Loads

The requirements in the IGF Code Part A-1 6.4.9 for Type C tanks should apply to ships using hydrogen as fuel.

6.4.18 Structural Integrity

The requirements in the IGF Code Part A-1 6.4.10 for Type C tanks should apply to ships using hydrogen as fuel.

6.4.19 Structural analysis

The requirements in the IGF Code Part A-1 6.4.11 for Type C tanks should apply to ships using hydrogen as fuel.

6.4.20 Design conditions

The requirements in the IGF Code Part A-1 6.4.12 for Type C tanks should apply to ships using hydrogen as fuel.

6.4.21 Materials and Construction

The requirements in the IGF Code Part A-1 6.4.13 for Type C tanks should apply to ships using hydrogen as fuel.

6.4.22 Construction processes

The requirements in the IGF Code Part A-1 6.4.14 for Type C tanks should apply to ships using hydrogen as fuel.

6.4.23 Tank Types

The requirements in the IGF Code Part A-1 6.4.15 for Type C tanks should apply to ships using hydrogen as fuel.

6.5 Portable liquefied fuel containment

6.5.1 The provisions for liquefied fuel containment in this Guidance are limited to fixed, vacuum-insulated Type C tanks. The requirements of section 6.5 of the IGF Code Part A-1 related to portable liquefied gas fuel tanks, should not apply to ships using liquid hydrogen as fuel.

6.6 Compressed fuel storage

6.6.1 Tanks for compressed hydrogen should be constructed according to a recognized international standard accepted by the Administration. *

* Examples of standards considered suitable for composite tanks (type 4 pressure vessels): EN 17339, ISO 11119-3, EN 12245

6.6.2 Each tank for compressed hydrogen should be arranged with an automatic, fail-safe, shut-off valve mounted directly on or within the hydrogen tank.

6.6.3 Means should be provided to prevent over-pressuring compressed hydrogen tanks during bunkering.

6.6.4 Adequate means should be provided to enable automatic depressurization of the tank in the event of a fire that could affect the tank's integrity.

6.6.5 Tanks and tank supports should be designed to withstand design loads as defined in 6.4.9 of the IGF Code Part-A1. Additionally, the following load cases should be considered:

- *.1 temperature changes due to pressure reduction or increase when the tank is depressurized or pressurized; and*
- *.2 fatigue loading as defined in 6.4.12.2 of the IGF Code, Part A-1.*

6.7 Portable compressed fuel storage

6.7.1 The provisions for compressed fuel containment in this Guidance are limited to fixed tanks.

6.7 Pressure relief systems

6.7.1 Unless expressly provided otherwise, the requirements of section 6.7 of the IGF Code should apply to ships using hydrogen as fuel.

6.7.2 The vent mast height and distance provisions for tank vents for compressed and liquefied fuel should be regarded as minimum values to be validated through dispersion analysis and heat radiation analysis.

6.7.3 The consequences of vented hydrogen being ignited should be subjected to dispersion analysis and heat radiation analysis to verify that it is at an acceptable level with respect to the effect on people, the ship structure and exposed equipment, including lifesaving appliances and escape routes.

The guidance outlined in section 11.8 Fire Risk Analysis should be followed to verify that consequences remain within the limitations specified in 6.7.3.

6.7.4 The vent mast and connected vent lines should be designed to minimize the risk of self-ignition in the vent line.

6.7.5 The vent mast and connected vent lines should have a design pressure of not less than 20 bar.

6.7.6 Vent masts and connected vent lines for liquefied fuel containment should be arranged to prevent accumulation of condensate air constituents inside and outside the vent lines and be suitably designed and constructed to prevent blockage due to the formation of ice.

6.7.7 Vent masts should generally not be fitted with flame arrestors; however, prevention of the ingress of foreign objects should be arranged.

6.7.8 Each of the minimum two pressure relief valves required by 6.7.2 of the IGF Code Part A-1 for liquefied fuel tanks should have 100% relieving capacity for the tank.

6.7.9 Each compressed fuel tank should be arranged with an individual manual remote depressurization valve connected to the vent mast to ensure safe depressurization of the tanks.

6.7.10 The adequate means for automatic depressurization referenced in 6.6.4 could be a temperature-actuated safety relief system, such as thermally activated pressure relief devices (TPRDs), or a similar system that automatically reduces tank pressure in the event of an external fire.

6.7.11 Due consideration should be taken in the design of thermally activated pressure relief devices to ensure that their function is not affected by environmental conditions.

6.7.12 Vent masts and connected vent lines should be dimensioned to accommodate the simultaneous depressurization of all connected tanks before the tank strength is unduly affected by the heat input from a fire.

6.7.13 High-pressure gas relief systems and low-pressure gas relief systems should not be combined.

6.7.14 Pressure relief device discharges from secondary enclosures should be directed to the vent mast.

6.7.15 Vent masts and connected vent lines should be electrically bonded to prevent the buildup of static electricity.

6.8 Loading limit for liquefied fuel tanks

6.8.1 Unless expressly provided otherwise, the requirements of section 6.8 of the IGF Code should apply to ships using hydrogen as fuel.

6.8.2 The acceptance of an increased loading limit to 95% in the IGF Code section 6.8.2 should not apply to ships using hydrogen as fuel.

6.9 Maintaining fuel storage conditions

6.9.1 The requirements of section 6.9 of the IGF Code should apply to ships using hydrogen as fuel.

6.10 Atmospheric control within the fuel containment system

6.10.1 A piping system should be arranged to enable each fuel tank to be safely gas-freed, and to be safely filled with fuel from a gas-free condition. The system should be arranged to minimize the possibility of pockets of gas or air remaining after changing the atmosphere.

The system should be designed to eliminate the possibility of a flammable mixture existing in the fuel tank during any part of the atmosphere change operation by utilizing an inerting medium as an intermediate step.

6.10.2 The gas-freeing system should be arranged to avoid inert gas condensing or solidifying in the system when cooling down and filling with liquefied hydrogen

6.10.3 The inert gas composition used to purge hydrogen from the tank should be of sufficient purity to prevent an ignitable atmosphere in the tank.

6.10.4 Inert gas used for gas freeing of fuel tanks may be supplied to the ship from external sources.

6.11 Atmosphere control within fuel storage hold spaces (Fuel containment systems other than type C independent tanks)

6.11.1 The provisions for liquefied hydrogen fuel containment in this Guidance are for vacuum-insulated Type C tanks only.
The requirements of section 6.11 of the IGF Code, part A-1, related to other tank types, should not apply to ships using liquid hydrogen as fuel.

6.12 Environmental control of spaces surrounding vacuum-insulated type C independent tanks in case of vacuum loss

6.12.1 The consequences of loss of vacuum insulation on the fuel storage hold space and other surrounding areas should be assessed within the risk analysis required by 4.2.2.

6.12.2 The spaces surrounding hydrogen tanks should be configured to withstand potential vacuum loss outcomes, such as:

.1 condensation of air, including the risk of oxygen enrichment;
.2 activation of tank pressure relief valves
.3 embrittlement of surrounding structures due to low temperatures.

6.13 Inerting

6.13.1 Arrangements to prevent back-flow of fuel vapour into the inert gas system should be provided as specified below.

6.13.2 To prevent the return of flammable gas through the inert gas system to any non-hazardous spaces, the inert gas supply line should be fitted with two shut-off valves in series with a venting valve in between (double block and bleed valves).

These valves should be considered a leak source for hydrogen and arranged in an inerted secondary enclosure.

6.14 Inert gas production and storage on board

6.14.1 Instead of 6.14.1 of the IGF Code, the following provisions apply.

6.14.2 The equipment should be capable of producing inert gas with oxygen content at no time greater than 3% by volume.

6.14.3 A continuous-reading oxygen content meter should be fitted to the inert gas supply from the equipment and should be fitted with an alarm set at a maximum of 3% oxygen content by volume.

6.14.4 Where a nitrogen generator or nitrogen storage facilities are installed in a separate compartment outside of the engine room, the separate compartment should be fitted with an independent mechanical extraction ventilation system, providing a minimum of 6 air changes per hour. A low oxygen alarm should be fitted.

6.14.5 Nitrogen pipes should only be led through well-ventilated spaces. Nitrogen pipes in enclosed spaces should:

- be fully welded;
- have only a minimum of flange connections as needed for the fitting of valves; and
- be as short as possible.

6.14.6 For hydrogen secondary enclosure inerting, inert gas supply should be redundant and with sufficient capacity, and the system should monitor and warn in case of excessive contamination with hydrogen.

6.14.7 The stored inert gas capacity should, at a minimum, be enough to safely purge all parts of the fuel piping system and secondary enclosures necessary to bring the system into a safe condition after a hydrogen leak.

6.15 Provisions on vacuum

6.15.1 Piping vacuum jacket spaces should be segregated to limit the area affected by vacuum loss as far as possible.

6.15.2 Pressure relief devices for piping vacuum jacket spaces should provide separate discharge to a vent mast capable of handling cryogenic hydrogen.

6.15.3 Pressure relief devices protecting vacuum spaces should be designed to prevent cryo-pumping of air.

7. MATERIAL AND GENERAL PIPE DESIGN

7.0 Hazards

7.0.1 Fuel piping systems may discharge hydrogen to the surroundings through leakages caused by, e.g., pressure ruptures, brittle fractures, corrosion failures, fatigue, freezing damages, or contraction damages. Other causes for hydrogen discharges may be due to mechanical damage during maintenance and as a result of erroneous maintenance, and operational and emergency pressure releases.

7.0.2 Hydrogen releases from the fuel piping systems may ignite, resulting in a fire, deflagration or detonation.

7.0.3 Liquefied hydrogen releases from the fuel piping systems may cool down surrounding structures, causing embrittlement.

7.0.4 Cold surfaces of the fuel piping systems may condense air, which may cause embrittlement and a fire hazard.

7.0.5 Air, nitrogen and humidity may enter liquefied hydrogen systems, and the resulting solidification may cause system damage and blockages.

7.0.6 The thermal expansion of liquefied hydrogen may cause over-pressurisation of piping systems.

7.0.7 Ship movements, vibrations and thermal effects may lead to fatigue and failure of the fuel piping systems.

7.1 Goal

The goal of this chapter is to ensure the safe handling of fuel under all operating conditions to minimize the risk to the ship, personnel and the environment, having regard to the nature of hydrogen.

7.2 Functional requirements

This section relates to functional requirements in **3.2.1**, **3.2.2**, **3.2.9 to 3.2.11**, **3.2.18** and **3.2.19**.

In particular, the following apply:

7.2.1 Fuel piping systems should be capable of absorbing thermal expansion or contraction caused by extreme temperatures of the fuel without developing substantial stresses.

7.2.2 Fuel piping systems should be protected from excessive stresses due to thermal movement of the fuel tank and from movements of the hull structure.

7.2.3 Fuel piping systems should be designed to minimize the likelihood and size of a leak.

7.2.4 Fuel piping systems for liquefied hydrogen should be thermally isolated from the adjacent hull structure, where necessary, to prevent the temperature of the hull from falling below the design temperature of the hull material.

7.2.5 Fuel piping systems should be manufactured from materials suitable for hydrogen service, preventing hydrogen embrittlement, hydrogen permeation, and hydrogen attack.

7.2.6 Fuel piping systems should be designed to avoid icing during normal operation.

7.2.7 Fuel piping systems should be designed to maintain fuel pressure and temperature within the approved design limits.

7.3 General pipe design

7.3.1 Unless expressly provided otherwise, the requirements of section 7.3 of the IGF Code should apply to ships using hydrogen as fuel.

7.3.2 Expansion joints and bellows should not be used in hydrogen fuel piping systems. Engine-mounted expansion bellows could be accepted based on evaluation, as reflected in the engine's safety concept.

7.3.3 The requirements of section 7.3.1.5 of the IGF Code should not apply to ships using hydrogen as fuel.

7.3.4 The materials to be used in hydrogen systems should be suitable for the medium and service for which the system is intended. This should be proven either by selection of materials according to, a recognized standard specifying the suitability of the material for the medium and service intended, or by adequate qualification testing. Test scope for qualification of a material should be acceptable to the Administration.

7.3.5 Typical properties to be considered during qualification testing are, as a minimum, yield stress, tensile strength, ductility, fracture toughness, fatigue properties, hydrogen embrittlement, hydrogen permeation properties, corrosion resistance (as relevant) and coefficient of thermal expansion.

7.3.6 Matters including, but not limited to, the following should also be considered and addressed during the special consideration review and acceptance of materials:

.1 resistance of materials to the chemical and physical action of hydrogen under the operating conditions, including considerations of permeability and porosity, strength and toughness (i.e. ductile-to-brittle transition), effects of high oxygen concentrations experienced at low working temperatures, hydrogen embrittlement effects and high temperature hydrogen attack;

.2 suitability of materials for the intended application, including low- and/or high temperature effects, thermal expansion and contraction, thermal gradients, compatibility of dissimilar metals in intimate contact and electrostatic charge build-up/ discharge in non-conductive materials; and

.3 if materials are subjected to laboratory qualification testing, with respect to the possible variation of the chemical composition between the laboratory test samples and the production material, the chemistry of the tested material should be recorded in the qualification test report and the difference in chemistry for the steels actually used should not exceed the "permissible difference" as per recognized standards.

7.3.7 A material should not be used for hydrogen service unless data is available to show that the material is suitable for the intended service conditions, or a suitable laboratory testing regime is agreed to demonstrate that materials in a hydrogen-charged atmosphere will retain the required properties for the foreseeable operational scenarios. Materials that have been successfully used with hydrogen should be preferred over those with little or no history of use in a hydrogen environment.

7.4 Metallic materials

7.4.1 The materials used in hydrogen systems shall be suitable for the medium and service for which the system is intended, considering the design temperature, design pressure, working stress levels and environmental conditions.

7.4.2 The test scope for the qualification of a material should be acceptable to the Administration. The qualification of metallic materials by testing should address:

.1 the degradation of the material properties due to exposure to hydrogen, where degradation is expected to increase with increasing temperature and pressure;

.2 the degradation of the material properties due to cryogenic temperature, where degradation is expected to increase with decreasing temperature; and

.3 the combined effect of these[2].

2 See Susceptibility of materials to embrittlement in hydrogen at 10,000 psi and 72°F (~22°C) in the ANSI/AIAA G-095-2004 Guide to Safety of Hydrogen and Hydrogen Systems.

7.4.3 Where materials are intended to be further processed/fabricated by forming or welding, the impact of the processing on the relevant properties should be considered.

7.5 Non-metallic materials

7.5.1 Non-metallic materials used in fuel tanks should be suitable for their intended use. Fire resistance, thermal expansion, thermal conductivity and hydrogen permeation should be considered when choosing composite materials.

7.5.2 Non-metallic materials used in gaskets, packing or other sealing elements should be suitable for their intended use. Fire resistance, thermal expansion, thermal conductivity and hydrogen permeation should be considered when choosing composite materials.

8. BUNKERING

8.0 Hazards

8.0.1 Hydrogen leakages and releases from the ship's bunkering system or the bunkering facility’s transfer system may ignite, resulting in a fire, deflagration, or detonation.

8.0.2 Liquefied hydrogen leakages and releases from the ship's bunkering system or the bunkering facility’s transfer system may cool down surrounding structures, causing embrittlement.

8.0.3 Cold surfaces of the ship's bunkering system or the bunkering facility’s transfer system may condense air, which may cause embrittlement and a fire hazard.

8.0.4 Relative movement between the ship and the bunkering facility may damage the ship's bunkering system and the bunkering facility’s transfer system, causing hydrogen leakages.

8.0.5 An ignited leakage in a confined bunkering station can result in pressure build-up with the potential to cause mechanical damage.

8.0.6 A collision impact on the ship's bunkering manifold may also damage the connected fuel containment system, causing hydrogen leakages.

8.0.7 Hydrogen leakages may occur in the ship's bunkering connection due to the connection and disconnection of the bunkering hose.

8.0.8 Unless all remains of air and inert gas are removed from the bunkering system, these gases may condense and solidify during the bunkering of liquefied hydrogen and cause obstructions and equipment malfunction. The evaporation of oxygen may also cause an explosion hazard when systems are heated up.

8.1 Goal

The goal of this chapter is to provide for suitable systems on board the ship to ensure that bunkering can be conducted without causing danger to persons, the ship or the environment.

8.2 Functional Requirements

This section relates to functional requirements in **3.2.1**, **3.2.2**, **3.2.4** to **3.2.11**, **3.2.12**, **3.2.17** to **3.2.20**.

In particular, the following apply:

8.2.1 The piping system for the transfer of fuel to the storage tank should be designed such that any leakage from the piping system cannot cause danger to personnel, the environment or the ship.

8.2.2 Bunkering systems should be protected from mechanical damage.

8.2.3 The bunkering station should be arranged to safely handle leakages during bunkering operations.

8.2.4 Bunkering systems should be arranged with the capability for remote and local emergency shutdown of fuel transfer.

8.2.5 The piping between the bunkering manifold and the fuel containment system should be designed to prevent damage to the fuel containment system in the event of a collision impacting the bunkering manifold.

8.2.6 The bunkering system should be designed to minimize the amount of hydrogen released to the air during filling of the fuel tanks.

8.2.7 Formation of oxygen-enriched environments should be prevented or mitigated.

8.2.8 In bunkering stations, the accumulation of gas should be prevented.

8.2.9 The ship and the bunkering facility should be able to communicate effectively to mitigate the consequences of unplanned events.

8.3 General

8.3.1 Whenever possible, bunkering stations should be located on the open deck to provide natural ventilation and unobstructed relief of leakages.

8.3.2 Bunkering stations which cannot be located on an open deck should be arranged to minimize the consequences of leakage by:

.1 Minimizing the volumes where a flammable atmosphere, caused by leakage, can accumulate

.2 Optimizing the geometry and ship-side openings to relieve the explosion pressure.

.3 Minimizing congestion to reduce the risk of severe explosion pressures.

.4 Minimizing the probability of ignition.

.5 Providing gas-tight bulkheads towards adjacent spaces.

The guidance outlined in section 11.8 (Fire Risk Analysis) and section 12.3 (Explosion Risk Analysis) should be followed to verify that fire and explosion consequences following a release of hydrogen caused by unintended events during bunkering remain within the limitations specified in 4.3.1.

8.3.3 Piping for bunkering should not pass through accommodation spaces, control stations or service spaces.

8.3.4 Piping for bunkering should be arranged with secondary enclosures up to the bunkering manifold.

8.3.5 Bunkering manifolds for the bunkering of liquefied hydrogen should be arranged with drip trays.

8.3.6 Bunker manifold connections and piping should be so positioned and arranged that any mechanical impact damage to the fuel piping does not cause damage to the ship's fuel containment system, resulting in an uncontrolled gas discharge.

8.3.7 Suitable means should be provided to depressurise and remove liquid contents from piping for bunkering. The liquefied hydrogen should be drained to the ship's fuel tanks or to the tanks of the bunker supplier.

8.3.8 Bunkering stations should be arranged to prevent surrounding hull or deck structures from being subjected to unacceptable cooling in the event of a fuel leak or condensation of air.

8.4 Bunkering manifolds

8.4.1 The ship's bunkering manifold should be designed to withstand the external loads it may be subjected to during bunkering, including in a drift-off scenario.

8.4.2 The bunkering coupling should be according to a recognized standard, appropriate for fuel bunkering operations and capable of withstanding the design temperature and design pressure.

8.4.3 The connections at the bunkering station for liquefied hydrogen should be arranged to facilitate a dry disconnect operation. The dry disconnect operation should be arranged by the use of a dry-disconnect/connect coupling.

8.4.4 The connections at the bunkering station for compressed hydrogen should be of a self-sealing type.

8.4.5 The bunkering hose should be equipped with a safety dry break-away coupling or a self-sealing quick-release coupling, ensuring that the tension in the bunkering assembly in a drift-off scenario does not destroy the bunkering hose or the ship's manifold.

8.5 Bunkering systems

8.5.1 Compressed hydrogen fuel tanks should not exceed the maximum design temperature during bunkering operations.

8.5.2 A manually operated stop valve and a remotely operated shutdown valve, mounted in series, should be fitted in the bunkering line close to the connecting point. A remotely operated valve with the possibility for local manual operation is an equivalent arrangement. It should be possible to operate the actuated valve at the control location for bunkering operations.

8.5.3 Bunkering systems are to be arranged for inerting and gas freeing.

8.5.4 When not engaged in bunkering, the remaining gaseous hydrogen pressure in the bunkering lines should be lowered to a suitable pressure above atmospheric pressure to prevent ingress of air and reduce the risk of high-pressure leakages.

8.5.5 A ship-shore link (SSL) or an equivalent means for automatic and manual ESD communication to the bunkering source should be fitted.

9. FUEL SUPPLY TO CONSUMERS

9.0 Hazards

9.0.1 Hydrogen leakages and releases from the fuel piping systems may ignite, resulting in a fire, deflagration, or detonation.

9.0.2 Liquefied hydrogen leakages and releases from the fuel piping systems may cool down surrounding structures, causing embrittlement.

9.0.3 Cold surfaces of the fuel piping systems may condense air, which may cause embrittlement and a fire hazard.

9.0.4 Loss of fuel supply to consumers may result in a loss of power generation and propulsion for the ship.

9.1 Goal

The goal of this chapter is to ensure the safe and reliable distribution of fuel to consumers.

9.2 Functional requirements

This section is related to functional requirements in **3.2.1** to **3.2.6**, **3.2.9** to **3.2.13** and **3.2.17** to **3.2.21**.

In particular, the following apply:

9.2.1 The fuel supply system should be so arranged that the consequences of any fuel release will be minimized.

9.2.2 The fuel supply system should be arranged to provide safe access for operation, maintenance and inspection.

9.2.3 The piping system for fuel transfer to consumers should be designed so that a failure of one barrier cannot lead to a leak from the piping system into the surrounding area, posing a danger to persons on board, the environment, or the ship.

9.2.4 Fuel piping systems should be installed and protected so as to minimize the risk of injury to personnel and damage to the ship in case of leakage.

9.2.5 Piping systems supplying fuel to consumers should be designed to minimize the amount of hydrogen released after a leak has occurred.

9.3 General fuel piping design and arrangement

9.3.1 Fuel piping systems located in enclosed spaces should be arranged with secondary enclosures designed to safely contain leakages.

9.3.2 Fuel piping systems located on the open deck should be arranged with secondary enclosures designed to safely contain leakages.

9.3.3 Any leaks from fuel piping systems should be detectable and automatically isolated from the source of the fuel supply.

9.3.4 Fuel piping systems should be designed to minimize the consequences of leakage by limiting the amount of fuel contained in the system to what is necessary for operation.

This could be obtained by:

- Using as small pipe dimensions as possible.
- Keeping the operating pressure as low as possible by applying pressure reduction devices where practicable.
- Providing automatically operated shut-down valves controlled by the safety system for pipe segmentation.

The consequences of leakage may be further reduced by use of flow restrictors or excess flow valves.

9.4 Redundancy of fuel supply

9.4.1 For single-fuel installations, the fuel supply system should be arranged with full redundancy and segregation all the way from the fuel tanks to the consumer so that leakage in one system does not result in an unacceptable loss of power.

9.4.2 For single-fuel installations, the fuel storage should be divided between two or more tanks. The tanks should be located in separate compartments.

9.4.3 For dual-fuel installations, the storage capacity of the other fuel should be sufficient to provide the necessary redundancy in case of loss of hydrogen fuel supply.

9.5 Fuel piping systems for liquefied fuel

9.5.1 The fuel piping and its components containing liquefied fuel or cold hydrogen vapour should be provided with a secondary enclosure designed to provide insulation and safely contain leakages.

Fully welded, open-ended fuel gas vent pipes routed through mechanically ventilated spaces do not need to be fitted with secondary enclosures but should be insulated to prevent air condensation.

9.5.2 The secondary enclosure should be made of a material that can withstand the pressure and temperature of a potential leak. Means of pressure relief, led to the vent mast, should be provided for the secondary enclosure.

9.5.3 To protect against the ignition of leaked hydrogen and to provide insulation, the space between liquefied fuel piping systems and the secondary enclosure should be vacuumed.

9.6 Fuel piping systems for gaseous fuel

9.6.1 The fuel piping and its components containing gaseous hydrogen should be provided with a secondary enclosure designed to safely contain leakages. To protect against the ignition of leaked hydrogen, the secondary enclosure around gaseous hydrogen piping systems should be inerted.

9.6.2 Secondary enclosures around fuel piping systems for gaseous hydrogen should be designed or arranged to prevent pressures in the annular space above the design capabilities of the piping system. Means of pressure relief leading to the vent mast should be provided for the secondary enclosure.

9.6.3 Fully welded, open-ended fuel gas vent pipes led through mechanically ventilated spaces need not be arranged with secondary enclosures.

9.6.4 Fuel piping systems for gaseous hydrogen, arranged in tank connection enclosures, need not be arranged with secondary enclosures.

9.7 Valve arrangements

9.7.1 Valves in the fuel piping system should be remotely operated to minimize personnel exposure. This does not apply to normally closed and locked valves not operated during normal service. Valves should be automatically operable when action is required by the safety system as per section 15.

9.7.2 Valves and their secondary enclosures should be easily accessible for inspection and maintenance.

9.7.3 Fuel storage tank inlets and outlets shall be provided with remotely operated shut-off valves located as close to the tank as possible.

9.7.4 The fuel supply line to each gas consumer or set of consumers should be equipped with a remotely operated stop valve and an automatically operated master gas fuel valve coupled in series or a combined remotely and automatically operated valve. The valves shall be situated in the part of the piping that is outside the machinery space containing gas consumers. The master gas fuel valve should automatically cut off the gas supply when activated by the safety system required in 15.2.2.

9.7.5 The gas supply line to each consumer should be provided with double-block-and-bleed valves. These valves should be arranged for automatic shutdown as given in Section 15.

9.7.6 The two shutoff valves should be in series in the gas fuel pipe to the gas-consuming equipment. The bleed valve should be in a pipe that vents to a safe location in the open air that portion of the gas fuel piping that is between the two valves in series

9.7.7 *The two shut-off valves should be of the fail-to-close type, while the bleed valve should be fail-to-open. Except in case of loss of operating power, the bleed valve should only remain open until the pressure is relieved and be kept closed to prevent ingress of air in the system. Means to detect a leakage in the stop valves should be arranged.*

9.7.8 An alarm for faulty operation of the valves should be provided. In this context:

- *block valves open and bleed valve open is an alarm condition,*
- *block valves closed and bleed valve closed is an alarm condition if leakage in the block valve is detected.*
- *Similarly, gas consumers stopped and block valves open is an alarm condition.*

9.7.9 The double block and bleed valves should also be used for normal stop of internal combustion engines.

9.7.10 When a leakage in the fuel system is detected by the safety system, followed by automatic shutdown of the master gas fuel valve, the complete fuel system downstream of the master valve should be automatically de-pressurized and purged with inert gas.

9.7.11 There should be one manually operated shutdown valve in the gas supply line to each consumer upstream of the double block and bleed valves to ensure safe isolation during maintenance on the consumer.

9.7.12 For single-engine installations and multi-engine installations, where a separate master valve is provided for each engine, the master gas fuel valve and the double block and bleed valve functions can be combined.

9.7.13 The master fuel valve(s) should be operable from safe locations on escape routes inside a machinery space containing a gas consumer, the engine control room, if applicable; outside the machinery space, and from the navigation bridge.

9.7.14 All automatic and remotely operated valves should be provided with indications for open and closed valve positions at the location where the valves are remotely operated.

10. PROPULSION AND POWER GENERATION

10.0 Hazards

10.0.1 Hydrogen may ignite in engine components, systems, and exhaust arrangements, resulting in a fire, deflagration, or detonation.

10.0.2 Hydrogen may leak into auxiliary systems and crankcases, causing deflagration or detonation

10.1 Goal

The goal of this chapter is to provide safe and reliable delivery of mechanical, electrical or thermal energy.

10.2 Functional requirements

This section is related to functional requirements in **3.2.1** to **3.2.3**, **3.2.6**, **3.2.9** to **3.2.11** and **3.2.19**.

In particular, the following apply:

10.2.1 The exhaust systems should be configured to prevent any accumulation of unburnt gaseous fuel.

10.2.2 Engine components or systems containing or likely to contain ignitable hydrogen should be designed with the strength to withstand the worst-case overpressure due to ignited gas leaks.

10.2.3 All fuel consumers should have separate exhaust systems.

10.2.4 Hydrogen consumers should be arranged to prevent hydrogen from leaking into auxiliary systems.

10.3 Internal combustion engines of piston type

10.3.1 Unless expressly provided otherwise, the requirements of section 10.3 of the IGF Code should apply to ships using hydrogen as fuel.

10.3.2 The arrangements for the purging of the engine and engine exhaust gas system are to be considered in the safety concept for the engine.

10.3.3 The safety concept should specifically demonstrate safe fuel supply changeover due to reasonably foreseeable failure modes (e.g. overspeed, gas leakage).

10.4 Provisions for gas consumers other than internal combustion engines of piston type

10.4.1 Fuel cells should be arranged in accordance with the Interim guidelines for the safety of ships using fuel cell power installations (MSC.1/Circ.1647).

10.5 Fuel reforming equipment

10.5.1 The fuel containment and piping systems for the primary fuel being reformed should be designed and arranged in accordance with the requirements applicable to that fuel.

10.5.2 Fuel-reforming equipment for converting primary fuels into hydrogen, along with the associated piping systems containing hydrogen, should be designed and arranged in accordance with the provisions outlined in this Guidance.

Reforming equipment and piping systems falling under the scope of Interim guidelines for the safety of ships using fuel cell power installations (MSC.1/Circ.1647) should be designed and arranged in accordance with the provisions therein.

11. FIRE SAFETY

11.0 Hazards

11.0.1 A fire unrelated to the fuel system may cause damage to fuel containment and piping systems.

11.0.2 A hydrogen jet fire may impinge on other parts of the hydrogen system, causing an escalation.

11.0.3 If hydrogen is discharged through the vent mast and ignited, the resulting jet fire may generate dangerous heat radiation levels.

11.0.4 When a hydrogen fire is attempted to be extinguished without first stopping the leakage, an accumulation of unburned hydrogen may re-ignite and cause an explosion.

11.0.5 Firewater directed towards the outlet from the vent mast may cause icing and prevent the proper functioning of pressure relief systems for fuel containment systems for liquefied hydrogen.

11.0.6 Hydrogen discharged through ventilation ducts may ignite and flashback to the space where the leakage occurred, causing a deflagration.

11.1 Goal

The goal of this chapter is to provide for fire protection, detection and fighting for all system components related to the storage, conditioning, transfer and use of hydrogen as ship fuel.

11.2 Functional Requirements

This section is related to functional requirements in **3.2.1**, **3.2.2**, **3.2.12** and **3.2.14**

In particular, the following apply:

11.2.1 Fuel containment systems should be located and arranged to minimize the risk of excessive heat input from a fire.

11.2.2 It should be possible to cool down fuel containment systems on open decks in a fire scenario.

11.2.3 It should be possible to detect a hydrogen fire, recognizing the potential for invisible hydrogen flames.

11.2.4 It should be possible to extinguish a fire caused by the hydrogen system.

11.2.5 Fixed fire-extinguishing systems should be installed having due regard to the fire growth potential of the protected spaces;

11.2.6 The ignition of operational or accidental fuel releases should not expose structural elements, equipment and people onboard to unacceptable heat radiation levels.

11.2.7 Isolation devices should be positioned in fuel systems to stop the hydrogen flow in case of a leak-fuelled fire.

11.3 Fire protection

11.3.1 Fire insulation should be appropriate for hydrogen fires and the identified fire scenarios. Fire protection for any boundary facing vent mast outlets should also be considered, taking into account the heat radiation analysis specified in 6.7.3.

11.3.2 Any boundary of accommodation spaces, service spaces, control stations, escape routes and machinery spaces, facing fuel tanks on open deck, should be shielded by suitable fire insulation. The fire insulation should extend up to the underside of the navigation bridge deck.

11.3.3 The space containing the fuel containment system should be separated from the machinery spaces of category A or other rooms with high fire risks. The separation should be done by a cofferdam of at least 900 mm with insulation of A-60 class.

When determining the insulation of the space containing the fuel containment system from other spaces with lower fire risks, the fuel containment system should be considered as a machinery space of category A, in accordance with SOLAS regulation II-2/9.

The fuel storage hold space may be considered as a cofferdam provided that:

.1 The type C tank is not located directly above machinery spaces of category A or other rooms with high fire risk; and

.2 The minimum distance to the A-60 boundary from the outer shell of the type C tank or the boundary of the tank connection space, if any, is not less than 900 mm.

11.3.4 The fuel storage hold space should not be used for machinery or equipment that may pose a fire risk.

11.3.5 Fuel storage and preparation equipment on an open deck, located directly above machinery spaces of category A or other rooms with a high fire risk, should be shielded by a cofferdam of at least 900 mm with insulation of A-60 class.

When determining the insulation of the fuel storage areas from other spaces with lower fire risks, the fuel storage area is to be regarded as a machinery space of category A.

11.3.6 The bunkering station should be separated from other spaces by suitable passive fire insulation, taking into consideration the fire risk associated with each space.

11.4 Fire extinguishing

11.4.1 Hydrogen fire-extinguishing should be based on the isolation and shut down of the hydrogen supply to the fire by automatic action by the fuel safety system.

11.4.2 The fuel safety system should ensure the safe isolation of the relevant hydrogen source of release, i.e. shutdown of tank valves, master gas fuel valves, bunker connection valve and isolation valves, before activating any fire-extinguishing method.

11.4.3 Fire-extinguishing systems for secondary fires caused by hydrogen fires should adequately consider the potential fire loads involved, including credible fire scenarios identified from the risk assessment. The fixed fire-extinguishing system's medium and concentration/application rate, including the possible use of local application systems as required by SOLAS, should be considered and documented as suitable for extinguishing and controlling the secondary fire as relevant, and for effective use on naturally ventilated open decks if applicable.

11.5 Fire main

11.5.1 If the fire main supplies water spray cooling systems, the fire pump capacity and pressure should be sufficient to serve both systems simultaneously.

11.5.2 When fuel storage tanks are located on the open deck, isolating valves shall be fitted in the fire main in order to isolate damaged sections of the fire main. Isolation of a section of the fire main should not deprive the fire line ahead of the isolated section of the supply of water.

11.6 Water spray cooling systems

11.6.1 A water spray cooling system should be installed to cool fuel containment systems on the open deck in the event of a fire.

11.6.2 The water spray cooling system should also provide cooling to surfaces exposed to heat radiation from sustained hydrogen fires from the vent mast opening.

11.6.3 The water spray cooling system should have an application rate of 10 l/min/m2 for horizontal projected surfaces and 4 l/min/m2 for vertical surfaces.

11.6.4 The capacity of the water spray pump should be sufficient to deliver the required amount of water to the hydraulically most demanding area to be protected.

11.6.5 If the water spray system is not part of the fire main system, a connection to the ship's fire main through a stop valve should be provided.

11.6.6 The remote start for the pumps that supply the water spray system and the remote operation valves to the system shall be positioned in a readily accessible location that is unlikely to be rendered inaccessible in the event of a fire in the protected areas.

11.6.7 The nozzles should be of an approved full-bore type, and they shall be arranged to ensure an effective distribution of water throughout the area being protected.

11.6.8 The function of temperature-actuated hydrogen safety relief systems should be designed and arranged so as not to be affected by the release of the water spray cooling system.

11.6.9 For liquefied hydrogen systems, the solidification of water resulting from the water spray system coming into contact with low-temperature areas of the pressure relief system, including the outlet(s), should be evaluated. Water should not be sprayed into vent masts or freeze pressure relief valves.

11.6.10 If deemed necessary by the risk assessment, water spray protection should be provided to enable cooling of any boundary of accommodation spaces, service spaces, control stations, machinery spaces, and escape routes, as well as embarkation stations and survival craft facing fuel tanks and fuel equipment on open deck.

11.7 Fire detection and fire alarm systems

11.7.1 A fixed fire detection and fire alarm system complying with the Fire Safety Systems Code should be provided.

11.7.2 Smoke detectors alone should not be considered sufficient for the rapid detection of a hydrogen fire.

11.8 Fire Risk Analysis

11.8.1 A fire risk analysis should be conducted to verify that the limitations of fire consequences listed in 4.3.1 and 6.7.8 are not exceeded.

11.8.2 All reasonably foreseeable operational and failure scenarios associated with the hydrogen fuel system should be considered in the fire risk analysis.

11.8.3 For fuel containment and piping systems containing liquefied hydrogen, the following scenarios should be considered at a minimum:

.1 Release of hydrogen through the tank vent system due to loss of insulation, a tank pressure exceeding the set pressure of tank safety valves, or through a faulty tank safety valve.

.2 Release of hydrogen through the vents from secondary enclosures due to leaks in the fuel piping system.

.3 Release of hydrogen through the vents from fuel piping systems as a result of heating trapped volumes of hydrogen.

.4 Release of hydrogen after unintended events during bunkering.

11.8.4 For fuel containment and piping systems containing compressed hydrogen, the following scenarios should be considered at a minimum:

.1 Release of hydrogen through the tank vent system due to the opening of automatic pressure relief.

.2 Release of hydrogen through the tank vent system due to the activation of manual remote pressure relief devices, assuming simultaneous release of all connected tanks.

.3 Release of hydrogen through vents from secondary enclosures as a result of leaks from the fuel piping system.

.4 Release of hydrogen through vents from tank connection enclosures due to leaks from the piping system.

.5 Release of hydrogen caused by unintended events during bunkering.

11.8.5 The fire risk analysis should include, at a minimum, the following information for the scenarios being assessed:

.1 The cause of the release of hydrogen.

.2 The process conditions for the releasing system (temperature, pressure, phase, etc.).

.3 The location of the release.

.4 Justification of the mass flow, observing the minimum leak size values in 12.3.6.

.5 Assumed release duration, considering detection methods and their reliability, available shut-down arrangements and amount of fuel contained in the system.

.6 Ambient conditions, geometry and other factors in the area of release which may affect the consequences of an ignition.

12. EXPLOSION PREVENTION

12.0 Hazards

12.01 A hydrogen leak or release may ignite, resulting in jet fire, deflagration or detonation.

12.02 Electrical installations may be ignition sources in a hydrogen leak or release scenario.

12.0.3 Hydrogen may ignite due to other external ignition mechanisms or self-ignition in a hydrogen leak or release scenario.

12.1 Goal

The goal of this chapter is to provide for the prevention of explosions and for the limitation of effects from explosion.

12.2 Functional requirements

This section is related to functional requirements in **3.2.1** to **3.2.5** and **3.2.8**.

In particular, the following apply:

12.2.1 *The probability and consequence of explosions resulting from hydrogen leaks or releases should be reduced to a minimum by:*

.1 reducing the number of sources of ignition to a minimum;
.2 reducing the probability of formation of ignitable mixtures to a minimum;
.3 optimizing layout and design to limit explosion severity and consequences; and
.4 minimizing segment volumes, leak rates, and the leak duration.

12.2.2 Areas where an explosive gas atmosphere may occur should be classified to facilitate the selection of suitable electrical equipment for these areas.

12.3 Explosion risk analysis

12.3.1 An explosion risk analysis should be conducted to verify that the limitations of explosion consequences listed in Section 4.3.1 are not exceeded.

12.3.2 All reasonably foreseeable operational and failure scenarios associated with the hydrogen fuel system should be considered in the analysis of explosion risk.

12.3.3 For fuel containment and piping systems containing liquefied hydrogen, the following scenarios should be considered at a minimum:

.1 Release of hydrogen through the tank vent system due to loss of insulation, a tank pressure exceeding the set pressure of tank safety valves, or through a faulty tank safety valve.

.2 Release of hydrogen through the vents from secondary enclosures due to leaks in the fuel piping system.

.3 Release of hydrogen through the vents from fuel piping systems as a result of heating trapped volumes of hydrogen.

.4 Release of hydrogen due to unintended events during bunkering.

12.3.4 For fuel containment and piping systems containing compressed hydrogen, the following scenarios should be considered at a minimum:

.1 Release of hydrogen through the tank vent system due to the opening of automatic pressure relief.

.2 Release of hydrogen through the tank vent system due to the activation of manual remote pressure relief devices, assuming simultaneous release of all connected tanks.

.3 Release of hydrogen through vents from secondary enclosures as a result of leaks from the fuel piping system.

.4 Release of hydrogen through vents from tank connection enclosures due to leaks from the piping system.

.5 Release of hydrogen caused by unintended events during bunkering.

12.3.5 Explosion risk analysis

.1 The explosion risk analysis should include, at a minimum, the following information for the scenarios being assessed:

.1 The cause of the release of hydrogen.

.2 The process conditions for the releasing system (temperature, pressure, phase, etc.).

.3 The location and direction of the leak or release.

.4 Justification of the mass flow, observing the minimum leak size values in 12.3.6.

.5 Assumed release duration, considering detection methods and their reliability, available shut-down arrangements and amount of fuel contained in the system.

.6 Timing and location of ignition, justifying any deviations from a worst-case scenario.

.7 Ambient conditions, geometry, and other factors in the area affected by the release that may influence the consequences of an ignition.

.8 The operational modes of the vessel included in the analysis.

.2 The results of the explosion risk analysis should include:

.1 The cloud sizes that are obtained from the leak and dispersion analysis.

.2 The explosion pressures that are obtained from explosion analysis.

.3 Tolerance levels for damage and pressure levels should also be given, e.g. acceptable pressure levels on walls, and fatality levels on personnel outdoors.

12.3.6 The following leakage sizes should be considered minimum values in the explosion and fire risk analyses:

Component	*Leakage size to be considered*
Pipe	*0,01D² (mm²) for D ≤ 100 mm, 100 mm² for D >100 mm*
Flange	*Blow out of gasket: π Dt/4*
Valve	*Bonnet failure when bolts are used for fastening: bonnet area = π DBt/4* *Valve flanges to be considered under flanges*
Flexible hose	*Full-bore rupture: π D² /4*
Pipe coupling and screwed connections	*Full-bore rupture: π D² /4*
D = pipe diameter, t = thickness of gasket, DB = flow diameter through bonnet	

12.4 Area classification

12.4.1 Area classification is a method of analysing and classifying the areas where explosive gas atmospheres may occur. The object of the classification is to allow the selection of electrical apparatus able to be operated safely in these areas.

12.4.2 In order to facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into zones 0, 1 and 2.

12.5 Hazardous area zones

12.5.1 Hazardous area zone 0

This zone includes, but is not limited to, the interiors of fuel tanks, any pipework for pressure-relief or other venting systems for fuel tanks, pipes and equipment containing fuel.

12.5.2 Hazardous area zone 1

This zone includes, but is not limited to:

.1 Secondary enclosures around piping systems, including gas valve units.

.2 Tank connection enclosures around tank connections for compressed hydrogen

.3 Areas on open deck, or semi-enclosed spaces on deck, within minimum distances as per section 12.5 of the IGF Code Part A-1 to any vent mast outlet, other gas outlet and bunker manifold.

12.5.3 Hazardous area zone 2

Areas on open deck, or semi-enclosed spaces on deck, within minimum distances as per Section 12.5 of the IGF Code Part A-1.

13. VENTILATION

13.0 Hazards

13.0.1 Ventilation systems can cause hydrogen released on open decks to enter enclosed spaces, creating an ignitable atmosphere.

13.1 Goal

The goal of this chapter is to ensure that ignitable hydrogen/air mixtures are not formed in enclosed spaces.

13.2 Functional Requirements

This section relates to the functional requirements in sections **3.2.1** to **3.2.3**, **3.2.6** and **3.2.11**.

In particular, the following apply:

13.2.1 Ventilation systems should be arranged to prevent hydrogen from being drawn into enclosed spaces through ventilation ducts.

13.3 General

13.3.1 Air inlets for non-hazardous enclosed spaces should be taken from non-hazardous areas at least 1.5 m away from the boundaries of any hazardous area.

13.3.2 Air outlets from non-hazardous spaces should be located outside hazardous areas

14. ELECTRICAL INSTALLATIONS

14.0 Hazards

14.0.1 Electrical installations may be ignition sources in a hydrogen release scenario.

14.0.2 Failure of electrical installations required to maintain normal operating limits for fuel tank pressures may lead to the release of hydrogen.

14.1 Goal

The goal of this chapter is to prevent electrical installations from becoming ignition sources in areas where a flammable atmosphere may be expected.

14.2 Functional Requirements

This section is related to functional requirements in **3.2.1, 3.2.2**, **3.2.5**, **3.2.8** and **3.2.17**.

In particular, the following apply:

14.2.1 Electrical installations should not be installed in areas where a flammable hydrogen atmosphere may occur unless they are essential for safety or operational reasons.

14.2.2 Electrical installations installed in areas where a flammable hydrogen atmosphere may occur should be designed to minimize the risk of igniting a flammable hydrogen atmosphere.

14.2.3 Electrical equipment that is essential for safety or operational purposes should be arranged or designed to function as intended, also after a loss of vacuum in fuel tanks or piping systems have lowered the ambient temperature.

14.3 General

14.3.1 Electrical equipment installed in hazardous areas should be in compliance with IEC 60079 Series or a standard acceptable to the Administration.

14.3.2 Where electrical equipment is installed in hazardous areas as provided in 14.2.1, it should be selected, installed and maintained in accordance with recognized standards. *

* Refer to the recommendation published by the International Electrotechnical Commission, in particular to publication IEC 60092-502:1999.
Equipment for hazardous areas should be evaluated and certified or listed by an accredited testing authority or notified body recognized by the Administration.

14.3.3 Where electrical equipment is installed in hazardous areas as provided in 14.2.1, the equipment group should be not less than IIC and the temperature class T1.

14.3.4 The installation on board of the electrical equipment units should be such as to ensure the safe bonding to the hull of the units themselves.

14.3.5 The de-energizing of electrical equipment is not accepted as a safety barrier.

15. CONTROL, MONITORING AND SAFETY SYSTEMS

15.0 Hazards

15.0.1 Hazardous events, such as fuel leakage, may develop undetected or too rapidly for manual intervention.

15.0.2 A malfunctioning control, monitoring, or safety system may cause a hazardous event or prevent the execution of safety actions required to limit the consequences of a hazardous event.

15.0.3 Actions initiated by the safety systems may lead to a loss of power generation for propulsion and auxiliary purposes.

15.1 Goal

The goal of this chapter is to provide for the arrangement of control, monitoring, and safety systems that support the efficient and safe operation of the hydrogen installation.

15.2 Functional requirements

This section is related to functional requirements in **3.2.1** to **3.2.3**, **3.2.9**, **3.2.11** to **3.2.14**, **3.2.17** and **3.2.20**.

In particular, the following apply:

15.2.1 The control, monitoring, and safety systems of the hydrogen installation should be arranged to ensure that a single failure in these systems does not lead to an unacceptable loss of power.

15.2.2 A fuel safety system should be arranged to close down the gas supply system automatically, upon failure in safety systems and upon other fault conditions which may develop too fast for manual intervention.

15.2.3 The safety functions should be arranged in a dedicated fuel safety system that is independent of the gas control system in order to avoid possible common cause failures. This includes power supplies and input and output signals.

15.2.4 The safety systems, including the field instrumentation, should be arranged to avoid spurious shutdown or unintended release, e.g. as a result of a faulty gas detector or a wire break in a sensor loop.

15.2.5 Where there are two or more hydrogen supply systems for redundancy, each system should be fitted with its own set of independent hydrogen control and hydrogen safety systems.

15.2.6 It should be possible to rapidly detect any leakage from the fuel system.

15.2.7 It should be possible to detect the failure of any safety function required to operate the ship safely.

15.2.8 Fuel containment systems and piping systems should be arranged with the means to ascertain the operating parameters required for safe operation.

15.2.9 Fuel containment systems should be designed and equipped to prevent overfilling during bunkering, transfer of fuel between tanks or due to the fuel's thermal expansion.

15.3 General

15.3.1 Suitable instrumentation devices should be fitted to allow-effective monitoring of essential parameters to ensure safe management of the whole fuel-gas installation, including bunkering.

15.3.2 The safety system should be independent of the control and monitoring system.

15.3.3 Tank connection spaces should be arranged with level indicators in bilge wells, providing a high-level alarm. A low-temperature indication in the space should activate the safety system.

15.4 Fuel containment system monitoring

15.4.1 Fuel containment systems for liquefied gas should be fitted with liquid level gauging devices that continuously monitor the liquid level. If only one liquid level gauge is installed, it should be designed to be maintained in operational condition without emptying or gas-freeing the tank.

15.4.2 Overflow control for liquefied fuel tanks:

Each fuel tank should be fitted with a high liquid level alarm operating independently of other liquid level indicators and giving an audible and visual warning when activated.

.1 An independent sensor, functioning separately from the high liquid level alarm, should stop the filling of the tank by automatically activating a shutoff valve in a way that prevents both excessive liquid pressure in the bunkering line and the liquefied gas fuel tank from becoming completely full.

.2 *All components of the level alarm system, including the electrical circuit and sensor(s) for the high and overfill alarms, should be capable of functional testing.*

.3 *Where arrangements are provided for overriding the overflow control system, they should be such that inadvertent operation is prevented. When this override is operated, a continuous visual indication should be provided at the navigation bridge, a continuously manned central control station or the onboard safety centre.*

15.4.3 The vapour space of each tank for liquefied fuel should be provided with pressure indication on the navigation bridge, a continuously manned central control station or the onboard safety centre.

15.4.4 A high-pressure alarm and, if vacuum protection is required, a low-pressure alarm should be provided on the navigation bridge and at a continuously manned central control station or onboard safety centre. Alarms should be activated before the opening pressure of the safety valves is reached.

15.4.5 A local-reading manifold pressure indicator should be provided to indicate the pressure between the ship's manifold valves and the hose connections to the shore.

15.4.6 For submerged fuel-pump motors and their supply cables, arrangements should be made to alarm at a low-liquid level and automatically shut down the motors in the event of a low-low liquid level. The automatic shutdown may be accomplished by sensing low pump discharge pressure, low motor current, or low-low liquid level. This shutdown should give an audible and visual alarm on the navigation bridge, a continuously manned central control station or the onboard safety centre.

15.4.7 Compressed hydrogen tanks should be provided with temperature monitoring to prevent overheating during bunkering.

15.5 Bunkering control

15.5.1 Control of the bunkering should be possible from a safe location remote from the bunkering station. At this location, the tank pressure, tank temperature, if relevant, and tank level shall be monitored. Remotely controlled valves required by 8.5.2 and 11.6.6 shall be capable of being operated from this location. Overfill alarm and automatic shutdown shall also be indicated at this location.

15.5.2 If leakage is detected in the secondary enclosure around the bunkering lines, an audible and visual alarm should be provided at the bunkering control location. The bunker valve and other valves required to isolate the leakage should be automatically closed by the safety system.

15.6 Engine monitoring

15.6.1 In addition to the instrumentation provided in accordance with part C of SOLAS chapter II-1, indicators should be fitted on the navigation bridge, the engine control room and the manoeuvring platform for:

.1 operation of the engine in case of gas-only engines; or

.2 operation and mode of operation of the engine in the case of dual-fuel engines.

15.7 Leakage detection

15.7.1

.1 Permanently installed gas detection should be fitted in:

.1 tank connection enclosures;

.2 bunkering stations; and
.3 secondary circuits for fuel heating and other auxiliary systems ;where hydrogen can leak directly into the medium

.2 To warn against operational and accidental releases of hydrogen, gas detectors should also be arranged in:

.1 the vicinity of hydrogen vent mast outlets; and
.2 tank connection spaces;

.3 Permanently installed gas detection or other leakage detection should be fitted in secondary enclosures around

.1 pipes containing gaseous fuel;
.2 pipes containing liquefied fuel;
.3 valves and components containing gaseous fuel; and
.4 valves and components containing liquefied fuel.

15.7.2 The number and location of detectors in each area should be considered, taking the arrangement into account.

15.7.3 Gas detection equipment should be designed, installed and tested in accordance with a recognized standard, such as IEC 60079-29.

15.7.4 Audible and visible alarm should be activated upon leakage detection, and the safety systems should be activated in accordance with Table 1.

15.7.5 Audible and visible alarms from the leakage detection equipment should be located on the navigation bridge, in the continuously manned central control station.

Leakage detection in spaces that are normally accessible shall initiate an audible and visible alarm locally.

15.7.6 Gas detection required by this section should be continuous without delay.

15.7.7 The integrity of secondary enclosures should be continuously monitored. Detected leakages from the outside should be alarmed, and the safety system should be activated in accordance with Table 1.

15.8 Fire detection

15.8.1 Required safety actions upon fire detection in the machinery space containing gas consumers and for fuel storage hold spaces are provided in Table 1 below.

15.8.2 Fire detectors shall be suitable for detection of hydrogen fires (i.e. flame, smoke, heat).

15.9 Safety functions of fuel supply systems

15.9.1 Compressors, pumps and fuel supply should be arranged for manual remote emergency stop from the following locations as applicable:

.1 navigation bridge;
.2 cargo control room;
.3 onboard safety centre;
.4 engine control room;

.5 fire control station; and
.6 close to the fuel preparation area.

Gas compressors should also be arranged for manual local emergency stop.

15.9.2 The heating medium for the liquefied gas vaporizer should be provided with temperature monitoring at the heat exchanger outlet. An alarm should be given at low temperature.

15.9.3 The heated fuel in supply lines to consumers should be provided with temperature monitoring at the heat exchanger outlet. An alarm should be given at low temperature.

Table 1: Monitoring of fuel installation

Parameter	Alarm	Automatic shutdown of the tank valves	Automatic shutdown of the master gas fuel valve(s)	Comments
Leakage detection				
Detected leakage in the piping for liquefied fuel	X	X		If leakage is detected in the bunkering lines, an audible and visual alarm should be sounded also at the bunkering control location. The bunker valve and other valves required to isolate the leakage should be automatically closed by the safety system.
Detected leakage in the secondary enclosure around piping for liquefied fuel	X	X		
Detected leakage in the tank connection enclosure for compressed hydrogen piping	X	X		
Detected leakage in piping for gaseous fuel outside the Machinery Space	X	X		If leakage is detected in the primary barrier in bunkering lines, an audible and visual alarm should be sounded also at the bunkering control location. The bunker valve and other valves required to isolate the leakage should be automatically closed by the safety system.
Detected leakage in the secondary enclosure around piping for gaseous fuel outside the machinery space	X	X	X	
Detected leakage in the piping for gaseous fuel inside the machinery Space	X		X	

Detected leakage in the secondary enclosure around piping for gaseous fuel inside the Machinery space	X		X	
Detected leakage into secondary circuits for fuel heating and other auxiliary systems where hydrogen can leak directly into the medium	X	X	X	For systems in the machinery space the master valve should close, for systems outside the machinery space the tank valves should close.
Detected leakage in the bunkering station	X			Initiate the stop of the bunkering operation, automatic closing of bunkering valve.
Gas detection in the vicinity of hydrogen vent mast outlet(s)	X			
Gas detection in tank connection spaces	X			
Fuel containment system				
High liquid level in tanks for liquefied hydrogen	X			
High-high liquid level in tanks for liquefied hydrogen	X	X		Should stop the filling of the tank by automatically activating a shutoff valve in a way that prevents both excessive liquid pressure in the bunkering line and the liquefied gas fuel tank from becoming liquid full
Low liquid level for submerged pumps	X			
Low-low liquid level for submerged pumps	X	X		Automatic shutdown of the pump motor
High pressure in liquefied hydrogen tanks	X			Before pressure relief valve opens
Low pressure in liquefied hydrogen tanks	X			

High pressure in compressed hydrogen tanks	X	X		During bunkering operations
High temperature in compressed hydrogen tanks	X	X		During bunkering operations
High level in bilge wells in the tank connection space	X			
Low temperature in the tank connection space	X	X		
Fuel heating				
Low heating medium temperature at vaporizer outlet	X			
Low gas temperature at vaporizer outlet	X	X		
Fire detection				
Detected fire in areas with hydrogen fuel installations	X	X	X	Valves required to isolate the leakage should be automatically closed by the safety system prior to fire extinguishing.
Manual shutdown				
Emergency shutdown of compressors and pumps				Should be available in the following places: Navigation bridge, cargo control room, onboard safety centre, engine control room, fire control station and close to the fuel preparation area.
Emergency shutdown of the fuel supply to the machinery space			X	Should be available in the following places: Navigation bridge, cargo control room, onboard safety centre, engine control room, fire control station and close to the fuel preparation area.
Emergency shutdown of bunkering				Shutdown of the bunker connection valve from the bunker control location

16. MANUFACTURE, WORKMANSHIP AND TESTING

16.0 Hazards

16.0.1 A sub-standard level of workmanship and testing may increase the risk of fuel system components failing and the risk of hydrogen leaks developing.

16.0.2 A sub-standard level of workmanship and testing may increase the failure rate of safety functions, which may escalate the consequences of hazardous events.

16.1 Goal

The goal of this chapter is to provide adequate standards for manufacture, workmanship and testing to ensure the safe handling of hydrogen under all operating conditions and minimize the risk to the ship, people and environment.

16.2 Functional requirements

This section is related to functional requirements in **3.2.1**, **3.2.2**, **3.2.11**, **3.2.15** and **3.2.16**.

In particular, the following apply:

16.2.1 The manufacture, testing, inspection and documentation of components and systems for hydrogen fuel should be performed to minimize the risk of undetected design and production errors.

16.3 General

16.13.1 The IGF Code Chapter 16 should be taken into account, where applicable, in order to fulfil the functional requirements.

16.3.2 For materials whose design temperature is lower than -165°C, the toughness tests should be carried out in accordance with recognised standards.

17. DRILLS AND EMERGENCY EXERCISES

17.0 Hazards

17.0.1 A hydrogen incident could escalate due to a lack of quick action and communication.

17.0.2 A hydrogen incident could escalate due to lack of appropriate response.

17.1 Goal

The goal of this chapter is to ensure that people onboard ships using hydrogen as a fuel are adequately prepared for their tasks.

17.2 Functional requirements

This section is related to functional requirements in **3.2.1** and **3.2.2**.

In particular, the following apply.

17.2.1 Drills and emergency exercises should be conducted regularly to ensure that people on board are adequately prepared for their tasks.

17.3 General

17.3.1 Drills and emergency exercises on board shall be conducted at regular intervals.

Such hydrogen-related exercises could include, for example:

.1 tabletop exercises;
.2 review of fuelling procedures based on the fuel handling manual;
.3 responses to potential contingencies;
.4 tests of equipment intended for contingency response; and
.5 reviews that assigned seafarers are trained to perform assigned duties during fuelling and contingency response.

17.3.2 Hydrogen-related exercises may be incorporated into periodical drills required by SOLAS.

17.3.3 The response and safety system for hazards and accident control should be reviewed and tested.

18. OPERATION

18.0 Hazards

18.0.1 Lack of adequate procedures for safe operation of the hydrogen system may lead to hazardous events during bunkering, storage, distribution and consumption of fuel.

18.0.2 Lack of adequate procedures for maintenance may lead to hazardous events during maintenance and deterioration of equipment.

18.0.3 Lack of adequate emergency procedures may lead to lack of appropriate response to emergencies.

18.0.4 Ship and cargo operations may cause damage to the fuel containment and piping system.

18.0.5 Breaking into containment during maintenance without properly isolating hydrogen system parts could result in a leak of liquefied or gaseous fuel.

18.0.6 Repairs using unsuitable replacement parts could lead to system failures.

18.0.7 Lack of maintenance may lead to degradation of safety functions intended to prevent and mitigate leakages.

18.1 Goal

The goal of this chapter is to ensure that operational procedures for the safe bunkering, storage, distribution and consumption of fuel, and maintenance and inspection of fuel systems, minimize the risk to personnel, the ship and the environment.

18.2 Functional requirements

This section relates to the functional requirements in **3.2.1 to 3.2.3**, **3.2.5**, **3.2.8**, **3.2.11**, **3.2.15**, **3.2.16** and **3.2.20**.

In particular, the following apply:

.1 Maintenance procedures and system descriptions for all hydrogen-related installations should be available on board.
.2 The ship should be provided with operational procedures, including a suitably detailed fuel handling manual, so trained personnel can safely operate the fuel bunkering, storage and transfer systems.
.3 The ship should be provided with suitable emergency procedures.
.4 Procedures should be in a working language of the ship.

18.3 Signboards

18.3.1 If a fuel leak leading to a fuel supply shutdown occurs, the fuel supply should not be operated until the leak has been found and dealt with. Instructions to this effect should be placed in a prominent position in the machinery space.

18.3.2 A caution placard or signboard should be permanently fitted in the machinery space containing gas-consumers stating that heavy lifting, implying danger of damage to the fuel pipes, should not be done when the engine(s) are running on gas.

18.4 Maintenance and inspection

18.4.1 Maintenance and repair procedures should include considerations with respect to the fuel containment systems and adjacent spaces.

18.4.2 Inspections and surveys of the fuel containment system should be carried out in accordance with the inspection/survey plan required by 6.4.1.8 of the IGF Code Part A-1.

18.4.3 Maintenance procedures and systems procedures should include maintenance of electrical equipment that is installed in explosion-hazardous spaces and areas. The inspection and maintenance of electrical installations in explosion-hazardous spaces should be performed in accordance with a recognized standard.

Refer to IEC 60079 17:2007 Explosive atmospheres – part 17: Electrical installations inspection and maintenance.

18.5 Bunkering operations

18.5.1 Responsibilities

18.5.1.1 Before any bunkering operation commences, the master of the receiving ship or his representative and the representative of the bunkering source are Persons In Charge (PIC) of the bunkering operations and should:

- agree in writing on the transfer procedure, including cooling down and, if necessary, gassing up; the maximum transfer rate at all stages and volume to be transferred;
- agree in writing action to be taken in an emergency; and
- complete and sign the bunker safety checklist.

18.5.1.2 Upon completion of bunkering operations, the ship PIC should receive a Bunker Delivery Note for the fuel delivered, completed and signed by the bunkering source PIC.

18.5.1.3 A fuel system schematic/piping and instrumentation diagram (P&ID) should be reproduced and permanently mounted in the ship's bunker control station and at the bunker station.

18.5.2 Pre-bunkering verification

18.5.2.1 Prior to conducting bunkering operations, pre-bunkering verification, including, but not limited to the following, should be carried out and documented in the bunker safety checklist:

- all communications methods, including ship-shore link (SSL), if fitted;
- operation of fixed gas and fire detection equipment;
- operation of portable gas detection equipment;
- operation of remotely controlled valves;
- inspection of hoses and couplings;
- operation of water spray system (if relevant).

18.5.2.2 Documentation of successful verification should be indicated by the mutually agreed and executed bunkering safety checklist signed by both Persons In Charge.

18.5.3 Communications between the ship and the bunkering source

18.5.3.1 Communication between the ship PIC and the bunkering source PIC should be maintained at all times during the bunkering operation. If communications cannot be maintained, bunkering should stop and not resume until communications are restored.

18.5.3.2 Bunkering communication devices should meet recognized standards.

18.5.3.3 PICs should maintain direct and immediate communication with everyone involved in the bunkering operation.
18.5.3.4 The ship-shore link (SSL), or an equivalent means, for automatic ESD communications to a bunkering source should be compatible with both the receiving ship and the delivering facility's ESD system.

18.5.4 Electrical bonding

18.5.4.1 Hoses, transfer arms, piping, and fittings supplied by the delivering facility for bunkering should be electrically continuous, adequately insulated, and ensure a level of safety that complies with recognized standards.

18.5.5 Conditions for fuel transfer

18.5.5.1 Warning signs should be posted at the access points to the bunkering area listing safety precautions during fuel transfer.

18.5.5.2 During the fuel transfer operation, access to the bunkering manifold area should be limited to essential personnel only. All staff involved in duties or present in the vicinity of the operations must wear appropriate personal protective equipment (PPE). A failure to uphold the necessary conditions for transfer should warrant stopping operations. Transfer should not resume until all required conditions are satisfied.

18.6 Inerting and purging of fuel systems

18.6.1 Procedures for inerting and purging of fuel systems should ensure that:

- air is not present in piping or a tank being filled with hydrogen,
- air is not leaking into piping or a tank containing hydrogen, and that
- hydrogen is not introduced into enclosures or spaces adjacent to fuel systems.

18.7 Fuel handling manual

18.7.1 The ship-specific fuel handling manual, as referred to in 18.2.3, should address the issues specified in this section and provide information regarding the following:

18.7.1.1 The overall operation of the ship related to the hydrogen installation, from dry-dock to dry-dock.

18.7.1.2 Arrangement and layout of the hydrogen fuel supply system, including:

- a description of the main components in the fuel supply system;
- a general description of how the fuel system is intended to work;
- a hazardous area plan.

18.7.1.3 Description of the safety system and automatic safety actions for the hydrogen fuel supply system, including:

.1 Procedures for handling leakages:

- in the fuel system;
- in the tank connection spaces;
- in the fuel preparation equipment;
- in the bunkering station; and
- from a fuel tank pressure relief valve.

.2 Procedures for how to respond to substantial discharges from the outlet from fuel tank pressure relief valves, including;

- closing of ventilation inlets;

.3 Procedures for how to respond to a fire in:

- the machinery space;or
- on deck;

in relation to the operation of the hydrogen fuel system.

18.7.1.4 Description of hazards in connection with exposure to hydrogen and procedures for how to avoid exposure to hydrogen during:

- bunkering operations
- normal operation
- entry of hazardous spaces or
- when performing maintenance on the hydrogen fuel system

18.7.1.5 Description of hazards in connection with exposure to inert gas and procedures for how to avoid exposure.

18.7.1.6 Description of entry procedures for:

- tank connection spaces;
- bunkering stations;

- hold spaces; and
- other spaces where entry may constitute a hazard to the ship or personnel.

18.7.1.7 Description of bunkering operations, including procedures to:

- ensure system readiness (fire, water spray, gas detection automatic valves, inert gas, pre-bunkering procedures, communication procedures);
- prevent overfilling of tanks (transfer rates, filling limits, high-level alarms);
- control the tank pressure when bunkering (vs. tank design temperature and pressure, spraying, vapour return);
- prevent release of fuel gases to atmosphere;
- purge the bunkering system at termination of bunkering operation; and
- ensure proper use of PPE.

18.7.1.8 Procedures for purging and gas freeing of hydrogen fuel containment and piping systems to ensure safe maintenance.

19. TRAINING

19.0 Hazards

19.0.1 Lack of understanding of hydrogen hazards onboard ships using hydrogen fuel may lead to hazardous events in normal operation and during maintenance and lack of appropriate response in emergencies.

19.0.2 A hydrogen incident could escalate due to a lack of quick action and communication.

19.0.3 A hydrogen incident could escalate due to lack of appropriate response in emergencies.

19.0.4 Lack of understanding about the criticality of ignition sources could increase the risk of explosions.

19.1 Goal

The goal of this chapter is to ensure that seafarers on board ships are adequately qualified, trained and experienced to safely operate a hydrogen-fuelled ship.

19.2 Functional requirements

This section relates to the functional requirements in **3.2.1**, **3.2.2**, **3.2.5**, **3.2.11**, **3.2.15**, and **3.2.20**.

In particular, the following apply:

19.2.1 The Company should ensure that seafarers on board ships using hydrogen as fuel have completed training to attain the abilities that are appropriate to the capacity to be filled, and duties and responsibilities to be taken up, especially in emergencies.

19.2.2 The master, officers, ratings and other personnel on ships using hydrogen fuel should have received training and be qualified in the use of gaseous fuel in accordance with the STCW Convention and the STCW Code, taking into account the specific hazards of hydrogen.

20. PERSONNEL PROTECTION

20.0 Hazards

20.0.1 Due to hydrogen's low ignition energy, personnel not wearing anti-static clothing may introduce a potential ignition source.

20.0.2 Hydrogen leakages could lead to asphyxiation due to oxygen displacement.

20.0.3 Exposure to liquid hydrogen could lead to cryogenic burns and internal damage due to cold vapour inhalation.

20.0.4 Low ambient temperatures as a result of liquefied hydrogen leakages may hinder escape.

20.0.5 Unprotected contact with cold surfaces may cause frostbite and skin freezing to the cold surface.

20.1 Goal

The goal of this chapter is to ensure that protective equipment is provided for people on board, considering both routine operations and emergencies and possible short- and long-term effects of hydrogen exposure.

20.2 Functional requirements

This section relates to functional requirements in **3.2.1**, **3.2.2** and **3.2.21**.

In particular, the following apply:

20.2.1 For the protection of crew members who are engaged in the operation and maintenance of hydrogen fuel systems, and emergency response, the ship should have on board protective equipment suitable for hydrogen exposure, taking the exposure risk of different operations into account.

20.2.2 For the protection and treatment of crew members affected by contact with hydrogen, the ship should have on board suitable emergency equipment.

20.3 Protective equipment

20.3.1 Suitable protective equipment, including cryogenic protection clothes and gloves, eye and ear protection, face shield, and respiratory protection to a recognized national or international standard, should be provided for the protection of crew members engaged in normal operations related to the hydrogen fuel system.

20.3.2 Personal protective and safety equipment required in this section should be kept in suitable, clearly marked lockers located in readily accessible places.

Appendix B Comparison between IMO interim Guidelines for the safety of ships using hydrogen as fuel and the Guidance for ships using hydrogen as fuel

Draft IG	EMSA Guidance	IMO Draft Interim Guidelines for the safety of ships using hydrogen as fuel (CCC 11/WP.4 Annex 2)	EMSA Guidance for ships using hydrogen as fuel	Justification and Comments
1	**1**	**INTRODUCTION**	**INTRODUCTION**	
1.1	1.1	The purpose of these Interim Guidelines is to provide an international standard for the safety of ships using hydrogen as fuel.	This EMSA Guidance for ships using hydrogen as fuel is a non-mandatory and advisory document. Most potential zero-carbon fuels, such as hydrogen, have properties that present different safety challenges compared to conventional fuel oils. Implementing hydrogen fuel systems onboard ships requires the development of regulations for safe design and use in parallel with the technological progress necessary for their adoption. The purpose of this Guidance is to support the industry in this development by providing recommendations for practical design solutions based on a structured process, as outlined in the IMO goal-based approach in MSC.1/Circ.1394, and informed by extensive risk assessment and reliability analysis.	
1.2	1.2	The basic philosophy of these Interim Guidelines is to provide provisions for the arrangement, installation, control and monitoring of machinery, equipment and systems using hydrogen as fuel in order to minimize the risk to the ship, persons on board and the environment.	The Guidance is the result of a structured set of safety assessments and reliability analyses addressing ships using hydrogen as fuel, conducted in the EMSA Study investigating the safety of hydrogen as fuel on ships, and reported in the following publications available on the EMSA website: 1. Mapping safety risks for hydrogen-fuelled ships 2. Reliability and safety analysis 3. Hazard identification of generic hydrogen fuel systems 4. Risk analysis of generic hydrogen fuel systems 5. Risk analysis of two specific ship types using hydrogen as fuel	The reports produced in the EMSA Study investigating the safety of hydrogen as fuel on ships by DNV are available through this link: https://www.emsa.europa.eu/publications/item/5263-mapping-safety-risks-for-hydrogen-fuelled-ships-study-investigating-the-safety-of-hydrogen-as-fuel-on-ships.html
1.3	1.3	Throughout the development of these Interim Guidelines it was recognized that the provisions therein must be based on sound naval architectural and engineering principles and the best understanding of operational experience, field data and research and development. These Interim Guidelines address areas identified as needing a special consideration for the use of hydrogen as fuel.	The Guidance follows the structural layout of the IGF Code. The first four chapters correspond with IGF Code Part A, which applies to all SOLAS ships using gaseous or low-flashpoint fuels. The subsequent chapter headings follow the IGF Code Parts A-1, B-1, C-1, and D structure, covering goals, functional requirements, and prescriptive regulations similar to those applicable to ships using natural gas as fuel. This is the same structure utilised by IMO in developing the Interim Guidelines for the safety of ships using hydrogen as fuel.	
1.4	1.4	These Interim Guidelines follow the goal-based approach (MSC.1/Circ.1394/Rev.2) by specifying goals and functional requirements for each section forming the basis for the design, construction and operation of ships using hydrogen as fuel.	The Guidance differs from Interim Guidelines in several areas. The main reason is that the Guidance recommends that all hydrogen leak sources be protected by secondary enclosures to prevent any leaks from spreading uncontrollably into enclosed spaces or areas on the open deck. This premise will particularly affect the provisions for Chapter 5: Ship design and arrangement, Chapter 12: Explosion prevention, Chapter 13: Ventilation, and Chapter 15: Control, monitoring and safety systems.	

1.5	1.5	The current version of these Interim Guidelines includes provisions to meet the functional requirements for hydrogen as fuel.	Since the Guidance is a non-mandatory advisory document, it does not include references to the IMO's alternative design process for designs that deviate from the provisions, as opposed to the Interim Guidelines.	
1.6	1.6	These Interim Guidelines have been closely aligned with the *International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels* (IGF Code), adopted by resolution MSC 391(95), as amended, in particular section 3 which is mainly text taken from chapter 3 of the IGF Code, albeit modified to reflect the recommendatory nature of these Interim Guidelines.	For ease of reference, guidance provisions that are the same as in the draft IMO Interim Guidelines for the safety of ships using hydrogen as fuel (CCC 11/WP.4 Annex 2) (Interim Guidelines) are presented in *italics.*	

Draft IG	EMSA Guidance	IMO Draft Interim Guidelines for the safety of ships using hydrogen as fuel (CCC 11/WP.4 Annex 2)	EMSA Guidance for hydrogen-fuelled ships	Justification and Comments
2	**2**	**GENERAL**	**GENERAL**	
2.1	**2.1**	**Application**	**Application**	
	2.1.1	Unless expressly provided otherwise, these Interim Guidelines apply to ships using liquified and/or compressed hydrogen as fuel to which part G of SOLAS chapter II-1 applies.	This Guidance applies to ships using liquified and/or compressed hydrogen as fuel to which Part G of SOLAS Chapter II-1 applies.	The scope of the EMSA Guidance (and thereby the application) is aligned with the IMO interim guidelines, as the EMSA Guidance is intended to supplement the IMO interim guidelines, which apply to SOLAS ships in international trade. Smaller vessels are outside the scope of the EMSA Guidance.
2.2	**2.2**	**Definitions and abbreviations**	**Definitions**	
-	2.2.1	Reference is made to the definitions provided in the International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels (IGF Code), adopted by resolution MSC 391(95), as amended, part A. 2.2. Additional definitions are provided below: For the purpose of these Interim Guidelines, the terms used have the meanings defined in the following paragraphs. Terms not defined have the same meaning as in SOLAS chapter II-2 and the IGF Code.	For this Guidance, the terms used have the meanings defined in the following paragraphs. Terms not defined have the same meaning as in SOLAS Chapter II-2 and the IGF Code.	
	2.2.2		*Bunkering systems* refer to all piping systems used for the transfer of fuel from the bunkering connection to the fuel containment system.	The EMSA Guidance includes a definition of bunkering systems to clarify the scope of requirements in Chapter 8.
2.2.1	2.2.3	*Cold hydrogen vapour* means hydrogen vapour at a sufficiently low temperature to cause condensation of air, at or below -183°C.	*Cold hydrogen vapour* means hydrogen vapour at a sufficiently low temperature to cause condensation of air, at or below -183°C.	
2.2.2	2.2.4	*Compressed hydrogen* means hydrogen in its gaseous state contained at any pressure above atmospheric pressure.	*Compressed hydrogen* means hydrogen in its gaseous state contained at any pressure above atmospheric pressure.	
2.2.3	2.2.5	*Condensed air* refers to the phase change of the constituent gases within air into liquid or solid form when air is exposed to cryogenic temperatures.	*Condensed air* refers to the phase change of the constituent gases within air into liquid or solid form when air is exposed to cryogenic temperatures.	
2.2.4	2.2.6	*Cryo-pumping* refers to a situation in cryogenic systems where air or other gases unintentionally enter a vacuum-insulated space due to a leak, and are subsequently trapped or immobilized on extremely cold surfaces inside the system.	*Cryo-pumping* refers to a situation in cryogenic systems where air or other gases unintentionally enter a vacuum-insulated space due to a leak, and are subsequently trapped or immobilized on extremely cold surfaces inside the system.	
2.2.5	2.2.7	*Fuel* means hydrogen, either in its liquefied or gaseous state.	*Fuel* means hydrogen, either in its liquefied or gaseous state.	

2.2.6	2.2.8	*Fuel reformer* is the arrangement of all related fuel-reforming equipment for processing gaseous or liquid primary fuels to reformed hydrogen for use as fuel.	*Fuel reformer* is the arrangement of all related fuel-reforming equipment for processing gaseous or liquid primary fuels to reformed hydrogen for use as fuel.	
	2.2.9		*Leak* is a term used to describe the accidental discharge of gaseous or liquefied hydrogen due to a defect in the fuel piping system.	The EMSA Guidance includes a definition of the terms leak and release, to ease the understanding of the provisions in contexts where these terms are used.
2.2.7	2.2.10	*Non-inert* refers to an atmosphere containing more than 3% oxygen.	*Non-inert* refers to an atmosphere containing more than 3% oxygen.	
2.2.8	2.2.11	*Oxygen enrichment/oxygen enriched* refers to the phenomenon of increase of oxygen concentration above 23.5% by volume in air, caused by the exposure of air to cryogenic temperatures.	*Oxygen enrichment* refers to the phenomenon of increase of oxygen concentration above 23.5% by volume in air, caused by the exposure of air to cryogenic temperatures.	
2.2.9	2.2.12	*Permeability* is a measure of how easily a material allows a substance (such as a fluid, or gas) to pass through it without defect.	*Permeability* is a measure of how easily a material allows a substance (such as a fluid, or gas) to pass through it without defect.	
2.2.10	2.2.13	*Permeation* is the process by which a gas, liquid, or vapour passes through a solid material (like a membrane, liner, or insulation) on a molecular level.	*Permeation* is the process by which a gas, liquid, or vapour passes through a solid material (like a membrane, liner, or insulation) on a molecular level.	
	2.2.14		*Piping* is a term that includes the following pipe components: - pipes - flanges with gaskets and bolts, and other pipe connections - expansion elements - valves, including hydraulic and pneumatic actuators, and fittings - hangers and supports - flexible hoses pump housings	The EMSA Guidance includes a definition of the term piping to clarify what is included when this term is used in the provisions. The definition is in line with the one applied by classification societies.
	2.2.15		*Piping systems* is a term that includes piping, as well as components in direct contact with the piping, such as pumps, compressors, heat exchangers, evaporators, independent tanks, etc., except for main components such as steam and gas turbines, diesel engines, reduction gears and boilers.	The EMSA Guidance includes a definition of the term piping system to clarify what is included when this term is used in the provisions. The definition is in line with the one applied by classification societies.
2.2.11	2.2.16	*Primary fuel* is the fuel supplied to the fuel reformer (e.g. ammonia, methanol, LNG, LOHC, etc.) that is reformed to hydrogen in the fuel reformer.	*Primary fuel* is the fuel supplied to the fuel reformer (e.g. ammonia, methanol, LNG, LOHC, etc.) that is reformed to hydrogen in the fuel reformer.	
2.2.12	2.2.17	*Reformed hydrogen* is hydrogen or hydrogen-rich gas generated in the fuel reformer.	*Reformed hydrogen* is hydrogen or hydrogen-rich gas generated in the fuel reformer.	
2.2.13	2.2.18	*Secondary enclosure* is an enclosure providing a gas and liquid-tight barrier for piping and equipment containing fuel. This includes, but is not limited to, double wall pipes and ducts.	*Secondary enclosure* is an enclosure providing a gas and liquid-tight barrier for piping and equipment containing fuel. This includes, but is not limited to, double-wall pipes.	The EMSA Guidance definition does not include ducts, as they are not considered suitable for containing a pressurised hydrogen leakage. To avoid confusion with ducts required for double-walled piping systems, such as those led through accommodation spaces.
2.2.14	2.2.19	*Self-ignition* refers to ignition without presence of any external ignition source. This includes also ignition due to low ignition energy (e.g. electrostatic discharges, diffusion ignition, etc.).	Self-ignition refers to ignition without the presence of any external ignition source.	The EMSA Guidance uses amended text for clarity. Listing potential ignition sources in the definition of “self-ignition” should be avoided.
2.3	-	**Alternative design**	-	The concept of alternative design is not applicable to the draft EMSA Guidance due to its non-regulatory, non-mandatory nature.

				Consequently, guidance on how to demonstrate the equivalence of alternative designs is not provided.
2.3.1	-	These Interim Guidelines contain functional requirements for all appliances and arrangements related to the usage of hydrogen as fuel.	-	
2.3.2	-	Appliances and arrangements of hydrogen fuel systems may deviate from those set out in these Interim Guidelines, provided such appliances and arrangements meet the intent of the goal and functional requirements concerned and provide an equivalent level of safety to the relevant sections.	-	
2.3.3	-	The equivalence of the alternative design should be demonstrated as specified in SOLAS regulation II-1/55 and approved by the Administration. However, the Administration should not allow operational methods or procedures to be applied as an alternative to a particular fitting, material, appliance, apparatus, item of equipment or type thereof which is prescribed by these Interim Guidelines.	-	

Draft IG	**EMSA Guidance**	**IMO Draft Interim Guidelines** for the safety of ships using hydrogen as fuel (CCC 11/WP.4 Annex 2)	**EMSA Guidance for hydrogen-fuelled ships**	**Justification and Comments**
3	**3**	**Goal and Functional Requirements**	**GOAL AND FUNCTIONAL REQUIREMENTS**	
3.1	**3.1**	**Goal**	**Goal**	
		The goal of these Interim Guidelines is to provide for safe and environmentally-friendly design, construction and operation of ships using hydrogen as fuel, in particular their installations of systems for propulsion machinery, auxiliary power generation machinery and/or other purpose machinery.	The goal of this Guidance is to provide for safe and environmentally friendly design, construction and operation of ships using hydrogen as fuel, in particular their installations of systems for propulsion machinery, auxiliary power generation machinery and/or other purpose machinery.	
3.2	**3.2**	**Functional requirements**	**Functional Requirements**	
3.2.1	3.2.1	The safety, reliability and dependability of the systems should be equivalent to that achieved with new and comparable conventional oil-fuelled main and auxiliary machinery.	The safety, reliability and dependability of the systems should be equivalent to that achieved with new and comparable conventional oil-fuelled main and auxiliary machinery.	
3.2.2	3.2.2	The probability and consequences of fuel-related hazards should be limited to a minimum through arrangement and system design. In the event of gas leakage or failure of the risk reducing measures, necessary safety actions should be initiated.	The probability and consequences of fuel-related hazards should be limited to a minimum through arrangement and system design. In the event of gas leakage or failure of the risk-reducing measures, necessary safety actions should be initiated.	
3.2.3	3.2.3	The design philosophy should ensure that risk reducing measures and safety actions for the hydrogen fuel installation do not lead to an unacceptable loss of power.	The design philosophy should ensure that risk-reducing measures and safety actions for the hydrogen fuel installation do not lead to an unacceptable loss of power.	
3.2.4	3.2.4	Hazardous areas should be restricted, as far as practicable, to minimize the potential risks that might affect the safety of the ship, persons on board, and equipment.	Hazardous areas should be restricted, as far as practicable, to minimize the potential risks that might affect the safety of the ship, persons on board, and equipment.	

3.2.5	3.2.5	Equipment installed in hazardous areas should be minimized to that required for operational purposes and should be suitably and appropriately certified.	The installation and use of equipment in hazardous areas should be minimized to that required for operational purposes and should be suitably and appropriately certified.	The EMSA Guidance text has been amended to clarify that it is the installation and use of equipment that should be minimized.
3.2.6	3.2.6	Unintended accumulation of explosive, flammable or harmful gas concentrations should be prevented.	Unintended accumulation of explosive, flammable, or harmful gas concentrations should be prevented.	
3.2.7	3.2.7	Fuel containment and fuel piping systems should be protected against external damages.	Fuel containment and fuel piping systems should be protected against external damages.	
3.2.8	3.2.8	Sources of ignition in hazardous areas should be minimized to reduce the probability of explosions.	Sources of ignition in hazardous areas should be minimized to reduce the probability of explosions.	
3.2.9	3.2.9	Safe and suitable fuel supply, storage and bunkering arrangements should be made, capable of receiving and containing the fuel in the required state without leakage. Other than when necessary for safety reasons, fuel supply, storage and bunkering arrangements should be designed to prevent venting under all normal operating conditions including idle periods.	Safe and suitable fuel supply, storage and bunkering arrangements should be made, capable of receiving and containing the fuel in the required state without leakage. Other than when necessary for safety reasons, fuel supply, storage and bunkering arrangements should be designed to prevent venting under all normal operating conditions, including idle periods.	
3.2.10	3.2.10	Piping systems, containment and over-pressure relief arrangements that are of suitable design, construction and installation for their intended application should be provided.	Piping systems, containment and over-pressure relief arrangements that are of suitable design, construction and installation for their intended application should be provided.	
3.2.11	3.2.11	Machinery, systems and components should be designed, constructed, installed, operated, maintained and protected to ensure safe and reliable operation.	Machinery, systems and components should be designed, constructed, installed, operated, maintained and protected to ensure safe and reliable operation.	
3.2.12	-	Spaces with a non-inert atmosphere and a source that might release fuel into the space should be arranged and located such that a fire or explosion will not lead to an unacceptable loss of power or render equipment in other compartments inoperable.	-	The EMSA Guidance contains provisions for secondary enclosures around all components which may release hydrogen into a non-inert atmosphere in enclosed spaces. Hence, this functional requirement is not included in the Guidance. The Guidance has included provisions for unacceptable loss of power due to fire/explosion in section 4.3.1.10.
3.2.13	3.2.12	Suitable control, alarm, monitoring and shutdown systems should be provided to ensure safe and reliable operation.	Suitable control, alarm, monitoring, and shutdown systems should be provided to ensure safe and reliable operation and limit the consequences of failures as far as possible.	The EMSA Guidance includes limiting the consequences of failures in the functional requirement. Alarm, monitoring and shutdown systems are equally important in a failure scenario.
3.2.14	3.2.13	Effective means of detecting a leakage, suitable for all spaces and areas concerned, should be arranged.	Effective means of detecting a leakage, suitable for all spaces and areas concerned, should be arranged.	
3.2.15	3.2.14	Fire detection, protection and extinction measures appropriate to the hazards concerned should be provided.	Fire detection, protection and extinction measures appropriate to the hazards concerned should be provided.	
3.2.16	3.2.15	Commissioning, trials, and maintenance of fuel systems and gas utilization equipment should satisfy the goal in terms of safety, availability, and reliability.	Commissioning, trials, and maintenance of fuel systems and gas utilization equipment should satisfy the goal in terms of safety, availability, and reliability.	
3.2.17	3.2.16	The technical documentation should permit an assessment of the compliance of the system and its components with the applicable rules, guidelines, design standards used and the principles related to safety, availability, maintainability and reliability.	The technical documentation should permit an assessment of the compliance of the system and its components with the applicable rules, guidelines, design standards used and the principles related to safety, availability, maintainability and reliability.	
3.2.18	3.2.17	A single failure in a technical system or component should not lead to an unsafe or unreliable situation.	A single failure in a technical system or component should not lead to an unsafe or unreliable situation.	
3.2.19	3.2.18	Measures should be taken to prevent the formation of oxygen-enriched or oxygen depleted atmospheres, as well as the	Measures should be taken to prevent the formation of oxygen-enriched or oxygen-depleted atmospheres, as well as the	

		accumulation of solid air deposits or liquid air pools caused by low temperatures.	accumulation of solid air deposits or liquid air pools caused by low temperatures.	
-	3.2.19	-	Sources of hydrogen leakages should be minimized to reduce the probability of explosions and exposure to humans and the environment.	The EMSA Guidance includes a functional requirement for minimising hydrogen leak sources (as also outlined in the interim guidelines for ammonia). This is connected to the FR about minimising sources of ignition to reduce the likelihood of explosions.
-	3.2.20	-	Direct release of hydrogen into the atmosphere during normal operation and any foreseeable and controllable abnormal scenario should be minimized.	The EMSA Guidance includes a functional requirement related to the direct release of hydrogen (similar to interim guidelines for ammonia).
-	3.2.21	-	Measures to minimize the health hazards associated with exposure to hydrogen should be provided.	The EMSA Guidance includes a functional requirement about health hazards related to exposure (as also included in the interim guidelines for ammonia). Hydrogen exposure is linked to the risk of asphyxiation and exposure to low temperatures. The functional requirement will have an impact on the requirements for PPE.

Draft IG	EMSA Guidance	IMO Draft Interim Guidelines for the safety of ships using hydrogen as fuel (CCC 11/WP.4 Annex 2)	EMSA Guidance for hydrogen-fuelled ships	Justification and Comments
4	**4**	**General requirements**	**GENERAL REQUIREMENTS**	
4.1	**4.1**	**Goal**	**Goal**	
		The goal of this chapter is to ensure that the necessary assessments of the risks involved are carried out in order to eliminate or mitigate any adverse effect to the persons on board, the environment or the ship.	The goal of this chapter is to ensure that the necessary assessments of the risks involved are carried out to eliminate or mitigate any adverse effects on the persons on board, the environment, or the ship.	
4.2	**4.2**	**Risk assessment**	**Risk assessment**	
4.2.1	4.2.1	A holistic risk assessment should be conducted to ensure that risks arising from the use of hydrogen affecting persons on board, the environment, the structural strength or the integrity of the ship are addressed. Consideration should be given to the hazards associated with physical layout, operation and maintenance, following any reasonably foreseeable failure.	A holistic risk assessment should be conducted to ensure that risks arising from the use of hydrogen, affecting persons on board, the environment, the structural strength, or the integrity of the ship, are addressed. Consideration should be given to the hazards associated with physical layout, operation and maintenance, following any reasonably foreseeable failure.	
4.2.2	4.2.2	The risk assessment should specifically consider the hydrogen system integrity with focus on its ability to prevent and isolate leakages and also evaluate potential ignition mechanisms and consequences of ignition. Special consideration should be given, but not limited to, the following specific hydrogen-related hazards and topics: .1 For all systems: .1 hydrogen embrittlement; .2 natural permeability; .3 detection of leaks; .4 ignition sources and self-ignition mechanisms; and .5 jet-fire, flashfire, deflagration, detonation and escalation;	The risk assessment should specifically consider the hydrogen system integrity with focus on its ability to prevent and isolate leakages and also evaluate potential ignition mechanisms and consequences of ignition. Special consideration should be given, but not limited to, the following specific hydrogen-related hazards and topics: .1 For all systems: .1 hydrogen embrittlement; .2 natural permeability; .3 detection of leaks; .4 ignition sources and self-ignition mechanisms; and .5 jet-fire, flashfire, deflagration, detonation and escalation;	

		.2 Additionally for liquefied hydrogen fuel systems: .1 effects of low temperatures; .2 condensation of air and other gases; .3 oxygen enrichment; .4 cryo-pumping; .3 Additionally for pressurized or compressed hydrogen fuel systems: .1 high-pressure leaks; and .2 opening of pressure relief device; .4 Additionally for portable fuel containment systems: .1 lifting operations; .2 connection and disconnection; .3 additional leak sources; and .4 the purging and gas freeing, re-purging and gassing up of hydrogen systems after each portable tank connection and disconnection.	.2 Additionally, for liquefied hydrogen fuel systems: .1 effects of low temperatures; .2 condensation of air and other gases; .3 oxygen enrichment; .4 cryo-pumping; .3 Additionally, for pressurized or compressed hydrogen fuel systems: .1 high-pressure leaks; and .2 opening of pressure relief device; .4 Additionally, for portable fuel containment systems: .1 lifting operations; .2 connection and disconnection; .3 additional leak sources; and .4 the purging and gas freeing, re-purging and gassing up of hydrogen systems after each portable tank connection and disconnection.	
4.2.3	4.2.3	The risk assessment process should demonstrate that the goal in 3.1 and functional requirements in 3.2 have been satisfied.	The risk assessment process should demonstrate that the goal in 3.1 and the functional requirements in 3.2 have been satisfied.	
4.2.4	4.2.4	The risks should be analysed using acceptable and recognized risk analysis techniques. The analysis should ensure that risks are eliminated wherever possible. Risks which cannot be eliminated should be mitigated as necessary. Details of risks, and the means by which they are mitigated, should be documented to the satisfaction of the Administration.	The risks should be analysed using acceptable and recognised risk analysis techniques. The analysis should ensure that risks are eliminated wherever possible. Risks which cannot be eliminated should be mitigated as necessary. Details of risks and the means by which they are mitigated should be documented.	
4.3	**4.3**	**Limitation of explosion and fire consequences**	**Limitations of explosion and fire consequences**	
4.3.1	4.3.1	An explosion or fire on open deck due to a hydrogen leak, or in a space containing hydrogen leak sources and a non-inert atmosphere, should not: .1 cause damage to or disrupt the proper functioning of equipment/systems located in any space other than that in which the incident occurs; .2 damage the ship in such a way that flooding of water below the main deck or any progressive flooding occur; .3 damage work areas or accommodation in such a way that persons who stay in such areas under normal operating conditions are injured; .4 disrupt the proper functioning of control stations and switchboard rooms necessary for power distribution; .5 damage life-saving equipment or associated launching arrangements; .6 disrupt the proper functioning of firefighting equipment located outside the explosion-damaged space;	An explosion or fire due to a hydrogen leak or release should not: .1 cause damage to or disrupt the proper functioning of equipment/systems located in any space other than that in which the incident occurs; .2 damage the ship in such a way that flooding of water below the main deck or any progressive flooding occurs; .3 damage work areas or accommodation in such a way that persons who stay in such areas under normal operating conditions are injured; .4 disrupt the proper functioning of control stations and switchboard rooms necessary for power distribution; .5 damage life-saving equipment or associated launching arrangements; .6 disrupt the proper functioning of fire-fighting equipment located outside the fire- or explosion-damaged space;	The purpose of this paragraph is to provide criteria for unacceptable consequences of a hydrogen-related explosion or fire, irrespective of the hydrogen system's location onboard. The first sentence of the EMSA Guidance text is simplified for clarity. Further, the EMSA Guidance provision stresses that a fire or explosion should not lead to an unacceptable loss of power. In the IMO interim guidelines this is included as a functional requirement in section 3.2. The high flammability of hydrogen requires careful consideration. In the first part of this study "Mapping safety risks for hydrogen-fuelled ships", we found that according to (ISO, 2015) and (NASA, 1997), regulators are advised to assume an ignition source is present even when acceptable standards for certified electrical equipment are followed (as per the provisions in 12.5 and 14.3). This implies that the ignition of hydrogen in a release scenario should be assumed, and further measures (e.g., secondary barriers) to prevent ignition should be taken unless the ignition event is within the ship's design capabilities.

		.7 affect other areas of the ship in such a way that chain reactions involving, inter alia, cargo, gas and bunker oil may arise; or .8 prevent persons access to life-saving appliances or impede escape routes; or .9 affect the fuel containment system.	.7 affect other areas of the ship in such a way that chain reactions involving, inter alia, cargo, gas and bunker oil may arise; or .8 prevent persons access to life-saving appliances or impede escape routes; or .9 affect the fuel containment system; .10 lead to an unacceptable loss of power.	
-	4.3.2	-	The guidance outlined in section 11.8 (Fire Risk Analysis) and section 12.3 (Explosion Risk Analysis) should be followed to verify that fire and explosion consequences remain within the limitations specified in 4.3.1. This includes defining relevant operational and failure scenarios to be considered in the analyses, as well as determining the relevant leakage sizes.	The EMSA Guidance includes a provision clarifying that the limitations on fire and explosion consequences listed in 4.3.1 are linked to the fire risk analysis in section 11.8 and the explosion risk analysis in section 12.3. The reasonably foreseeable operational and failure scenarios associated with the hydrogen fuel system that should be considered at a minimum in the analyses are listed in those sections, as well as the leakage sizes that should be considered as minimum values for various piping components.
4.3.2	-	Piping and equipment containing fuel protected by secondary enclosures are not considered as potential hydrogen leak sources.	-	The EMSA Guidance includes text in section 12.3, which relates to fuel pipes protected by secondary enclosures not being considered as leak sources, in connection with the minimum values for leakage sizes for various piping components.

Draft IG	**EMSA Guidance**	**IMO Draft Interim Guidelines for the safety of ships using hydrogen as fuel (CCC 11/WP.4 Annex 2)**	**EMSA Guidance for hydrogen-fuelled ships**	**Justification and comments**
5	**5**	**SHIP DESIGN AND ARRANGEMENT**	**SHIP DESIGN AND ARRANGEMENT**	
-	**5.0**	-	**5.0 Hazards**	
-	5.0.1	-	Fuel containment systems and fuel piping systems may be damaged by external events, such as collisions, groundings, fire, explosions, cargo operations, ship operations, and environmental conditions, resulting in hydrogen releases.	
-	5.0.2	-	Damage to fuel containment systems for liquefied hydrogen may result in a Boiling Liquid Expanding Vapour Explosion (BLEVE), releasing all the hydrogen in the tank.	
-	5.0.3	-	Damage to fuel containment systems for compressed hydrogen may result in the sudden release of stored energy.	
-	5.0.4	-	Hydrogen releases may ignite, resulting in a fire, deflagration, or detonation.	
-	5.0.5	-	Liquefied hydrogen releases may cool down surrounding structures, causing embrittlement.	
-	5.0.6	-	Cold surfaces may condense air, potentially cause embrittlement and create a fire hazard.	

-	5.0.7	-	Cold surfaces may cool down surrounding structures, systems and equipment, causing structural damage or system malfunctions.	
5.1	**5.1**	**Goal**	**Goal**	
		The goal of this chapter is to provide for safe location, space arrangements and mechanical protection of power generation equipment, hydrogen storage systems, hydrogen supply equipment and refuelling systems.	The goal of this chapter is to provide for safe location, space arrangements and mechanical protection of power generation equipment, fuel storage systems, fuel supply equipment and refuelling systems.	The EMSA Guidance uses the term 'fuel' throughout, meaning hydrogen, either in its liquefied or gaseous state (as defined in Chapter 2).
5.2	**5.2**	**Functional Requirements**	**Functional Requirements**	
5.2.1		5.2.1 This chapter is related to functional requirements in 3.2.1 to 3.2.3, 3.2.5, 3.2.6, 3.2.8, 3.2.12 to 3.2.15 and 3.2.17 to 3.2.19. In particular, the following apply:	This chapter is related to functional requirements in **3.2.1** to **3.2.4**, **3.2.6** to **3.2.11**, **3.2.17** and **3.2.18.** In particular, the following apply:	
5.2.1.1	5.2.1	fuel containment system(s) should be located in such a way as to minimize: .1 probability of damage following a collision or grounding taking into account the safe operation of the ship and other hazards that may be relevant to the ship; and .2 risk of mechanical damage from ship operations, cargo operations, and environmental conditions, either by locating the fuel tanks away from such hazards or by providing mechanical protection;	The fuel containment system(s) should be located and arranged in such a way as to minimize: .4 the probability of damage following a collision or grounding taking into account the safe operation of the ship and other hazards that may be relevant to the ship; .5 the probability of mechanical damage from ship operations, cargo operations, and environmental conditions, either by locating the fuel tanks away from such hazards or by providing mechanical protection; and .6 the probability of mechanical damage from explosions, either by locating the fuel tanks away from areas of explosion risks, by providing mechanical protection, or by reducing the risk of explosions.	With reference to the hazards listed in 5.0, damage to the fuel containment system may have severe consequences. Hence, the EMSA Guidance stresses that: - it is the probability of damage that should be minimized (risk = probability x consequence). - This may be achieved by the location and arrangement of the fuel containment system Furthermore, the EMSA Guidance includes a functional requirement to mitigate the potential for mechanical damage from areas of explosion risk (e.g., cargo tanks or cargo holds).
5.2.1.2	5.2.2	fuel containment systems, fuel piping and other fuel sources of release should be so located and arranged that released hydrogen is led to a safe location in the open air, and on open deck, not accumulating in confined or congested areas	Fuel containment systems, fuel piping and other fuel sources of release should be so located and arranged that released hydrogen is led to a safe location in the open air, and on an open deck, not accumulating in confined or congested areas.	
5.2.1.3	5.2.3	the access or other openings to spaces containing hydrogen sources of release should be so arranged that flammable or, asphyxiating gas cannot escape to spaces that are not designed for the presence of such gases;	The access or other openings to spaces containing fuel sources of release should be so arranged that flammable or asphyxiating gas cannot escape to spaces that are not designed for the presence of such gases.	The EMSA Guidance use the term fuel for hydrogen throughout. See above regarding the definition of fuel sources of release.
5.2.1.4	5.2.4	fuel piping systems should be located and arranged to minimize: .1 probability of damage following a collision or grounding taking into account the safe operation of the ship and other hazards that may be relevant to the ship; and .2 risk of mechanical damage from ship operations, cargo operations, and environmental conditions.	Fuel piping systems should be located and arranged to minimize: .3 the probability of damage following a collision or grounding taking into account the safe operation of the ship and other hazards that may be relevant to the ship; and .4 the probability of mechanical damage from ship operations, cargo operations, and environmental conditions, either by locating the piping systems away from such hazards or by providing mechanical protection.	With reference to the hazards listed in 5.0, damage to the fuel piping system may have severe consequences. Hence, the EMSA Guidance stresses that: - it is the probability of damage that should be minimized (risk = probability x consequence). - This may be achieved either by locating the piping systems away from such hazards or by providing mechanical protection.

5.2.1.5	5.2.5	the propulsion and hydrogen supply system should be so designed that safety actions after any hydrogen leakage do not lead to an unacceptable loss of power;	The propulsion, power-generating and fuel supply systems should be so designed that automatic safety actions after a fuel leakage or other fault conditions, as described in chapter 15, do not lead to an unacceptable loss of power.	The EMSA Guidance contains provisions to ensure that power-generating systems should not be unacceptably affected by safety actions, and that this applies to all automatic safety actions (not only leakage detection).
5.2.1.6	5.2.6	the probability of a hydrogen explosion in spaces containing hydrogen consumers or fuel piping systems should be minimized;	The probability of a hydrogen explosion in spaces containing hydrogen consumers or fuel piping systems should be minimized.	
5.2.1.7	5.2.7	spaces containing fuel piping systems should be arranged to prevent damage from pressure build-up caused by hydrogen leakage;	Spaces containing fuel piping systems should be arranged to prevent damage from pressure build-up caused by hydrogen leakage.	
5.2.1.8	5.2.8	in spaces containing liquefied hydrogen, fuel leakage, loss of vacuum, or deterioration of insulation of tanks or piping systems should not compromise the integrity of structural materials; and	In spaces containing liquefied hydrogen, fuel leakage, loss or deterioration of vacuum insulation of tanks or piping systems should not compromise the integrity of structural materials; and	Assuming that storage tanks for liquefied hydrogen will be vacuum-insulated due to the low storage temperature and holding time requirements, the EMSA Guidance is rephrased from “deterioration of insulation of tanks” to “loss or deterioration of vacuum insulation of tanks” for clarity.
5.2.1.9	5.2.9	in spaces containing liquefied hydrogen, fuel leakage, loss of vacuum, or deterioration of insulation of tanks or piping systems should not compromise the functionality of safety systems or components necessary for the ship's safety.	In spaces containing liquefied hydrogen, fuel leakage or a loss or deterioration of vacuum insulation of tanks or piping systems should not compromise the functionality of safety systems or components necessary for the ship’s safety.	
5.3	**5.3**	**General Provisions**	**General Provisions**	
5.3.1	5.3.1	The requirements of section 5.3.3 or 5.3.4 of the IGF Code, part A-1, should apply to ships using hydrogen as fuel.	The requirements of sections 5.3.3 and 5.3.4 of the IGF Code, part A-1, should apply to ships using hydrogen as fuel.	5.3.4 of the IGF Code Part A-1 is an alternative to 5.3.3.1. Hence, the remaining part of 5.3.3 (e.g. distance from bottom) still applies if this alternative is chosen. Hence, the EMSA Guidance stresses that 5.3.3 and 5.3.4 of the IGF Code Part- A-1 should apply to ships using hydrogen as fuel.
5.3.2	5.3.2	Spaces, compartments and areas on open deck containing hydrogen sources of release, including bunkering stations, should not allow accumulation of hydrogen gas, and an unobstructed dispersion pathway should be arranged.	Areas on open deck containing hydrogen sources of release, including bunkering stations and equipment for fuel preparation, should not allow accumulation of hydrogen gas, and provide unobstructed dispersion of hydrogen.	The EMSA Guidance use the phrase “provide unobstructed dispersion of hydrogen” instead of “an unobstructed dispersion pathway should be arranged”, as this can be interpreted as only one unobstructed pathway should be arranged. It also includes “equipment for fuel preparation”. “Spaces and compartments” are excluded as the Guidance contains provisions for secondary enclosures in enclosed spaces.
5.3.3	5.3.3	Muster stations and life-saving appliances and their access routes should not be located in hazardous areas as specified in 12.5.	Muster stations, life-saving appliances, and their access routes should not be located in hazardous areas.	The EMSA Guidance generally omits references to improve readability and understanding of the provisions.
5.4	**5.4**	**Provisions for machinery space arrangement**	**Machinery space arrangement**	
5.4.1	5.4.1	Machinery spaces containing hydrogen fuel systems and/or hydrogen-fuelled machinery should be arranged such that the spaces may be considered gas-safe under all conditions, normal as well as abnormal conditions, i.e. inherently gas-safe.	Machinery spaces containing hydrogen systems and/or hydrogen fuelled machinery should be arranged such that the spaces may be considered gas-safe under all conditions, normal as well as abnormal conditions, i.e. inherently gas-safe.	
5.4.2	5.4.2	In a gas-safe machinery space, a single failure should not lead to the release of fuel gas into the machinery space.	In a gas-safe machinery space, a single failure should not lead to the release of fuel gas into the machinery space.	
5.4.3	5.4.3	A gas-safe machinery space may be arranged as a conventional machinery space	A gas safe machinery space may be arranged as a conventional machinery space.	

5.4.4	5.4.4	All fuel piping within machinery space boundaries should be enclosed in a gas-tight enclosure in accordance with the provisions of chapter 9.	All fuel piping within machinery space boundaries should be enclosed in a gas-tight secondary enclosure.	The EMSA guidance uses the defined term “secondary enclosure” for clarity.
5.4.5	5.4.5	Access to machinery spaces should not be arranged from hazardous areas	Access to machinery spaces should not be arranged from hazardous areas.	
5.4.6	-	Notwithstanding provisions above, other machinery space concepts may be permitted provided that the provisions of section 2.3 are met. The approval of such arrangements should as a minimum take into account the hazards and topics listed in provision 4.2.2.	-	The EMSA Guidance is a non-mandatory, advisory document in which references to IMO alternative design approval are not relevant.
5.5	**5.5**	**Arrangement principles for fuel cell power installations**	**Fuel cell power installations**	
5.5.1	5.5.1	Fuel cell power installations should be arranged in accordance with the *Interim guidelines for the safety of ships using fuel cell power installations* (MSC.1/Circ.1647).	Fuel cell power installations should be arranged in accordance with the Interim guidelines for the safety of ships using fuel cell power installations (MSC.1/Circ.1647).	
5.6	**5.6**	**Provisions for location and protection of fuel piping**	**Location and protection of fuel piping**	
5.6.1	5.6.1	Fuel piping should not be located less than 800 mm from the side shell, which includes the aft end of the ship.	Fuel piping should not be located less than 800 mm from the side shell, which includes the aft end of the ship.	
5.6.2	5.6.2	Fuel piping should not be led directly through accommodation spaces, service spaces, electrical equipment rooms or control stations, as defined in the SOLAS Convention, even though the piping is protected by secondary enclosures.	Fuel piping protected by secondary enclosures should not be led directly through accommodation spaces, service spaces, electrical equipment rooms or control stations as defined in the SOLAS Convention.	The EMSA Guidance is rephrased for clarity.
5.6.3	5.6.3	Fuel piping led through ro-ro spaces, special category spaces and on open decks should be protected against mechanical damage.	Fuel piping led through Ro-Ro spaces, special category spaces and on open decks should be particularly considered with respect to protection against mechanical damage.	The EMSA Guidance uses the term “particularly considered” to emphasise that all fuel pipes should be protected against mechanical damage as per 5.2.1.4. Guidance text amended to clarify that these spaces need particular attention, as the risk of mechanical damage is greater in these areas.
5.7	**5.7**	**Provisions for fuel preparation arrangements**	**Fuel preparation arrangements**	
5.7.1	5.7.1	The equipment for fuel preparation should be located in an area on the open deck providing natural ventilation and unobstructed relief of leakages.	The equipment for fuel preparation should be located in an area on the open deck providing natural ventilation and unobstructed relief of leakages.	
5.7.2	5.7.2	Notwithstanding provision 5.7.1, vaporizers, heat exchangers, and motors for pumps submerged in tanks may also be located in tank connection spaces, if any, or other spaces meeting the provisions in 5.8	Notwithstanding provision 5.7.1, vaporizers, heat exchangers, and motors for pumps submerged in tanks may also be located in tank connection spaces.	The EMSA Guidance does not include the reference to “other spaces meeting the provisions in 5.8” as they would be tank connection spaces by definition.
5.7.3	-	Notwithstanding 5.7.1, fuel preparation equipment may be permitted in enclosed or semi-enclosed space provided that the provisions of section 2.3 are met. The approval of such arrangements should, as a minimum, take into account the hazards and topics listed in provision 4.2.2.	-	The EMSA Guidance is a non-mandatory, advisory document in which references to IMO alternative design approval are not relevant.
5.8	**5.8**	**Provisions for tank connection spaces for liquefied hydrogen**	**Tank connection spaces for liquefied hydrogen**	
5.8.1	5.8.1	Unless located on the open deck providing natural ventilation and unobstructed relief of leakages, fuel tank connections, flanges, and tank valves should be enclosed in a tank connection space arranged in accordance with these provisions.	Unless located on the open deck providing natural ventilation and unobstructed relief of leakages, fuel tank connections, flanges, and tank valves should be enclosed in a tank connection space arranged in accordance with these provisions.	The EMSA Guidance have provisions for full secondary enclosure for all liquefied and gaseous fuel piping also on open deck. Even so, the location should provide natural ventilation and unobstructed relief of leakages considering that there may be maintenance work etc.

5.8.2	5.8.2	All parts of the piping systems in tank connection spaces should be arranged with secondary enclosures designed to safely contain any leakage from the fuel system.	All parts of the piping systems in tank connection spaces should be arranged with secondary enclosures designed to safely contain any leakage from the fuel system.	This design concept is further explained in Section 9.2
5.8.3	5.8.3	Tank connection space boundaries should be gastight towards other spaces in the ship.	Tank connection space boundaries should be gas-tight towards other spaces in the ship.	
5.8.4	5.8.4	The material of the bulkheads of the tank connection space should have a design temperature corresponding with the lowest temperature it can be subject to.	The material of the bulkheads of the tank connection space should have a design temperature corresponding with the lowest temperature it can be subject to.	
5.8.5	5.8.5	A loss of vacuum insulation in tanks or piping systems for liquid hydrogen should not render necessary safety functions in the tank connection space out of order due to low temperatures.	A loss of vacuum insulation in tanks or piping systems for liquid hydrogen should not render necessary safety functions in the tank connection space inoperable due to low temperatures.	
5.8.6	5.8.6	Unless the tank connection space access is independent and direct from the open deck, it should be provided through a bolted hatch. The bolted hatch should be located in a protective entry space of gastight construction accessed through an airlock.	Unless the tank connection space access is independent and direct from the open deck, it should be provided through a bolted hatch.	The concept in the EMSA Guidance is to provide secondary enclosures around all fuel piping in the tank connection space. Hence, the tank connection space is not defined as a hazardous zone 1 and air lock access is not required.
-	5.8.7	-	Tank connection spaces should not contain equipment for fuel preparation. As an exemption to this provision, vaporizers, heat exchangers, and motors for pumps submerged in tanks may also be located in tank connection spaces.	The EMSA Guidance (and the IGF Code) have provisions against locating equipment for fuel preparation in the TCS. The integrity of tank valves in TCS is critical for safety. Equipment for fuel preparation includes rotating equipment and other components that can damage tank valves and other safety equipment and introduce a higher fire risk. Further, equipment for fuel preparation will require more frequent access by crew than a tank connection space with bolted access. The exemption is for equipment not considered to increase the risk level in the TCS.
5.9	**5.9**	**Provisions for tank connection enclosures for compressed hydrogen**	**Tank connection enclosures for compressed hydrogen**	The EMSA Guidance has provisions for a secondary enclosure around tank connections for compressed hydrogen tanks, as simulations show that a critical gas cloud could build up faster than safety systems can detect and stop a leakage. In contrast to tank connection spaces for liquefied hydrogen storage tanks, provisions for secondary enclosures around piping are not included in tank connection enclosures for compressed hydrogen storage. This is justified by the provisions to arrange tank connection enclosures on open deck, and it should be arranged to minimize the volume as far as possible without access for entry.
5.9.1	5.9.1	Unless located on the open deck providing natural ventilation and unobstructed relief of leakages, fuel tank connections, flanges, and tank valves should be placed in a tank connection enclosure in accordance with these provisions.	Fuel tank connections, flanges, and tank valves should be placed in a tank connection enclosure in accordance with these provisions.	The EMSA Guidance has provisions for arranging tank connection enclosures on the open deck. Hydrogen installations on open decks encounter challenges in managing leakages within a timeframe adequate to prevent critical cloud build-up. Implementing double barriers facilitates detection, prevents ignition, and avoids ignitable hydrogen

				concentrations, as hydrogen released within a double barrier can be vented to a safe location. A TCE can provide a double barrier for the typically complex piping systems in the manifold area, where achieving double-walled piping is challenging. To function as a secondary enclosure, the TCE must be gas-tight and equipped with pressure relief devices to prevent overpressure. The safety philosophy is based on the premise that the inert atmosphere within the enclosure will eliminate the risk of hydrogen gas ignition inside the TCE. It is presumed that the inert condition is continuously monitored. This is further discussed in EMSA reports “Hazard identification of generic systems” and “Risk analysis of generic systems”
5.9.2	5.9.2	Tank connection enclosures should be designed to prevent ignition of leaked gas within the enclosure by maintaining an inert atmosphere at all times.	Tank connection enclosures should be designed to prevent ignition of leaked gas within the enclosure by maintaining an inert atmosphere at all times.	
5.9.3	5.9.3	Tank connection enclosures should be arranged to minimize the volume of the enclosure as far as possible.	Tank connection enclosures should be arranged to minimize the volume as far as possible.	
5.9.4	5.9.4	Tank connection enclosures should be gastight.	Tank connection enclosures should be gas-tight.	
5.9.5	5.9.5	Tank connection enclosures should be able to withstand the highest pressure that may arise in a leakage scenario	Tank connection enclosures should be able to withstand the highest pressure that may arise in a leakage scenario.	
5.9.6	5.9.6	Tank connection enclosures should be provided with continuous effective means of leak detection.	Tank connection enclosures should be arranged with continuous gas detection.	The EMSA Guidance has provisions for gas detection as the means of detecting leakage in a TCE. A gas detection system can identify smaller hydrogen leaks more reliably and quickly than monitoring the pressure in the TCE. Unlike inert gas-protected double-walled piping systems, where pressure monitoring may be used for leak detection, the overpressure level in a TCE is much lower, which can lead to other sources of pressure increase, such as temperature changes and variations in inert gas supply pressure.
5.9.7	5.9.7	Tank connection enclosures should be arranged with a pressure relief device with a vent system that directs leaked gas to a safe location on the open deck.	Tank connection enclosures should be arranged with a pressure relief device with a vent system that directs leaked gas to a safe location on the open deck.	
5.10	**5.10**	**Provisions for bilge systems**	**Bilge Systems**	
5.10.1	5.10.1	Bilge systems installed in areas where hydrogen can be present should be segregated from the bilge system of spaces where hydrogen cannot be present.	Bilge systems installed in areas where hydrogen can be present should be segregated from the bilge system of spaces where hydrogen cannot be present.	
5.10.2	-	Bilge systems for fuel storage hold spaces not considered hazardous but arranged with inerted atmosphere should be segregated from the bilge system for other spaces.	-	The EMSA Guidance only contains provisions for vacuum-insulated Type C tanks. Hence, paragraph 5.9.2, relating to inerted fuel hold spaces, is not included.
5.10.3	5.10.2	The bilge system should have bilge well high-level alarms. Low-temperature alarms should be fitted if liquid hydrogen leakage is possible.	The bilge system should have bilge well high-level alarms.	The EMSA Guidance (and the IMO IG) has provisions for secondary enclosures for all piping for liquefied hydrogen. Hence, cryogenic leakages where bilge systems may be arranged should not be an issue. Low-temperature alarm not included.

5.11	**5.11**	**Provisions for drip trays**	**Protection against condensation of air**	In 5.10 of the IGF Code Part A-1, this section is related to drip trays protecting the ship structure against LNG leakages. In the interim guidelines for hydrogen, the substance of this section is changed to protect against condensation of air (not hydrogen leakages). To make this clear, the heading is updated in the EMSA Guidance.
5.11.1	5.11.1	Drip trays should be fitted where condensation of air may occur which can cause damage to the ship structure, or where condensate air due to a cold gas release otherwise may impinge on ship structures.	Drip trays or similar protection should be fitted were uninsulated components, or a loss of vacuum, may result in surface temperatures below the condensation temperature of air Alternatively, components may be arranged with additional insulation to prevent surface temperatures falling below that required to condensate air.	The EMSA Guidance is more specific to where condensation of air may occur and includes other methods to prevent the condensation of air through insulation of outer surfaces.
5.11.2	5.11.2	Drip trays should be made of materials suitable to collect liquid oxygen.	The protection should be made of materials suitable for the collection of condensed air.	The EMSA Guidance refer to condensed air since the temperature of condensed nitrogen is lower than that of oxygen. (boiling temperature of -196 °C).
5.11.3	5.11.3	The drip tray should be thermally insulated from the ship's structure so that the surrounding hull or deck structures are not exposed to unacceptable cooling.	If drip trays are used for protection, they should be thermally insulated from the ship's structure so that the surrounding hull or deck structures are not exposed to unacceptable cooling.	
5.11.4	5.11.4	Each tray should be fitted with a drain valve to enable rainwater to be drained over the ship's side.	Where relevant, drip trays should be fitted with a drain valve to enable rainwater to be drained over the ship's side.	
5.11.5	5.11.5	Each tray should have a sufficient volume and thermal capacity to ensure that the maximum amount of potential air condensate according to the risk assessment can be handled. Active heating arrangements could also be considered.	Each tray should have sufficient volume and thermal capacity to ensure that the maximum amount of potential air condensate, according to the risk assessment, can be handled. Active heating arrangements could also be considered.	
5.11.6	5.11.6	Where capturing condensed air in drip trays, ensure through design that liquid hydrogen leaks cannot combine with condensed oxygen in any scenario.	Where capturing condensed air in drip trays, ensure through design that liquid hydrogen leaks cannot combine with condensed oxygen in any scenario.	In the EMSA Guidance, this is ensured by provisions for secondary enclosure for LH2 systems except in the bunkering connection, where there is a possibility of LH2 leak. Hence, this issue must be specifically considered at this location.
5.12	**5.12**	**Provisions for arrangement of entrances and other openings in enclosed spaces**	**Arrangement of entrances and other openings in enclosed spaces**	
5.12.1	5.12.1	Direct access should not be permitted from a non-hazardous area to a hazardous area. Where such openings are necessary for operational reasons, an airlock which complies with 5.13 should be provided.	Direct access should not be permitted from a non-hazardous area to a hazardous area. Where such openings are necessary for operational reasons, an airlock should be provided.	
5.12.2	-	If the fuel preparation room is approved to be located below deck, the room should, as far as practicable, have an independent access direct from the open deck. Where a separate access from deck is not practicable, an airlock which complies with 5.13 should be provided.	-	The EMSA Guidance only contains provisions for fuel preparation areas on the open deck due to the challenges of arranging secondary enclosures around all leak points in a fuel preparation room with compressors and other leak-prone equipment.
5.12.3	-	Unless access to the tank connection space is independent and direct from open deck it should be arranged as a bolted hatch. The space containing the bolted hatch will be a hazardous space.	-	The EMSA Guidance has provisions for tank connection spaces access in 5.8.6 and defines hazardous areas in 12.
5.12.4	5.12.2	For inerted spaces access arrangements should be such that unintended entry by personnel should be prevented. If access to such spaces is not from an open deck, sealing arrangements	For inerted spaces, access arrangements should be designed to prevent unintended entry by personnel. If access to these spaces	

		should ensure that leakages of inert gas to adjacent spaces are prevented.	is not from an open deck, the arrangements should ensure that any leakage of inert gas to adjacent spaces is prevented.	
5.13	**5.13**	**Provisions for airlocks**	**Airlocks**	
5.13.1	5.13.1	An airlock is a space enclosed by gastight bulkheads with two substantially gastight doors spaced at least 1.5 m and not more than 2.5 m apart. Unless subject to the requirements of the International Convention on Load Lines, the sill height of the door leading to the hazardous area should not be less than 300 mm in height. The doors should be self-closing without any holding back arrangements.	Airlocks should be enclosed by gastight bulkheads with two substantially gastight doors spaced at least 1.5 m and not more than 2.5 m apart. Unless subject to the International Convention on Load Lines requirements, the door sill towards the hazardous side should not be less than 300 mm in height. The doors should be self-closing without any holding-back arrangements.	
5.13.2	5.13.2	Airlocks should be mechanically ventilated at an overpressure relative to the adjacent hazardous area or space.	Airlocks should be mechanically ventilated at an overpressure relative to the adjacent hazardous area or space.	
5.13.3	5.13.3	The airlock should be designed in such a way that no gas can be released from the gas dangerous space to safe spaces, even in the case of the most critical event in the hazardous space separated by the airlock. The events should be evaluated in the risk analysis according to 4.2.	Airlocks should be designed to ensure that no gas can escape into safe areas during the most critical incidents occurring in gas-hazardous spaces separated by the airlock. These incidents should be assessed in the risk analysis as outlined in section 4.2.	
5.13.4	5.13.4	Airlocks should have a suitable geometrical form geometrical form to prevent hydrogen accumulation.	Airlocks should be designed with a geometry that facilitates the removal of accumulated hydrogen.	
5.13.5	5.13.5	Airlocks should provide free and easy passage of personnel, and should have a deck area not less than 1.5 m2 . Airlocks should not be used for other purposes, for instance as store rooms	Airlocks should allow free and easy passage for personnel and cover a deck area of no less than 1.5 m^2. They should not be used for other purposes, such as storage rooms.	
5.13.6	5.13.6	An audible and visual alarm system to give a warning on both sides of the airlock should be provided to indicate if more than one door is moved from the closed position.	An audible and visual alarm system should be provided to issue a warning on both sides of the airlock if more than one door is opened from the closed position.	
5.13.7	5.13.7	For non-hazardous spaces with access from hazardous spaces below deck where the access is protected by an airlock, upon loss of under pressure in the hazardous space access to the space should be restricted until the ventilation has been reinstated. Audible and visual alarms should be given at a manned location to indicate both loss of pressure and opening of the airlock doors when pressure is lost.	Access to hazardous spaces below deck must be restricted if there is a loss of underpressure in the hazardous space. Audible and visual alarms should be activated at a manned location to signal both the loss of pressure and the opening of the airlock doors when the pressure differential is lost between a hazardous and a non-hazardous space.	The EMSA Guidance has rephrased the IGF text to improve clarity.
5.13.8	5.13.8	Where an airlock is arranged for access to small spaces serving as a staging area for the hatch to an inerted space, such as a tank connection space, the small space should be arranged with ventilation and oxygen deficiency detection.	Where an airlock is arranged for access to small spaces serving as a staging area for the hatch to an inerted space, such as TCS, the space should be arranged with ventilation and oxygen deficiency detection.	
5.13.9	-	Essential equipment required for safety should not be de-energized and should be of a certified safe type. This may include lighting, fire detection, public address, general alarms systems.	-	The EMSA Guidance does not include provisions for de-energizing equipment because all spaces with hydrogen installations are recommended to be arranged with secondary enclosures. This will significantly reduce the probability of hydrogen leaks in spaces inside the vessel.
5.14	**5.14**	**Storage arrangements for compressed hydrogen**	**Storage arrangements for compressed hydrogen**	
5.14.1	5.14.1	The fuel containment system and associated connections and equipment for compressed hydrogen should be located in an area on the open deck providing natural ventilation and unobstructed relief of leakages.	The fuel containment system and associated connections and equipment for compressed hydrogen should be located in an area on the open deck that provides natural ventilation and unobstructed relief for leakages.	

5.14.2	-	Notwithstanding 5.14.1, hydrogen storage may be permitted in an enclosed or semi-enclosed space provided that the provisions of section 2.3 are met. The approval of such arrangements should as a minimum take into account the hazards and topics listed in provision 4.2.2.	-	The EMSA Guidance is a non-mandatory, advisory document in which references to IMO alternative design approval are not relevant.
5.15	**5.15**	**Storage arrangements for liquified hydrogen**	**Storage arrangements for liquified hydrogen**	
5.15.1	5.15.1	The fuel containment system and associated connections and equipment for liquified hydrogen should be located in an area on the open deck providing natural ventilation and unobstructed relief of leakages.	The fuel containment system and associated connections and equipment for liquefied hydrogen should be located in an area on the open deck, providing natural ventilation and unobstructed relief of leakages.	
5.15.2	5.15.2	Notwithstanding 5.15.1, hydrogen storage may be permitted in an enclosed or semi-enclosed space provided that the provisions of section 2.3 are met. The approval of such arrangements should as a minimum take into account the hazards and topics listed in provision 4.2.2.	Vacuum-insulated type C tanks with tank connection spaces may be considered located in enclosed spaces, provided that: - The possibility of hydrogen leakages into the tank connection space is eliminated by applying secondary enclosures around all tank connections, pipes and components. - The fuel containment system is located in a dedicated fuel storage hold space in accordance with Part-A1 of the IGF Code. - The dedicated fuel storage hold space is arranged to manage the cooling effects of loss of tank insulation safely.	The EMSA Guidance includes specific provisions for fuel containment systems for liquefied hydrogen located in enclosed spaces. A complete application of secondary enclosures around fuel piping systems in the tank connection space conditions this.

Draft IG	EMSA Guidance	IMO Draft Interim Guidelines for the safety of ships using hydrogen as fuel (CCC 11/WP.4 Annex 2)	EMSA Guidance for hydrogen-fuelled ships	Justification and comments
6	**6**	**FUEL CONTAINMENT SYSTEM**	**FUEL CONTAINMENT SYSTEM**	
-	**6.0**	-	**Hazards**	
-	6.0.1	-	Hydrogen released from the fuel containment system may ignite, resulting in a fire, deflagration or detonation.	
-	6.0.2	-	Liquefied hydrogen released from the fuel containment system may cool down surrounding materials, causing embrittlement.	
-	6.0.3	-	The loss of insulation properties for fuel containment systems for liquefied hydrogen, which increases the heat ingress to the fuel, may result in significant hydrogen releases.	
-	6.0.4	-	Cold surfaces on the fuel containment system may condense air, causing embrittlement and a fire hazard due to oxygen enrichment.	
-	6.0.5	-	Cold surfaces on the fuel containment system may cool down surrounding structures, systems and equipment, causing structural damage or system malfunctions.	
-	6.0.6	-	The volume increase of liquefied hydrogen with increasing temperatures may result in a liquid-full containment system, corresponding over-pressurization of the tank, and overflow of liquefied hydrogen through the vent system.	

-	6.0.7	-	Hydrogen embrittlement of materials may lead to failure of the fuel containment system.	
-	6.0.8	-	Thermal effects and ship movements may lead to fatigue and failure of the fuel containment system.	
6.1	**6.1**		**Goal**	
		The goal of this chapter is to provide for safe location, space arrangements and mechanical protection of power generation equipment, hydrogen storage systems, hydrogen supply equipment and refuelling systems.	The goal of this chapter is to provide that hydrogen storage is adequate so as to minimize the risk to personnel, the ship and the environment to a level that is equivalent to a conventional oil-fuelled ship.	The EMSA Guidance adopts the goal of the IGF Code Part-A1 chapter 6, considering that the structure and substance of the chapter are the same.
6.2	**6.2**	**Functional Requirements**	**Functional Requirements**	
		This chapter relates to functional requirements in 3.2.1 to 3.2.19. In particular the following apply:	This chapter relates to functional requirements in **3.2.1** to **3.2.6**, **3.2.9** to **3.2.11** and **3.2.17** to **3.2.20**. In particular, the following apply:	
6.2.1	6.2.1	The fuel containment system should be so designed that a leak from the tank or its connections does not endanger the ship, persons on board or the environment. Potential risks to be avoided include: .1 formation of ice from moisture in the air; .2 formation of frozen or liquified air; .3 exposure of ship materials to temperatures below acceptable limits; .4 fuel leaking to form a flammable or explosive atmosphere; .5 oxygen deficiency due to fuel and inert gases; .6 flammable fuels spreading to locations with ignition sources; .7 restriction of access to muster stations, escape routes and life-saving appliances (LSA); and .8 reduction in availability of LSA.	The fuel containment system should be so designed that a leak from the tank or its connections does not endanger the ship, persons on board or the environment. Potential risks to be avoided include: .9 formation of ice from moisture in the air; .10 formation of frozen or liquified air; .11 exposure of ship materials to temperatures below acceptable limits; .12 fuel leaking to form a flammable or explosive atmosphere; .13 oxygen deficiency due to fuel and inert gases; .14 flammable fuels spreading to locations with ignition sources; .15 restriction of access to muster stations, escape routes and life-saving appliances (LSA); and .16 reduction in availability of LSA.	
6.2.2	6.2.2	Fuel containment systems should be designed to keep the fuel temperature and pressure within the design limits.	Fuel containment systems should be designed to keep the fuel temperature and pressure within the design limits.	
6.2.3	6.2.3	Fuel containment systems for liquefied hydrogen should be designed to minimize operational discharges by providing adequate insulation and/or through systems handling boil-off gas.	Fuel containment systems for liquefied hydrogen should be designed to minimize operational discharges by providing adequate insulation and/or through systems handling boil-off gas.	
6.2.4	6.2.4	The fuel containment system arrangement should be designed to ensure that automatic safety actions after any gas leakage do not lead to an unacceptable loss of power.	The fuel containment system should be designed to ensure that automatic safety actions after a fuel leakage or other fault conditions as described in chapter 15 do not lead to an unacceptable loss of power.	The EMSA Guidance includes all automatic safety actions related to the hydrogen system, not just those related to gas leakage.

6.2.5	-	If portable tanks are used for fuel storage, the design of the fuel containment system should provide equivalent safety to that of permanently installed tanks.	-	The EMSA Guidance does not include provisions for portable tanks.
6.2.6	6.2.5	Fuel containment systems should be manufactured from materials suitable for hydrogen service.	Fuel containment systems should be manufactured from materials suitable for hydrogen service.	
6.2.7	6.2.6	Fuel containment systems for compressed hydrogen made of composite materials should be designed to provide an equivalent level of safety as fuel tank types defined by the IGF Code, taking into account fire resistance, impact resistance, pressure relief arrangements and isolation of connected systems.	Fuel containment systems for compressed hydrogen made of composite materials should be designed to provide an equivalent level of safety as fuel tank types defined by the IGF Code, including fire resistance, impact resistance, pressure relief arrangements and isolation of connected systems.	
6.2.8	6.2.7	The fuel containment system should be arranged with a pressure relief system designed to safely discharge hydrogen to a safe location in the open air.	The fuel containment system should be arranged with a pressure relief system designed to safely discharge hydrogen in an open-air location.	
6.2.9	6.2.8	Fuel containment systems should be capable of absorbing thermal expansion or contraction caused by extreme fuel temperatures, as well as movements and deflections of the fuel tank and hull structure, without developing substantial stresses.	Fuel containment systems should be capable of absorbing thermal expansion or contraction caused by extreme fuel temperatures, as well as movements of the fuel tank and hull structure, without developing substantial stresses.	
6.2.10	6.2.9	Loss of vacuum should not lead to an unsafe condition.	Loss of vacuum should not lead to an unsafe condition.	
6.3	**6.3**	**General provisions for fuel containment systems**	**General provisions**	
6.3.1	6.3.1	For Type C tanks, piping between the tank and the first valve should have equivalent safety as the Type C tank, with dynamic stress not exceeding the values given in 6.4.15.3.1.2 of the IGF Code, Part A-1.	Piping between the tank and the first valve should have equivalent safety as the type C tank, with dynamic stress not exceeding the values given in 6.4.15.3.1.2 of the IGF Code Part A-1.	The EMSA Guidance adopts the wording from the IGF Code Part A-1.
6.3.2	6.3.2	Means should be provided whereby the storage tanks can be safely emptied.	Means should be provided whereby the storage tanks can be safely emptied to shore.	The EMSA Guidance includes a provision for the emergency discharging of fuel tanks to shore. Allowing hydrogen gas to boil off through the vent mast is not considered a safe arrangement.
6.4	**6.4**	**Provisions for liquefied gas fuel containment**	**Liquefied fuel containment**	
6.4.1	6.4.1	Unless expressly provided otherwise, the requirements of section 6.4 of the IGF Code should apply to ships using hydrogen as fuel.	Unless expressly provided otherwise, the requirements of section 6.4 of the IGF Code should apply to ships using hydrogen as fuel.	
6.4.2	6.4.2	The provisions for liquefied hydrogen fuel containment in this interim guideline are for vacuum insulated type C tanks only. The requirements of section 6.4 of the IGF Code, part A-1, related to other tank types, should not apply to ships using liquid hydrogen as fuel.	The provisions for liquefied fuel containment in this Guidance are for vacuum-insulated type C tanks only. The requirements of section 6.4 of the IGF Code Part A-1 related to other tank types should not apply to ships using liquid hydrogen as fuel.	
6.4.3	-	Notwithstanding 6.4.2, liquefied hydrogen storage in other tank types than vacuum insulated type C may be permitted provided that the provisions of section 2.3 are met. The approval of such arrangements should as a minimum take into account the hazards and topics listed in provision 4.2.2.	-	The EMSA Guidance is a non-mandatory, advisory document in which references to IMO alternative design approval are not relevant.
6.4.4	-	The dynamic membrane stress in paragraph 6.4.15.3.1.2 of the IGF Code should be assessed taking into account the exposure of the material of the tank shell to hydrogen and the intended temperature of application.	-	
6.4.5	6.4.3	In addition to section 6.4.8 of the IGF Code, the following provisions regarding thermal insulation apply:	In addition to section 6.4.8 of the IGF Code, the following provisions regarding thermal insulation apply:	

6.4.5.1	6.4.4	when deterioration of insulation capability by single damage is possible, appropriate safety measures should be adopted taking into account the deterioration. For vacuum insulated tanks, the pressure relief valves' capacity and associated piping should be dimensioned for a simultaneous fire heat load, and loss of insulation. When it is justified by the risk assessment, the pressure relief valves capacity and associated piping may be dimensioned for a fire heat load or loss of vacuum insulation, whichever is greater;	For vacuum-insulated tanks, the pressure relief valve capacity should be dimensioned for loss of vacuum and a fire scenario.	The EMSA Guidance has provisions for assuming that the vacuum insulation may be lost in a fire scenario, and that consequently the vent system must be dimensioned for both happening simultaneously. HAZID report: Calculations estimating maximum boil-off rates and the consequences of delayed ignition and a subsequent jet fire from the top of the vent mast must likely be performed on a case-by-case basis. Ship standards base the worst-case scenario on the fire engulfment of the tank. Shore-based standards also require checking for loss of vacuum.
6.4.5.2	-	thermal insulation should prevent liquefaction and solidification of ambient air i.e. oxygen, nitrogen etc.;	-	The EMSA Guidance cover this provision in section 5.10 - protection against the condensation of air.
6.4.5.3	-	thermal insulation should be resistant to the effects of high oxygen concentrations caused by air condensation and subsequent evaporation at low temperatures;	-	The EMSA Guidance does not include provisions for conventional insulation in addition to vacuum insulation, as it will be a prerequisite to prevent cold spots from introducing heat into the tank for safe storage of liquefied hydrogen. Conventional insulation may also lead to condensation and freezing of air between the tank shell and the insulation layer. Additional thermal insulation may be a way to comply with the functional requirement of managing the consequences of vacuum loss.
6.4.5.4	6.4.5	vacuum jacket systems should be designed to accommodate the thermal flexibility of the inner boundary and allow for the jacket to follow its natural thermal displacement; and	The vacuum jacket systems should be designed to accommodate the thermal flexibility of the inner boundary and allow for the jacket to follow its natural thermal displacement.	
6.4.5.5	6.4.6	the fuel containment vacuum jacket systems should be separate from the piping vacuum jacket system.	The fuel containment vacuum jacket systems should be separate from the piping vacuum jacket systems.	
6.4.6	-	In place of 6.4.14.1.1 of the IGF Code, all welded joints of the shells of fuel tanks should be of the in-plane butt weld full penetration type. For dome-to-shell connections only, tee welds of the full penetration type may be used depending on the results of the tests carried out at the approval of the welding procedure.	-	
6.4.7	6.4.7	Piping connected to the tank should be protected by a secondary enclosure including within the vacuum insulation space and up to the first valve.	Piping connected to the tank should be protected by a secondary enclosure, including within the vacuum insulation space and up to the first valve.	Leakage from hydrogen pipes routed through the vacuum space between the inner and outer tank may lead to loss of vacuum and the need for venting of hydrogen to a safe location on the open deck, significantly complicating the arrangement. A secondary enclosure around this piping eliminates this hazard. For tanks located in enclosed spaces, this is essential.
6.4.8	6.4.8	It should be possible to empty, purge and vent fuel storage tanks using the fuel piping systems. Instructions for carrying out these procedures should be available on board. Inerting should be performed with an inert gas prior to venting with dry air to avoid an explosion hazardous atmosphere in tanks and fuel pipes. See detailed provisions in 6.10.	It should be possible to empty, inert and gas-free fuel storage tanks and associated fuel piping systems. Instructions for carrying out these procedures should be available on board. Inerting should be performed prior to venting with dry air to prevent the formation of an explosion hazardous atmosphere in tanks and fuel pipes.	The EMSA Guidance use the term gas-freeing when referring to the change of atmosphere from inert to air. The Guidance does not specify that gas-freeing must be done “using the fuel piping system”. The EMSA Guidance specifies that the fuel piping system also needs to be arranged for the possibility of gas-freeing.
-	**6.4.9**	-	**General**	

-		-	The requirements in the IGF Code Part A-1 6.4.1 for Type C tanks should apply to ships using hydrogen as fuel.	
-	**6.4.10**	-	**Liquefied gas fuel containment safety principles**	
-		-	The requirements in the IGF Code Part A-1 6.4.2 for Type C tanks should apply to ships using hydrogen as fuel.	
-	**6.4.11**	-	**Secondary barriers in relation to tank types**	
-		-	The requirements in the IGF Code Part A-1 6.4.3 for Type C tanks should apply to ships using hydrogen as fuel.	
-	**6.4.12**	-	**Design of secondary barriers**	
-		-	The provisions for liquefied hydrogen fuel containment in this Guidance are for vacuum-insulated Type C tanks only. Hence, the requirements in the IGF Code Part A-1 6.4.4 are not applicable for ships covered by these provisions.	
-	**6.4.13**	-	**Partial secondary barriers and primary barrier small leak protection system**	6.4.5 of the IGF Code NA for Type C tanks/Guidance
-		-	The provisions for liquefied hydrogen fuel containment in this Guidance are for vacuum-insulated Type C tanks only. Hence, the requirements in the IGF Code Part A-1 6.4.5 are not applicable for ships covered by these provisions.	
-	**6.4.14**	-	**Supporting arrangements**	
-		-	The requirements in the IGF Code Part A-1 6.4.6 for Type C tanks should apply to ships using hydrogen as fuel.	
-	**6.4.15**	-	**Associated structure and equipment**	
-		-	The requirements in the IGF Code Part A-1 6.4.7 for Type C tanks should apply to ships using hydrogen as fuel.	
-	**6.4.16**	-	**Thermal insulation**	
-		-	The requirements in the IGF Code Part A-1 6.4.8 for Type C tanks should apply to ships using hydrogen as fuel.	
-	**6.4.17**	-	**Design Loads**	
-		-	The requirements in the IGF Code Part A-1 6.4.9 for Type C tanks should apply to ships using hydrogen as fuel.	
-	**6.4.18**	-	**Structural Integrity**	
-		-	The requirements in the IGF Code Part A-1 6.4.10 for Type C tanks should apply to ships using hydrogen as fuel.	
-	**6.4.19**	-	**Structural analysis**	
-		-	The requirements in the IGF Code Part A-1 6.4.11 for Type C tanks should apply to ships using hydrogen as fuel.	
-	**6.4.20**	-	**Design conditions**	
-		-	The requirements in the IGF Code Part A-1 6.4.12 for Type C tanks should apply to ships using hydrogen as fuel.	
-	**6.4.21**	-	**Materials and Construction**	

-		-	The requirements in the IGF Code Part A-1 6.4.13 for Type C tanks should apply to ships using hydrogen as fuel.	
	6.4.22	-	**Construction processes**	
-		-	The requirements in the IGF Code Part A-1 6.4.14 for Type C tanks should apply to ships using hydrogen as fuel.	
-	**6.4.23**	-	**Tank Types**	
-		-	The requirements in the IGF Code Part A-1 6.4.15 for Type C tanks should apply to ships using hydrogen as fuel.	
6.5	**6.5**	**Provisions for portable liquefied hydrogen tanks**	**Portable liquefied fuel containment**	
	6.5.1	Provisions for portable liquefied hydrogen tanks are not included in these Interim Guidelines. The requirements of section 6.5 of the IGF Code, part A-1,	The provisions for liquefied fuel containment in this Guidance are limited to fixed, vacuum-insulated Type C tanks. The requirements of section 6.5 of the IGF Code Part A-1 related to portable liquefied gas fuel tanks, should not apply to ships using liquid hydrogen as fuel.	The EMSA Guidance does not include provisions for portable tanks. Each case will require special consideration and may be better suited for alternative design approval.
6.5.2	-	Notwithstanding 6.5.1, liquefied hydrogen storage in portable tanks may be permitted provided that the provisions of section 2.3 are met. The approval of such arrangements should as a minimum take into account the hazards and topics listed in provision 4.2.2.	-	The EMSA Guidance is a non-mandatory, advisory document in which references to IMO alternative design approval are not relevant.
6.6	**6.6**	**Provisions for compressed hydrogen storage**	**Compressed fuel storage**	The EMSA Guidance is developed with full content for this section as reference to the IGF Code Part A-1 6.6 is not found suitable for hydrogen.
6.6.1	6.6.1	Tanks for compressed hydrogen should be constructed according to a recognized international standard[1] and accepted by the Administration for the intended application. 1 Examples of standards considered suitable for composite tanks (type 4 pressure vessels): EN 17339, ISO 11119-3, EN 12245	Tanks for compressed hydrogen should be constructed according to a recognized international standard accepted by the Administration. * * Examples of standards considered suitable for composite tanks (type 4 pressure vessels): EN 17339, ISO 11119-3, EN 12245	The standards EN 17339, ISO 11119-3, and EN 12245 are commonly used by the industry for the design of pressure vessels of type 4 (composite tanks).
6.6.2	6.6.2	Each compressed hydrogen cylinder should be arranged with an automatic, fail-safe, shut-off valve mounted directly on or within the hydrogen cylinder.	Each tank for compressed hydrogen should be arranged with an automatic, fail-safe, shut-off valve mounted directly on or within the hydrogen tank.	EMSA Guidance do not use the term “hydrogen cylinder” for consistency.
	6.6.3		Means should be provided to prevent over-pressuring compressed hydrogen tanks during bunkering.	The EMSA Guidance includes requirements for pressure relief to prevent overpressure during bunkering
6.6.3	6.6.4	Adequate means should be provided to depressurize the tank in case of a fire which can affect the tank. This may include temperature-actuated safety relief systems, e.g. thermally activated pressure relief devices (TPRDs). The relieving capacity and area of the safety relief devices should be designed and calculated to ensure the rated capacity.	Adequate means should be provided to enable automatic depressurization of the tank in the event of a fire that could affect the tank's integrity.	The EMSA Guidance recognise that automatic depressurization in a fire scenario is required, but does not address specific technologies.
6.6.4	6.6.5	Tanks and tank supports should be designed to withstand design loads as defined in 6.4.9 of the IGF Code, part A-1. Additionally, the following load cases should be considered: .1 temperature changes due to pressure reduction or increase when the tank is depressurized or pressurized; and	Tanks and tank supports should be designed to withstand design loads as defined in 6.4.9 of the IGF Code Part-A1. Additionally, the following load cases should be considered: .1 temperature changes due to pressure reduction or increase when the tank is depressurized or pressurized; and	

		.2 fatigue loading as defined in 6.4.12.2 of the IGF Code, Part A-1.	.2 fatigue loading as defined in 6.4.12.2 of the IGF Code, Part A-1.	
6.6.5	**6.7**	**Portable compressed hydrogen containment**	**Portable compressed fuel storage**	
6.6.5.1	6.7.1	In addition to 6.6.1 to 6.6.4, the following provisions apply for portable compressed hydrogen containment.	The provisions for compressed fuel containment in this Guidance are limited to fixed tanks.	The EMSA Guidance does not include provisions for portable tanks. Individual arrangements will need special consideration in each case and, consequently, be more suitable for alternative design approval. One challenge with portable tanks related to the provisions of the EMSA Guidance is the difficulty in arranging secondary enclosures due to the non-permanent connections, which must be operated at every refuelling operation. As a result, the possibility of having reliable leakage detection, which enables rapid shutdown—a feature of the double-walled piping design—is reduced. A single-walled hydrogen system on deck will rely on leakage detection located in open air to identify and stop a hydrogen leak.
6.6.5.2	-	Portable tanks containing compressed hydrogen may be designed either as a multiple element gas container (MEGC) or a tank container, or a similar containment system.	-	
6.6.5.3	-	The tank support and/or container frame should be designed for the intended purpose.	-	
6.6.5.4	-	Portable tanks arranged for lifting on board should be designed for the worst case drop scenario during loading and offloading, to be considered under the risk analysis of 4.2.2.	-	
6.6.5.5	-	Portable fuel tanks should be located in dedicated areas arranged in accordance with the provisions of this guideline.	-	
6.6.5.6	-	Portable fuel tanks should be secured to the deck while connected to the ship systems. The arrangement for supporting and fixing the tanks should be designed for design loads, taking into account the ship characteristics and the position of the tanks.	-	
6.6.5.7	-	The pressure relief system of portable tanks should be connected to a fixed venting system complying with 6.7.	-	
6.6.5.8	-	Connections to the ship's fuel piping systems should be made by means of approved flexible hoses or other suitable means designed to provide sufficient flexibility.	-	
6.6.5.9	-	The connections at the tank should be arranged in order to achieve a dry disconnect operation.	-	
6.6.5.10	-	Arrangements should be provided to minimize the quantity of fuel released in case of inadvertent disconnection or rupture of the non-permanent connections.	-	
6.6.5.11	-	Means should be provided to verify the loading condition (fuel temperature and pressure) of the portable storage tank and cylinders before connection to the ship's fuel system.	-	

6.6.5.12	-	Control and monitoring systems for portable fuel tanks should be integrated into the ship's control and monitoring system. The safety system for portable fuel tanks should be integrated into the ship's safety system (e.g. shutdown systems for tank valves, leak/gas detection systems).	-	
6.6.5.13	-	Safe access to tank connections for the purpose of inspection and maintenance shall be ensured.	-	
6.6.5.14	-	After connection to the ship's fuel piping system, each portable tank should be capable of being isolated at any time, with the exception of the pressure relief system. Isolation of one tank should not impair the availability of the remaining portable tanks.	-	
6.6.5.15	-	The design life of portable fuel tanks should not be less than 20 years.	-	
6.7	**6.7**	**Provisions for pressure relief systems**	**Pressure relief systems**	
6.7.1	6.7.1	Unless expressly provided otherwise, the requirements of section 6.7 of the IGF Code should apply to ships using hydrogen as fuel.	Unless expressly provided otherwise, the requirements of section 6.7 of the IGF Code should apply to ships using hydrogen as fuel.	
6.7.2	6.7.2	The vent mast height and distance requirements for tank vents, compressed and liquefied, should be considered minimum values, to be validated by dispersion analysis and heat radiation analysis, taking into account 6.7.3. If shown to provide equivalent safety vent mast height and distance could be limited to a lower value according to special consideration by the Administration.	The vent mast height and distance provisions for tank vents for compressed and liquefied fuel should be regarded as minimum values to be validated through dispersion analysis and heat radiation analysis.	The EMSA Guidance consider IGF requirements for vent mast height and safety distances to be minimum values that should be validated by CFD analysis. Further, the required height of the vent mast may also be dictated by acceptable heat radiation limits from a jet fire at the top of the vent mast (due to loss of vacuum or depressurization of compressed hydrogen tanks).
6.7.3	6.7.3	The consequences of vented hydrogen being ignited should be subjected to dispersion analysis and heat radiation analysis to verify that it is at an acceptable level with respect to the effect on people, the ship structure and exposed equipment including lifesaving appliances and escape routes.	The consequences of vented hydrogen being ignited should be subjected to dispersion analysis and heat radiation analysis to verify that it is at an acceptable level with respect to the effect on people, the ship structure and exposed equipment, including lifesaving appliances and escape routes. The guidance outlined in section 11.8 Fire Risk Analysis should be followed to verify that consequences remain within the limitations specified in 6.7.3.	The EMSA Guidance Section 11.8 contains provisions on a fire risk analysis, which should be conducted to verify that the limitations of fire consequences listed in 4.3.1 and 6.7.3 are not exceeded.
6.7.4	6.7.4	The vent mast and connected vent lines should be designed to minimize the risk of self-ignition in the vent line.	The vent mast and connected vent lines should be designed to minimize the risk of self-ignition in the vent line.	
6.7.5	6.7.5	The vent mast and connected vent lines should be designed to withstand the maximum expected explosion pressure in all foreseeable scenarios.	The vent mast and connected vent lines should have a design pressure of not less than 20 bar.	The EMSA Guidance text clarifies that the maximum pressure at a detonation in the vent system can reach close to 20 bar.
6.7.6	-	Where the potential for explosions damaging masts and systems exists, inert gas systems should be installed to prevent the formation of explosive clouds.	-	Covered above as the EMSA Guidance provisions say that the vent system should withstand a worst-case explosion (detonation). It should be noted that designing for 20 bar as a passive prevention barrier is more reliable than an active inerting barrier that has to function continuously through the ship's operational lifetime.
6.7.7	6.7.6	Vent masts and connected vent lines for liquefied hydrogen fuel containment should be arranged to prevent accumulation of condensate air constituent in or on the vent lines and be suitably	Vent masts and connected vent lines for liquefied fuel containment should be arranged to prevent accumulation of condensate air constituents inside and outside the vent lines, and	

		designed and constructed to prevent blockage due to formation of ice.	be suitably designed and constructed to prevent blockage due to the formation of ice.	
6.7.8	6.7.7	Vent masts should generally not be fitted with flame arrestors, however prevention of ingress of foreign objects should be arranged.	Vent masts should generally not be fitted with flame arrestors; however, prevention of the ingress of foreign objects should be arranged.	
6.7.9	6.7.8	Each liquefied fuel containment system relief valve should be designed for 100% capacity and relief lines should be dimensioned for simultaneous release of all connected tanks.	Each of the minimum two pressure relief valves required by 6.7.2 of the IGF Code Part A-1 for liquefied fuel tanks should have 100% relieving capacity for the tank.	The EMSA Guidance text clarifies that each of the minimum two pressure relief valves should have 100% capacity. Simultaneous release of several tanks is assumed to be more relevant for compressed hydrogen tanks.
6.7.10	6.7.9	Each compressed hydrogen cylinder should have an individual pressure relief device or emergency relief valve that is connected to a vent mast, and is capable of manual initiation from a safe location.	Each compressed fuel tank should be arranged with an individual manual remote depressurization valve connected to the vent mast to ensure safe depressurization of the tanks.	The EMSA Guidance has provisions for manual remote depressurization valves for each tank in addition to the automatic valve specified in 6.6.4. It stresses that it should be possible to depressurise all tanks simultaneously in a fire scenario. Composite tanks may lose their structural integrity from heat input, making them incapable of sustaining their original design pressure.
6.7.11	6.7.10	Adequate means should be provided to depressurize the tank in case of a fire which can affect the tank. This may include temperature-actuated safety relief systems, e.g. thermally activated pressure relief devices (TPRDs). The relieving capacity and area of the safety relief devices should be designed and calculated to ensure the rated capacity.	The adequate means for automatic depressurization referenced in 6.6.4 could be a temperature-actuated safety relief system, such as thermally activated pressure relief devices (TPRDs), or a similar system that automatically reduces tank pressure in the event of an external fire.	
6.7.11bis	6.7.11	The effect of environmental elements, such as rain, ice, etc. on the performance of TPRDs (where provided), should be evaluated and suitable or alternative measures be provided.	Due consideration should be taken in the design of thermally activated pressure relief devices to ensure that their function is not affected by environmental conditions.	
6.7.12	6.7.12	The pressure relief devices should be capable of fully venting the cylinder content, also during emergency venting scenarios. A multiple cylinder arrangement should be possible to be vented either individually or simultaneously during a controlled blow-down or emergency venting scenario.	Vent masts and connected vent lines should be dimensioned to accommodate the simultaneous depressurization of all connected tanks before the tank strength is unduly affected by the heat input from a fire.	The EMSA Guidance has rephrased the provision for clarity.
6.7.13	6.7.13	High-pressure gas relief systems and low-pressure gas relief systems should not be combined.	High-pressure gas relief systems and low-pressure gas relief systems should not be combined.	
6.7.14	6.7.14	Pressure relief device discharges on secondary enclosures should be directed to the vent mast.	Pressure relief device discharges from secondary enclosures should be directed to the vent mast.	
6.7.15	6.7.15	The vent mast and connected vent lines should be electrically bonded to prevent built up of static electricity.	Vent masts and connected vent lines should be electrically bonded to prevent the buildup of static electricity.	
6.7.16	-	The requirements of 6.7.2.3 of the IGF Code do not apply to ships using hydrogen as fuel unless accepted by the Administration as specified in 6.4.3.	-	The EMSA Guidance only includes provisions for liquefied fuel containment of Type C.
6.8	**6.8**	**Provisions on loading limit for liquefied hydrogen tanks**	**Loading limit for liquefied fuel tanks**	
6.8.1	6.8.1	Unless expressly provided otherwise, the requirements of section 6.8 of the IGF Code should apply to ships using hydrogen as fuel.	Unless expressly provided otherwise, the requirements of section 6.8 of the IGF Code should apply to ships using hydrogen as fuel.	

	6.8.2		The acceptance of an increased loading limit to 95% in the IGF Code section 6.8.2 should not apply to ships using hydrogen as fuel.	The EMSA Guidance recommends not allowing acceptance of a loading limit up to 95%. Considering the difference in heating properties, thermal expansion, and sensitivity to insulation loss, this allowance should be further evaluated before being applied for hydrogen storage.
6.9	**6.9**	**Provisions for the maintaining of fuel storage condition for liquefied hydrogen**	**Maintaining fuel storage conditions**	
6.9.1	6.9.1	Unless expressly provided otherwise, the requirements of section 6.9 of the IGF Code should apply to ships using hydrogen as fuel.	The requirements of section 6.9 of the IGF Code should apply to ships using hydrogen as fuel.	
6.10	**6.10**	**Provisions on atmospheric control within the fuel containment system for liquefied hydrogen**	**Atmospheric control within the fuel containment system**	
6.10.1	6.10.1	A piping system should be arranged to enable each fuel tank to be safely gas-freed with an inert gas, and to be safely filled with fuel from a gas free condition. The system should be arranged to minimize the possibility of pockets of gas or air remaining after changing the atmosphere.	A piping system should be arranged to enable each fuel tank to be safely gas-freed, and to be safely filled with fuel from a gas-free condition. The system should be arranged to minimize the possibility of pockets of gas or air remaining after changing the atmosphere. The system should be designed to eliminate the possibility of a flammable mixture existing in the fuel tank during any part of the atmosphere change operation by utilizing an inerting medium as an intermediate step.	
6.10.2	6.10.2	The system should be arranged to avoid inert gas condensing or solidifying in the system when cooling down and filling with liquefied hydrogen.	The gas-freeing system should be arranged to avoid inert gas condensing or solidifying in the system when cooling down and filling with liquefied hydrogen	
6.10.3	-	Gas sampling points should not be fitted unless necessary for safe gas freeing.	-	The EMSA Guidance does not include provisions for gas sampling points. The advantages of having possibilities to sample gas do not seem to match the disadvantages of having to design and operate such a system.
6.10.4	6.10.3	The inert gas composition used to purge hydrogen from the tank should be of sufficient purity to prevent an ignitable atmosphere in the tank.	The inert gas composition used to purge hydrogen from the tank should be of sufficient purity to prevent an ignitable atmosphere in the tank.	
6.10.5	6.10.4	Inert gas utilized for gas freeing of fuel tanks may be provided externally to the ship.	Inert gas used for gas freeing of fuel tanks may be supplied to the ship from external sources.	
6.11	**6.11**	**Provisions on atmosphere control within fuel storage hold spaces (Fuel containment systems other than type C independent tanks)**	**Atmosphere control within fuel storage hold spaces (Fuel containment systems other than type C independent tanks)**	
6.11.1	6.11.1	The provisions for liquefied hydrogen fuel containment in this interim guideline are for vacuum insulated type C tanks only. The requirements of section 6.11 of the IGF Code, part A-1, related to other tank types, should not apply to ships using liquid hydrogen as fuel.	The provisions for liquefied hydrogen fuel containment in this Guidance are for vacuum insulated Type C tanks only. The requirements of section 6.11 of the IGF Code, part A-1, related to other tank types, should not apply to ships using liquid hydrogen as fuel.	
6.11.2	-	Notwithstanding 6.11.1, hydrogen storage in other tank types than vacuum insulated type C may be permitted provided that the provisions of section 2.3 are met. The approval of such arrangements should as a minimum take into account the hazards and topics listed in provision 4.2.2.	-	The EMSA Guidance is a non-mandatory, advisory document in which references to IMO alternative design approval are not relevant.

6.12	**6.12**	**Provisions on environmental control of spaces surrounding vacuum insulated type C independent tanks in case of vacuum loss**	**Environmental control of spaces surrounding vacuum-insulated type C independent tanks in case of vacuum loss**	
6.12.1	6.12.1	The impact/consequences of loss of vacuum insulation on the atmosphere within the fuel storage hold (for tanks fitted with vacuum insulation) should be assessed within the holistic risk analysis required by 4.2.2.	The consequences of loss of vacuum insulation on the fuel storage hold space and other surrounding areas should be assessed within the risk analysis required by 4.2.2.	The EMSA Guidance recognise that other surrounding areas may also be affected by a loss of tank vacuum and should be assessed within the risk analysis.
6.12.2	6.12.2	The spaces surrounding hydrogen tanks should be configured to withstand potential vacuum loss outcomes, such as: .1. generation of liquid air; .2 oxygen enrichment; and .3 activation of relief mechanisms in case of a sudden loss of vacuum.	The spaces surrounding hydrogen tanks should be configured to withstand potential vacuum loss outcomes, such as: .4 condensation of air, including the risk of oxygen enrichment; .5 activation of tank pressure relief valves .6 embrittlement of surrounding structures due to low temperatures.	The EMSA Guidance provides further clarity on hazards to be considered.
6.13	**6.13**	**Provisions on inerting**	**Inerting**	
6.13.1	6.13.1	Arrangements to prevent back-flow of fuel vapour into the inert gas system should be provided as specified below.	Arrangements to prevent back-flow of fuel vapour into the inert gas system should be provided as specified below.	
6.13.2	6.13.2	To prevent the return of flammable gas to any non-hazardous spaces, the inert gas supply line should be fitted with two shut-off valves in series with a venting valve in between (double block and bleed valves). These valves should be located outside non-hazardous spaces.	To prevent the return of flammable gas through the inert gas system to any non-hazardous spaces, the inert gas supply line should be fitted with two shut-off valves in series with a venting valve in between (double block and bleed valves). These valves should be considered a leak source for hydrogen and arranged in an inerted secondary enclosure.	The EMSA Guidance acknowledges that valves directly connected to the fuel system become potential hydrogen leak sources. Given the EMSA provisions for secondary enclosures around all hydrogen leak sources, it is clarified that this type of valve so also be arranged in a secondary enclosure.
6.13.3	-	Where the connections to the fuel piping systems are non-permanent, two non-return valves may be substituted for the valves required in 6.13.2.	-	The EMSA Guidance does not recommend non-permanent connections to the fuel system, as these connections will represent leak points in enclosed spaces.
6.13.4	-	The arrangements should be such that each space being inerted can be isolated and the necessary controls and relief valves, etc. should be provided for controlling pressure in these spaces.	-	The EMSA Guidance does not include this provision, as it will severely complicate the inert gas system without having any safety benefits for a hydrogen fuel system as opposed to e.g., arrangements with multiple inerted cargo tanks.
6.13.5	-	In addition, purge gases should be suitable for the system operating temperatures, considering the respective boiling point of the purge gases. Arrangements should be provided to safely monitor the purging effectiveness.	-	For liquefied hydrogen systems, systems should be arranged to enable the purging of inert gas with warm hydrogen before cryogenic hydrogen is introduced, to avoid contamination with frozen nitrogen. Similar arrangements should be provided for gas-freeing operations.
6.14	**6.14**	**Provisions on inert gas production and storage on board**	**Inert gas production and storage on board**	
6.14.1	-	Unless expressly provided otherwise, the requirements of section 6.14 of the IGF Code should apply to ships using hydrogen as fuel.	-	The EMSA Guidance contains the full content for this section since other provisions apply to hydrogen than those for natural gas.
6.14.2	6.14.1	Instead of 6.14.1 of the IGF Code, the following provisions apply.	Instead of 6.14.1 of the IGF Code, the following provisions apply.	
6.14.2.1	6.14.2	The equipment should be capable of producing inert gas with oxygen content at no time greater than 3% by volume.	The equipment should be capable of producing inert gas with oxygen content at no time greater than 3% by volume.	

6.14.2.2	6.14.3	A continuous-reading oxygen content meter should be fitted to the inert gas supply from the equipment and should be fitted with an alarm set at a maximum of 3% oxygen content by volume.	A continuous-reading oxygen content meter should be fitted to the inert gas supply from the equipment and should be fitted with an alarm set at a maximum of 3% oxygen content by volume.	
-	6.14.4	-	Where a nitrogen generator or nitrogen storage facilities are installed in a separate compartment outside of the engine room, the separate compartment should be fitted with an independent mechanical extraction ventilation system, providing a minimum of 6 air changes per hour. A low oxygen alarm should be fitted.	From 6.14.3 of the IGF Code Part A-1 The EMSA Guidance contains provisions to safeguard against asphyxiation due to nitrogen leakages.
-	6.14.5	-	Nitrogen pipes should only be led through well-ventilated spaces. Nitrogen pipes in enclosed spaces should: - be fully welded; - have only a minimum of flange connections as needed for the fitting of valves; and - be as short as possible.	From 6.14.4 of the IGF Code Part A-1 The EMSA Guidance contains provisions to safeguard against asphyxiation due to nitrogen leakages.
6.14.3	-	In addition to 6.14 of the IGF Code, the following provisions apply.	-	
6.14.3.1	6.14.6	For hydrogen secondary enclosure inerting, inert gas supply should be redundant and with sufficient capacity, and the system should monitor and warn in case of excessive contamination with hydrogen.	For hydrogen secondary enclosure inerting, inert gas supply should be redundant and with sufficient capacity, and the system should monitor and warn in case of excessive contamination with hydrogen.	
6.14.3.2	6.14.7	For high pressure hydrogen systems secondary enclosures, the capacity of the inert gas system is to be suitable for purging of the enclosures after a high pressure leak and subsequent loss of containment integrity (e.g. burst discs rupturing).	The stored inert gas capacity should, at a minimum, be enough to safely purge all parts of the fuel piping system and secondary enclosures necessary to bring the system into a safe condition after a hydrogen leak.	The EMSA Guidance recognizes that it must be possible to bring any system to a safe state after a leakage.
6.15	**6.15**	**Provisions on vacuum**	**Provisions on vacuum**	
6.15.1	6.15.1	Piping vacuum jacket spaces should be segregated to limit the area affected by vacuum loss as far as possible.	Piping vacuum jacket spaces should be segregated to limit the area affected by vacuum loss as far as possible.	
6.15.2	-	Pressure relief devices for vacuum systems should provide separate discharge to a vent mast capable of handling cryogenic hydrogen.	Pressure relief devices for piping vacuum jacket spaces should provide separate discharge to a vent mast capable of handling cryogenic hydrogen.	
6.15.3	6.15.2	Pressure relief devices on vacuum spaces should be designed to prevent cryo-pumping of air.	Pressure relief devices protecting vacuum spaces should be designed to prevent cryo-pumping of air.	

Draft IG	EMSA Guidance	IMO Draft Interim Guidelines for the safety of ships using hydrogen as fuel (CCC 11/WP.4 Annex 2)	EMSA Guidance for hydrogen-fuelled ships	Justification and comments
7	**7**	**MATERIAL AND GENERAL PIPE DESIGN**	**MATERIAL AND GENERAL PIPE DESIGN**	
-	**7.0**	-	**Hazards**	
-	7.0.1	-	Fuel piping systems may discharge hydrogen to the surroundings through leakages caused by, e.g., pressure ruptures, brittle fractures, corrosion failures, fatigue, freezing damages, or contraction damages. Other causes for hydrogen discharges may be due to mechanical damage during maintenance and as a result of erroneous maintenance, and operational and emergency pressure releases.	
-	7.0.2	-	Hydrogen releases from the fuel piping systems may ignite, resulting in a fire, deflagration or detonation.	
-	7.0.3	-	Liquefied hydrogen releases from the fuel piping systems may cool down surrounding structures, causing embrittlement.	
-	7.0.4	-	Cold surfaces of the fuel piping systems may condense air, which may cause embrittlement and a fire hazard.	
-	7.0.5	-	Air, nitrogen and humidity may enter liquefied hydrogen systems, and the resulting solidification may cause system damage and blockages.	
-	7.0.6	-	The thermal expansion of liquefied hydrogen may cause over-pressurisation of piping systems.	
-	7.0.7	-	Ship movements, vibrations and thermal effects may lead to fatigue and failure of the fuel piping systems.	
7.1	**7.1**	**Goal**	**Goal**	
		The goal of this chapter is to ensure the safe handling of fuel, under all operating conditions, to minimize the risk to the ship, persons on board and to the environment, having regard to the nature of the products involved.	The goal of this chapter is to ensure the safe handling of fuel under all operating conditions to minimize the risk to the ship, personnel and the environment, having regard to the nature of hydrogen.	
7.2	**7.2**	**Functional requirements**	**Functional requirements**	
7.2.1		This chapter relates to functional requirements in 3.2.1, 3.2.5, 3.2.6, 3.2.8, 3.2.9 and 3.2.10. In particular, the following provisions apply.	This section relates to functional requirements in **3.2.1**, **3.2.2**, **3.2.9 to 3.2.11**, **3.2.18** and **3.2.19**. In particular, the following apply:	
7.2.2	7.2.1	Fuel piping should be capable of absorbing thermal expansion or contraction caused by extreme temperatures of the fuel without developing substantial stresses.	Fuel piping systems should be capable of absorbing thermal expansion or contraction caused by extreme temperatures of the fuel without developing substantial stresses.	
7.2.3	7.2.2	Provision should be made to protect the piping, piping system and components and fuel tanks from excessive stresses due to thermal movement and from movements of the fuel tank and hull structure.	Fuel piping systems should be protected from excessive stresses due to thermal movement of the fuel tank and from movements of the hull structure.	The EMSA guidance clarifies: - Fuel piping systems cover “piping, piping system and components” - Protection of fuel tanks from thermal expansion is covered in section 6.2.9.

7.2.4	7.2.3	Provisions should be made to minimize the likelihood and size of a leak from the piping system.	Fuel piping systems should be designed to minimize the likelihood and size of a leak.	The use of leak-prone components and couplings should be minimized when designing hydrogen systems. Leakage sources in hydrogen piping systems should be minimized by avoiding detachable pipe connections, and reducing the number of valves and other leakage sources as much as possible.) (From EMSA D.1 Mapping safety risks for hydrogen-fuelled ships All fuel piping systems should be designed and arranged to minimize the probability of leakages. This implies using materials that are not deteriorated by hydrogen, are suitable for the system's design temperature, are arranged and supported to ensure that operational conditions do not cause undue stresses, and are connected by welding whenever possible. Where welding is not possible, joining methods are chosen to minimize the probability of leakage.
7.2.5	7.2.4	Fuel piping systems for liquefied hydrogen should be thermally isolated from the adjacent hull structure, where necessary, to prevent the temperature of the hull from falling below the design temperature of the hull material.	Fuel piping systems for liquefied hydrogen should be thermally isolated from the adjacent hull structure, where necessary, to prevent the temperature of the hull from falling below the design temperature of the hull material.	
7.2.6	7.2.5	Materials used in all components in contact with hydrogen should withstand phenomena such as, but not limited to, hydrogen embrittlement and hydrogen attack.	Fuel piping systems should be manufactured from materials suitable for hydrogen service, preventing hydrogen embrittlement, hydrogen permeation, and hydrogen attack.	The EMSA Guidance states that materials should be suitable for hydrogen service specifically, and additionally specify resistance to embrittlement, permeation and attack.
7.2.7	-	Materials used in components that may come into contact with oxygen-rich atmosphere should be resistant to the effects of high oxygen concentration.	-	The EMSA Guidance has provisions for hydrogen piping and components to be insulated by vacuum enclosures, preventing the outer surface temperature from reaching the condensation temperature of oxygen.
7.2.8	7.2.6	The temperature of the outer surface of secondary enclosures should in normal operation not be less than -183°C (oxygen boiling point at atmospheric pressure).	Fuel piping systems should be designed to avoid icing during normal operation.	The EMSA Guidance includes provisions to avoid icing due to air moisture on cold surfaces in normal operation. This is a stricter requirement than avoiding oxygen condensation.
7.2.9	-	The thermal insulation efficiency of secondary enclosures should be sufficient to minimize condensation of moisture, and the enclosures should be arranged for collection and handling of condensed air constituent gases, in case of any single failure.	-	It is noted that secondary enclosures cannot be arranged for the collection and handling of condensed air. This must be managed by other means (material choice, drip trays)
7.2.10	-	Components in the fuel containment systems and piping systems with low surface temperatures should be so installed and protected as to reduce to a minimum any danger to persons on board, and to prevent operational problems due to icing.	-	The EMSA Guidance provisions recommend that fuel piping systems should be designed to avoid icing due to air moisture during normal operation (7.2.6), which will also eliminate the risk of injuries due to low surface temperatures.
-	7.2.7	-	Fuel piping systems should be designed to maintain fuel pressure and temperature within the approved design limits.	(From EMSA D.1 Mapping safety risks for hydrogen-fuelled ships All fuel piping systems for liquefied hydrogen should be arranged with a system to manage the heating up and corresponding pressure increase of trapped volumes of liquefied hydrogen and vent it to open air at the safest location possible. Fuel piping systems for liquefied hydrogen should be designed to prevent overpressure when the fuel is heating up in the system under both normal and abnormal operating conditions.)
7.3	**7.3**	**General**	**General pipe design**	

7.3.1	7.3.1	Unless expressly provided otherwise, the requirements of section 7.3 of the IGF Code should apply to ships using hydrogen as fuel.	Unless expressly provided otherwise, the requirements of section 7.3 of the IGF Code should apply to ships using hydrogen as fuel.	The IGF Code section 7.3 – Regulations for general pipe design referred to in the EMSA Guidance addresses the following subjects: General Wall thickness Design conditions Allowable stress Flexibility of piping Piping fabrication and joining details
7.3.2	7.3.2	Expansion joints and bellows should be avoided, as far as practicable, in hydrogen fuel piping systems. Engine mounted expansion bellows could be accepted based on evaluation as reflected in the safety concept of the engine.	Expansion joints and bellows should not be used in hydrogen fuel piping systems. Engine-mounted expansion bellows could be accepted based on evaluation, as reflected in the engine's safety concept.	The EMSA Guidance considers expansion joints and bellows to be unsuitable for hydrogen fuel systems. Expansion bellows are prone to leakage and sensitive to improper installation and have small installation tolerances. Considering the consequences of major leakages, the expansion and contraction of piping systems should be managed by means other than installing expansion bellows in fuel systems.
-	7.3.3	-	The requirements of section 7.3.1.5 of the IGF Code should not apply to ships using hydrogen as fuel.	The EMSA Guidance does not recommend allowing other piping systems inside the secondary enclosures around hydrogen pipes. Therefore, the reference to IGF 7.3.1.5 is not included.
7.4	-	**Materials**	-	
7.4.1	-	**General**	-	
7.4.1.1	7.3.4	The materials to be used in hydrogen systems should be suitable for the medium and service for which the system is intended. This should be proven either by selection of materials according to, a recognized standard specifying the suitability of the material for the medium and service intended, or by adequate qualification testing. Test scope for qualification of a material should be acceptable to the Administration.	The materials to be used in hydrogen systems should be suitable for the medium and service for which the system is intended. This should be proven either by selection of materials according to, a recognized standard specifying the suitability of the material for the medium and service intended, or by adequate qualification testing. Test scope for qualification of a material should be acceptable to the Administration.	
7.4.1.2	-	Requirements for materials whose design temperature is lower than -165°C should be agreed with the Administration.	-	Covered by Guidance above.
7.4.1.3	7.3.5	Typical properties to be considered during qualification testing are, as a minimum, yield stress, tensile strength, ductility, fracture toughness, fatigue properties, hydrogen embrittlement, hydrogen permeation properties, corrosion resistance (as relevant) and coefficient of thermal expansion.	Typical properties to be considered during qualification testing are, as a minimum, yield stress, tensile strength, ductility, fracture toughness, fatigue properties, hydrogen embrittlement, hydrogen permeation properties, corrosion resistance (as relevant) and coefficient of thermal expansion.	
7.4.1.4	7.3.6	Matters including, but not limited to, the following should also be considered and addressed during the special consideration review and acceptance of materials: .1 resistance of materials to the chemical and physical action of hydrogen under the operating conditions, including considerations of permeability and porosity, strength and toughness (i.e. ductile-to-brittle transition), effects of high oxygen concentrations experienced at low working temperatures, hydrogen embrittlement effects and high temperature hydrogen attack;	Matters including, but not limited to, the following should also be considered and addressed during the special consideration review and acceptance of materials: .4 resistance of materials to the chemical and physical action of hydrogen under the operating conditions, including considerations of permeability and porosity, strength and toughness (i.e. ductile-to-brittle transition), effects of high oxygen concentrations experienced at low working temperatures, hydrogen embrittlement effects and high temperature hydrogen attack; .5 suitability of materials for the intended application, including low- and/or high temperature effects, thermal	

		.2 suitability of materials for the intended application, including low- and/or high temperature effects, thermal expansion and contraction, thermal gradients, compatibility of dissimilar metals in intimate contact and electrostatic charge build-up/ discharge in non-conductive materials; and .3 if materials are subjected to laboratory qualification testing, with respect to the possible variation of the chemical composition between the laboratory test samples and the production material, the chemistry of the tested material should be recorded in the qualification test report and the difference in chemistry for the steels actually used should not exceed the "permissible difference" as per recognized standards.	expansion and contraction, thermal gradients, compatibility of dissimilar metals in intimate contact and electrostatic charge build-up/ discharge in non-conductive materials; and .6 if materials are subjected to laboratory qualification testing, with respect to the possible variation of the chemical composition between the laboratory test samples and the production material, the chemistry of the tested material should be recorded in the qualification test report and the difference in chemistry for the steels actually used should not exceed the "permissible difference" as per recognized standards.	
7.4.1.5	7.3.7	A material should not be used for hydrogen service unless data is available to show that the material is suitable for the intended service conditions, or a suitable laboratory testing regime is agreed to demonstrate that materials in a hydrogen charged atmosphere will retain the required properties for the foreseeable operational scenarios. Materials that have been used successfully with hydrogen should be preferred over materials with little or no history of use within a hydrogen environment.	A material should not be used for hydrogen service unless data is available to show that the material is suitable for the intended service conditions, or a suitable laboratory testing regime is agreed to demonstrate that materials in a hydrogen-charged atmosphere will retain the required properties for the foreseeable operational scenarios. Materials that have been successfully used with hydrogen should be preferred over those with little or no history of use in a hydrogen environment.	
7.4.1.6	-	All materials to be used in the construction of bunkering stations, the fuel containment system (including piping), the fuel supply system and consumers should be identified and considered, as appropriate, in the risk assessment.	-	The EMSA Guidance does not specify this. The materials used in the hydrogen system should be documented in the technical documentation as stated in the overall functional requirements in Chapter 3.
7.4.2	**7.4**	**Metallic materials**	**Metallic materials**	
7.4.2.1	7.4.1	Metallic materials to be used in hydrogen systems should be suitable for their intended use.	The materials used in hydrogen systems shall be suitable for the medium and service for which the system is intended, considering the design temperature, design pressure, working stress levels and environmental conditions.	
7.4.2.2	-	The base metal of clad materials used for hydrogen tank construction should be an acceptable material for liquid hydrogen service. The thickness used in pressure design should not include the thickness of the clad or lining.	-	A special case that should be considered case-by-case.
7.4.2.3	-	The allowable stress used should be that for the base metal at the design temperature.	-	See above.
7.4.2.4	7.4.2	Test scope for qualification of a material should be acceptable to the Administration. The qualification of metallic materials by testing should address: .1 the degradation of the material properties due to exposure to hydrogen, where degradation is expected to increase with increasing temperature and pressure; .2 the degradation of the material properties due to cryogenic temperature, where degradation is expected to increase with decreasing temperature; and	The test scope for the qualification of a material should be acceptable to the Administration. The qualification of metallic materials by testing should address: .1 the degradation of the material properties due to exposure to hydrogen, where degradation is expected to increase with increasing temperature and pressure; .2 the degradation of the material properties due to cryogenic temperature, where degradation is expected to increase with decreasing temperature; and	

		.3 the combined effect of these.[2] [2] See Susceptibility of materials to embrittlement in hydrogen at 10,000 psi and 72°F (~22°C) in the ANSI/AIAA G-095-2004 Guide to Safety of Hydrogen and Hydrogen Systems.	.3 the combined effect of these[2]. 2 See Susceptibility of materials to embrittlement in hydrogen at 10,000 psi and 72°F (~22°C) in the ANSI/AIAA G-095-2004 Guide to Safety of Hydrogen and Hydrogen Systems.	
7.4.2.5	7.4.3	Where materials are intended to be further processed/fabricated by forming or welding, the impact of the processing on the relevant properties should be considered.	Where materials are intended to be further processed/fabricated by forming or welding, the impact of the processing on the relevant properties should be considered.	
7.4.3	**7.5**	**Non-metallic materials**	**Non-metallic materials**	
7.4.3.1	7.5.1	Non-metallic materials to be used in hydrogen systems should be suitable for their intended use.	Non-metallic materials used in fuel tanks should be suitable for their intended use. Fire resistance, thermal expansion, thermal conductivity and hydrogen permeation should be considered when choosing composite materials.	The EMSA Guidance limits the use of non-metallic materials to fuel tanks, excluding other parts of the fuel piping system, except for gaskets, packing, or other sealing elements.
7.4.3.2	-	Coefficients of thermal expansion (CTE), thermal conductivity and permeation by hydrogen should be considered when choosing materials.	-	The EMSA Guidance includes this in the provision above.
7.4.3.3	7.5.2	Fire resistance properties should be considered for use in gaskets, packing or other sealing elements.	Non-metallic materials used in gaskets, packing or other sealing elements should be suitable for their intended use. Fire resistance, thermal expansion, thermal conductivity and hydrogen permeation should be considered when choosing composite materials.	The EMSA Guidance emphasises that, in addition to fire properties, thermal expansion, thermal conductivity, and hydrogen permeation should be considered when selecting composite materials for gaskets, packing, or other sealing elements suitable for hydrogen service.

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8	**8**	**BUNKERING**	**BUNKERING**	
-	**8.0**	-	**Hazards**	
-	8.0.1	-	Hydrogen leakages and releases from the ship's bunkering system or the bunkering facility's transfer system may ignite, resulting in a fire, deflagration, or detonation.	
-	8.0.2	-	Liquefied hydrogen leakages and releases from the ship's bunkering system or the bunkering facility's transfer system may cool down surrounding structures, causing embrittlement.	
-	8.0.3	-	Cold surfaces of the ship's bunkering system or the bunkering facility's transfer system may condense air, which may cause embrittlement and a fire hazard.	
-	8.0.4	-	Relative movement between the ship and the bunkering facility may damage the ship's bunkering system and the bunkering facility's transfer system, causing hydrogen leakages.	
-	8.0.5	-	An ignited leakage in a confined bunkering station can result in pressure build-up with the potential to cause mechanical damage.	
-	8.0.6	-	A collision impact on the ship's bunkering manifold may also damage the connected fuel containment system, causing hydrogen leakages.	

-	8.0.7	-	Hydrogen leakages may occur in the ship's bunkering connection due to the connection and disconnection of the bunkering hose.	
-	8.0.8	-	Unless all remains of air and inert gas are removed from the bunkering system, these gases may condense and solidify during the bunkering of liquefied hydrogen and cause obstructions and equipment malfunction. The evaporation of oxygen may also cause an explosion hazard when systems are heated up.	
8.1	**8.1**	**Goal**	**Goal**	
8.1.1		The goal of this chapter is to provide for suitable systems on board the ship to ensure that bunkering can be conducted without causing danger to persons, the environment or the ship.	The goal of this chapter is to provide for suitable systems on board the ship to ensure that bunkering can be conducted without causing danger to persons, the ship or the environment.	
8.2	**8.2**	**Functional Requirements**	**Functional Requirements**	
8.2.1		This chapter relates to functional requirements in 3.2.1 to 3.2.11, 3.2.13 to 3.2.17 and 3.2.19. In particular, the following provisions apply.	This section relates to functional requirements in **3.2.1**, **3.2.2**, **3.2.4** to **3.2.11**, **3.2.12**, **3.2.17** to **3.2.20**. In particular, the following apply:	
8.2.2	8.2.1	The piping system for transfer of fuel to the storage tank should be designed such that any leakage from the piping system cannot cause danger to persons, the environment or the ship.	The piping system for the transfer of fuel to the storage tank should be designed such that any leakage from the piping system cannot cause danger to personnel, the environment or the ship.	
8.2.3	8.2.2	Bunkering systems should be protected from mechanical damage.	Bunkering systems should be protected from mechanical damage.	
8.2.4	8.2.3	The bunkering station should be arranged to safely handle leakages during bunkering operations.	The bunkering station should be arranged to safely handle leakages during bunkering operations.	
8.2.5	8.2.4	Bunkering systems should be arranged with the possibility of remote and local emergency stop of fuel transfer.	Bunkering systems should be arranged with the capability for remote and local emergency shutdown of fuel transfer.	
8.2.6	8.2.5	The piping between the bunkering manifold and the fuel containment system should be designed to prevent fuel containment system damage in case of collision impact on the bunkering manifold.	The piping between the bunkering manifold and the fuel containment system should be designed to prevent damage to the fuel containment system in the event of a collision impacting the bunkering manifold.	
8.2.7	8.2.6	The bunkering system should be designed to minimize the amount of hydrogen released to air during filling of the fuel tanks.	The bunkering system should be designed to minimize the amount of hydrogen released to the air during filling of the fuel tanks.	
8.2.8	8.2.7	Formation of oxygen enriched environments should be prevented or at least mitigated.	Formation of oxygen-enriched environments should be prevented or mitigated.	
8.2.9	8.2.8	In bunkering stations, the accumulation of gas should be prevented.	In bunkering stations, the accumulation of gas should be prevented.	
-	8.2.9	-	The ship and the bunkering facility should be able to communicate effectively to mitigate the consequences of unplanned events.	
8.3	**8.3**	**Bunkering stations**	**General**	

8.3.1	8.3.1	Bunkering stations should be located on open deck providing natural ventilation and unobstructed relief of leakages. The bunkering station should be designed to minimize the risk from leaks to persons, the environment and ship.	Whenever possible, bunkering stations should be located on the open deck to provide natural ventilation and unobstructed relief of leakages.	The EMSA Guidance cover the second sentence in functional requirements (8.2.1 and 8.2.3).
8.3.2	8.3.2	Notwithstanding 8.3.1, bunker stations arranged in an enclosed or semi-enclosed space may be permitted provided that the requirements of alternative design (SOLAS II-1/55) are met to the satisfaction of the Administration. Such bunkering stations should be arranged to minimize the consequence of leakage by: .1 minimizing the volumes where a flammable atmosphere caused by leakage can accumulate; .2 optimizing the geometry of the space and ship-side openings to relieve explosion pressure; .3 minimizing congestion, including but not limited to the elimination of non-essential machinery and equipment, to reduce the risk of severe explosion pressures; .4 minimizing the probability of ignition; and .5 providing gas-tight bulkheads towards adjacent spaces.	Bunkering stations which cannot be located on an open deck should be arranged to minimize the consequences of leakage by: .6 Minimizing the volumes where a flammable atmosphere, caused by leakage, can accumulate .7 Optimizing the geometry and ship-side openings to relieve the explosion pressure. .8 Minimizing congestion to reduce the risk of severe explosion pressures. .9 Minimizing the probability of ignition. .10 Providing gas-tight bulkheads towards adjacent spaces. The guidance outlined in section 11.8 (Fire Risk Analysis) and section 12.3 (Explosion Risk Analysis) should be followed to verify that fire and explosion consequences following a release of hydrogen caused by unintended events during bunkering remain within the limitations specified in 4.3.1.	(From EMSA D.1 Mapping safety risks for hydrogen-fuelled ships The ship bunkering station should be arranged to reduce the consequences of an ignition event as far as possible. This implies preferably locating the bunkering station on the open deck. When having the bunkering station on the open deck is not possible, the volume of the bunkering station subjected to potential leakage should be minimized, and openings should be arranged to optimise the relief of explosion pressure. The fitting of unnecessary equipment and items causing congestion increases the risk of deflagrations and detonations and should be avoided in bunkering stations.)
8.3.3	-	Arrangements should be made for safe management of any leaked fuel or condensed air.	-	The EMSA Guidance provision 8.3.2 is a list of arrangements recommended to manage leaked fuel. Mitigating the consequences of condensed air cooling down ship structures is covered in 8.3.8.
8.3.4	-	Control of bunkering should be possible from a safe location. At this location, the tank pressure and automatic and manual shutdown should be indicated. In addition, the following should be provided: .1 For liquefied hydrogen bunkering, monitoring of level of filling and overfill alarm and shutdown. .2 For compressed hydrogen bunkering, high temperature alarm.	-	The EMSA Guidance provides more detailed provisions for bunkering control in section 15.5.
8.3.5	8.3.3	Bunkering lines should not pass through accommodation spaces, control stations or service spaces.	Piping for bunkering should not pass through accommodation spaces, control stations or service spaces.	The EMSA Guidance uses the defined term “piping” instead of “lines”.
8.3.6	8.3.4	Bunkering lines should be arranged with secondary enclosures in accordance with 9.5 and 9.6 up to the bunkering manifold.	Piping for bunkering should be arranged with secondary enclosures up to the bunkering manifold.	
	8.3.5	-	Bunkering manifolds for the bunkering of liquefied hydrogen should be arranged with drip trays.	
8.3.7	8.3.6	Bunker manifold connections and piping should be so positioned and arranged that any mechanical impact damage to the fuel piping does not cause damage to the ship's fuel containment system resulting in an uncontrolled gas discharge.	Bunker manifold connections and piping should be so positioned and arranged that any mechanical impact damage to the fuel piping does not cause damage to the ship's fuel containment system, resulting in an uncontrolled gas discharge.	

8.3.8	8.3.7	Suitable means should be provided to depressurize and remove liquid contents from bunker lines. Liquid should be discharged to the liquefied fuel tanks or other suitable location.	Suitable means should be provided to depressurise and remove liquid contents from piping for bunkering. The liquefied hydrogen should be drained to the ship's fuel tanks or to the tanks of the bunker supplier.	The EMSA Guidance consider that draining the lines to storage tanks or bunkering facilities is the best and safest option.
8.3.9	8.3.8	Bunkering stations should be arranged to prevent surrounding hull or deck structures from being subjected to unacceptable cooling in the event of a leakage of fuel and/or condensation of air.	Bunkering stations should be arranged to prevent surrounding hull or deck structures from being subjected to unacceptable cooling in the event of a fuel leak or condensation of air.	
8.3.10	-	The ship's fuel hoses and associated fittings should be in accordance with the requirements of section 8.3.2 of the IGF Code.	-	The EMSA Guidance does not include provisions for fuel hoses. For LNG, this requirement is largely redundant, as the ship typically does not provide the bunkering hose.
8.4	**8.4**	**Bunkering manifolds**	**Bunkering manifolds**	
8.4.1	8.4.1	The ship's bunkering manifold should be designed to withstand the external loads it may be subjected to during bunkering, including in a drift-off scenario.	The ship's bunkering manifold should be designed to withstand the external loads it may be subjected to during bunkering, including in a drift-off scenario.	
8.4.2	8.4.2	The bunkering coupling should be according to a recognized standard, appropriate for fuel bunkering operations and capable of withstanding the design temperature and design pressure.	The bunkering coupling should be according to a recognized standard, appropriate for fuel bunkering operations and capable of withstanding the design temperature and design pressure.	
8.4.3	8.4.3	The connections at the bunkering station should be arranged in order to achieve a dry disconnect operation. The dry disconnect operation should be arranged by the use of a dry-disconnect/connect coupling.	The connections at the bunkering station for liquefied hydrogen should be arranged to facilitate a dry disconnect operation. The dry disconnect operation should be arranged by the use of a dry-disconnect/connect coupling.	
8.4.4	-	Notwithstanding 8.4.3, the following alternative means for achieving dry disconnect operation may be permitted provided that the provisions of section 2.3 are met to the satisfaction of the Administration: .1 a manual connect coupler or hydraulic connect coupler, used to connect the bunker system to the receiving ship bunkering manifold presentation flange; or .2 a bolted flange to flange assembly.	-	The EMSA Guidance does not include provisions for a bolted flange assembly, as this will not achieve a dry disconnect. Also, the bunkering system from the bunkering facility tank to the ship fuel containment system must be drained, depressurised, purged, and gas-freed before a flange connection can be de-coupled. It is noted that the option to use a flange connection for connecting the bunkering line has been reintroduced in IGF for natural gas. This was to accommodate large-diameter bunkering lines where dry-disconnect couplings become difficult to manage (> 8"). These sizes of bunkering lines are less relevant for hydrogen bunkering.
8.4.5	-	When intended to use either of the connections specified in paragraphs 8.4.3 and 8.4.3, these shall be combined with operating procedures that ensure a dry-disconnect is achieved. The arrangement shall be subject to special consideration informed by a bunkering arrangement risk assessment conducted at the design stage and considering dynamic loads at the bunkering manifold connection to a recognized standard acceptable to the Administration, the safe operation of the ship and other hazards that may be relevant to the ship during bunkering operation. The fuel handling manual required by 18.2.1.3 shall include documentation that the bunkering	-	

		arrangement risk assessment was conducted, and that special consideration was granted under this requirement.		
-	8.4.4	-	The connections at the bunkering station for compressed hydrogen should be of a self-sealing type.	
8.4.6	8.4.5	An Emergency Release Coupler (ERC)/Emergency Release System (ERS) or equivalent means should be provided, unless installed on the bunkering supply side of the bunkering line, and said means should be in accordance with a standard equivalent to those acceptable to the Administration, it should enable a quick physical disconnection 'dry break-away' of the bunker system in an emergency event.	The bunkering hose should be equipped with a safety dry break-away coupling or a self-sealing quick-release coupling, ensuring that the tension in the bunkering assembly in a drift-off scenario does not destroy the bunkering hose or the ship's manifold.	The EMSA Guidance includes a provision modelled on the IGF Code. IGF: The bunkering manifold shall be designed to withstand the external loads during bunkering. The connections at the bunkering station shall be of dry-disconnect type **equipped with additional safety dry break-away coupling/ self-sealing quick release.** The couplings shall be of a standard type.
8.5	**8.5**	**Bunkering systems**	**Bunkering systems**	
8.5.1	8.5.1	Compressed hydrogen fuel tanks should not exceed the maximum design temperature during bunkering operations.	Compressed hydrogen fuel tanks should not exceed the maximum design temperature during bunkering operations.	
8.5.2	8.5.2	A manually operated stop valve and a remote operated shutdown valve in series, or a combined manually operated and remote valve should be fitted in every bunkering line close to the connecting point. It should be possible to operate the remote valve in the control location for bunkering operations and/or from another safe location.	A manually operated stop valve and a remotely operated shutdown valve, mounted in series, should be fitted in the bunkering line close to the connecting point. A remotely operated valve with the possibility for local manual operation is an equivalent arrangement. It should be possible to operate the actuated valve at the control location for bunkering operations.	The EMSA Guidance does not include the option of bunkering operation "from another safe location". Remote operation should be possible from the location where the operator has information regarding the bunkering operation, which is defined as the control location for bunkering. Consequently, we do not regard another safe location where such info is not available as an equivalent solution for hydrogen bunkering.
8.5.3	8.5.3	Bunkering lines are to be arranged for inerting and gas freeing for shut down and maintenance.	Bunkering systems are to be arranged for inerting and gas freeing.	
8.5.4	8.5.4	When not engaged in bunkering, the remaining gaseous hydrogen pressure in the bunkering lines should be lowered to a suitable pressure above atmospheric pressure, to prevent ingress of air and reduce the risk of high-pressure leakages.	When not engaged in bunkering, the remaining gaseous hydrogen pressure in the bunkering lines should be lowered to a suitable pressure above atmospheric pressure to prevent ingress of air and reduce the risk of high-pressure leakages.	The EMSA Guidance is aimed at avoiding introducing inert gas to the system and simultaneously avoiding high pressure against the bunkering valve after bunkering, thereby minimizing the risk of high-pressure gas leakage to the atmosphere (especially important for compressed hydrogen).
8.5.5	-	Where bunkering pipes are arranged with a cross-over, suitable isolation arrangements should be provided that fuel cannot be transferred inadvertently to the ship side not in use for bunkering.	-	The EMSA Guidance does not include this IG provision because bunkering manifolds are already arranged with remote and manual valves in each bunkering station + a dry-disconnect to prevent this from happening.
8.5.6	8.5.5	A bunkering safety link or an equivalent means for automatic and manual ESD communication to the bunkering source should be fitted.	A ship-shore link (SSL) or an equivalent means for automatic and manual ESD communication to the bunkering source should be fitted.	

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9	**9**	**Fuel Supply to Consumers**	**FUEL SUPPLY TO CONSUMERS**	
-	**9.0**	-	**Hazards**	

-	9.0.1	-	Hydrogen leakages and releases from the fuel piping systems may ignite, resulting in a fire, deflagration, or detonation.	
-	9.0.2	-	Liquefied hydrogen leakages and releases from the fuel piping systems may cool down surrounding structures, causing embrittlement.	
-	9.0.3	-	Cold surfaces of the fuel piping systems may condense air, which may cause embrittlement and a fire hazard.	
-	9.0.4	-	Loss of fuel supply to consumers may result in a loss of power generation and propulsion for the ship.	Relevant for consumers with a single fuel supply. This hazard is mitigated by secondary fuel for DF ICE.
9.1	**9.1**	**Goal**	**Goal**	
		The goal of this chapter is to ensure the safe and reliable distribution of fuel to the consumers.	The goal of this chapter is to ensure the safe and reliable distribution of fuel to consumers.	
9.2	**9.2**	**Functional requirements**	**Functional requirements**	
9.2.1		This chapter is related to functional requirements in 3.2.1 to 3.2.6, 3.2.8 to 3.2.11 and 3.2.13 to 3.2.17 and 3.2.19. In particular, the following provisions apply.	This section is related to functional requirements in **3.2.1** to **3.2.6**, **3.2.9** to **3.2.13** and **3.2.17** to **3.2.21**. In particular, the following apply:	
9.2.2	9.2.1	The fuel supply system should be so arranged that the consequences of any release of fuel will be minimized.	The fuel supply system should be so arranged that the consequences of any fuel release will be minimized.	
9.2.3	9.2.2	The fuel supply system should be arranged to provide safe access for operation, maintenance, testing and inspection.	The fuel supply system should be arranged to provide safe access for operation, maintenance and inspection.	
9.2.4	9.2.3	The piping system for fuel transfer to the consumers should be designed in a way that a failure of one barrier cannot lead to a leak from the piping system into the surrounding area causing danger to the persons on board, the environment or the ship.	The piping system for fuel transfer to consumers should be designed so that a failure of one barrier cannot lead to a leak from the piping system into the surrounding area, posing a danger to persons on board, the environment, or the ship.	
9.2.5	9.2.4	Fuel lines should be installed and protected so as to minimize the risk of injury to personnel and damage to the ship in case of leakage.	Fuel piping systems should be installed and protected so as to minimize the risk of injury to personnel and damage to the ship in case of leakage.	The EMSA Guidance use the term “fuel piping systems” when referring to the complete system (ref definitions).
9.2.6	9.2.5	Piping systems supplying fuel to consumers should be designed to minimize the amount of hydrogen released after a leak has occurred.	Piping systems supplying fuel to consumers should be designed to minimize the amount of hydrogen released after a leak has occurred.	The EMSA Guidance includes the following technical provisions to support this functional requirement: ○ Minimize the use of high-pressure piping systems by applying pressure reduction as early as practically possible. ○ Use the minimum piping diameter and operational pressure possible to satisfy the system’s requirement for mass flow rate. ○ Segregate piping systems into shorter pipe segments using automatically operated valves controlled by the fuel safety system. ○ Arranging flow restrictors or excess flow valves in the piping system as close to the connection
9.3	**9.3**	**General hydrogen piping design and arrangement**	**General fuel piping design and arrangement**	

9.3.1	9.3.1	Fuel piping systems located in enclosed spaces should be arranged with secondary enclosures designed to safely contain leakages.	Fuel piping systems located in enclosed spaces should be arranged with secondary enclosures designed to safely contain leakages.	The EMSA Guidance recommend applying a secondary enclosure around all piping systems in enclosed spaces, as single-walled piping systems may create an explosion risk. Studies have shown that it is challenging to prevent the generation of an explosive atmosphere in enclosed spaces through dilution ventilation. The alternative of using an inert gas to make the atmosphere in the space non-flammable raises several design and operational issues: - An inert atmosphere prevents access for inspection and maintenance. Gas-freeing for entry would remove the primary safeguard that prevents an explosion. - Maintaining an inert atmosphere would require that ventilation arrangements be closed off to prevent the inert gas from escaping. This implies that the protected space is vulnerable to pressure increases due to leaks. A pressure relief system with sufficient capacity would have to be arranged to prevent damage due to pressure rise from rapidly evaporating LH2 or CH2. - Hydrogen can ignite with less oxygen than the ignition of natural gas would require (5% vs 12%). This would put stricter requirements on inert gas quality. The presence of ventilation systems could introduce air into the inert space. - A leakage of LH2 can cool down the space below the condensation temperature of nitrogen in seconds We have also concluded that it is difficult to categorically exclude the possibility of ignition through the certification of electrical equipment. As a result, the EMSA Guidance seeks to minimise the risk of hydrogen explosions in confined spaces by requiring secondary enclosures capable of safely containing any leaks that could occur from hydrogen piping systems in tank connection spaces, fuel preparation rooms, and other locations prone to hydrogen leaks. This arrangement is considered a prerequisite for accepting hydrogen storage in places other than on the open deck.
-	9.3.2	-	Fuel piping systems located on the open deck should be arranged with secondary enclosures designed to safely contain leakages.	The EMSA Guidance recommend applying a secondary enclosure around all piping systems also on open deck, as single-walled piping systems may create an explosion risk. A ‘critical cloud’ that can cause significant damage and harm to the ship and its systems if ignited, can form within seconds. Recent studies by DNV indicate that the build-up of a critical gas cloud can occur in just 5 seconds with leaks in the range of 0.1 kg/s. Traditional gas detectors are not likely to detect and stop leaks in time to prevent this. Achieving detector coverage on an open deck, where leakages can occur anywhere along the pipe routing, will further exacerbate this problem. The use of strategically mounted excess flow valves and restrictive orifices can be used

				to limit full-bore leakages. Orifices will not stop a leak, and excess flow valves require a significant increase in flow rate to close. Additionally, our study indicates low reliability of excess flow valves. Applying double barriers for compressed hydrogen piping systems would facilitate detection, prevent ignition, and prevent ignitable hydrogen concentration in confined or semi-enclosed spaces, as hydrogen released within the double barrier can be vented to a safe location. The same argument can be made for liquefied hydrogen systems, where the secondary barrier, in addition, would protect the ship structure against cryogenic damage.
9.3.2	-	Hydrogen piping systems should as far as practicable be joined by welding.	-	The EMSA Guidance makes IGF Code 7.3 applicable in Chapter 7, which states that: IGF 7.3.6.3 The piping system shall be joined by welding with a minimum of flange connections. Gaskets shall be protected against blow-out.
9.3.3	9.3.3	It should be possible to detect leakages in a fuel piping system and automatically isolate the leakage from the source.	Any leaks from fuel piping systems should be detectable and automatically isolated from the source of the fuel supply.	
9.3.4	-	It should be possible to automatically isolate the piping systems for fuel at the tank boundary.	-	The EMSA Guidance covers this provision in 9.7.3: 9.7.3 Fuel storage tank inlets and outlets shall be provided with remotely operated shut-off valves located as close to the tank as possible.
9.3.5	-	The arrangement and installation of fuel piping should provide the necessary flexibility to maintain the integrity of the piping system in the actual service situations, taking the potential for fatigue into account.	-	The EMSA Guidance makes IGF Code 7.3 applicable in Chapter 7, which states that: IGF 7.3.6.3 The arrangement and installation of fuel piping shall provide the necessary flexibility to maintain the integrity of the piping system in the actual service situations, taking the potential for fatigue into account.
9.3.6	-	Where tanks or piping are separated from the ship's structure by thermal insulation, provision should be made for electrically bonding to the ship's structure both the piping and the tanks. All gasketed pipe joints and hose connections should be electrically bonded.	-	The EMSA Guidance makes IGF Code 7.3 applicable in Chapter 7, which has the same provision in 7.3.1.2
-	9.3.4	-	Fuel piping systems should be designed to minimize the consequences of leakage by limiting the amount of fuel contained in the system to what is necessary for operation. This could be obtained by: - Using as small pipe dimensions as possible. - Keeping the operating pressure as low as possible by applying pressure reduction devices where practicable. - Providing automatically operated shut-down valves controlled by the safety system for pipe segmentation.	From D.3.2: Minimize system inventory. Piping systems supplying fuel to consumers should be designed to minimize the amount of hydrogen released after a leak has occurred by not using dimensions larger than necessary for proper system functioning and operating pressures higher than needed for sufficient mass flow of hydrogen. Reducing system inventory through segmentation, using as small dimensions as possible, and keeping as low pressure as possible at all times can decrease the amount of hydrogen released during

			The consequences of leakage may be further reduced by use of flow restrictors or excess flow valves.	a leak. However, segmentation may also increase leak frequency due to the additional connections and valves required.)
9.4	**9.4**	**Regulations on redundancy of fuel supply**	**Redundancy of fuel supply**	
9.4.1	9.4.1	For single fuel installations, the fuel supply system should be arranged with redundancy and segregation, so that a leakage in one system, or failure of one of the fuel supply essential auxiliaries, does not lead to an unacceptable loss of power. In the event of a leakage or failure, and in accordance with SOLAS regulation II-1/26.3, the Administration, having regard to overall safety considerations, may accept a partial reduction in propulsion capability from normal operation.	For single-fuel installations, the fuel supply system should be arranged with full redundancy and segregation all the way from the fuel tanks to the consumer so that leakage in one system does not result in an unacceptable loss of power.	The EMSA Guidance is a non-mandatory, advisory document in which references to how deviations are formally managed are not relevant.
9.4.2	9.4.2	For single fuel installations, the fuel storage should be divided between two or more tanks. The tanks should be arranged to provide redundancy in order to achieve the provisions of section 4.3.	For single-fuel installations, the fuel storage should be divided between two or more tanks. The tanks should be located in separate compartments.	The EMSA Guidance is aligned with the IGF Code Part A-1 text.
9.4.3	-	For type C tank only, one tank may be accepted if two completely separate tank connection spaces are installed for the one tank.	-	The EMSA Guidance does not recommend only one fuel tank for liquefied storage for single-fuel vessels. A vacuum loss may empty the tank in hours, irrespective of the TCS redundancy.
-	9.4.3	-	For dual-fuel installations, the storage capacity of the other fuel should be sufficient to provide the necessary redundancy in case of loss of hydrogen fuel supply.	The EMSA Guidance emphasizes the need for redundant fuel capacity for dual fuel installations.
9.5	**9.5**	**Fuel piping systems containing liquefied hydrogen and cold hydrogen vapour**	**Fuel piping systems for liquefied fuel**	
9.5.1	9.5.1	Fuel piping systems for liquefied hydrogen and cold hydrogen vapour should be arranged with secondary enclosures designed to provide insulation and safely contain leakages.	The fuel piping and its components containing liquefied fuel or cold hydrogen vapour should be provided with a secondary enclosure designed to provide insulation and safely contain leakages. Fully welded, open-ended fuel gas vent pipes routed through mechanically ventilated spaces do not need to be fitted with secondary enclosures but should be insulated to prevent air condensation.	The EMSA Guidance has general provisions for surface temperature, including insulation of cold vapour piping. The Guidance does not have recommendations for secondary enclosures around open-ended vent lines if they are fully welded and arranged in well-ventilated spaces.
9.5.2	9.5.2	The secondary enclosure should be made of a material that can withstand the pressure and temperature of a potential leak. Means of pressure relief led to the vent mast should be provided for the secondary enclosure.	The secondary enclosure should be made of a material that can withstand the pressure and temperature of a potential leak. Means of pressure relief, led to the vent mast, should be provided for the secondary enclosure.	
9.5.3	9.5.3	The outer surface of the secondary enclosures should in normal operation not cause condensation of air constituent gases and should be arranged for collection and drainage of such condensation, or equivalent solutions, in case of any single failure.	To protect against the ignition of leaked hydrogen and to provide insulation, the space between liquefied fuel piping systems and the secondary enclosure should be vacuumed.	The EMSA Guidance clearly states that vacuum should be provided for liquefied fuel piping secondary enclosures – both for insulation and protection against ignition of leaked hydrogen. Hence, air will not condensate on the surface in normal operation. Further, protection against condensation of air in case of any single failure is covered in section 5.11 of the Guidance.
9.5.4	-	A complete stress analysis, taking into account all the stresses due to the weight of pipes, including acceleration loads if significant, internal pressure, thermal contraction and loads induced by hog and sag of the ship should be carried out for each branch of the piping system.	-	The EMSA Guidance addresses this provision through a reference to IGF Code 7.3, which states that: IGF 7.3.4.5 When the design temperature is minus 110°C or colder, a complete stress analysis, taking into account all the

				stresses due to weight of pipes, including acceleration loads if significant, internal pressure, thermal contraction and loads induced by hog and sag of the ship shall be carried out for each branch of the piping system. Consequently, the IG provision is covered by the reference to the IGF Code.
9.5.5	-	Sections of hydrogen piping that can be isolated should be protected by a suitable pressure relief device venting to a safe location, to prevent pressure build-up from trapped hydrogen.	-	The EMSA Guidance addresses prevention of pressure build-up from trapped hydrogen through the reference in chapter 7 to IGF Code 7.3, which states that: 7.3.1.3 All pipelines or components which may be isolated in a liquid full condition shall be provided with relief valves.
9.6	**9.6**	**Fuel piping systems containing gaseous fuels**	**Fuel piping systems for gaseous fuel**	
9.6.1	9.6.1	The piping and its components containing gaseous hydrogen should be provided with: .1 an inerted secondary enclosure, such as a double-walled system; or .2 ventilated secondary enclosure, such as a double walled pipe, except the enclosures described in section 5.9, where the ventilation has sufficient capacity to prevent an explosion that can exceed the design pressure of the enclosure, to be demonstrated according to the provisions of chapters 12.3, 13 and 4.3.	The fuel piping and its components containing gaseous hydrogen should be provided with a secondary enclosure designed to safely contain leakages. To protect against the ignition of leaked hydrogen, the secondary enclosure around gaseous hydrogen piping systems should be inerted.	The EMSA Guidance has provisions for inerted secondary enclosures for gaseous fuel piping. The EMSA Guidance does not allow for ventilated secondary enclosures due to the following: The ventilation rate achievable in double-walled piping systems is insufficient to dilute hydrogen leaks below the Lower Explosive Limit (LEL). Example: inner pipe ø50mm, outer pipe ø60mm, length 10 m, 30 ac/hr Ventilation rate 0,07 litres per second to achieve 30 air changes per hour, which is sufficient to dilute a hydrogen leakage of **0,0035 litres per second**. To be effective, the ventilation rate would have to be orders of magnitude higher, which is not practically feasible. Additionally, the concept of dilution ventilation would not prevent the ignition of hydrogen at the leak point.
9.6.2	-	Single wall piping can be accepted for open deck installations subject to dispersion analysis, and explosion analysis if needed according to section 12.3 if an ignitable cloud which may affect adjacent structures or persons cannot be excluded.	-	The EMSA Guidance has provisions for secondary enclosures around fuel systems for gaseous hydrogen irrespective of location (to ease detection and shut-down, prevent uncontrolled dispersion of leaked hydrogen and provide the possibility for leading leakages to a safe area). Simulations indicate that safety actions will likely be insufficient to prevent the buildup of an ignitable cloud in the event of larger hydrogen leakages.
-	9.6.2	-	Secondary enclosures around fuel piping systems for gaseous hydrogen should be designed or arranged to prevent pressures in the annular space above the design capabilities of the piping system. Means of pressure relief leading to the vent mast should be provided for the secondary enclosure.	

-	9.6.3	-	Fully welded, open-ended fuel gas vent pipes led through mechanically ventilated spaces need not be arranged with secondary enclosures.	
-	9.6.4	-	Fuel piping systems for gaseous hydrogen, arranged in tank connection enclosures, need not be arranged with secondary enclosures.	
9.6.3	-	Fuel piping systems should be designed to minimize the size, pressure and duration of a leak. This should be obtained by: .1 keeping the operating pressure as low as possible by applying pressure reduction devices where practicable; and .2 providing automatically operated shut-down valves controlled by the safety system.	-	The EMSA Guidance includes this as a general provision in 9.3.2.
9.6.4	-	The consequences of leakage should be further reduced by use of flow restrictors or excess flow valves or similar devices.	-	The EMSA Guidance has this as a general provision in 9.3.2.
9.7	**9.7**	**Valve arrangements**	**Valve arrangements**	
9.7.1	9.7.1	Valves in the fuel piping system should be remotely operated to minimize personnel exposure. This does not apply to normally closed and locked valves not operated during normal service. Valves should be automatically operable when action is required by the safety system as per section 15.	Valves in the fuel piping system should be remotely operated to minimize personnel exposure. This does not apply to normally closed and locked valves not operated during normal service. Valves should be automatically operable when action is required by the safety system as per section 15.	
9.7.2	9.7.2	Valves should be easily accessible for inspection and maintenance.	Valves and their secondary enclosures should be easily accessible for inspection and maintenance.	The EMSA Guidance has provisions for secondary enclosures around all hydrogen fuel systems. Hence, the text stresses that the location of the valves and their secondary enclosures should provide access for inspection and maintenance of the valves.
-	9.7.3	-	Fuel storage tank inlets and outlets shall be provided with remotely operated shut-off valves located as close to the tank as possible.	
9.7.3	9.7.4	The main fuel supply line to each gas consumer or set of consumers should be equipped with a remotely operated stop valve and an automatically operated master gas fuel valve coupled in series. The valves should be situated in the part of the piping that is outside the machinery spaces containing gas consumers and placed as near as possible to the installation for heating the gas, if fitted. The master gas fuel valve should automatically cut off the gas supply when activated by the safety system as required in 15.2.2	The fuel supply line to each gas consumer or set of consumers should be equipped with a remotely operated stop valve and an automatically operated master gas fuel valve coupled in series or a combined remotely and automatically operated valve. The valves shall be situated in the part of the piping that is outside the machinery space containing gas consumers. The master gas fuel valve should automatically cut off the gas supply when activated by the safety system required in 15.2.2.	The EMSA Guidance includes the option of combining the remote and automatic operation in one valve to reduce the number of leakage points. This is in line with the requirement in the IGF Code Part A-1.
9.7.4	9.7.5	The gas supply line to each consumer should be provided with double-block-and-bleed valves. These valves should be arranged for automatic shutdown as given in section 15.	The gas supply line to each consumer should be provided with double-block-and-bleed valves. These valves should be arranged for automatic shutdown as given in Section 15.	
9.7.5	9.7.6	The two shut-off valves should be in series in the gas fuel pipe to the gas consuming equipment. The bleed valve should be in a pipe that vents to a safe location in the open air that portion of the gas fuel piping that is between the two valves in series.	The two shutoff valves should be in series in the gas fuel pipe to the gas-consuming equipment. The bleed valve should be in a pipe that vents to a safe location in the open air that portion of the gas fuel piping that is between the two valves in series	

9.7.6	9.7.7	The two shut-off valves should be of the fail-to-close type, while the bleed valve should be fail-to-open. Except in case of loss of operating power, the bleed valve should only remain open until the pressure is relieved and be kept closed to prevent ingress of air in the system. Means to detect a leakage in the stop valves should be arranged.	The two shut-off valves should be of the fail-to-close type, while the bleed valve should be fail-to-open. Except in case of loss of operating power, the bleed valve should only remain open until the pressure is relieved and be kept closed to prevent ingress of air in the system. Means to detect a leakage in the stop valves should be arranged.	
9.7.7	-	Notwithstanding 9.7.6, other means for prevention of ingress of air in the system when the bleed valve is operated, such as inerting, may be permitted.	-	
9.7.8	9.7.8	An alarm for faulty operation of the valves should be provided. In this context: block valves open and bleed valve open is an alarm condition, block valves closed and bleed valve closed is an alarm condition if leakage in the block valve is detected. Similarly, internal combustion engines stopped and block valves open is an alarm condition.	An alarm for faulty operation of the valves should be provided. In this context: - block valves open and bleed valve open is an alarm condition, - block valves closed and bleed valve closed is an alarm condition if leakage in the block valve is detected. - Similarly, gas consumers stopped and block valves open is an alarm condition.	
9.7.9	9.7.9	The double block and bleed valves should also be used for normal stop of internal combustion engines.	The double block and bleed valves should also be used for normal stop of internal combustion engines.	
9.7.10	9.7.10	When a leakage in the fuel system is detected by the safety system followed by automatic shutdown of the master gas fuel valve, the complete fuel system downstream of the master valve should be automatically de-pressurized and purged with inert gas.	When a leakage in the fuel system is detected by the safety system, followed by automatic shutdown of the master gas fuel valve, the complete fuel system downstream of the master valve should be automatically de-pressurized and purged with inert gas.	
9.7.11	9.7.11	There should be one manually operated shutdown valve in the gas supply line to each consumer upstream of the double block and bleed valves to assure safe isolation during maintenance on the engine.	There should be one manually operated shutdown valve in the gas supply line to each consumer upstream of the double block and bleed valves to ensure safe isolation during maintenance on the consumer.	
9.7.12	9.7.12	For single-engine installations and multi-engine installations, where a separate master valve is provided for each engine, the master gas fuel valve and the double block and bleed valve functions can be combined.	For single-engine installations and multi-engine installations, where a separate master valve is provided for each engine, the master gas fuel valve and the double block and bleed valve functions can be combined.	
9.7.13	9.7.13	The automatic master fuel valve(s) should be operable from safe locations on escape routes inside a machinery space containing a gas consumer, the engine control room, if applicable; outside the machinery space, and from the navigation bridge.	The master fuel valve(s) should be operable from safe locations on escape routes inside a machinery space containing a gas consumer, the engine control room, if applicable; outside the machinery space, and from the navigation bridge.	
9.7.14	9.7.14	All automatic and remotely operated valves should be provided with indications for open and closed valve positions at the location where the valves are remotely operated.	All automatic and remotely operated valves should be provided with indications for open and closed valve positions at the location where the valves are remotely operated.	

Draft IG	EMSA Guidance	IMO Draft Interim Guidelines for the safety of ships using hydrogen as fuel (CCC 11/WP.4 Annex 2)	EMSA Guidance for hydrogen-fuelled ships	Justification and comments
10	**10**	**Power generation including propulsion and other fuel consumers**	**PROPULSION AND POWER GENERATION**	

-	**10.0**	-	**Hazards**	
-	10.0.1	-	Hydrogen may ignite in engine components, systems, and exhaust arrangements, resulting in a fire, deflagration, or detonation.	
-	10.0.2	-	Hydrogen may leak into auxiliary systems and crankcases, causing deflagration or detonation	
10.1	**10.1**	**Goal**	**Goal**	
10.1.1		The goal of this chapter is to provide safe and reliable delivery of mechanical, electrical or thermal energy.	The goal of this chapter is to provide safe and reliable delivery of mechanical, electrical or thermal energy.	
10.2	**10.2**	**Functional requirements**	**Functional requirements**	
10.2.1		This chapter is related to functional requirements in 3.2.1, 3.2.3, 3.2.11, 3.2.13, and 3.2.16 to 3.2.19. In particular, the following provisions apply:	This section is related to functional requirements in **3.2.1** to **3.2.3**, **3.2.6**, **3.2.9** to **3.2.11** and **3.2.19**. In particular, the following apply:	
10.2.2	10.2.1	The exhaust systems should be configured to prevent any accumulation of un-burnt gaseous fuel.	The exhaust systems should be configured to prevent any accumulation of unburnt gaseous fuel.	
10.2.3	10.2.2	Engine components or systems containing or likely to contain ignitable hydrogen should be designed with the strength to withstand the worst case overpressure due to ignited gas leaks.	Engine components or systems containing or likely to contain ignitable hydrogen should be designed with the strength to withstand the worst-case overpressure due to ignited gas leaks.	
10.2.4	10.2.3	All fuel consumers should have separate exhaust systems. This does not apply to fuel cell power installations.	All fuel consumers should have separate exhaust systems.	The EMSA Guidance clarifies that it does not include provisions for fuel cell power installations in section 5.5.
10.2.5	10.2.4	Hydrogen consumers should be arranged to prevent hydrogen from leaking into auxiliary systems.	Hydrogen consumers should be arranged to prevent hydrogen from leaking into auxiliary systems.	
10.3	**10.3**	**Provisions for internal combustion engines of piston type**	**Internal combustion engines of piston type**	
10.3.1	10.3.1	Unless expressly provided otherwise, the requirements of section 10.3 of the IGF Code should apply to ships using hydrogen as fuel.	Unless expressly provided otherwise, the requirements of section 10.3 of the IGF Code should apply to ships using hydrogen as fuel.	
10.3.2	10.3.2	The arrangements for the purging of the engine and engine exhaust gas system are to be considered in the safety concept for the engine.	The arrangements for the purging of the engine and engine exhaust gas system are to be considered in the safety concept for the engine.	
10.3.3	10.3.3	The safety concept should specifically demonstrate safe fuel supply changeover due to reasonably foreseeable failure modes (e.g. overspeed, gas leakage).	The safety concept should specifically demonstrate safe fuel supply changeover due to reasonably foreseeable failure modes (e.g. overspeed, gas leakage).	
10.4	**10.4**	**Provisions for gas consumers other than internal combustion engines of piston type**	**Provisions for gas consumers other than internal combustion engines of piston type**	
10.4.1	10.4.1	Fuel cells should be arranged in accordance with the *Interim guidelines for the safety of ships using fuel cell power installations* (MSC.1/Circ.1647).	Fuel cells should be arranged in accordance with the Interim guidelines for the safety of ships using fuel cell power installations (MSC.1/Circ.1647).	
10.4.2	-	Other gas consumers, such as main and auxiliary boilers or gas turbines, may be permitted provided that the provisions of section 2.3 are met to the satisfaction of the Administration.	-	The EMSA Guidance is a non-mandatory, advisory document in which references to IMO alternative design approval are not relevant.
10.5	**10.5**	**Provisions for fuel reforming equipment**	**Fuel reforming equipment**	

10.5.1	10.5.1	The primary fuel system should be designed and arranged in accordance with the requirements or provisions of existing Codes or Interim guidelines covering the primary fuel. Other primary fuels may be permitted, provided that the provisions of section 2.3 are met to the satisfaction of the Administration.	The fuel containment and piping systems for the primary fuel being reformed should be designed and arranged in accordance with the requirements applicable to that fuel.	The EMSA Guidance includes the following definition: Primary fuel is the fuel supplied to the fuel reformer (e.g. ammonia, methanol, LNG, LOHC, etc.) that is reformed to hydrogen in the fuel reformer. The EMSA Guidance is a non-mandatory, advisory document in which references to IMO alternative design approval are not relevant.
10.5.2	10.5.2	Fuel-reforming equipment for processing gaseous or liquid primary fuels to reformed hydrogen for use in the fuel cells should be arranged in accordance with the *Interim guidelines for the safety of ships using fuel cell power installations* (MSC.1/Circ.1647)	Fuel-reforming equipment for converting primary fuels into hydrogen, along with the associated piping systems containing hydrogen, should be designed and arranged in accordance with the provisions outlined in this Guidance. Reforming equipment and piping systems falling under the scope of Interim guidelines for the safety of ships using fuel cell power installations (MSC.1/Circ.1647) should be designed and arranged in accordance with the provisions therein.	
10.5.3	-	Fuel-reforming equipment for processing gaseous or liquid primary fuels to reformed hydrogen for use in internal combustion engines may be permitted provided that the provisions of section 2.3 are met. The approval of such arrangements should as a minimum take into account the hazards and topics listed in provision 4.2.2.	-	The EMSA Guidance is a non-mandatory, advisory document in which references to IMO alternative design approval are not relevant.

Draft IG	EMSA Guidance	IMO Draft Interim Guidelines for the safety of ships using hydrogen as fuel (CCC 11/WP.4 Annex 2)	EMSA Guidance for hydrogen-fuelled ships	Justification and comments
11	**11**	**Fire Safety**	**FIRE SAFETY**	
-	**11.0**	-	**Hazards**	
-	11.0.1	-	A fire unrelated to the fuel system may cause damage to fuel containment and piping systems.	
-	11.0.2	-	A hydrogen jet fire may impinge on other parts of the hydrogen system, causing an escalation.	
-	11.0.3	-	If hydrogen is discharged through the vent mast and ignited, the resulting jet fire may generate dangerous heat radiation levels.	
-	11.0.4	-	When a hydrogen fire is attempted to be extinguished without first stopping the leakage, an accumulation of unburned hydrogen may re-ignite and cause an explosion.	
-	11.0.5	-	Firewater directed towards the outlet from the vent mast may cause icing and prevent the proper functioning of pressure relief systems for fuel containment systems for liquefied hydrogen.	
-	11.0.6	-	Hydrogen discharged through ventilation ducts may ignite and flashback to the space where the leakage occurred, causing a deflagration.	
11.1	**11.1**	**Goal**	**Goal**	
		The goal of this chapter is to provide for fire protection, detection and fighting for all system components related to the storage, conditioning, transfer and use of hydrogen as fuel.	The goal of this chapter is to provide for fire protection, detection and fighting for all system components related to the storage, conditioning, transfer and use of hydrogen as ship fuel.	
11.2	**11.2**	**Functional Requirements**	**Functional Requirements**	
11.2.1		This chapter is related to functional requirements in 3.2.2, 3.2.4, 3.2.5, 3.2.6, 3.2.7, 3.2.12, 3.2.14, 3.2.15, 3.2.17 and 3.2.19.	This section is related to functional requirements in **3.2.1**, **3.2.2**, **3.2.12** and **3.2.14** In particular, the following apply:	
11.2.2	11.2.1	Fuel containment systems should be located and arranged to minimize the risk of excessive heat input from a fire.	Fuel containment systems should be located and arranged to minimize the risk of excessive heat input from a fire.	The EMSA Guidance considers that the principles outlined in the IGF Code to safeguard LNG systems from external fire damage are also applicable to hydrogen systems. However, the following need to be further investigated: - High-pressure tanks made of composite materials are commonly used to store CH2, as they are lightweight. It is necessary to analyse and understand the behaviour of these tanks in fire scenarios to determine if the current fire protection regulations outlined in the IGF Code provide adequate protection for this type of tank. - Passive fire protection suitability for hydrogen needs to be investigated (higher heat loads, burning velocities). The A-60 standard is not necessarily suitable for hydrogen fires.
11.2.3	11.2.2	It should be possible to cool down fuel containment systems on open decks in a fire scenario.	It should be possible to cool down fuel containment systems on open decks in a fire scenario.	▪

11.2.4	11.2.3	It should be possible to detect a hydrogen fire, recognizing the potential for invisible hydrogen flames.	It should be possible to detect a hydrogen fire, recognizing the potential for invisible hydrogen flames.	
11.2.5	11.2.4	It should be possible to extinguish a fire caused by the hydrogen system.	It should be possible to extinguish a fire caused by the hydrogen system.	
11.2.6	11.2.5	Fixed fire-extinguishing systems should be installed having due regard to the fire growth potential of the protected spaces;	Fixed fire-extinguishing systems should be installed having due regard to the fire growth potential of the protected spaces;	
11.2.7	11.2.6	The ignition of operational and accidental fuel releases should not expose structural elements, equipment and people onboard to unacceptable heat radiation levels.	The ignition of operational or accidental fuel releases should not expose structural elements, equipment and people onboard to unacceptable heat radiation levels.	(From EMSA D.1 Mapping safety risks for hydrogen-fuelled ships If hydrogen discharged to the open deck is ignited, the consequences for the ship with respect to pressure effects and heat load should be manageable. This includes scenarios with flash fire, jet fire, and deflagrations. Deflagration-to-detonation and detonation should be avoided by design. Manageable implies that heat loads and pressure shocks should be at a level that allows people to evacuate the area without injuries and that access to muster stations, escape routes, and life-saving appliances is not restricted.)
11.2.8	11.2.7	Isolation devices should be positioned in fuel systems to stop the hydrogen flow in case of a leak-fuelled fire.	Isolation devices should be positioned in fuel systems to stop the hydrogen flow in case of a leak-fuelled fire.	
11.3	**11.3**	**Fire protection**	**Fire protection**	The EMSA Guidance provides specific provisions for fire protection, recognising that not all requirements in 11.3 of the IGF Code Part-A1 are applicable to hydrogen: - Fuel preparation rooms are not recommended below deck/in enclosed spaces (IGF 11.3.1 not applicable) - ESD-protected machinery spaces are not recommended (IGF 11.3.7 not applicable) - The type of fire insulation for hydrogen fires must be investigated. Hydrogen fuel tanks should not be arranged in areas intended for packaged goods.
11.3.1	-	Unless expressly provided otherwise, the requirements of section 11.3 of the IGF Code should apply to ships using hydrogen as fuel.	-	The EMSA Guidance provide specific provisions for fire protection and is not referring to the IGF Code.
11.3.2	11.3.1	Fire insulation should be appropriate for hydrogen fires and the identified fire scenarios. Fire protection for any boundary facing vent mast outlets should also be considered, taking into account the heat radiation analysis specified in 6.7.3.	Fire insulation should be appropriate for hydrogen fires and the identified fire scenarios. Fire protection for any boundary facing vent mast outlets should also be considered, taking into account the heat radiation analysis specified in 6.7.3.	
-	11.3.2	-	Any boundary of accommodation spaces, service spaces, control stations, escape routes and machinery spaces, facing fuel tanks on open deck, should be shielded by suitable fire insulation. The fire insulation should extend up to the underside of the navigation bridge deck.	The EMSA Guidance have functional provisions for passive fire protection and does not refer to the A-60 standard applied in the IGF Code for natural gas fires. The suitability of applied passive fire protection needs to be investigated for protection against hydrogen fires (higher heat loads, burning velocities).
-	11.3.3	-	The space containing the fuel containment system should be separated from the machinery spaces of category A or other rooms with high fire risks. The separation should be done by a cofferdam of at least 900 mm with insulation of A-60 class.	The EMSA Guidance apply the fire protection strategy of the IGF Code for natural gas, as the fires that the fuel containment systems should be protected against are "generic" ship fires, not related to the combustion of hydrogen.

			When determining the insulation of the space containing the fuel containment system from other spaces with lower fire risks, the fuel containment system should be considered as a machinery space of category A, in accordance with SOLAS regulation II-2/9. The fuel storage hold space may be considered as a cofferdam provided that: .1 The type C tank is not located directly above machinery spaces of category A or other rooms with high fire risk; and .2 The minimum distance to the A-60 boundary from the outer shell of the type C tank or the boundary of the tank connection space, if any, is not less than 900 mm.	The EMSA Guidance applies to the below-deck location of vacuum-insulated type C tanks, with tank connection spaces and secondary enclosures surrounding all tank connections, pipes, and components in enclosed spaces, provided that these are located in a dedicated fuel storage hold space.
-	11.3.4	-	The fuel storage hold space should not be used for machinery or equipment that may pose a fire risk.	
-	11.3.5	-	Fuel storage and preparation equipment on an open deck, located directly above machinery spaces of category A or other rooms with a high fire risk, should be shielded by a cofferdam of at least 900 mm with insulation of A-60 class. When determining the insulation of the fuel storage areas from other spaces with lower fire risks, the fuel storage area is to be regarded as a machinery space of category A.	The EMSA Guidance recommends that fuel tanks and fuel preparation equipment located on open deck should be shielded from fire loads from, e.g. machinery spaces of category A.
-	11.3.6	-	The bunkering station should be separated from other spaces by suitable passive fire insulation, taking into consideration the fire risk associated with each space.	Rephrased in the EMSA Guidance to simplify and clarify the provision. Passive fire protection suitability for hydrogen needs to be investigated (higher heat loads, burning velocities).
11.4	**11.4**	**Fire extinguishing**	**Fire extinguishing**	
11.4.1	11.4.1	Hydrogen fire-extinguishing should be based on the isolation and shut down of hydrogen supply to the fire by automatic action by the hydrogen safety system.	Hydrogen fire-extinguishing should be based on the isolation and shut down of the hydrogen supply to the fire by automatic action by the fuel safety system.	
11.4.2	11.4.2	The hydrogen safety system, should ensure the safe isolation of the relevant hydrogen source of release, i.e. shutdown of tank valves, master gas fuel valves, bunker connection valve and isolation valves, before activating any fire-extinguishing method.	The fuel safety system should ensure the safe isolation of the relevant hydrogen source of release, i.e. shutdown of tank valves, master gas fuel valves, bunker connection valve and isolation valves, before activating any fire-extinguishing method.	
11.4.3	11.4.3	Fire-extinguishing system for secondary fires caused by the hydrogen fire should adequately consider the potential fire loads involved including the credible fire scenarios identified from the holistic risk assessment. The fixed fire-extinguishing system medium, and concentration/application rate, including the possible use of local application systems as required by SOLAS, should be considered and documented suitable for extinguishing and control of the secondary fire as relevant, and effective use on naturally ventilated open deck if applicable.	Fire-extinguishing systems for secondary fires caused by hydrogen fires should adequately consider the potential fire loads involved, including credible fire scenarios identified from the risk assessment. The fixed fire-extinguishing system's medium and concentration/application rate, including the possible use of local application systems as required by SOLAS, should be considered and documented as suitable for extinguishing and controlling the secondary fire as relevant, and for effective use on naturally ventilated open decks if applicable.	
-	**11.5**	-	**Fire main**	The EMSA Guidance includes provisions for the fire main from the IGF Code.

-	11.5.1	-	If the fire main supplies water spray cooling systems, the fire pump capacity and pressure should be sufficient to serve both systems simultaneously.	The EMSA Guidance is rephrased compared to the IGF text to clarify/simplify.
-	11.5.2	-	When fuel storage tanks are located on the open deck, isolating valves shall be fitted in the fire main in order to isolate damaged sections of the fire main. Isolation of a section of the fire main should not deprive the fire line ahead of the isolated section of the supply of water.	
11.5	**11.6**	**Provisions for water spray cooling systems**	**Water spray cooling systems**	The EMSA Guidance has been revised from IGF to clarify the intention of the water spray cooling system.
11.5.1	11.6.1	A water spray cooling system should be installed to cool down fuel containment systems on the open deck in case of a fire.	A water spray cooling system should be installed to cool fuel containment systems on the open deck in the event of a fire.	
11.5.2	11.6.2	The water spray cooling system should also provide cooling to surfaces being exposed to heat radiation from sustained hydrogen fires from the vent mast opening.	The water spray cooling system should also provide cooling to surfaces exposed to heat radiation from sustained hydrogen fires from the vent mast opening.	
11.5.3	11.6.3	The water spray cooling system should have an application rate of 10 L/min/m2 for horizontal projected surfaces and 4 l/min/m2 for vertical surfaces.	The water spray cooling system should have an application rate of 10 l/min/m2 for horizontal projected surfaces and 4 l/min/m2 for vertical surfaces.	
11.5.4	11.6.4	The capacity of the water spray pump should be sufficient to deliver the required amount of water to the hydraulically most demanding area to be protected.	The capacity of the water spray pump should be sufficient to deliver the required amount of water to the hydraulically most demanding area to be protected.	
11.5.5	11.6.5	If the water spray system is not part of the fire main system, a connection to the ship's fire main through a stop valve should be provided.	If the water spray system is not part of the fire main system, a connection to the ship's fire main through a stop valve should be provided.	
11.5.6	11.6.6	The remote start for the pumps that supply the water spray system and the remote operation valves to the system should be positioned in a readily accessible location that is unlikely to be rendered inaccessible in the event of a fire in the protected areas.	The remote start for the pumps that supply the water spray system and the remote operation valves to the system shall be positioned in a readily accessible location that is unlikely to be rendered inaccessible in the event of a fire in the protected areas.	
11.5.7	11.6.7	The nozzles should be of an approved full-bore type, and they should be arranged to ensure an effective distribution of water throughout the area being protected.	The nozzles should be of an approved full-bore type, and they shall be arranged to ensure an effective distribution of water throughout the area being protected.	
11.5.8	11.6.8	If a water spray system is installed for cooling and fire prevention for exposed parts of fuel tanks located on open deck this system should be designed not to interfere with the function of other hydrogen safety systems e.g. heat radiation monitoring (such as temperature activated safety relief systems).	The function of temperature-actuated hydrogen safety relief systems should be designed and arranged so as not to be affected by the release of the water spray cooling system.	The EMSA Guidance does not include any limitations on coverage of compressed hydrogen systems, as the cooling of particularly composite storage tanks is considered essential in a fire scenario. Any thermal release devices should be designed and/or arranged to function with the water spray system in operation.
11.5.9	11.6.9	For liquefied hydrogen systems, solidification of water caused by the water spray system contacting low-temperature areas of the pressure relief system including pressure relief system outlet(s) should be assessed. Water should not be sprayed into vent masts and freeze pressure relief valves.	For liquefied hydrogen systems, the solidification of water resulting from the water spray system coming into contact with low-temperature areas of the pressure relief system, including the outlet(s), should be evaluated. Water should not be sprayed into vent masts or freeze pressure relief valves.	
11.5.10	11.6.10	If deemed necessary by the risk assessment, water spray protection should be provided to protect any boundary of accommodation spaces, service spaces, control stations, machinery spaces, and escape routes, embarkation stations and	If deemed necessary by the risk assessment, water spray protection should be provided to enable cooling of any boundary of accommodation spaces, service spaces, control stations, machinery spaces, and escape routes, as well as embarkation	

		survival craft facing fuel tanks and fuel equipment on open deck, in addition to fuel arrangement and equipment on open deck.	stations and survival craft facing fuel tanks and fuel equipment on open deck.	
11.6	**11.7**	**Fire detection and fire alarm systems**	**Fire detection and fire alarm systems**	
11.6.1	11.7.1	A fixed fire detection and fire alarm system complying with the Fire Safety Systems Code should be provided for the fuel storage hold spaces and the ventilation trunk for fuel containment system below deck, and for all other rooms of the fuel gas system where fire cannot be excluded.	A fixed fire detection and fire alarm system complying with the Fire Safety Systems Code should be provided.	
11.6.2	11.7.2	Smoke detectors alone should not be considered sufficient for rapid detection of a fire.	Smoke detectors alone should not be considered sufficient for the rapid detection of a hydrogen fire.	
-	**11.8**	-	**Fire Risk Analysis**	The EMSA Guidance provisions specify limitations on fire consequences in 4.3. This section includes provisions for verifying that fire consequences due to foreseeable events remain within the limitations specified in 4.3.1.
-	11.8.1	-	A fire risk analysis should be conducted to verify that the limitations of fire consequences listed in 4.3.1 and 6.7.8 are not exceeded.	
-	11.8.2	-	All reasonably foreseeable operational and failure scenarios associated with the hydrogen fuel system should be considered in the fire risk analysis.	
-	11.8.3	-	For fuel containment and piping systems containing liquefied hydrogen, the following scenarios should be considered at a minimum: .5 Release of hydrogen through the tank vent system due to loss of insulation, a tank pressure exceeding the set pressure of tank safety valves, or through a faulty tank safety valve. .6 Release of hydrogen through the vents from secondary enclosures due to leaks in the fuel piping system. .7 Release of hydrogen through the vents from fuel piping systems as a result of heating trapped volumes of hydrogen. .8 Release of hydrogen after unintended events during bunkering.	
-	11.8.4	-	For fuel containment and piping systems containing compressed hydrogen, the following scenarios should be considered at a minimum: .6 Release of hydrogen through the tank vent system due to the opening of automatic pressure relief. .7 Release of hydrogen through the tank vent system due to the activation of manual remote pressure relief devices, assuming simultaneous release of all connected tanks.	

			.8 Release of hydrogen through vents from secondary enclosures as a result of leaks from the fuel piping system. .9 Release of hydrogen through vents from tank connection enclosures due to leaks from the piping system. .10 Release of hydrogen caused by unintended events during bunkering.	
-	11.8.5	-	The fire risk analysis should include, at a minimum, the following information for the scenarios being assessed: .7 The cause of the release of hydrogen. .8 The process conditions for the releasing system (temperature, pressure, phase, etc.). .9 The location of the release. .10 Justification of the mass flow, observing the minimum leak size values in 12.3.6. .11 Assumed release duration, considering detection methods and their reliability, available shut-down arrangements and amount of fuel contained in the system. .12 Ambient conditions, geometry and other factors in the area of release which may affect the consequences of an ignition.	

Draft IG	EMSA Guidance	IMO Draft Interim Guidelines for the safety of ships using hydrogen as fuel (CCC 11/WP.4 Annex 2)	EMSA Guidance for hydrogen-fuelled ships	Justification and comments
12	**12**	**Explosion Prevention**	**EXPLOSION PREVENTION**	
-	**12.0**	-	**Hazards**	
-	12.01	-	A hydrogen leak or release may ignite, resulting in jet fire, deflagration or detonation.	
-	12.02	-	Electrical installations may be ignition sources in a hydrogen leak or release scenario.	
-	12.0.3	-	Hydrogen may ignite due to other external ignition mechanisms or self-ignition in a hydrogen leak or release scenario.	Fires and explosions have occurred in various components of hydrogen systems due to various ignition sources. Ignition sources have included mechanical sparks from rapidly closing valves, electrostatic discharges in ungrounded particulate filters, sparks from electrical equipment, welding and cutting operations, catalyst particles, and lightning strikes near the vent stack. In some situations, such as when hydrogen is suddenly released from a high-pressure system, it may be challenging to determine the exact source of the energy (ISO, 2015) (NASA, 1997).
12.1	**12.1**	**Goal**	**Goal**	

		The goal of this chapter is to provide for the prevention of explosions and for the limitation of effects from explosion.	The goal of this chapter is to provide for the prevention of explosions and for the limitation of effects from explosion.	
12.2	**12.2**	**Functional requirements**	**Functional requirements**	
12.2.1		This chapter is related to functional requirements in 3.2.2 to 3.2.5, 3.2.6, 3.2.7, 3.2.8, 3.2.12 to 3.2.14 and 3.2.17. In particular the following apply:	This section is related to functional requirements in **3.2.1** to **3.2.5** and **3.2.8**. In particular, the following apply:	
12.2.2	12.2.1	The probability and consequence of explosions should be reduced to a minimum by: .1 reducing number of sources of ignition; .2 reducing the probability of formation of ignitable mixtures; .3 optimizing layout and design to limit explosion severity and consequences; and .4 minimizing segment volumes that can leak, maximum leak rates, and duration of leak.	The probability and consequence of explosions resulting from hydrogen leaks or releases should be reduced to a minimum by: .5 reducing the number of sources of ignition to a minimum; .6 reducing the probability of formation of ignitable mixtures to a minimum; .7 optimizing layout and design to limit explosion severity and consequences; and .8 minimizing segment volumes, leak rates, and the leak duration.	The EMSA Guidance emphasises that the number of ignition sources and the probability of forming ignitable mixtures should be minimised to reduce the likelihood and consequences of an explosion to a minimum.
-	12.2.2	-	Areas where an explosive gas atmosphere may occur should be classified to facilitate the selection of suitable electrical equipment for these areas.	
12.3	**12.3**	**Explosion risk analysis**	**Explosion risk analysis**	
12.3.1	12.3.1	An explosion risk analysis (ERA) of the ship should be carried out to evaluate the risks of explosions. The objective of the analysis is to inform the suitability of the design and arrangement with respect to the likelihood and consequences of hydrogen explosions to humans, equipment and structure as listed in 4.3.	An explosion risk analysis should be conducted to verify that the limitations of explosion consequences listed in Section 4.3.1 are not exceeded.	The EMSA Guidance emphasises that the purpose of the explosion risk analysis is to verify that the limitations on explosion consequences in Section 4.3 are not exceeded. Section 4.3 does not specify a provision for the likelihood of explosions; instead, it stipulates that the consequences of explosions should not exceed certain limitations.
12.3.2	12.3.2	All reasonably foreseeable operational and failure scenarios associated with the hydrogen fuel system should be considered in the ERA. This should include normal operation, start-up, normal shutdown, non-use and emergency shutdown of the fuel-gas system, taking into account ship operations (e.g. under way, under way restricted waters, manoeuvring, alongside, maintenance/inspection, etc.).	All reasonably foreseeable operational and failure scenarios associated with the hydrogen fuel system should be considered in the analysis of explosion risk.	The EMSA Guidance acknowledges that applying secondary enclosures around leak points does not eliminate the risk of explosions from hydrogen releases through tank and system vents or leakages during bunkering, where providing double barriers to protect the bunkering manifold connection is a challenge. Operational scenarios to be considered in the risk analysis are specified in sections 12.3.3 and 12.3.4 of the EMSA Guidance.
12.3.2.1	12.3.3	For systems fully protected by inerted and/or vacuum secondary enclosures, the explosion risk analysis should consider, as a minimum, the following reasonably foreseeable scenarios: .1 release from liquefied hydrogen storage through the tank vent system due to loss of insulation; .2 release from compressed hydrogen storage through the tank vent system due to the need for depressurization; .3 release of hydrogen due to leakages into enclosures from a separate vent outlet than tank vent system; and .4 release of hydrogen due to unintended events during bunkering.	For fuel containment and piping systems containing liquefied hydrogen, the following scenarios should be considered at a minimum: .5 Release of hydrogen through the tank vent system due to loss of insulation, a tank pressure exceeding the set pressure of tank safety valves, or through a faulty tank safety valve. .6 Release of hydrogen through the vents from secondary enclosures due to leaks in the fuel piping system.	The EMSA Guidance clarifies the scenarios that should be considered as a minimum. The EMSA Guidance defines additional scenarios that can lead to hydrogen release and should be considered • Tank pressure exceeding the set point of the tank safety valve • A faulty tank safety valve Scenarios related to liquefied hydrogen and compressed hydrogen are split into two paragraphs.

			.7 Release of hydrogen through the vents from fuel piping systems as a result of heating trapped volumes of hydrogen. .8 Release of hydrogen due to unintended events during bunkering.	
-	12.3.4	-	For fuel containment and piping systems containing compressed hydrogen, the following scenarios should be considered at a minimum: .6 Release of hydrogen through the tank vent system due to the opening of automatic pressure relief. .7 Release of hydrogen through the tank vent system due to the activation of manual remote pressure relief devices, assuming simultaneous release of all connected tanks. .8 Release of hydrogen through vents from secondary enclosures as a result of leaks from the fuel piping system. .9 Release of hydrogen through vents from tank connection enclosures due to leaks from the piping system. .10 Release of hydrogen caused by unintended events during bunkering.	
12.3.2.2	-	In addition, for systems designed with single walled fuel piping, release(s) due to the reasonably foreseeable leakage scenario(s) should be included.	-	The EMSA Guidance recommends secondary enclosures around all piping, i.e. no single-walled fuel piping. It is recognised that allowing for systems that can leak into a non-inert atmosphere in open air or in enclosed spaces will require individual assessments with respect to explosion risk. The result of such an analysis will depend on a number of assumptions, as illustrated in IG 12.3.3. Consequently, the results will have a high degree of uncertainty, compounded by the uncertainty inherent in each assumption. Basing ship design on this type of analysis will reduce the predictability of design acceptance.
12.3.2.3	-	In addition, for systems designed with ventilated double wall piping, the release due to the reasonably foreseeable leakage scenario(s) in the annular space should be included, including release from vent outlet if relevant.	-	The EMSA Guidance recommends inerted or vacuum-filled secondary enclosures, i.e. no ventilated double-wall piping. See comment above.
12.3.3	12.3.5	The ERA should provide, as a minimum, the following information for the scenarios being evaluated: <u>.1 initiating hazardous event causing the leak;</u>	Explosion risk analysis .1The explosion risk analysis should include, at a minimum, the following information for the scenarios being assessed:	The EMSA Guidance is amended to provide further clarity to the information to be included in the explosion risk analysis.

		.2 process conditions (e.g. temperature, pressure, etc.). .3 leakage location; .4 leak size (e.g. geometry, coefficient of discharge, etc.); .5 leakage duration; .6 phase (i.e. gas, liquified, two-phase); .7 leak orientation (e.g. vertical, vertical down, etc.); .8 ignition mechanisms and characteristics (timing/location); and .9 space/area ventilation conditions.	.9 The cause of the release of hydrogen. .10 The process conditions for the releasing system (temperature, pressure, phase, etc.). .11 The location and direction of the leak or release. .12 Justification of the mass flow, observing the minimum leak size values in 12.3.6. .13 Assumed release duration, considering detection methods and their reliability, available shut-down arrangements and amount of fuel contained in the system. .14 Timing and location of ignition, justifying any deviations from a worst-case scenario. .15 Ambient conditions, geometry, and other factors in the area affected by the release that may influence the consequences of an ignition. .16 The operational modes of the vessel included in the analysis. .2 The results of the explosion risk analysis should include: .1 The cloud sizes that are obtained from the leak and dispersion analysis. .2 The explosion pressures that are obtained from explosion analysis. .3 Tolerance levels for damage and pressure levels should also be given, e.g. acceptable pressure levels on walls, and fatality levels on personnel outdoors.	When an explosion risk analysis is conducted, it encompasses both frequency and consequence assessments, and the combination is used to determine the risk levels. The outcome of an ERA is a cloud size exceedance curve and a pressure exceedance curve. This curve can be used to decide the design pressure and indicate which scenarios contribute to the risk. It can also be employed to identify risk drivers and give advice on improvements. 12.3.5.1.5: An evaluation of the reliability of the entire safety system, including gas detection, shutdown, and blowdown systems, should be included. If the reliability is low and the failure frequency is high, the leak duration should also include scenarios where the shutdown is not working as intended. 12.3.5.1.7: a. Total volume of the area where the hydrogen equipment is located. The area is normally segregated from other areas using bulkheads, blast walls and roofs/decks with some openings, and/or separation distance to other areas. The total volume is therefore defined by these physical barriers, where gas can be accumulated inside. If this volume exceeds a certain threshold and the area is sufficiently confined and congested, detonation may potentially occur. b. Congestion level in the area should be shown in a figure and described. The congestion level is defined by several factors, including the distance between storage cylinders and pipes, the total volume of the congested area, and the overall degree of blocking. These factors help quantify the congestion level. c. Ventilation concept in the area, natural ventilation or mechanical; drawings of weather and wave protecting bulkheads and roofs, if there are smaller volumes with H2 equipment that have their own cabinet that is either naturally or mechanically ventilated, it should be described. Each such area needs a separate analysis. d. Description of confinement and the venting capacity in the area in case of an explosion. To avoid pressure buildup due to confinement, a certain degree of opening around the hydrogen equipment is needed. e. Explosion design loads that are applied to walls, decks, and piping. If decks and walls are reinforced to withstand an explosion, this reinforcement should be related to a design load determined by the explosion risk analysis. Piping and equipment should be designed with a blast drag load that is also obtained from the explosion risk analysis.
12.3.4	12.3.6	The following leakage scenarios, at a minimum, should be taken into account as an input to the ERA in 12.3.1:	The following leakage sizes should be considered minimum values in the explosion and fire risk analyses:	The EMSA Guidance does not refer to recognized standards regarding leak sizes to stress that the table values are minimum values. E.g., IEC 60079-10 does not account for accidental

<table>
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<tr><td>Component</td><td>Leakage size to be considered</td></tr>
<tr><td>Pipe</td><td>$0,01D^2$ (mm^2) for D ≤ 100 mm, 100 mm^2 for D >100 mm</td></tr>
<tr><td>Flange</td><td>Blow out of gasket: π Dt/4</td></tr>
<tr><td>Valve</td><td>Bonnet failure when bolts are used for fastening: bonnet area = π DBt/4 Valve flanges to be considered under flanges</td></tr>
<tr><td>Flexible hose</td><td>Full-bore rupture: π D^2 /4</td></tr>
<tr><td>Pipe coupling and screwed</td><td>Full-bore rupture: π D^2 /4</td></tr>
<tr><td colspan="2">D = pipe diameter, t = thickness of gasket, DB = flow diameter through bonnet</td></tr>
</table>
In addition, leakage scenarios in accordance with a recognized standard acceptable to the Administration could also be applied.

Footnote for pipe:

The possibility of a full-bore rupture, if indicated by the risk assessment, should not be excluded
</td>
<td>
<table>
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</table>
Fuel pipes protected by secondary enclosures are not considered as leak sources.

Footnote for pipe:

The possibility of a full-bore rupture, if indicated by the risk assessment, should not be excluded
</td>
<td>leakages and is therefore not considered a suitable standard for evaluating relevant leakage scenarios for a fuel system.

The EMSA Guidance clarifies that fuel pipes protected by secondary enclosures are not considered as leak sources here (IG clarifies this in 4.3).

Further, it is clarified that the table is input also to the fire risk analysis.</td>
</tr>
<tr><td>12.4</td><td>12.4</td><td>Provisions on area classification</td><td>Area classification</td><td></td></tr>
<tr><td>12.4.1</td><td>12.4.1</td><td>Area classification is a method of analysing and classifying the areas where explosive gas atmospheres may occur. The object of the classification is to allow the selection of electrical apparatus able to be operated safely in these areas.</td><td>Area classification is a method of analysing and classifying the areas where explosive gas atmospheres may occur. The object of the classification is to allow the selection of electrical apparatus able to be operated safely in these areas.</td><td></td></tr>
<tr><td>12.4.2</td><td>12.4.2</td><td>In order to facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into zones 0, 1 and 2.</td><td>In order to facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into zones 0, 1 and 2.</td><td></td></tr>
<tr><td>12.4.3</td><td>-</td><td>Ventilation ducts should have the same area classification as the ventilated space it serves.</td><td>-</td><td>The EMSA Guidance provisions exclude hazardous zones in enclosed spaces.</td></tr>
<tr><td>12.4.4</td><td>-</td><td>Hazardous areas on open deck and other spaces not addressed in this chapter should classified in accordance with a recognized standard. The electrical equipment fitted within hazardous areas should be accordance with the same standard.</td><td>-</td><td></td></tr>
<tr><td>12.4.5</td><td>-</td><td>Electrical equipment and wiring should in general not be installed in hazardous areas unless essential for operational purposes based on a recognized standard (4).

Footnote on standard:

Refer to IEC standard 60092-502: IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features and IEC 60079-10-1:2020 Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres, according to the area classification.</td><td>-</td><td>The EMSA Guidance includes provisions for electrical equipment in Chapter 14 Electrical Installations.</td></tr>
<tr><td>12.4.6</td><td>-</td><td>Equipment groups and temperature classes should be determined according to a recognized standard (5) acceptable to</td><td>-</td><td>The EMSA Guidance includes provisions for electrical equipment in Chapter 14 Electrical Installations.</td></tr>
</table>

		the Administration considering the categories of the flammable gas which may occur and accumulate in a hazardous area. Footnote on standard: Refer to IEC 60079 series standards, as applicable.		
12.5	**12.5**	**Hazardous area classification**	**Hazardous area zones**	
12.5.1	12.5.1	Hazardous area zone 0: This zone includes, but is not limited to the interiors of fuel tanks, any pipework for pressure-relief or other venting systems for fuel tanks, pipes and equipment containing fuel.	Hazardous area zone 0 This zone includes, but is not limited to, the interiors of fuel tanks, any pipework for pressure-relief or other venting systems for fuel tanks, pipes and equipment containing fuel.	
12.5.2	12.5.2	Hazardous area zone 1: This zone includes, but is not limited to: .1 tank connection spaces, tank connect enclosures, secondary enclosures around piping systems, fuel storage hold spaces (6) and the Gas Valve Unit (GVU) space; .2 fuel preparation room; .3 enclosed or semi-enclosed spaces in which pipes containing fuel are located, e.g. ducts around fuel pipes, semi-enclosed bunkering stations; and .4 a space protected by an airlock is considered as non-hazardous area during normal operation, but will require equipment required to operate following loss of differential pressure between the protected space and the hazardous area to be certified as suitable for zone 1. Footnote (6): Fuel storage hold spaces for type C tanks are normally not considered as zone 1.	Hazardous area zone 1 This zone includes, but is not limited to: .4 Secondary enclosures around piping systems, including gas valve units. .5 Tank connection enclosures around tank connections for compressed hydrogen .6 Areas on open deck, or semi-enclosed spaces on deck, within minimum distances as per section 12.5 of the IGF Code Part A-1 to any vent mast outlet, other gas outlet and bunker manifold.	The EMSA Guidance provisions is based on the IGF text, but amended for hydrogen installations covered by the Guidance. The concept in the EMSA Guidance is to provide secondary enclosures around all fuel piping in the tank connection space. Hence, the tank connection space is not defined as a hazardous zone 1.
12.5.3	12.5.3	Hazardous area zone 2: This zone includes, but is not limited to: .1 areas within 1.5 m surrounding open or semi-enclosed spaces of zone 1; .2 space separated from a zone 1 area with a bolted hatch; and .3 airlocks between a zone 1 area and a non-hazardous area.	Hazardous area zone 2 Areas on open deck, or semi-enclosed spaces on deck, within minimum distances as per Section 12.5 of the IGF Code Part A-1.	
12.5.4	-	Hazardous areas on open deck and in semi-enclosed spaces: The classification and extent of hazardous areas for the following locations may be determined using IEC 60079-10-1 with special consideration of the Administration, however, at a minimum the hazardous zones should follow those prescribed for natural gas in chapter 12.5 of the IGF Code:	-	

		.1 areas on open deck, or semi-enclosed spaces on deck, surrounding any fuel tank outlet, gas or vapour outlet, bunker manifold valve, other fuel valve, fuel pipe flange, fuel preparation room ventilation outlets, fuel tank pressure release valve outlets and ventilation outlets from zone 1 spaces; .2 areas on open deck or semi-enclosed spaces on deck, surrounding any fuel preparation room entrances, fuel preparation room ventilation inlets and other openings into zone 1 spaces; .3 spaces on the open deck within and surrounding drip trays for bunker manifold valve; and .4 an area on deck or semi-enclosed space surrounding a bolted hatch to tank connection space.		

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13	**13**	**Ventilation**	**VENTILATION**	In the IGF Code Part A-1 for natural gas, ventilation systems are used as a means to evacuate natural gas from secondary enclosures after a leakage (tank connection spaces, fuel preparation rooms, double-walled piping, gas valve units, etc.). EMSA D.2 Reliability and Safety Analysis, Chapter 4.4.2, refers to the MarHySafe project and studies by Gexcon, showing that dilution-ventilation cannot mitigate explosive atmospheres if the leak rate exceeds a certain value. When considered in relation to the ease of ignition of hydrogen atmospheres, it becomes clear that ventilation systems should not be used in the same manner for hydrogen systems. This implies that provisions for ventilation in the EMSA Guidance focus on ensuring that ventilation systems do not introduce hazards by providing oxygen to a hydrogen atmosphere and preventing leaked hydrogen from reaching spaces inside the ship through the ventilation system.
-	**13.0**	-	**Hazards**	
-	13.0.1	-	Ventilation systems can cause hydrogen released on open decks to enter enclosed spaces, creating an ignitable atmosphere.	
13.1	**13.1**	**Goal**	**Goal**	
		The goal of this chapter is to provide for the ventilation and atmospheric control of enclosed spaces required for safe operation of hydrogen-fuelled machinery and equipment, except fuel cell power installations.	The goal of this chapter is to ensure that ignitable hydrogen/air mixtures are not formed in enclosed spaces.	The goal of the EMSA Guidance differs from the IMO IG and reflects the objective explained above.
13.2	**13.2**	**Functional Requirements**	**Functional Requirements**	

13.2.1		This chapter is related to functional requirements in 3.2.2, 3.2.5, 3.2.6, 3.2.8, 3.2.10, 3.2.12 to 3.2.14, 3.2.17 and 3.2.19. In particular the following provisions apply:	This section relates to the functional requirements in sections **3.2.1** to **3.2.3**, **3.2.6** and **3.2.11**. In particular, the following apply:	
13.2.2	-	Ventilation systems, where installed, should be arranged to avoid generation of a flammable hydrogen-air mixture in enclosed spaces and ducting with explosion pressure exceeding the enclosure design pressure.	-	
13.2.3	-	Ventilation systems, where installed, should be arranged to avoid stratification of oxygen-rich atmosphere in all reasonably foreseeable scenarios.	-	
-	13.2.1	-	Ventilation systems should be arranged to prevent hydrogen from being drawn into enclosed spaces through ventilation ducts.	
13.3	**13.3**	**General provisions**	**General**	
13.3.1	-	Enclosed hazardous spaces with a potential source of release should be inerted or arranged with vacuum.	-	The EMSA Guidance has provisions for secondary enclosures around all leak points in hydrogen fuel systems. Consequently, enclosed spaces will not be exposed to hydrogen leaks.
13.3.2	-	Notwithstanding 13.3.1, ventilation arrangements may be permitted provided that the provisions of section 2.3 are met. The approval of such arrangements should as a minimum take into account the hazards and topics listed in provision 4.2.2, and: .1 the enclosure or space should have sufficient strength to withstand the effects of a local gas explosion in the space, as established in the provisions under 12.3. .2 the ventilation capacity should be sufficient to reduce the explosive force in compliance with 13.3.2.1, or dilute the average gas/vapour concentration below 25% of LEL, whichever is greater. .3 the ventilation system should provide effective ventilation of the complete space, also taking into consideration the density of the leaking fuel gases and any internal obstructions, e.g. piping, equipment, valves, structures, etc. .4 any ducting used for the ventilation of hazardous spaces should be separate from that used for the ventilation of non-hazardous spaces. The ventilation should function at all temperatures and environmental conditions the ship will be operating in. .5 ventilation ducts from hazardous spaces should be vertical or steadily ascending and without sharp bends to avoid any possibility for gas to accumulate. .6 electric motors for ventilation fans should not be located in ventilation ducts for hazardous spaces unless the motors are certified for hydrogen use and are certified for the same hazard zone as the space served.	-	The EMSA Guidance is a non-mandatory, advisory document in which references to IMO alternative design approval are not relevant. EMSA D.2 Reliability and Safety Analysis, section 4.4.2, refers to the MarHySafe project and studies by Gexcon, showing that dilution-ventilation cannot mitigate explosive atmospheres if the leak rate exceeds a certain value.

		.7 two fans should be installed for the ventilation of the hazardous space with 100% capacity each. Both fans should be supplied from separate circuits. The ventilation fans should be operated in an alternating cycle to test that all fans are operable at all times. Loss of ventilation should cause automatic shutdown of all tank valves and master fuel valves required to isolate the hydrogen supply to the hazardous space. .8 the required capacity of the ventilation plant is normally based on the total volume of the room. An increase in required ventilation capacity may be necessary for rooms having a complicated form. .9 air inlets for hazardous enclosed spaces should be taken from areas that, in the absence of the considered inlet, would be non-hazardous. Where the inlet duct passes through a more hazardous space, the duct should be gas-tight and have over-pressure relative to this space. .10 air inlets to hazardous enclosed spaces should be close to the floor and the air extraction should be placed close to the ceiling of said space. Additional extraction outlets will be required to be placed in areas where there is a risk of formation of gas pockets from ceiling configurations (e.g. structural beams, cable trays and pipe racks). The space geometry should also be taken into account when locating the air inlets and air extraction. .11 air outlets from hazardous enclosed spaces should be located in an open area that, in the absence of the considered outlet, would be of the same or lesser hazard than the ventilated space. .12 the arrangement of the ventilation system should eliminate or at least minimize areas where gas may accumulate. .13 localized ventilation should be provided with gas detection at locations where a fuel release is reasonably foreseeable (i.e. flange, valve, seals, etc.) or where gas may accumulate (i.e. structural beams, cable trays and pipe racks).		
13.3.3	13.3.1	Air inlets for non-hazardous enclosed spaces should be taken from non-hazardous areas at least 1.5 m away from the boundaries of any hazardous area.	Air inlets for non-hazardous enclosed spaces should be taken from non-hazardous areas at least 1.5 m away from the boundaries of any hazardous area.	
13.3.4	13.3.2	Air outlets from non-hazardous spaces should be located outside hazardous areas.	Air outlets from non-hazardous spaces should be located outside hazardous areas	

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14	**14**	**Electrical Installations**	**ELECTRICAL INSTALLATIONS**	
-	**14.0**	-	**Hazards**	
-	14.0.1	-	Electrical installations may be ignition sources in a hydrogen release scenario.	
-	14.0.2	-	Failure of electrical installations required to maintain normal operating limits for fuel tank pressures may lead to the release of hydrogen.	
14.1	**14.1**	**Goal**	**Goal**	
		The goal of this chapter is to provide for electrical installations that minimize the risk of ignition in the presence of a flammable atmosphere.	The goal of this chapter is to prevent electrical installations from becoming ignition sources in areas where a flammable atmosphere may be expected.	The EMSA Guidance has rephrased the goal to reflect that electrical installations should primarily be avoided in areas where a flammable atmosphere may be expected.
14.2	**14.2**	**Functional Requirements**	**Functional Requirements**	
14.2.1		This chapter is related to functional requirements in 3.2.1, 3.2.2, 3.2.3, 3.2.4, 3.2.7, 3.2.8, 3.2.11, 3.2.13 and 3.2.16 to 3.2.18. In particular the following provisions apply:	This section is related to functional requirements in **3.2.1**, **3.2.2**, **3.2.5**, **3.2.8** and **3.2.17**. In particular, the following apply:	
14.2.2	14.2.1	Electrical installations should not be installed in areas where a flammable hydrogen atmosphere may occur unless they are essential for safety or operational reasons.	Electrical installations should not be installed in areas where a flammable hydrogen atmosphere may occur unless they are essential for safety or operational reasons.	
14.2.3	14.2.2	Electrical installations installed in areas where a flammable hydrogen atmosphere may occur should be designed to minimize the risk of igniting a flammable hydrogen atmosphere.	Electrical installations installed in areas where a flammable hydrogen atmosphere may occur should be designed to minimize the risk of igniting a flammable hydrogen atmosphere.	
14.2.4	14.2.3	Electrical equipment should function as intended for all normal and reasonably foreseeable abnormal environments	Electrical equipment that is essential for safety or operational purposes should be arranged or designed to function as intended, also after a loss of vacuum in fuel tanks or piping systems have lowered the ambient temperature.	The EMSA Guidance clarifies that abnormal events relate to low ambient temperatures after a cryogenic incident.
14.3	**14.3**	**Regulations – General**	**General**	
14.3.1	-	Unless expressly provided otherwise, the requirements of section 14.3 of the IGF Code should apply to ships using hydrogen as fuel.	-	The EMSA Guidance contains specific requirements in lieu of reference 14.3 of the IGF Code.
14.3.2	14.3.1	Electrical equipment installed in hazardous areas should be in compliance with IEC 60079 Series or a standard acceptable to the Administration.	Electrical equipment installed in hazardous areas should be in compliance with IEC 60079 Series or a standard acceptable to the Administration.	
14.3.3	-	Electrical equipment fitted in areas with potential of oxygen enrichment should consider excluding all possible ignition sources as far as practicable and be in compliance with recognized standards where relevant.	-	The EMSA Guidance does not contain specific provisions for electrical equipment installed in areas potentially affected by air condensation. The gas group for hydrogen in hazardous areas (IIC) is also suitable for oxygen-enriched atmospheres. The IIC gas group required for hydrogen atmospheres is designated for gases and vapours that are the easiest to ignite, meaning they have the lowest minimum ignition energy.

				Oxygen is highly reactive and requires the highest level of caution in hazardous areas, as addressed by the IIC equipment rating.
-	14.3.2	-	Where electrical equipment is installed in hazardous areas as provided in 14.2.1, it should be selected, installed and maintained in accordance with recognized standards. * __________ * Refer to the recommendation published by the International Electrotechnical Commission, in particular to publication IEC 60092-502:1999. Equipment for hazardous areas should be evaluated and certified or listed by an accredited testing authority or notified body recognized by the Administration.	
-	14.3.3	-	Where electrical equipment is installed in hazardous areas as provided in 14.2.1, the equipment group should be not less than IIC and the temperature class T1.	
-	14.3.4	-	The installation on board of the electrical equipment units should be such as to ensure the safe bonding to the hull of the units themselves.	
14.3.4	14.3.5	The de-energizing of electrical equipment is not accepted as a safety barrier, except for spaces protected by airlocks.	The de-energizing of electrical equipment is not accepted as a safety barrier.	The EMSA Guidance does not include provisions for de-energizing equipment because all spaces with hydrogen installations are recommended to be arranged with secondary enclosures. This will significantly reduce the probability of hydrogen leaks in spaces inside the vessel.

Draft IG	EMSA Guidance	IMO Draft Interim Guidelines for the safety of ships using hydrogen as fuel (CCC 11/WP.4 Annex 2)	EMSA Guidance for hydrogen-fuelled ships	Justification and comments
15	**15**	**Control, Monitoring and Safety Systems**	**CONTROL, MONITORING AND SAFETY SYSTEMS**	
-	**15.0**	-	**Hazards**	
-	15.0.1	-	Hazardous events, such as fuel leakage, may develop undetected or too rapidly for manual intervention.	
-	15.0.2	-	A malfunctioning control, monitoring, or safety system may cause a hazardous event or prevent the execution of safety actions required to limit the consequences of a hazardous event.	
-	15.0.3	-	Actions initiated by the safety systems may lead to a loss of power generation for propulsion and auxiliary purposes.	
15.1	**15.1**	**Goal**	**Goal**	
		The goal of this chapter is to provide for the arrangement of control, monitoring and safety systems that support the efficient and safe operation of the hydrogen installations.	The goal of this chapter is to provide for the arrangement of control, monitoring, and safety systems that support the efficient and safe operation of the hydrogen installation.	
15.2	**15.2**	**Functional requirements**	**Functional requirements**	
15.2.1		This chapter is related to functional requirements in 3.2.1, 3.2.2, 3.2.11, 3.2.13 to 3.2.15, 3.2.17 and 3.2.18 and 3.2.19. In particular, the following provisions apply.	This section is related to functional requirements in **3.2.1** to **3.2.3**, **3.2.9**, **3.2.11** to **3.2.14**, **3.2.17** and **3.2.20**. In particular, the following apply:	

15.2.2	15.2.1	The control, monitoring and safety systems of the hydrogen installation should be so arranged to a ensure that a single failure in these systems does not lead to an unacceptable loss of power.	The control, monitoring, and safety systems of the hydrogen installation should be arranged to ensure that a single failure in these systems does not lead to an unacceptable loss of power.	
15.2.3	15.2.2	A hydrogen safety system should be arranged to close down the gas supply system automatically, upon failure in systems as described in table 1 and upon other fault conditions which may develop too fast for manual intervention.	A fuel safety system should be arranged to close down the gas supply system automatically, upon failure in safety systems and upon other fault conditions which may develop too fast for manual intervention.	The EMSA Guidance does not refer to prescriptive requirements (table 1) in the definition of functional requirements.
15.2.4	15.2.3	The safety functions should be arranged in a dedicated hydrogen safety system that is independent of the gas control system in order to avoid possible common cause failures. This includes power supplies and input and output signal.	The safety functions should be arranged in a dedicated fuel safety system that is independent of the gas control system in order to avoid possible common cause failures. This includes power supplies and input and output signals.	
15.2.5	15.2.4	The safety systems including the field instrumentation should be arranged to avoid spurious shutdown or unintended release, e.g. as a result of a faulty gas detector or a wire break in a sensor loop.	The safety systems, including the field instrumentation, should be arranged to avoid spurious shutdown or unintended release, e.g. as a result of a faulty gas detector or a wire break in a sensor loop.	
15.2.6	15.2.5	Where there are two or more hydrogen supply systems, each system should be fitted with its own set of independent hydrogen control and hydrogen safety systems.	Where there are two or more hydrogen supply systems for redundancy, each system should be fitted with its own set of independent hydrogen control and hydrogen safety systems.	The EMSA Guidance clarifies that the intention with this provision is to maintain redundancy upon failure in control and safety systems.
15.2.7	15.2.6	It should be possible to detect any fuel leakage in enclosed spaces and on the open deck.	It should be possible to rapidly detect any leakage from the fuel system.	The EMSA Guidance recommend arranging for rapid leak detection irrespective of location. (From EMSA D.1 Mapping safety risks for hydrogen-fuelled ships Any leaks from tanks and piping systems should be detectable and automatically isolated from the source of the hydrogen supply. Segregation valves should be arranged to limit the amount of hydrogen being discharged after a leakage is detected and stopped. The bunkering system should be arranged with means to detect leakage and systems to automatically stop the bunkering process. Hydrogen installations should be equipped with appropriate systems to detect leakages at an early stage, and the systems should be arranged to automatically isolate the leakage so that the risk is minimized.)
15.2.8	15.2.7	It should be possible to detect the failure of any safety function required to operate the ship safely.	It should be possible to detect the failure of any safety function required to operate the ship safely.	
-	15.2.8	-	Fuel containment systems and piping systems should be arranged with the means to ascertain the operating parameters required for safe operation.	The EMSA Guidance contains functional requirements for monitoring relevant operating parameters (From EMSA D.1 Mapping safety risks for hydrogen-fuelled ships Fuel containment systems for liquefied hydrogen should be arranged with the means to ascertain the tank pressure, temperature and filling level.) Fuel containment systems for liquefied hydrogen should be arranged with information on acceptable filling levels to prevent a liquid-full tank. Alarms and shut-down systems should be

				arranged to prevent overfilling during bunkering or transfer between tanks.
-	15.2.9	-	Fuel containment systems should be designed and equipped to prevent overfilling during bunkering, transfer of fuel between tanks or due to the fuel's thermal expansion.	
15.3	**15.3**	**General arrangement**	**General**	
15.3.1	15.3.1	Suitable instrumentation devices should be fitted to allow effective monitoring of essential parameters to ensure a safe management of the whole fuel-gas equipment including bunkering.	Suitable instrumentation devices should be fitted to allow-effective monitoring of essential parameters to ensure safe management of the whole fuel-gas installation, including bunkering.	
15.3.2	-	For tanks not permanently installed in the ship a monitoring system should be provided as for permanently installed tanks.	-	The EMSA Guidance does not provide provisions for portable tanks.
15.3.3	15.3.2	The safety system is to be independent of the control and monitoring system.	The safety system should be independent of the control and monitoring system.	
15.3.4	15.3.3	Tank connection spaces should be arranged with level indicators in bilge wells providing a high-level alarm. Low temperature indication in the space should activate the safety system.	Tank connection spaces should be arranged with level indicators in bilge wells, providing a high-level alarm. A low-temperature indication in the space should activate the safety system.	A general temperature monitoring of TCS could indicate a loss of vacuum.
15.4	**15.4**	**Provisions for fuel containment system monitoring**	**Fuel containment system monitoring**	
15.4.1	15.4.1	Fuel containment systems for liquefied gas should be fitted with liquid level gauging devices that continuously monitor the liquid level. If only one liquid level gauge is installed, it should be designed to be maintained in operational condition without emptying or gas freeing the tank.	Fuel containment systems for liquefied gas should be fitted with liquid level gauging devices that continuously monitor the liquid level. If only one liquid level gauge is installed, it should be designed to be maintained in operational condition without emptying or gas-freeing the tank.	
15.4.2	15.4.2	Overflow control should be as follows: .1 each liquefied gas fuel tank should be fitted with a high liquid level alarm operating independently of other liquid level indicators and giving an audible and visual warning when activated; .2 an independent sensor, functioning separately from the high liquid level alarm, should stop the filling of the tank by automatically activating a shut-off valve in a way that prevents both excessive liquid pressure in the bunkering line and the liquefied gas fuel tank from becoming completely full; .3 all components of the level alarm system, including the electrical circuit and sensor(s) for the high and overfill alarms, should be capable of functional testing; and .4 where arrangements are provided for overriding the overflow control system, they should be such that inadvertent operation is prevented. When this override is operated, a continuous visual indication is to be provided at the navigation bridge, a continuously manned central control station or the onboard safety centre.	Overflow control for liquefied fuel tanks: .1 Each fuel tank should be fitted with a high liquid level alarm operating independently of other liquid level indicators and giving an audible and visual warning when activated. .2 An independent sensor, functioning separately from the high liquid level alarm, should stop the filling of the tank by automatically activating a shutoff valve in a way that prevents both excessive liquid pressure in the bunkering line and the liquefied gas fuel tank from becoming completely full. .3 All components of the level alarm system, including the electrical circuit and sensor(s) for the high and overfill alarms, should be capable of functional testing. .4 Where arrangements are provided for overriding the overflow control system, they should be such that inadvertent operation is prevented. When this override is operated, a continuous visual indication should be provided at the navigation bridge, a continuously manned central control station or the onboard safety centre.	The EMSA Guidance text is amended compared to the IGF text for clarity. Item 3 in the IGF text, related to testing high-level alarms by raising the fuel liquid level, has been challenging for LNG-fuelled ships. Not included in the draft EMSA Guidance.
15.4.3	15.4.3	The vapour space of each fuel tank should be provided with a direct pressure reading gauge. Additionally, an indirect pressure	The vapour space of each tank for liquefied fuel should be provided with pressure indication on the navigation bridge, a	The EMSA Guidance include provisions for secondary enclosures around all fuel piping. This is in conflict with the requirement for

		indication should be provided on the navigation bridge, a continuously manned central control station or the onboard safety centre.	continuously manned central control station or the onboard safety centre.	local reading which may be challenging to enclose. Consequently, the principle in the draft EMSA Guidance is to rely on remote monitoring.
15.4.4	-	The pressure indicators should be clearly marked with the highest and lowest pressure permitted in the liquefied gas fuel tank.	-	See above.
15.4.5	15.4.4	A high-pressure alarm and, if vacuum protection is required, a low-pressure alarm should be provided on the navigation bridge and at a continuously manned central control station or onboard safety centre. Alarms should be activated before the opening pressure of the safety valves is reached.	A high-pressure alarm and, if vacuum protection is required, a low-pressure alarm should be provided on the navigation bridge and at a continuously manned central control station or onboard safety centre. Alarms should be activated before the opening pressure of the safety valves is reached.	
15.4.6	15.4.5	A local-reading manifold pressure indicator should be provided to indicate the pressure between the ship's manifold valves and the hose connections to the shore.	A local-reading manifold pressure indicator should be provided to indicate the pressure between the ship's manifold valves and the hose connections to the shore.	
15.4.8	15.4.6	For submerged fuel-pump motors and their supply cables, arrangements should be made to alarm in low liquid level and automatically shut down the motors in the event of low-low liquid level. The automatic shutdown may be accomplished by sensing low pump discharge pressure, low motor current, or low-low liquid level. This shutdown should give an audible and visual alarm on the navigation bridge, continuously manned central control station or onboard safety centre.	For submerged fuel-pump motors and their supply cables, arrangements should be made to alarm at a low-liquid level and automatically shut down the motors in the event of a low-low liquid level. The automatic shutdown may be accomplished by sensing low pump discharge pressure, low motor current, or low-low liquid level. This shutdown should give an audible and visual alarm on the navigation bridge, a continuously manned central control station or the onboard safety centre.	
-	15.4.7	-	Compressed hydrogen tanks should be provided with temperature monitoring to prevent overheating during bunkering.	The EMSA Guidance includes provisions for temperature monitoring reflecting the provision in section.8.5.1
-	**15.5**	-	**Bunkering control**	The EMSA Guidance is based on the IGF text, amended for clarity and applicability to hydrogen.
-	15.5.1	-	Control of the bunkering should be possible from a safe location remote from the bunkering station. At this location, the tank pressure, tank temperature, if relevant, and tank level shall be monitored. Remotely controlled valves required by 8.5.2 and 11.6.6 shall be capable of being operated from this location. Overfill alarm and automatic shutdown shall also be indicated at this location.	
-	15.5.2	-	If leakage is detected in the secondary enclosure around the bunkering lines, an audible and visual alarm should be provided at the bunkering control location. The bunker valve and other valves required to isolate the leakage should be automatically closed by the safety system.	The EMSA Guidance text is amended to clarify the “emergency shut-down” reference in the IGF text.
15.5	-	**Compressed hydrogen bunkering and fuel tank monitoring**	-	Covered by **15.5 Bunkering control** above.
15.5.1	-	The control location for bunkering should be in a safe location remote from the bunkering operations. At this location, the information relevant to safe bunkering operation should be available.	-	The EMSA Guidance provides general provisions for bunkering control irrespective of fuel condition (compressed or liquefied) in 15.5 above.
15.5.2	-	Alarm for high pressure, temperature and any other leakage detection method should be indicated at this location and on the navigation bridge, as well as leakage detection alarms for the secondary enclosure if fitted.	-	The EMSA Guidance provides general provisions for bunkering control irrespective of fuel condition (compressed or liquefied) in 15.5 above.
-	**15.6**	-	**Engine monitoring**	

-	15.6.1	-	In addition to the instrumentation provided in accordance with part C of SOLAS chapter II-1, indicators should be fitted on the navigation bridge, the engine control room and the manoeuvring platform for: .3 operation of the engine in case of gas-only engines; or .4 operation and mode of operation of the engine in the case of dual-fuel engines.	The EMSA Guidance includes provisions on engine monitoring from chapter 15 of the IGF Code Part A-1.
15.6	**15.7**	**Gas detection**	**Leakage detection**	The EMSA Guidance includes provisions for both gas and liquid leakage detection.
15.6.1	15.7.1	Permanently installed gas detectors should be fitted in: .1 the tank connection spaces; .2 fuel preparation spaces; .3 secondary enclosures around pipes containing gaseous fuels (7); .4 gas-safe machinery spaces above engine; .5 bunker station; .6 secondary circuits where hydrogen crossover is credible (e.g. cooling/heating circuits); .7 airlocks; .8 fuel storage hold spaces (not relevant for tanks located on open deck area providing natural ventilation and unobstructed relief of leakages); and .9 other spaces if identified by the risk assessment. Footnote (7): Appropriate means for detecting leakage into the annular space should be accepted as an alternative, e.g. pressure monitoring.	1. Permanently installed gas detection should be fitted in: .4 tank connection enclosures; .5 bunkering stations; and .6 secondary circuits for fuel heating and other auxiliary systems ;where hydrogen can leak directly into the medium 2. To warn against operational and accidental releases of hydrogen, gas detectors should also be arranged in: .3 the vicinity of hydrogen vent mast outlets; and .4 tank connection spaces; 3. Permanently installed gas detection or other leakage detection should be fitted in secondary enclosures around .5 pipes containing gaseous fuel; .6 pipes containing liquefied fuel; .7 valves and components containing gaseous fuel; and .8 valves and components containing liquefied fuel.	The EMSA Guidance does not have provisions for gas detection in enclosed spaces due to the concept of having secondary enclosures around all fuel piping irrespective of location. The provision has been split up to clarify where gas detection is required and where other methods can be used to detect leakages. Further, gas detection should be installed in the vicinity of vent mast outlets and tank connection spaces to warn against accidental releases.
15.6.2	15.7.2	The number of detectors in each space should be considered taking into account the leakage scenario, size, layout and ventilation of the space	The number and location of detectors in each area should be considered, taking the arrangement into account.	
15.6.3	-	The detection equipment should be located where gas may accumulate and in the ventilation outlets. Gas dispersal analysis should be used to find the best arrangement for complex geometries.	-	The EMSA Guidance do not cover fuel installations where a single failure can lead to a leakage into enclosed spaces.
15.6.4	-	The detection strategy for leakage should be based on diversity and a combination of different detection principles should be considered to ensure adequate coverage for the variety of leakage scenarios in the relevant spaces.	-	The EMSA Guidance do not cover fuel installations where a single failure can lead to a leakage into enclosed spaces.
	15.7.3	Gas detection equipment should be designed, installed and tested in accordance with a recognized standard, such as IEC 60079-29.	Gas detection equipment should be designed, installed and tested in accordance with a recognized standard, such as IEC 60079-29.	
15.6.5	15.7.4	An audible and visible alarm should be activated at a gas vapour concentration of 20% of the lower explosion limit (LEL). The safety system should be activated at 40% of LEL at two detectors (see footnote 1 in table 1).	Audible and visible alarm should be activated upon leakage detection, and the safety systems should be activated in accordance with Table 1.	The EMSA Guidance has provisions for safety actions at the first indication of a hydrogen leakage. Alarm limits to be considered.

15.6.6	15.7.5	Audible and visible alarms from the gas detection equipment should be located on the navigation bridge or in the continuously manned central control station.	Audible and visible alarms from the leakage detection equipment should be located on the navigation bridge, in the continuously manned central control station. Leakage detection in spaces that are normally accessible shall initiate an audible and visible alarm locally.	The EMSA Guidance includes provisions for a local alarm where the leakage is detected. This is to prevent potential entry and trigger escape for spaces normally accessible.
15.6.7	15.7.6	Gas detection required by this section should be continuous without delay.	Gas detection required by this section should be continuous without delay.	
-	15.7.7	-	The integrity of secondary enclosures should be continuously monitored. Detected leakages from the outside should be alarmed, and the safety system should be activated in accordance with Table 1.	The EMSA Guidance includes provisions for monitoring of secondary barriers to reduce the risk of hidden failures.
15.7	**15.8**	**Fire detection**	**Fire detection**	
15.7.1	15.8.1	Required safety actions upon fire detection in the machinery space containing gas-consumers and for fuel storage hold spaces are given in table 1 below.	Required safety actions upon fire detection in the machinery space containing gas consumers and for fuel storage hold spaces are provided in Table 1 below.	
15.7.2	15.8.2	Fire detectors shall be suitable for detection of hydrogen fires (i.e. flame, smoke, heat).	Fire detectors shall be suitable for detection of hydrogen fires (i.e. flame, smoke, heat).	
15.8	-	**Loss of vacuum or ventilation**	-	
15.8.1	-	The following scenarios should give an audible and visual alarm on the navigation bridge or in a continuously manned central control station or safety centre: .1 loss of vacuum or inert atmosphere for tank connection space; .2 loss of vacuum or inert atmosphere for fuel preparation space; .3 loss of vacuum or inert atmosphere for secondary enclosures around hydrogen piping where fitted; .4 loss of the required ventilating capacity; and .5 loss of vacuum in vacuum-insulated liquefied hydrogen containment system (8). Footnote (8): Notwithstanding normal vacuum integrity indications, cryo-pumping of air in vacuum spaces cannot be excluded.	-	The EMSA Guidance is based on secondary enclosures around all fuel piping. Hence, tank connection spaces or fuel preparation rooms with vacuum, inert atmosphere or mechanical ventilation are out of scope for the Guidance. Leakage detection and alarm location for secondary enclosures are covered by section 15.7 of the EMSA Guidance.
15.9	-	**Cryogenic monitoring**	-	
15.9.1	-	Pressure or low temperature detection for vacuum enclosures containing cryogenic systems should result in automatic closing of all valves necessary to isolate the leakage from the inner pipes.	-	The EMSA Guidance covers detection of leakages from the inner pipe into secondary enclosures in section 15.7.1.3 and related automatic safety actions described in Table 1.
15.9.2	-	Piping in the fuel system containing cryogenic liquids should be provided with means for detection of leakages from the inner pipes into the secondary enclosure. Detection of leakages should result in automatic closing of all valves required to isolate the leakage. Leakage detection in the secondary enclosure of the	-	The EMSA Guidance covers detection of leakages from the inner pipe into secondary enclosures in section 15.7.1.3 and related automatic safety actions described in Table 1.

		bunkering line should immediately result in automatic closing of the bunkering valve.		
15.10	**15.9**	**<u>Safety functions of fuel supply systems</u>**	**Safety functions of fuel supply systems**	
15.10.1	-	If the fuel supply is shut-off due to activation of an automatic valve, the fuel supply should not be opened until the reason for the disconnection is ascertained and the necessary precautions taken. A readily visible notice giving instruction to this effect should be placed at the operating station for the shut-off valves in the fuel supply lines.	-	The EMSA Guidance provides provisions for signboards in chapter 18 and does not repeat it here.
15.10.2	15.9.1	Safe shut down of compressors, pumps and fuel supply should be arranged for manual remote emergency stop from the following locations, as applicable: .1 navigation bridge; .2 cargo control room; .3 onboard safety centre; .4 engine control room; .5 fire control station; and .6 adjacent to the exit of fuel preparation rooms. The gas compressor should also be arranged for manual local emergency stop.	Compressors, pumps and fuel supply should be arranged for manual remote emergency stop from the following locations as applicable: .7 navigation bridge; .8 cargo control room; .9 onboard safety centre; .10 engine control room; .11 fire control station; and .12 close to the fuel preparation area. Gas compressors should also be arranged for manual local emergency stop.	The EMSA Guidance does not include provisions for fuel preparation rooms, stating that relevant equipment should be located in a fuel preparation are on open deck.
-	15.9.2	-	The heating medium for the liquefied gas vaporizer should be provided with temperature monitoring at the heat exchanger outlet. An alarm should be given at low temperature.	The EMSA Guidance includes provisions for temperature monitoring of the heating medium used in vaporisers to give early warning in case of reduced circulation, which may lead to freezing of the heating medium and damage to the heat exchanger.
-	15.9.3	-	The heated fuel in supply lines to consumers should be provided with temperature monitoring at the heat exchanger outlet. An alarm should be given at low temperature.	The EMSA Guidance includes provisions for temperature monitoring of the heated fuel at the heat exchanger outlet to give a warning prior to shut-down of fuel supply (see Table 1).
Table 1	Table 1	**Monitoring of gas supply system to gas consumers** (See below)	**Table 1: Monitoring of fuel installation** (See below)	

EMSA Guidance for hydrogen-fuelled ships **Table 1 - Monitoring of fuel installation**				
Parameter	**Alarm**	**Automatic shutdown of the tank valves**	**Automatic shutdown of the master gas fuel valve(s)**	**Comments**
Leakage detection				
Detected leakage in the piping for liquefied fuel	X	X		If leakage is detected in the bunkering lines, an audible and visual alarm should be sounded also at the bunkering control location. The bunker valve and other valves required to isolate the leakage should be automatically closed by the safety system.
Detected leakage in the secondary enclosure around piping for liquefied fuel	X	X		
Detected leakage in the tank connection enclosure for compressed hydrogen piping	X	X		

Detected leakage in piping for gaseous fuel outside the Machinery Space	X	X		If leakage is detected in the primary barrier in bunkering lines, an audible and visual alarm should be sounded also at the bunkering control location. The bunker valve and other valves required to isolate the leakage should be automatically closed by the safety system.
Detected leakage in the secondary enclosure around piping for gaseous fuel outside the machinery space	X	X	X	
Detected leakage in the piping for gaseous fuel inside the machinery Space	X		X	
Detected leakage in the secondary enclosure around piping for gaseous fuel inside the Machinery space	X		X	
Detected leakage into secondary circuits for fuel heating and other auxiliary systems where hydrogen can leak directly into the medium	X	X	X	For systems in the machinery space the master valve should close, for systems outside the machinery space the tank valves should close.
Detected leakage in the bunkering station	X			Initiate the stop of the bunkering operation, automatic closing of bunkering valve.
Gas detection in the vicinity of hydrogen vent mast outlet(s)	X			
Gas detection in tank connection spaces	X			
Fuel containment system				
High liquid level in tanks for liquefied hydrogen	X			
High-high liquid level in tanks for liquefied hydrogen	X	X		Should stop the filling of the tank by automatically activating a shutoff valve in a way that prevents both excessive liquid pressure in the bunkering line and the liquefied gas fuel tank from becoming liquid full
Low liquid level for submerged pumps	X			
Low-low liquid level for submerged pumps	X	X		Automatic shutdown of the pump motor
High pressure in liquefied hydrogen tanks	X			Before pressure relief valve opens
Low pressure in liquefied hydrogen tanks	X			
High pressure in compressed hydrogen tanks	X	X		During bunkering operations
High temperature in compressed hydrogen tanks	X	X		During bunkering operations
High level in bilge wells in the tank connection space	X			
Low temperature in the tank connection space	X	X		
Fuel heating				
Low heating medium temperature at vaporizer outlet	X			
Low gas temperature at vaporizer outlet	X	X		
Fire detection				

Detected fire in areas with hydrogen fuel installations	X	X	X	Valves required to isolate the leakage should be automatically closed by the safety system prior to fire extinguishing.
Manual shutdown				
Emergency shutdown of compressors and pumps				Should be available in the following places: Navigation bridge, cargo control room, onboard safety centre, engine control room, fire control station and close to the fuel preparation area.
Emergency shutdown of the fuel supply to the machinery space			X	Should be available in the following places: Navigation bridge, cargo control room, onboard safety centre, engine control room, fire control station and close to the fuel preparation area.
Emergency shutdown of bunkering				Shutdown of the bunker connection valve from the bunker control location
(CCC 11/WP.4 Annex 2) Table 1 -Monitoring of gas supply system to gas consumers				
Parameter	**Alarm**	**Automatic shutdown of tank valve[6)]**	**Automatic shutdown of gas supply to machinery space containing gas-fuelled engines**	**Comments**
Loss of Vacuum for Liquefied Hydrogen Fuel Tank	X	X		
Loss of vacuum or inert gas for tank connection spaces and enclosures	X			
Loss of Vacuum or Inert Gas for Fuel Preparation Room	X			
Loss of Vacuum or inert gas for secondary enclosure	X			
Loss of Vacuum or inert gas for fuel piping	X			
Gas detection in tank connection spaces and enclosures at 20% LEL	X			
Gas detection on two detectors[1] in tank connection spaces and enclosures at 40% LEL	X	X		
Fire detection in fuel storage hold space	X	X		
Fire detection in ventilation trunk for fuel containment system below deck	X			
Bilge well high level in tank connection space	X			
Bilge well low temperature in tank connection space	X	X		
Gas detection in duct between tank and machinery space containing gas-fuelled engines at 20% LEL	X			

Gas detection on two detectors[1)] in duct between tank and machinery space containing gas-fuelled engines at 40% LEL	X	X[2)]		
Gas detection in fuel preparation room at 20% LEL	X			
Gas detection on two detectors[1)] in fuel preparation room at 40% LEL	X	X[2)]		
Loss of ventilation in duct between tank and machinery space containing gas-fuelled engines	X		X[2)]	
Loss of ventilation in duct inside machinery space containing gas-fuelled engines[5)]	X		X[3)]	If double pipe fitted in machinery space containing gas-fuelled engines
Fire detection in machinery space containing gas-fuelled engines	X			
Abnormal gas pressure in gas supply pipe	X			
Failure of valve control actuating medium	X		X[4)]	Time delayed as found necessary
Automatic shutdown of engine (engine failure)	X		X[4)]	
Manually activated emergency shutdown of engine	X		X	
Compressed Hydrogen Tank/Cylinder High Internal Temperature	X	X		
Compressed Hydrogen Tank/Cylinder High Internal Pressure	X	X		
Fire in the Compressed Hydrogen Tank Area/Hold	X	X		

1. Two independent gas detectors located close to each other are required for redundancy reasons. If the gas detector is of self-monitoring type the installation of a single gas detector can be permitted.
2. If the tank is supplying gas to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected should close.
3. If the gas is supplied to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct and outside of the machinery space containing gas-fuelled engines, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected should close.
4. Only double block and bleed valves to close.
5. If the duct is protected by inert gas (see 9.6.1.1 of the IGF Code) then loss of inert gas overpressure should lead to the same actions as given in this table.
6. Valves referred to in 9.4.1 of the IGF Code.

Draft IG	EMSA Guidance	IMO Draft Interim Guidelines for the safety of ships using hydrogen as fuel (CCC 11/WP.4 Annex 2)	EMSA Guidance for hydrogen-fuelled ships	Justification and comments
16	**16**	**Manufacture, Workmanship and Testing**	**MANUFACTURE, WORKMANSHIP AND TESTING**	
-	**16.0**	-	**Hazards**	
-	16.0.1	-	A sub-standard level of workmanship and testing may increase the risk of fuel system components failing and the risk of hydrogen leaks developing.	
-	16.0.2	-	A sub-standard level of workmanship and testing may increase the failure rate of safety functions, which may escalate the consequences of hazardous events.	
16.1	**16.1**	**Goal**	**Goal**	
16.1.1		The goal of this chapter is to provide for adequate standards for manufacture, workmanship and testing to ensure the safe handling of hydrogen under all operating conditions and minimize the risk to the ship, people and environment.	The goal of this chapter is to provide adequate standards for manufacture, workmanship and testing to ensure the safe handling of hydrogen under all operating conditions and minimize the risk to the ship, people and environment.	
-	**16.2**	-	**Functional requirements**	
-		-	This section is related to functional requirements in **3.2.1**, **3.2.2**, **3.2.11**, **3.2.15** and **3.2.16**. In particular, the following apply:	
-	16.2.1	-	The manufacture, testing, inspection and documentation of components and systems for hydrogen fuel should be performed to minimize the risk of undetected design and production errors.	In EMSA D.1 Mapping safety risks for hydrogen-fuelled ships, it was established that many hydrogen-related accidents in other industries could be linked to the erroneous manufacturing of components and systems. Consequently, proper shipbuilding standards should be established to minimize the frequency of this happening on ships
16.2	**16.3**	**General**	**General**	
16.2.1	16.3.1	IGF Code Chapter 16 should be taken into account, where applicable, in order to fulfil the functional requirements.	The IGF Code Chapter 16 should be taken into account, where applicable, in order to fulfil the functional requirements.	
16.2.2	16.3.2	For materials whose design temperature is lower than -165°C, the toughness tests should be carried out in accordance with recognized standards.	For materials whose design temperature is lower than -165°C, the toughness tests should be carried out in accordance with recognised standards.	
16.2.3	-	Any microsection and/or hardness test requirements should be in accordance with the agreed project specification.	-	
16.2.4	-	The requirements for liquefied gas fuel containment are applicable to IMO Type C tanks only; all other tank types should be considered on a case-by-case basis.	-	
16.2.5	-	For vacuum insulated Type-C vessels and piping, the welding of metallic materials and non-destructive testing should be in accordance with recognised Standards	-	
16.2.6	-	The leak tests for hydrogen installations such as fuel tanks and piping systems should use helium or a mixture of 5 percent hydrogen and 95 percent nitrogen as the tightness test medium.	-	

16.2.7		Expansion joints and bellows should be avoided, as far as practicable, in hydrogen fuel piping systems. Engine mounted expansion bellows could be accepted based on evaluation as reflected in the safety concept of the engine.	-	
16.2.8	-	The overall performance of the fuel containment system should be verified for compliance with the design parameters during the first liquified hydrogen bunkering, when steady thermal conditions of the liquefied gas fuel are reached, in accordance with the requirements of the Administration. Records of the performance of the components and equipment, essential to verify the design parameters, should be maintained on board and be available to the Administration.	-	
16.2.9	-	The fuel containment system should be inspected for cold spots during or immediately following the first liquified hydrogen bunkering, when steady thermal conditions are reached. Inspection of the integrity of thermal insulation surfaces that cannot be visually checked should be carried out in accordance with the requirements of the Administration.	-	

Draft IG	EMSA Guidance	IMO Draft Interim Guidelines for the safety of ships using hydrogen as fuel (CCC 11/WP.4 Annex 2)	EMSA Guidance for hydrogen-fuelled ships	Justification and comments
17	**17**	**Drills and emergency exercises**	**DRILLS AND EMERGENCY EXERCISES**	Ch.17 of the IGF Code Part C-1 does not include goal and functional requirements. This is included in the draft EMSA Guidance. The draft Guidance includes a complete chapter based on the IGF Code Ch.17 but amended for hydrogen.
-	17.0	-	**Hazards**	
-	17.0.1	-	A hydrogen incident could escalate due to a lack of quick action and communication.	
-	17.0.2	-	A hydrogen incident could escalate due to lack of appropriate response.	
17.1	**17.1**	**Goal**	**Goal**	
		The goal of this chapter is to ensure that people onboard ships using hydrogen as a fuel are adequately prepared for their tasks.	The goal of this chapter is to ensure that people onboard ships using hydrogen as a fuel are adequately prepared for their tasks.	
-	**17.2**	**-**	**Functional requirements**	
-		-	This section is related to functional requirements in **3.2.1** and **3.2.2**. In particular, the following apply:	
-	17.2.1	-	Drills and emergency exercises should be conducted regularly to ensure that people on board are adequately prepared for their tasks.	EMSA D.1 Mapping safety risks for hydrogen-fuelled ships showed through accident analysis that rapid and correct intervention could significantly reduce the consequences of a hydrogen-related event. It also found it reported that emergency response teams sometimes lacked the knowledge to intervene in the most effective way.

				Consequently, drills and emergency exercises will be important tools to support knowledge gained through training and apply it to the specific conditions onboard.
17.2	**17.3**	**General**	**General**	
17.2.2	17.3.1	Drills and emergency exercises on board should be conducted at regular intervals. Such hydrogen-related exercises could include for example: .1 tabletop exercise; .2 review of fuelling procedures based in the fuel handling manual; .3 responses to potential contingences; .4 tests of equipment intended for contingency response; and .5 reviews that assigned seafarers are trained to perform assigned duties during fuelling and contingency response.	Drills and emergency exercises on board shall be conducted at regular intervals. Such hydrogen-related exercises could include, for example: .6 tabletop exercises; .7 review of fuelling procedures based on the fuel handling manual; .8 responses to potential contingencies; .9 tests of equipment intended for contingency response; and .10 reviews that assigned seafarers are trained to perform assigned duties during fuelling and contingency response.	
17.2.3	17.3.2	Hydrogen-related exercises may be incorporated into periodical drills required by SOLAS.	Hydrogen-related exercises may be incorporated into periodical drills required by SOLAS.	
17.3.3	17.3.3	The response and safety system for hazards and accident control should be reviewed and tested.	The response and safety system for hazards and accident control should be reviewed and tested.	

Draft IG	EMSA Guidance	IMO Draft Interim Guidelines for the safety of ships using hydrogen as fuel (CCC 11/WP.4 Annex 2)	EMSA Guidance for hydrogen-fuelled ships	Justification and comments
18	**18**	**Operation**	**OPERATION**	Goal and functional requirements are modelled on Chapter 18 of the IGF Code. The EMSA Guidance includes a complete chapter based on the IGF Code Chapter 18, but is amended for hydrogen.
-	**18.0**	-	**Hazards**	
-	18.0.1	-	Lack of adequate procedures for safe operation of the hydrogen system may lead to hazardous events during bunkering, storage, distribution and consumption of fuel.	
-	18.0.2	-	Lack of adequate procedures for maintenance may lead to hazardous events during maintenance and deterioration of equipment.	
-	18.0.3	-	Lack of adequate emergency procedures may lead to lack of appropriate response to emergencies.	
-	18.0.4	-	Ship and cargo operations may cause damage to the fuel containment and piping system.	
-	18.0.5	-	Breaking into containment during maintenance without properly isolating hydrogen system parts could result in a leak of liquefied or gaseous fuel.	
-	18.0.6	-	Repairs using unsuitable replacement parts could lead to system failures.	

-	18.0.7	-	Lack of maintenance may lead to degradation of safety functions intended to prevent and mitigate leakages.	
18.1	**18.1**	**Goal**	**Goal**	
		The goal of this chapter is to ensure that operational procedures for the loading, storage, operation, maintenance, and inspection of systems for hydrogen minimize the risk to persons on board, the ship, and the environment.	The goal of this chapter is to ensure that operational procedures for the safe bunkering, storage, distribution and consumption of fuel, and maintenance and inspection of fuel systems, minimize the risk to personnel, the ship and the environment.	
18.2	**18.2**	**Functional requirements**	**Functional requirements**	
18.2.1		This chapter relates to the functional provisions in 3.2.1 to 3.2.3, 3.2.9, 3.2.11, 3.2.14, 3.2.15 and 3.2.16 of these Interim Guidelines. In particular, the following provisions apply:	This section relates to the functional requirements in **3.2.1 to 3.2.3**, **3.2.5**, **3.2.8**, **3.2.11**, **3.2.15**, **3.2.16** and **3.2.20**. In particular, the following apply:	
	18.2.1	1 a copy of these Interim Guidelines, or national regulations incorporating the provisions of the same, should be on board every ship covered by these Interim Guidelines; .2 maintenance procedures and information for all hydrogen related installations should be available on board; .3 the ship should be provided with operational procedures including a suitably detailed fuel handling manual, such that trained personnel can safely operate the fuel bunkering, storage and transfer systems, including, but not limited to, the provisions of 6.3.2 and 6.4.8; .4 the ship should be provided with suitable emergency procedures; and .5 all documentation specified in 18.2 should be in a working language of the ship.	.5 Maintenance procedures and system descriptions for all hydrogen-related installations should be available on board. .6 The ship should be provided with operational procedures, including a suitably detailed fuel handling manual, so trained personnel can safely operate the fuel bunkering, storage and transfer systems. .7 The ship should be provided with suitable emergency procedures. .8 Procedures should be in a working language of the ship.	From EMSA D.1 Mapping safety risks for hydrogen-fuelled ships - Bunkering procedures should ensure that bunkering of fuel with a high percentage of ortho-hydrogen is avoided - Operational procedures should be guiding the crew in how to avoid contaminations of liquefied hydrogen systems Operational procedures to support trained personnel in safely operating the fuel bunkering, storage, and transfer systems should be available onboard. From EMSA D.1 Mapping safety risks for hydrogen-fuelled ships - Maintenance procedures and information for all hydrogen-related installations should be available on board; Procedures for heating and purging liquefied hydrogen tanks periodically to remove accumulated From EMSA D.1 Mapping safety risks for hydrogen-fuelled ships Emergency procedures accounting for any hazardous situation that may arise should be available onboard, special training for first responders should be provided and drills and emergency exercises should be conducted at regular intervals.
-	**18.3**	-	**Signboards**	
18.2.2	18.3.1	If a fuel leak leading to a fuel supply shutdown occurs, the fuel supply should not be operated until the leak has been found and dealt with. Instructions to this effect should be placed in a prominent position in the machinery space.	If a fuel leak leading to a fuel supply shutdown occurs, the fuel supply should not be operated until the leak has been found and dealt with. Instructions to this effect should be placed in a prominent position in the machinery space.	
18.2.3	18.3.2	A caution placard or signboard should be permanently fitted in the machinery space containing gas-consumers stating that heavy lifting, implying danger of damage to the fuel pipes, should not be done when the engine(s) is running on gas.	A caution placard or signboard should be permanently fitted in the machinery space containing gas-consumers stating that heavy lifting, implying danger of damage to the fuel pipes, should not be done when the engine(s) are running on gas.	
18.2.4	-	Chapter 18 of the IGF Code should be taken into account, where applicable, in order to fulfil the functional requirements.	-	The draft EMSA Guidance provides specific provisions for operational procedures.
18.2.5	-	For liquefied hydrogen, an appropriate procedure should be established for warm-up, inert gas purge, gas free, hydrogen purge and pre-cooling. The procedure should as a minimum include:	-	The draft EMSA Guidance provides specific provisions for operational procedures, but at a higher level than this provision.

		.1 selection of inert gas in relation to temperature limit; .2 measurement of gas concentration; .3 measurement of temperature; .4 rates of supply of gases; .5 conditions for commencement, suspension, resuming and termination of each operation; .6 treatment of return gases; and .7 discharge of gases.		
18.2.6	-	For liquefied hydrogen, the fuel handling manual as referred to in section 18.2.1.3, should take into account as a minimum that during warm up of vacuum protected tanks and piping, cryo-pumped nitrogen and oxygen in the insulation space should be assumed to be present as evaporation of these can occur, creating potential hazards.	-	
-	**18.4**	-	**Maintenance and inspection**	
-	18.4.1	-	Maintenance and repair procedures should include considerations with respect to the fuel containment systems and adjacent spaces.	
-	18.4.2	-	Inspections and surveys of the fuel containment system should be carried out in accordance with the inspection/survey plan required by 6.4.1.8 of the IGF Code Part A-1.	
-	18.4.3	-	Maintenance procedures and systems procedures should include maintenance of electrical equipment that is installed in explosion-hazardous spaces and areas. The inspection and maintenance of electrical installations in explosion-hazardous spaces should be performed in accordance with a recognized standard. __________ Refer to IEC 60079 17:2007 Explosive atmospheres – part 17: Electrical installations inspection and maintenance.	
-	**18.5**	-	**Bunkering operations**	
-	**18.5.1**	-	**Responsibilities**	
-	18.5.1.1		Before any bunkering operation commences, the master of the receiving ship or his representative and the representative of the bunkering source are Persons In Charge (PIC) of the bunkering operations and should: - agree in writing on the transfer procedure, including cooling down and, if necessary, gassing up; the maximum transfer rate at all stages and volume to be transferred; - agree in writing action to be taken in an emergency; and - complete and sign the bunker safety checklist.	
-	18.5.1.2	-	Upon completion of bunkering operations, the ship PIC should receive a Bunker Delivery Note for the fuel delivered, completed and signed by the bunkering source PIC.	
-	18.5.1.3	-	A fuel system schematic/piping and instrumentation diagram (P&ID) should be reproduced and permanently mounted in the ship's bunker control station and at the bunker station.	

-	**18.5.2**	-	**Pre-bunkering verification**	
-	18.5.2.1	-	Prior to conducting bunkering operations, pre-bunkering verification, including, but not limited to the following, should be carried out and documented in the bunker safety checklist: - all communications methods, including ship-shore link (SSL), if fitted; - operation of fixed gas and fire detection equipment; - operation of portable gas detection equipment; - operation of remotely controlled valves; - inspection of hoses and couplings; - operation of water spray system (if relevant).	
-	18.5.2.2	-	Documentation of successful verification should be indicated by the mutually agreed and executed bunkering safety checklist signed by both Persons In Charge.	
-	**18.5.3**	-	**Communications between the ship and the bunkering source**	
-	18.5.3.1	-	Communication between the ship PIC and the bunkering source PIC should be maintained at all times during the bunkering operation. If communications cannot be maintained, bunkering should stop and not resume until communications are restored.	
-	18.5.3.2	-	Bunkering communication devices should meet recognized standards.	
-	18.5.3.3	-	PICs should maintain direct and immediate communication with everyone involved in the bunkering operation.	
-	18.5.3.4	-	The ship-shore link (SSL), or an equivalent means, for automatic ESD communications to a bunkering source should be compatible with both the receiving ship and the delivering facility's ESD system.	
-	**18.5.4**	-	**Electrical bonding**	
-	18.5.4.1	-	Hoses, transfer arms, piping, and fittings supplied by the delivering facility for bunkering should be electrically continuous, adequately insulated, and ensure a level of safety that complies with recognized standards.	
-	**18.5.5**	-	**Conditions for fuel transfer**	
-	18.5.5.1	-	Warning signs should be posted at the access points to the bunkering area listing safety precautions during fuel transfer.	
-	18.5.5.2	-	During the fuel transfer operation, access to the bunkering manifold area should be limited to essential personnel only. All staff involved in duties or present in the vicinity of the operations must wear appropriate personal protective equipment (PPE). A failure to uphold the necessary conditions for transfer should warrant stopping operations. Transfer should not resume until all required conditions are satisfied.	
-	**18.6**	-	**Inerting and purging of fuel systems**	
-	18.6.1	-	Procedures for inerting and purging of fuel systems should ensure that:	

			- air is not present in piping or a tank being filled with hydrogen, - air is not leaking into piping or a tank containing hydrogen, and that - hydrogen is not introduced into enclosures or spaces adjacent to fuel systems.	
-	**18.7**	-	**Fuel handling manual**	
-	18.7.1	-	The ship-specific fuel handling manual, as referred to in 18.2.3, should address the issues specified in this section and provide information regarding the following:	The EMSA Guidance includes specific provisions for fuel handling manual content. Even though the ship is designed to be safe, it must be operated in a safe manner. A clear, structured, and relevant operational manual can be beneficial in this regard. The requirements are intended to guide the development of the manual in this direction.
-	18.7.1.1	-	The overall operation of the ship related to the hydrogen installation, from dry-dock to dry-dock.	
-	18.7.1.2	-	Arrangement and layout of the hydrogen fuel supply system, including: - a description of the main components in the fuel supply system; - a general description of how the fuel system is intended to work; - a hazardous area plan.	
-	18.7.1.3	-	Description of the safety system and automatic safety actions for the hydrogen fuel supply system, including: .1 Procedures for handling leakages: - in the fuel system; - in the tank connection spaces; - in the fuel preparation equipment; - in the bunkering station; and - from a fuel tank pressure relief valve. .2 Procedures for how to respond to substantial discharges from the outlet from fuel tank pressure relief valves, including; - closing of ventilation inlets; .3 Procedures for how to respond to a fire in: - the machinery space;or - on deck; in relation to the operation of the hydrogen fuel system.	
-	18.7.1.4	-	Description of hazards in connection with exposure to hydrogen and procedures for how to avoid exposure to hydrogen during: - bunkering operations - normal operation - entry of hazardous spaces or	

			- when performing maintenance on the hydrogen fuel system	
-	18.7.1.5	-	Description of hazards in connection with exposure to inert gas and procedures for how to avoid exposure.	
-	18.7.1.6	-	Description of entry procedures for: - tank connection spaces; - bunkering stations; - hold spaces; and - other spaces where entry may constitute a hazard to the ship or personnel.	
-	18.7.1.7	-	Description of bunkering operations, including procedures to: - ensure system readiness (fire, water spray, gas detection automatic valves, inert gas, pre-bunkering procedures, communication procedures); - prevent overfilling of tanks (transfer rates, filling limits, high-level alarms); - control the tank pressure when bunkering (vs. tank design temperature and pressure, spraying, vapour return); - prevent release of fuel gases to atmosphere; - purge the bunkering system at termination of bunkering operation; and - ensure proper use of PPE.	
-	18.7.1.8	-	Procedures for purging and gas freeing of hydrogen fuel containment and piping systems to ensure safe maintenance.	

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19	**19**	**TRAINING**	**TRAINING**	Training provisions in the EMSA Guidance are modelled on the IGF Code Part D Ch.19
-	**19.0**	-	**Hazards**	
-	19.0.1	-	Lack of understanding of hydrogen hazards onboard ships using hydrogen fuel may lead to hazardous events in normal operation and during maintenance and lack of appropriate response in emergencies.	
-	19.0.2	-	A hydrogen incident could escalate due to a lack of quick action and communication.	
-	19.0.3	-	A hydrogen incident could escalate due to lack of appropriate response in emergencies.	
-	19.0.4	-	Lack of understanding about the criticality of ignition sources could increase the risk of explosions.	
19.1	**19.1**	**Goal**	**Goal**	
		The goal of this chapter is to ensure that seafarers on board ships are adequately qualified, trained, and experienced, to safely operate a hydrogen-fuelled ship.	The goal of this chapter is to ensure that seafarers on board ships are adequately qualified, trained and experienced to safely operate a hydrogen-fuelled ship.	

19.2	**19.2**	**Functional requirements**	**Functional requirements**	
-		-	This section relates to the functional requirements in **3.2.1**, **3.2.2**, **3.2.5**, **3.2.11**, **3.2.15**, and **3.2.20**. In particular, the following apply:	
19.2.1	19.2.1	The Company should ensure that seafarers on board ships using hydrogen as fuel have completed training to attain the abilities that are appropriate to the capacity to be filled, and duties and responsibilities to be taken up, especially in emergency situations.	The Company should ensure that seafarers on board ships using hydrogen as fuel have completed training to attain the abilities that are appropriate to the capacity to be filled, and duties and responsibilities to be taken up, especially in emergency situations.	
19.2.2	19.2.2	The master, officers, ratings and other personnel on ships using hydrogen fuel should have received training and be qualified in the use of gaseous fuel in accordance with the STCW Convention and the STCW Code, taking into account the specific hazards of hydrogen.	The master, officers, ratings and other personnel on ships using hydrogen fuel should have received training and be qualified in the use of gaseous fuel in accordance with the STCW Convention and the STCW Code, taking into account the specific hazards of hydrogen.	
Draft IG	**EMSA Guidance**	**IMO Draft Interim Guidelines for the safety of ships using hydrogen as fuel (CCC 11/WP.4 Annex 2)**	**EMSA Guidance for hydrogen-fuelled ships**	**Justification and comments**
20	**20**	**PERSONNEL PROTECTION**	**PERSONNEL PROTECTION**	
-	**20.0**	-	**Hazards**	
-	20.0.1	-	Due to hydrogen's low ignition energy, personnel not wearing anti-static clothing may introduce a potential ignition source.	
-	20.0.2	-	Hydrogen leakages could lead to asphyxiation due to oxygen displacement.	
-	20.0.3	-	Exposure to liquid hydrogen could lead to cryogenic burns and internal damage due to cold vapour inhalation.	
-	20.0.4	-	Low ambient temperatures as a result of liquefied hydrogen leakages may hinder escape.	
-	20.0.5	-	Unprotected contact with cold surfaces may cause frostbite and skin freezing to the cold surface.	
20.1	**20.1**	**Goal**	**Goal**	
		The goal of this chapter is to ensure that protective equipment is provided for persons, considering both routine operations and emergency situations and possible effects of hydrogen exposure.	The goal of this chapter is to ensure that protective equipment is provided for people on board, considering both routine operations and emergencies and possible short- and long-term effects of hydrogen exposure.	
20.2	**20.2**	**Functional requirements**	**Functional requirements**	
20.2.1		This chapter relates to functional requirements in 3.2.1, 3.2.11 and 3.2.15. In particular the following provisions apply: .1 for the protection of crew members who are engaged in the operation and maintenance of hydrogen fuel systems, and emergency response, the ship should have on board protective equipment suitable for hydrogen exposure, taking the exposure risk of different operations into account; and	This section relates to functional requirements in **3.2.1**, **3.2.2** and **3.2.21**. In particular, the following apply:	

		.2 for the protection and treatment of crew members affected by contact with hydrogen, the ship should have on board suitable emergency equipment.		
-	20.2.1	-	For the protection of crew members who are engaged in the operation and maintenance of hydrogen fuel systems, and emergency response, the ship should have on board protective equipment suitable for hydrogen exposure, taking the exposure risk of different operations into account.	
-	20.2.2	-	For the protection and treatment of crew members affected by contact with hydrogen, the ship should have on board suitable emergency equipment.	
20.3	**20.3**	**Protective equipment**	**Protective equipment**	
20.3.1	20.3.1	Suitable protective equipment should be provided for the protection of personnel engaged in normal operations related to the hydrogen fuel system, considering the specific hydrogen-related hazards specified in 4.2.2 and the ship's operational procedures.	Suitable protective equipment, including cryogenic protection clothes and gloves, eye and ear protection, face shield, and respiratory protection to a recognized national or international standard, should be provided for the protection of crew members engaged in normal operations related to the hydrogen fuel system.	
20.3.2	20.3.2	Personal protective and safety equipment required in this section should be kept in suitable, clearly marked lockers located in readily accessible places.	Personal protective and safety equipment required in this section should be kept in suitable, clearly marked lockers located in readily accessible places.	

Appendix C Proposed structure of a goal-based guidance addressing the hydrogen bunkering process

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Appendix A Description of Bunkering Checklists

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