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INTERIM GUIDELINES FOR THE SAFETY OF SHIPS USING HYDROGEN AS FUEL

1 The Maritime Safety Committee, at its 111th session (13 to 22 May 2026), having considered a proposal by the Sub-Committee on Carriage of Cargoes and Containers, at its eleventh session (8 to 12 September 2025), recognizing the importance of providing criteria for the safe use of hydrogen fuels on board ships so as to provide at least the same level of safety and reliability as new and comparable conventional oil-fuelled main and auxiliary machinery installations, approved the *Interim guidelines for the safety of ships using hydrogen as fuel* (the Interim Guidelines), as set out in the annex.

2 Member States are invited to bring the Interim Guidelines to the attention of shipbuilders, manufacturers, shipowners, ship managers, masters and ship crews, bareboat charterers and all other parties concerned.

3 Member States are also invited to recount their experience gained through the use of the Interim Guidelines to the Organization for the Committee to keep them under review.

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ANNEX

INTERIM GUIDELINES FOR THE SAFETY OF SHIPS USING HYDROGEN AS FUEL

1 INTRODUCTION

1.1 The purpose of these Interim Guidelines is to provide an international standard for the safety of ships using hydrogen as fuel.

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.

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 special consideration for the use of hydrogen as fuel.

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.

1.5 The current version of these Interim Guidelines includes provisions to meet the functional requirements for hydrogen as fuel.

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 chapter 3, which is mainly text taken from chapter 3 of the IGF Code, albeit modified to reflect the recommendatory nature of these Interim Guidelines.

2 GENERAL

2.1 Application

Unless expressly provided otherwise, these Interim Guidelines should apply to ships using liquified and/or compressed hydrogen as fuel to which part G of SOLAS chapter II-1 applies.

2.2 Definitions and abbreviations

2.2.1 Reference is made to the definitions provided in the IGF Code, adopted by resolution MSC 391(95), as amended, part A, paragraph 2.2. Additional definitions are provided below.

2.2.2 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.

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

2.2.10 *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.

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

2.2.12 *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.

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

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

2.2.15 *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.

2.2.16 *Self-ignition* refers to ignition without the presence of any external ignition source. Thisalso includes ignition due to low ignition energy (e.g. electrostatic discharges, diffusion ignition).

2.3 Alternative design

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.

3 GOAL AND FUNCTIONAL REQUIREMENTS

3.1 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.

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 Equipment installed 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 overpressure 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 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.

3.2.13 Suitable control, alarm, monitoring and shutdown systems should be provided to ensure safe and reliable operation.

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

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

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

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

3.2.19 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.

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 in order to eliminate or mitigate any adverse effect to 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 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 be 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; and

.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 functional requirements in 3.2 have been satisfied.

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.

4.3 Limitation of explosion and fire consequences

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 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 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;

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

.9 affect the fuel containment system.

4.3.2 Piping and equipment containing fuel protected by secondary enclosures are not considered as potential hydrogen leak sources.

5 SHIP DESIGN AND ARRANGEMENT

5.1 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.

5.2 Functional requirements

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 provisions should apply:

.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;

.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;

.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;

.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;

.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;

.6 the probability of a hydrogen explosion in spaces containing hydrogen consumers or fuel piping systems should be minimized;

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

.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

.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.

5.3 General provisions

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

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.

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.

5.4 Provisions for machinery space arrangement

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.

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 gastight enclosure in accordance with the provisions of chapter 9.

5.4.5 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 2.3 are met. The approval of such arrangements should, as a minimum, take into account the hazards and topics listed in 4.2.2.

5.5 Arrangement principles for fuel cell power installations

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 Provisions for 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 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.

5.6.3 Fuel piping led through ro-ro spaces, special category spaces and on open decks, should be protected against mechanical damage.

5.7 Provisions for 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 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.

5.7.3 Notwithstanding 5.7.1, fuel preparation equipment may be permitted in enclosed or semi-enclosed space provided that the provisions of 2.3 are met. The approval of such arrangements should, as a minimum, take into account the hazards and topics listed in 4.2.2.

5.8 Provisions for 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 gastight 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 with 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 out of order owing 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. The bolted hatch should be located in a protective entry space of gastight construction accessed through an airlock.

5.9 Provisions for tank connection enclosures for compressed hydrogen

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.

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 of the enclosure as far as possible.

5.9.4 Tank connection enclosures should be gastight.

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 provided with continuous effective means of leak 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 Provisions for 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 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.

5.10.3 The bilge system should have bilge well high-level alarms. Low-temperature alarms should be fitted if liquid hydrogen leakage is possible.

5.11 Provisions for drip trays

5.11.1 Drip trays should be fitted where condensation of air may occur that can cause damage to the ship structure, or where condensate air due to a cold gas release otherwise may impinge on ship structures.

5.11.2 Drip trays should be made of materials suitable to collect liquid oxygen.

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.

5.11.4 Each drip tray should be fitted with a drain valve to enable rainwater to be drained over the ship's side.

5.11.5 Each drip 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, it should be ensured through design that liquid hydrogen leaks cannot combine with condensed oxygen in any scenario.

5.12 Provisions for 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 that complies with 5.13 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 that complies with 5.13 should be provided.

5.12.3 Unless access to the tank connection space is independent and direct from the open deck, it should be arranged as a bolted hatch. The space containing the bolted hatch will be a hazardous space.

5.12.4 For inerted spaces, access arrangements should be such that unintended entry by personnel can be prevented. If access to such spaces is not from an open deck, sealing arrangements should ensure that leakages of inert gas to adjacent spaces are prevented.

5.13 Provisions for airlocks

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 hold-back arrangements.

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

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 assessment according to 4.2.

5.13.4 Airlocks should have a suitable geometrical form to prevent hydrogen accumulation.

5.13.5 Airlocks should provide free and easy passage of personnel, and should have a deck area not less than 1.5 m^2. Airlocks should not be used for other purposes, for instance as store rooms.

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.

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 underpressure 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.

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.

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 and general alarm systems.

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 providing natural ventilation and unobstructed relief of 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 2.3 are met. The approval of such arrangements should, as a minimum, take into account the hazards and topics listed in 4.2.2.

5.15 Storage arrangements for liquified hydrogen

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.

5.15.2 Notwithstanding 5.15.1, hydrogen storage may be permitted in an enclosed or semi-enclosed space provided that the provisions of 2.3 are met. The approval of such arrangements should at a minimum, take into account the hazards and topics listed in 4.2.2.

6 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 persons on board, the ship and the environment, to a level that is equivalent to a conventional oil-fuelled ship

6.2 Functional requirements

6.2.1 This chapter relates to functional requirements in 3.2.1 to 3.2.19. In particular, the following provisions should apply.

6.2.2 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.

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

6.2.4 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.

6.2.5 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.

6.2.6 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.

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

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

6.2.9 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.

6.2.10 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.

6.2.11 Loss of vacuum insulation should not lead to an unsafe condition.

6.3 General provisions for fuel containment systems

6.3.1 For type C independent tanks, piping between the tank and the first valve should have equivalent safety as the type C independent 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.

6.4 Provisions for liquefied gas fuel containment

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

6.4.2 The provisions for liquefied hydrogen fuel containment in these Interim Guidelines are for vacuum-insulated type C independent tanks only. The requirements of 6.4 of the IGF Code, part A-1, related to other tank types, should not apply to ships using liquefied 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 2.3 are met. The approval of such arrangements should, as a minimum, take into account the hazards and topics listed in 4.2.2.

6.4.4 The dynamic membrane stress in 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 In addition to 6.4.8 of the IGF Code, the following provisions regarding thermal insulation should apply:

.1 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.

.2 Thermal insulation should prevent liquefaction and solidification of ambient air, i.e. oxygen, nitrogen, etc.

.3 Thermal insulation should be resistant to the effects of high oxygen concentrations caused by air condensation and subsequent evaporation at low temperatures.

.4 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.

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

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 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, 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.

6.5 Provisions for portable liquefied hydrogen tanks

6.5.1 Provisions for portable liquefied hydrogen tanks are not included in these Interim Guidelines. The requirements of 6.5 of the IGF Code, part A-1, related to portable liquefied gas fuel tanks, should not apply to ships using liquefied hydrogen as fuel.

6.5.2 Notwithstanding 6.5.1, liquefied hydrogen storage in portable tanks may be permitted provided that the provisions of 2.3 are met. The approval of such arrangements should, as a minimum, take into account the hazards and topics listed in 4.2.2.

6.6 Provisions for compressed hydrogen containment

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.

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.

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

6.6.3 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.

6.6.4 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

.2 fatigue loading as defined in 6.4.12.2 of the IGF Code, part A-1.

6.6.5 Portable compressed hydrogen containment

6.6.5.1 In addition to 6.6.1 to 6.6.4, the following provisions should apply for portable compressed hydrogen containment.

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 assessment of 4.2.2.

6.6.5.5 Portable fuel tanks should be located in dedicated areas arranged in accordance with the provisions of these Interim Guidelines.

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 should 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 Provisions for pressure relief systems

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

6.7.2 The vent mast height and distance requirements for tank vents, compressed and liquefied, should be considered as 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.

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

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 be designed to withstand the maximum expected explosion pressure in all foreseeable scenarios.

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.

6.7.7 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 designed and constructed to prevent blockage due to formation of ice.

6.7.8 Vent masts should generally not be fitted with flame arrestors. However, prevention of ingress of foreign objects should be arranged.

6.7.9 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.

6.7.10 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.

6.7.11 Compressed hydrogen cylinders should be fitted with temperature-actuated safety relief systems, e.g. thermally activated pressure relief devices (TPRDs), or a similar system, that automatically reduces tank pressure in case of external fire.

6.7.12 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.

6.7.13 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 blowdown or emergency venting scenario.

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

6.7.15 Pressure relief device discharges on secondary enclosures should be directed to the vent mast.

6.7.16 The vent mast and connected vent lines should be electrically bonded to prevent build-up of static electricity.

6.7.17 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.

6.8 Provisions on loading limit for liquefied hydrogen tanks

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

6.9 Provisions for maintaining the fuel storage condition for liquefied hydrogen

6.9.1 Unless expressly provided otherwise, the requirements of 6.9 of the IGF Code should apply to ships using hydrogen as fuel.

6.10 Provisions on atmospheric control within the fuel containment system for liquefied hydrogen

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.

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.

6.10.3 Gas sampling points should not be fitted unless necessary for safe gas freeing.

6.10.4 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 Inert gas utilized for gas freeing of fuel tanks may be provided externally to the ship.

6.11 Provisions on 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 these Interim Guidelines are for vacuum-insulated type C independent tanks only. The requirements of 6.11 of the IGF Code, part A-1, related to other tank types, should not apply to ships using liquefied 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 2.3 are met. The approval of such arrangements should, as a minimum, take into account the hazards and topics listed in 4.2.2.

6.12 Provisions on environmental control of spaces surrounding vacuum-insulated type C independent tanks in case of vacuum loss

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 assessment required by 4.2.2.

6.12.2 The spaces or areas 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.

6.13 Provisions on 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 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.

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.

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.

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.

6.14 Provisions on inert gas production and storage on board

6.14.1 Unless expressly provided otherwise, the requirements of 6.14 of the IGF Code should apply to ships using hydrogen as fuel.

6.14.2 Instead of 6.14.1 of the IGF Code, the following provisions should apply:

.1 the equipment should be capable of producing inert gas with oxygen content at no time greater than 3% by volume; and

.2 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.

6.14.3 In addition to 6.14 of the IGF Code, the following provisions should apply:

.1 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; and

.2 for high-pressure hydrogen system secondary enclosures, the capacity of the inert gas system should be suitable for purging of the enclosures after a high-pressure leak and subsequent loss of containment integrity (e.g. burst discs rupturing).

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 vacuum systems should provide separate discharge to a vent mast capable of handling cryogenic hydrogen.

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

7 MATERIAL AND GENERAL PIPE DESIGN

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, persons on board and the environment, having regard to the nature of the products involved.

7.2 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 should apply.

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

7.2.3 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.

7.2.4 Provisions should be made to minimize the likelihood and size of a leak from the piping system.

7.2.5 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 Materials used in all components in contact with hydrogen should withstand phenomena such as, but not limited to, hydrogen embrittlement and hydrogen 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.

7.2.8 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).

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.

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.

7.3 General

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

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.

7.4 Materials

7.4.1 General

7.4.1.1 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.

7.4.1.3 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 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.

7.4.1.5 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.

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.

7.4.2 Metallic materials

7.4.2.1 Metallic materials to be used in hydrogen systems should be suitable for their intended use.

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.

7.4.2.3 The allowable stress used should be that for the base metal at the design temperature.

7.4.2.4 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

.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 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 Non-metallic materials

7.4.3.1 Non-metallic materials to be used in hydrogen systems should be suitable for their intended use.

7.4.3.2 Coefficients of thermal expansion (CTE), thermal conductivity and permeation by hydrogen should be considered when choosing materials.

7.4.3.3 Fire resistance properties should be considered for use in gaskets, packing or other sealing elements.

8 BUNKERING

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 environment or the ship.

8.2 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 should apply.

8.2.2 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.

8.2.3 Bunkering systems should be protected from mechanical damage.

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

8.2.5 Bunkering systems should be arranged with the possibility of remote and local emergency stop of fuel transfer.

8.2.6 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.

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

8.2.8 Formation of oxygen-enriched environments should be prevented or at least mitigated.

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

8.3 Bunkering stations

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 the ship.

8.3.2 Notwithstanding 8.3.1, bunkering stations arranged in an enclosed or semi-enclosed space may be permitted provided that the requirements of alternative design (SOLAS regulation 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 gastight bulkheads towards adjacent spaces.

8.3.3 Arrangements should be made for safe management of any leaked fuel or condensed air.

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.

8.3.5 Bunkering lines should not pass through accommodation spaces, control stations or service spaces.

8.3.6 Bunkering lines should be arranged with secondary enclosures in accordance with 9.5 and 9.6 up to the bunkering manifold.

8.3.7 Bunkering 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 Suitable means should be provided to depressurize and remove liquid contents from bunkering lines. Liquid should be discharged to the liquefied fuel tanks or other suitable location.

8.3.9 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.

8.3.10 The ship's fuel hoses and associated fittings should be in accordance with the requirements of 8.3.2 of the IGF Code.

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 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.

8.4.4 Notwithstanding 8.4.3, the following alternative means for achieving dry-disconnect operation may be permitted provided that the provisions of 2.3 are met to the satisfaction of the Administration:

.1 a manual connect coupler or hydraulic connect coupler, used to connect the bunkering system to the receiving ship’s bunkering manifold presentation flange; or

.2 a bolted flange-to-flange assembly.

8.4.5 When it is intended to use either of the connections specified in 8.4.3 and 8.4.4, these should be combined with operating procedures that ensure a dry-disconnect is achieved. The arrangement should 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 should include documentation that the bunkering arrangement risk assessment was conducted, and that special consideration was granted under this requirement.

8.4.6 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 the said means should be in accordance with a standard equivalent to that acceptable to the Administration. It should enable a quick physical disconnection "dry break-away" of the bunkering system in an emergency event.

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 in series, or a combined manually operated and remotely operated 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.

8.5.3 Bunkering lines should be arranged for inerting and gas freeing for shutdown and maintenance.

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 Where bunkering pipes are arranged with a crossover, suitable isolation arrangements should be provided so that fuel cannot be transferred inadvertently to the ship side not in use for bunkering.

8.5.6 A bunkering safety link or an equivalent means for automatic and manual emergency shutdown (ESD) communication to the bunkering source should be fitted.

9 FUEL SUPPLY TO CONSUMERS

9.1 Goal

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

9.2 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 should apply.

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

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

9.2.4 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.

9.2.5 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.

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

9.3 General hydrogen 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 Hydrogen piping systems should as far as practicable be joined by welding.

9.3.3 It should be possible to detect leakages in a fuel piping system and automatically isolate the leakage from the source.

9.3.4 It should be possible to automatically isolate the piping systems for fuel at the tank boundary.

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.

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.

9.4 Regulations on redundancy of fuel supply

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 essential auxiliaries of the fuel supply, 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.

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 4.3.

9.4.3 For type C independent tank only, one tank may be accepted if two completely separate tank connection spaces are installed for the one tank.

9.5 Fuel piping systems containing liquefied hydrogen and cold hydrogen vapour

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.

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 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.

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.

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.

9.6 Fuel piping systems containing gaseous fuels

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 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 in 4.3, 12.3 and chapter 13.

9.6.2 Single-wall piping can be accepted for open deck installations subject to dispersion analysis, and explosion analysis if needed according to 12.3, if an ignitable cloud which may affect adjacent structures or persons cannot be excluded.

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 shutdown valves controlled by the safety system.

9.6.4 The consequences of leakage should be further reduced by use of flow restrictors or excess flow valves or similar devices.

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 chapter 15.

9.7.2 Valves should be easily accessible for inspection and maintenance.

9.7.3 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 or a combined remotely and automatically operated valve. 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 consumer. The master gas fuel valve should automatically cut off the gas supply when activated by the safety system as required in 15.2.2.

9.7.4 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 chapter 15.

9.7.5 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.

9.7.6 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 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.

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 of the engine.

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 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.

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 POWER GENERATION, INCLUDING PROPULSION AND OTHER FUEL CONSUMERS

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

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 should apply.

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

10.2.3 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 All fuel consumers should have separate exhaust systems. This does not apply to fuel cell power installations.

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

10.3 Provisions for internal combustion engines of piston type

10.3.1 Unless expressly provided otherwise, the requirements of 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 should 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).

10.4.2 Other gas consumers, such as main and auxiliary boilers or gas turbines, may be permitted provided that the provisions of 2.3 are met to the satisfaction of the Administration.

10.5 Provisions for fuel reforming equipment

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 2.3 are met to the satisfaction of the Administration.

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).

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 2.3 are met. The approval of such arrangements should, as a minimum, take into account the hazards and topics listed in 4.2.2.

11 FIRE SAFETY

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 fuel.

11.2 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.

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

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

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

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

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

11.2.7 The ignition of operational and accidental fuel releases should not expose structural elements, equipment and people on board to unacceptable heat radiation levels.

11.2.8 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 Unless expressly provided otherwise, the requirements of 11.3 of the IGF Code should apply to ships using hydrogen as fuel.

11.3.2 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.

11.4 Fire-extinguishing

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

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, bunkering connection valve and isolation valves, before activating any fire-extinguishing method.

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 as suitable for extinguishing and control of the secondary fire as relevant, and effective use on naturally-ventilated open deck if applicable.

11.5 Provisions for water spray cooling systems

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

11.5.2 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.

11.5.3 The water spray cooling system should have an application rate of 10 $L/min/m^2$ for horizontal projected surfaces and 4 $L/min/m^2$ for vertical surfaces.

11.5.4 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.

11.5.5 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.

11.5.6 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.

11.5.7 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.

11.5.8 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).

11.5.9 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.

11.5.10 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 survival craft facing fuel tanks and fuel equipment on open deck, in addition to fuel arrangement and equipment on open deck.

11.6 Fire detection and fire alarm systems

11.6.1 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.

11.6.2 Smoke detectors alone should not be considered sufficient for rapid detection of a fire.

12 EXPLOSION PREVENTION

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

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 provisions should apply.

12.2.2 The probability and consequence of explosions should be reduced to a minimum by:

.1 reducing the 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.

12.3 Explosion risk analysis

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 on 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.

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 in restricted waters, manoeuvring, alongside, maintenance/inspection).

12.3.2.1 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 other than the tank vent system; and

.4 release of hydrogen due to 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.

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.

12.3.3 The ERA should provide, as a minimum, the following information for the scenarios being evaluated:

.1 initiating hazardous event causing the leak;

.2 process conditions (e.g. temperature, pressure);

.3 leakage location;

.4 leak size (e.g. geometry, coefficient of discharge);

.5 leakage duration;

.6 phase (i.e. gas, liquified, two-phase);

.7 leak orientation (e.g. vertical, vertical down);

.8 ignition mechanisms and characteristics (timing/location); and

.9 space/area ventilation conditions.

12.3.4 The following leakage scenarios, as a minimum, should be taken into account as an input to the ERA in 12.3.1:

Component	Leakage size to be considered
Pipe[3]	0.01 D^2 (mm^2) for $D \leq 100$ mm, 100 mm^2 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: $\pi D^2 /4$
Pipe coupling and screwed connections	Full-bore rupture: $\pi D^2 /4$
D = pipe diameter, t = thickness of gasket, DB = flow diameter through bonnet	

12.3.5 In addition, leakage scenarios in accordance with a recognized standard acceptable to the Administration could also be applied.

12.4 Provisions on 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.

12.4.3 Ventilation ducts should have the same area classification as the ventilated space it serves.

12.4.4 Hazardous areas on open deck and other spaces not addressed in this chapter should be classified in accordance with a recognized standard. The electrical equipment fitted within hazardous areas should be in accordance with the same standard.

12.4.5 Electrical equipment and wiring should, in general, not be installed in hazardous areas unless essential for operational purposes based on a recognized standard.[4]

12.4.6 Equipment groups and temperature classes should be determined according to a recognized standard[5] acceptable to the Administration considering the categories of the flammable gases which may occur and accumulate in a hazardous area.

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3 The possibility of a full-bore rupture, if indicated by the risk assessment, should not be excluded.

4 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.

5 Refer to IEC 60079 series standards, as applicable.

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 tank connection spaces, tank connection 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.

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.

12.5.4 With regard to 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, as a minimum, the hazardous zones should follow those prescribed for natural gas in 12.5 of the IGF Code. The aforementioned locations are the following:

.1 areas on open deck, or semi-enclosed spaces on deck, surrounding any fuel tank outlet, gas or vapour outlet, bunkering 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 bunkering manifold valve; and

.4 an area on deck or semi-enclosed space surrounding a bolted hatch to tank connection space.

[6] Fuel storage hold spaces for type C independent tanks are normally not considered as zone 1.

13 VENTILATION

13.1 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.

13.2 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.

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.

13.3 General provisions

13.3.1 Enclosed hazardous spaces with a potential source of release should be inerted or arranged with vacuum.

13.3.2 Notwithstanding 13.3.1, ventilation arrangements may be permitted provided that the provisions of 2.3 are met. The approval of such arrangements should, as a minimum, take into account the hazards and topics listed in 4.2.2, and the following:

.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.

.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.

.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 gastight and have overpressure 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 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 Air outlets from non-hazardous spaces should be located outside hazardous areas.

14 ELECTRICAL INSTALLATIONS

14.1 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.

14.2 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 should apply.

14.2.2 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 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 Electrical equipment should function as intended for all normal and reasonably foreseeable abnormal environments.

14.3 Provisions – general

14.3.1 Unless expressly provided otherwise, the requirements of 14.3 of the IGF Code should apply to ships using hydrogen as fuel.

14.3.2 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.

14.3.4 The de-energizing of electrical equipment is not accepted as a safety barrier, except for spaces protected by airlocks.

15 CONTROL, MONITORING AND SAFETY SYSTEMS

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 installations.

15.2 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 should apply.

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

15.2.3 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.

15.2.4 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 signals.

15.2.5 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 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.

15.2.7 It should be possible to detect any fuel leakage in enclosed or semi-enclosed spaces and on the open deck.

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

15.3 General arrangement

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 equipment including bunkering.

15.3.2 For tanks not permanently installed in the ship, a monitoring system should be provided as is the case for permanently installed tanks.

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

15.3.4 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.

15.4 Provisions for 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 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.

.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, the continuously manned central control station or the onboard safety centre.

15.4.3 The vapour space of each fuel tank should be provided with a direct pressure reading gauge. Additionally, an indirect pressure indication should be provided on the navigation bridge, the continuously manned central control station or the onboard safety centre.

15.4.4 The pressure indicators should be clearly marked with the highest and lowest pressure permitted in the liquefied gas fuel tank.

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

15.4.6 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.

15.4.7 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, the continuously manned central control station or the onboard safety centre.

15.5 Compressed hydrogen bunkering and fuel tank monitoring

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.

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.

15.6 Gas detection

15.6.1 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 bunkering 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.

15.6.2 The number of detectors in each space should be considered taking into account the leakage scenario, size, layout and ventilation of the space.

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.

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[7] Appropriate means for detecting leakage into the annular space should be accepted as an alternative, e.g. pressure monitoring.

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.

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

15.6.6 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).

15.6.7 Audible and visible alarms from the gas detection equipment should be located on the navigation bridge or in the continuously manned central control station.

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

15.7 Fire detection

15.7.1 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.

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

15.8 Loss of vacuum, inert atmosphere, or ventilation

15.8.1 The following scenarios should give an audible and visual alarm on the navigation bridge or in the continuously manned central control station or the 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]

15.8.2 Vacuum monitoring equipment on vacuum spaces should be designed to prevent cryo-pumping of air.

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.

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

[8] Notwithstanding normal vacuum integrity indications, cryo-pumping of air in vacuum spaces cannot be excluded.

leakages should result in automatic closing of all valves required to isolate the leakage. Leakage detection in the secondary enclosure of the bunkering line should immediately result in automatic closing of the bunkering valve.

15.10 Safety functions of fuel supply systems

15.10.1 If the fuel supply is shut off owing 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.

15.10.2 Safe shutdown 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.

15.10.3 The gas compressor should also be arranged for manual local emergency stop.

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	X	X[2]		

Parameter	**Alarm**	**Automatic shutdown of tank valve[6]**	**Automatic shutdown of gas supply to machinery space containing gas-fuelled engines**	**Comments**
containing gas-fuelled engines at 40% LEL				
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		

Parameter	Alarm	Automatic shutdown of tank valve[6]	Automatic shutdown of gas supply to machinery space containing gas-fuelled engines	Comments

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), 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.

16 MANUFACTURE, WORKMANSHIP AND TESTING

16.1 Goal

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 to minimize the risk to the ship, the people and the environment.

16.2 General

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

16.2.2 For materials whose design temperature is lower than -165°C, the toughness tests should be carried out in accordance with recognized 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 independent 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 recognized 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% hydrogen and 95% 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 liquefied 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 liquefied 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.

17 DRILLS AND EMERGENCY EXERCISES

17.1 Goal

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

17.2 General

17.2.1 Drills and emergency exercises on board should be conducted at regular intervals.

17.2.2 Such hydrogen-related exercises could include, for example:

.1 tabletop exercise;

.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.

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

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

18 OPERATION

18.1 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.

18.2 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 should apply:

.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.

18.2.2 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 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.

18.2.4 Chapter 18 of the IGF Code should be taken into account, where applicable, in order to fulfil the functional requirements.

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:

.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 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.

19 TRAINING

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

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.

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

20.1 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.

20.2 Functional requirements

This chapter relates to functional requirements in 3.2.1, 3.2.11 and 3.2.15. In particular, the following provisions should 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

.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 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.

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.

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