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D8.2 – "Guidelines for the update of existing International (IMO, EU) and National regulation and standards related to the use of ENGIMMONIA Clean energy technologies in maritime sector"

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Abbreviations and acronyms

ABS	American Bureau of Shipping
AC	Adsorption chillers
A.C.	Alternating Current
AFIR	Alternative Fuels Infrastructure Regulation
AIP	Approval in Principle
ALARP	As Low As Reasonably Practicable
BV	Bureau Veritas
CCC	IMO sub-Committee on Carriage of Cargoes and Containers
D.C.	Direct Current
DNV	Det Norske Veritas
EMS	Energy Management System
ETS	Emissions Trading Scheme
FCHJU	Fuel Cells and Hydrogen Joint Undertaking
FMEA	Failure Mode and Effect Analysis
FSA	Formal Safety Assessment
GHG	Greenhouse Gases
GT	Gross Tonnage
HAZID	Hazard Identification
HAZOP	Hazard and Operability
HFO	Heavy Fuel Oil
HSE	Health, Safety & Environment
HT FW	High-Temperature Fresh Water
HVAC	Heating, Ventilation & Air Conditioning
IACS	International Association of Classification Societies
IACS UR	IACS Unified Requirements
ICE	Internal Combustion Engines
IDHL	Immediate Danger to Life or Health
IGC	International Code of the Construction and Equipment of Carrying Liquefied Gases in Bulk
IGF	International Code of Safety for Ship Using Gases or Other flashpoint Fuels
IMO	International Maritime Organization
ISM	International Safety Management
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LR	Lloyd's Register
MARPOL	International Convention for the Prevention of Pollution from Shi
MDO	Marine Diesel Oil
MED	Marine Equipment Directive
MPPT	Max Power Point Tracking
MR	Mutual Recognition
MSC	IMO Maritime Safety Committee
MTBF	Mean Time Between Failures
NH3	Ammonia
OPS	Onshore Power Supply
ORC	Organic Rankine Cycles
P&ID	Piping and Instrumentation Diagram
PDA	Prototype Design Assessment
PEL	Permissible Exposure Limits
PV	Photovoltaics
RCO	Risk Control Options
REL	Recommended Exposure Limits
RO	Recognised Organisation
SOLAS	IMO International Convention for the Safety of Life at Sea
STCW	IMO International Convention on Standards of Training, Certific and Watchkeeping for Seafarers
TA	Type Approval
TQP	Technology Qualification Process
UI	IACS Unified Interpretation

WH	Waste Heat
WHAT-IF	“What-if” methodology, in a risk analysis
ZEWT	Zero Emission Waterborne Transport

1. Executive summary

This D8.2 belongs to ENGIMMONIA WP 8 *"Regulatory, policy, infrastructure and safety aspects"*. This public deliverable is based upon D8.1, which has already presented a review of the current marine regulatory framework, used as baseline to develop the variety of ENGIMMONIA technologies and including international regulations (IMO, EU), national provisions and classification rules.

D6.2 *"Engineering design of demo-vessels and integration of solutions to be demonstrated"* - which is developed in parallel to D8.2 - is another essential reference, detailing the design criteria of the various energy saving technologies implemented on the selected ships, namely a VLCC (FAMOUS Princess Vanya), a containership (DANAOS Zim Luanda) and a ro-ro passenger ship (ANEK Elyros).
The added value of this D8.2 is the update of the continuously evolving regulatory framework at the time of the issue of the deliverable, and a verification of the impact of this evolution on the ENGIMMONIA technologies. In other words, the design of the innovative systems of the Project is progressing while the mandatory provisions (by IMO) are also evolving.

This dynamic situation is not necessarily a barrier to the Project finalization and the market uptake of its solutions. On the contrary, the design in progress and the lessons learnt from the implementation of the technologies on the selected ships may offer the opportunity to interact positively with the new / updated regulations.
It is recalled that ENGIMMONIA focus different technologies:

- Ammonia fuelled engines and their integration on board.
- Other clean energy technologies:
  - Organic Rankine Cycle (ORC) solutions, using waste heat to generate electricity.
  - Adsorption Chillers (AC) driven by waste heat used for cooling.
  - Photovoltaic (PV) solutions, supplementing the electrical generation on board.

This deliverable is aimed at outlining the specific and complex evolution of the IMO *"Guidelines for the safety of ships using ammonia as fuel"* and reassuring on the feasibility of the "other clean energy technologies", which are not limited or impacted by the current regulatory framework.
Based upon these conclusions, it will be seen that the technical developments in WP5 and WP6 can progress unaffected and be used on a variety of new or existing ships.

2. Regulatory aspects applicable to clean energy technologies in the maritime sector.

2.1 Regulations and standards - Industrial vs. Maritime.

D8.1 already showed how the regulatory framework applicable to the maritime sector has often been the result of a fragmented approach. The recent IMO developments aimed at defining a set of Guidelines applicable to alternative low flashpoint fuels confirms an approach which follows the principles broadly inspired by the IMO goal-based standards (MSC.1/Circ.1394/Rev.2), identifying: 1) goals, 2) functional requirements; 3) prescriptive requirements – supplemented by Class rules – and 4) industry standards developed by standards organizations (ISO, IEC…), which are vendor-neutral.
.
The final assessment of the safety of the ship in which the new technologies are implemented is under the responsibility of the relevant Flag Administration. Several acceptance criteria are left to the discretion of the Administration which, in turn, relies upon the experience of the Recognized Organizations (in general Classification Societies) to

define in detail the assessment methods, the needed simulations / models / calculations / certified software, the testing criteria of systems and components, and the certification process (e.g. type approval, MED compliance, etc.). Class rules and industrial standards can be derived from land-based applications, subject to the necessary "marinization" process,

3. AMMONIA as fuel.

3.1 Ammonia as marine fuel.

Reference is made to D8.1 section 3, which already outlined the potential of ammonia as marine fuel and the current regulatory framework. The situation presented in D8.1, linked to the outcome of the IMO CCC 7 Sub-Committee has evolved in the meantime. The following section presents updated the state of play of the international provisions of ammonia as fuel.

3.2 IMO Guidelines for the safety of ships using ammonia as fuel.

The IMO CCC 9 Sub-Committee established a Working Group (WG) on *"Development of Technical Provisions for Safety of Ships Using Alternative Fuels"*. The WG met from 20 to 28 September 2023, was chaired by Mr. C. Allgeier (Germany).

The purpose of these Interim Guidelines is to provide an international standard for ships using Ammonia as fuel.
The goal of these Interim Guidelines is to provide for safe and environmentally friendly design, construction and operation of ships and in particular their installations of systems for propulsion machinery, auxiliary power generation machinery and/or other purpose machinery using ammonia as fuel to minimize the risk to the ship, its crew and the environment, having regard to the nature of the fuel involved.

The Interim Guidelines follow the Generic guidelines for developing IMO goal-based standards (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 Ammonia as fuel.

It is recalled that the Interim Guidelines are closely aligned with the International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels (IGF Code - resolution MSC 391(95) which is made mandatory as part of the SOLAS Convention, modified to reflect the recommendatory and non-prescriptive nature of the Interim Guidelines.

The CCC 9 WG further specified overarching principles and directions that will guide the next Correspondence Group (CG) during its intersessional work towards finalization of the Interim Guidelines at CCC 10 in September 2024.

The essential aspects are summarised as follows:

- The Interim Guidelines apply to ships using ammonia as fuel, and do not address ships using ammonia cargo as fuel, which are regulated by the ICG Code.
- The use of ammonia constitutes a different risk profile compared to LNG or hydrogen and requires careful consideration of safety provisions that address all properties of ammonia, including toxicity and corrosivity.

- the use of ammonia would require setting permissible limits of exposure (short/long-term) to humans.
- A holistic risk assessment should be carried out for the approval of ships using ammonia as fuel, either in its liquefied or gaseous state.
- The Interim Guidelines shall consider refrigerated and semi-refrigerated ammonia storage options. Pressurized ammonia will be covered through alternative design process.
- Portable tank provisions for ammonia shall not be specifically developed but can be considered through an alternative design process.
- The Guidelines will not consider Emergency Shut Down (ESD) principles related to the use of single-walled piping systems. Administrations will need to go through the alternative design process.
- Safe refuge on board ships using ammonia as fuel in case of ammonia contamination / leaks, should consider the ship type and number of people on board. In this regard, it could be possible that the application of the interim Guidelines could exclude or discourage the use on specific ship types (e.g., cruise ships and passenger ferries !!!).
- Provisions for personnel safety and personal protective equipment (PPE) is recognized as a last line of defence, and should be developed, taking into account shore-based industry practice and Class rules.
- During normal operations there should be no release of ammonia.
- To address ammonia release in the case of safety reasons (e.g., as in a system shut-down scenario) – but not in emergency – release mitigating measures should be considered which may include ammonia scrubbers. In preparing such provisions the disposal of residues from the process should be considered.
- Concentration limits for ammonia exposure for personnel should be considered in emergency cases with a major release of ammonia.
- The Interim Guidelines introduce the concept of Toxic Area and provisions for Toxic Area classification. Toxic Area is defined as an area in which health-affecting concentrations of ammonia vapour is or may be expected to be present. The concentration level beyond which ammonia vapour should be considered toxic is under discussion [300 ppm] [50 ppm], depending on the effects which could limit the actions by personnel on board to mitigate the consequences of an ammonia leakage.
- A dispersion analysis (e.g. using CFD simulations) should be carried out. The boundary conditions should be approved by the Administration. The analysis should include, but not be limited to, discharges from the pressure relief valves protecting the tank containment system, discharges from secondary barriers around fuel tanks and discharges from secondary enclosures around ammonia leakage sources.
- Risks which cannot be eliminated should be mitigated as necessary to the satisfaction of the Administration.
- The functional requirements for safe location, space arrangements and mechanical protection of power generation equipment, fuel storage systems, fuel supply equipment and refuelling systems include that the fuel tank(s) should be located in such a way that the probability for the tank(s) to be damaged following a collision or grounding is reduced to a minimum taking into account the safe operation of the ship and other hazards that may be relevant to the ship.

The CCC 9 WG prepared a revised draft for these Interim Guidelines for further consideration by the intersessional Correspondence Group (CG).

Besides this short brief and the full set of the Interim Guidelines - which can be consulted in doc. CCC 9/WP.3 - some comments are needed:

- 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 available of current operational experience, field data and research and development. These Interim Guidelines address all areas that need special consideration for the use of Ammonia as fuel. It is emphasized that their goal is the safety of the ship and of her occupants.

- A *Safety Concept* is tentatively introduced, as a document describing the safety philosophy with regard to ammonia fuel. It identifies potential sources of ammonia and describes how risks associated with this type of fuel are mitigated / controlled under reasonably foreseeable abnormal conditions as well as possible failure scenarios and their control measures.
- Appliances and arrangements of ammonia 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.
- The ammonia fuel tank(s) should be protected against mechanical damage and be located in such a way that the probability for the tank(s) to be damaged following a collision or grounding is reduced to a minimum taking into account the safe operation of the ship and other hazards that may be relevant to the ship. This functional requirement opens a discussion – which is still to be made - on the minimum distance of the boundary of the ammonia tanks from the side shell and the keel / double bottom. Unless expressed otherwise, the requirements of the IGF Code Part A-1 apply.
- Ammonia pipe design and metallic materials for ammonia containment should ensure a safe and reliable operation and maintenance, with design conditions as specified in the Interim Guidelines
- Materials which may be exposed to fuel during normal operations should be resistant to the corrosive action of ammonia. In addition, mercury, copper, copper alloys, zinc and cadmium should not be used for the construction of fuel tanks as well as associated pipelines, valves, fittings and other items of equipment normally in direct contact with the fuel liquid or vapour.
- Anhydrous ammonia may cause stress corrosion cracking in containment and process systems made of carbon manganese steel or nickel steel. To minimize the risk of this occurring, measures specified in the Interim Guidelines (in 7.4.3.2 to 7.4.3.8) should be taken as appropriate to minimize this risk.
- Bunkering of ammonia required suitable systems on board the ship, to ensure that bunkering can be conducted without causing danger to persons, the environment or the ship.
- One of the key aspects in the Interim Guidelines is the fuel containment system. The toxicity of ammonia and its corrosivity imply different and substantial additional risks compared to LNG or hydrogen. Ammonia leakage cannot be excluded, and the requirements for ammonia venting should be considered in the possible scenarios. Dispersion analysis of the ammonia cloud (e.g., from the vent mast) would be an essential design verification. Some preliminary assessment has already shown that the ammonia cloud can completely engulf the ships, with consequent need of adopting a safe area, well out of the toxic area, and the need for personal protective equipment (PPE). These provisions may strongly limit the use of ammonia in passenger ships. Moreover, it must be considered that ammonia leaks may occur when the ship is in port, or during bunkering operations. In these scenarios the risks would extend from the ship to the surrounding harbour area, or the city in close proximity.

For further consideration on the current Interim Guidelines, these are attached in Appendix 1, noting that the target completion date for their revision and finalization at CCC 10 is September 2024.

The following Table summarizes the updated IMO work plan for the development of new alternative fuels under the IGF Code:

ISWG-AF 1* 9-13 Sep 2024	- further develop/finalize guidelines for ships using hydrogen as fuel. - **further develop/finalize guidelines for ships using ammonia as fuel.** - If time permits, further develop guidelines for low-flashpoint oil fuels.

CCC 10 **16-20Sep 2024**	-	prepare amendments to the IGF Code and Natural Gas
	-	finalize guidelines for ships using hydrogen as fuel.
	-	**finalize guidelines for ships using ammonia as fuel.**
	-	if time permits, further develop guidelines for low flashpoint oil fuels.
	-	if time permits, start to discuss the development of mandatory instruments regarding methyl/ethyl alcohols.
MSC 109 (2-6 Dec 2024)	-	approval of the guidelines for ships using hydrogen as fuel.
	-	**approval of the guidelines for ships using ammonia as fuel.**

* *The establishment of the Intersessional WG on Development of technical provisions for safety of ships using alternative fuels (ISWG-AF) is subject to approval by MSC 108 and endorsement by IMO Council.*

3.3 Classification Societies

Class Rules support the energy transition, nevertheless many issues remain to be solved before introducing ammonia on a large-scale, starting from its availability (especially from renewable sources) and distribution worldwide – i.e., the zero-carbon fuel ecosystem.
Most Classification Societies have issued their Rules on the use of ammonia as marine fuel (ref. D8.1) but it is expected that upon finalization of the IMO Interim Guideline the Class rules will need to be revised accordingly, Moreover, further guidance should be proposed to assist Administrations in the Alternative design methodology and on the acceptance criteria of the results of direct models / simulations / calculations (e.g., CFD dispersion analysis).

4. Development of a safety regulatory framework to support the reduction of GHG emissions from ships using new technologies and alternative fuels.

4.1 Additional regulatory provisions and standards

The IMO Maritime Safety Committee at its 107th session (MSC 107) agreed to include in its biennial agenda for 2024-2025 a continuous output on "Development of a safety regulatory framework to support the reduction of GHG emissions from ships using new technologies and alternative fuels", assigning MSC as the coordinating organ, in association with the CCC, HTW, III, SSE and SDC Sub-Committees, as and when requested by MSC, and invited the Maritime Environmental Protection Committee (MEPC) to consider being an associated organ.

The following terms of reference have been agreed for the Correspondence Group (CG) under the coordination of the United States:

1. identify and update a list of fuels and technologies which will assist international shipping to support the reduction of GHG emissions from ships using new technologies and alternative fuels.
2. conduct an assessment for each identified fuel and new technologies (e.g. the state of knowledge of risks and the technical considerations of solutions, Hazards and Risks, Risk Control Measures) in sub-paragraph .1 in relation to persons, ships (new built and converted) and applicable operations for these, from e.g. projects applying alternative design and approval process where permitted.
3. based on the outcomes of .1 and .2 above, develop a record for safety obstacles and gaps in the current IMO instruments that may impede the use of the alternative fuel or new technology; and

4. submit a written report to MSC 108.

The CG had its first meeting on October 13th, 2023, coordinated by Timothy Meyers (USCG). A first round of comments was already submitted, with focus on the list of fuels to be considered, the method of work (iterative process), the coordination with ongoing activities in other IMO instruments, the ref. to available studies, etc.
The CG coordinator will circulate the outcome tentatively in early November and propose a second round of questions.
It goes without saying that ammonia is one of the key fuels in the CG agenda.

NOTE:
RINA is an active member of all the above mentioned CGs / WGs on behalf of IACS and of the Italian Administration.

The progressive introduction of the Interim Guidelines (non-mandatory IMO Guidelines → progressive implementation by the industry → revision and incorporation into IMO mandatory instruments, such as SOLAS / IGC Code) will trigger the need for future legislation, extended to other international conventions in addition to SOLAS (with relevant Codes) and MARPOL, such as:

– the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) concerning the education, training and certification of seafarers.
– the International Safety Management (ISM) Code, setting international standard for the safe management of ships and for pollution prevention. whose main objectives are to provide safe practices in ship operation and working environments; establish safeguards against all identified risks and continuously improve safety management skills of personnel onboard ships.
– Directive 2008/106/EC, which transposes the STCW Convention within the EU.
– Regulation (EC) No 336/2206 on the implementation of the ISM Code within the EU.
– The Marine Equipment Directive (MED) which complements the IMO requirements through the specification of relevant standards for safety equipment to be installed on board EU flagged ships.

5. ENGIMMONIA – Other clean energy technologies

As outlined in the Executive Summary of this D8.2, ENGIMMONIA focus different clean energy technologies in addition to ammonia:

- Organic Rankine Cycle (ORC) solutions, using waste heat to generate electricity.
- Adsorption Chillers (AC) driven by waste heat used for cooling.
- Photovoltaic (PV) solutions, supplementing the electrical generation on board.

For these technologies the regulatory compliance is less complex because there is no evolution of the applicable rules and regulations comparable to the IMO Interim Guidelines on ammonia.

5.1 Regulatory compliance - safety

In ENGIMMONIA, the assessment and plan approval of the three selected clean energy technologies have followed a conventional process, substantially guided by the verification of compliance with known and published Class rules.
Although the selected technologies are innovative in their design and implementation, one of the key elements for their approval was the confirmation that they are to be considered as non-essential ship services, as defined by IACS Unified Interpretation (UI) SC134.
The technologies as a whole and all their parts (machinery, piping, fittings, accessories, electrical and mechanical components, materials, structures etc.) are already fully covered by existing Classification Rules.

At the time being, the IMO and IACS work plans do not include any substantial evolution of these provisions, although some minor changes could be expected in general on any Class rule, but not within the timeframe of the ENGIMMONIA Project.

It is reminded that the main difference between (auxiliary) systems which serve essential or non-essential services is the assessment of their reliability, availability and redundancy. This difference is always related to the safety of the ship rather than on the efficiency of the energy saving technologies.
For the technologies supplying energy to non-essential ship services, it is assumed that their performance and efficiency do not compromise the safety of the ship and that they can be switched off or disconnected without any adverse impact on ship essential services.

The innovative power generation systems intended to be used for non-essential ship services only, can be assessed considering:

- documentation providing evidence that the equipment and/or its main components comply with mandatory safety standards and class rules.
- documentation providing evidence that on-board integration of the equipment does not negatively affect the safety of the ship.

The performance and redundancy of the innovative power generation systems, when used for non-essential ship services only, are not relevant for Class certification.

The assumptions made in ENGIMMONIA are not to be considered as a limit if these technologies will be scaled-up and provide substantial contribution to the power generation on board, to the point of becoming essential ship services.
In this case there is no need of new rules or regulations, because the compliance with the reliability, availability and redundancy provisions is already a common assessment process.

In this context, the following definitions are recalled:

- ***Reliability*** is the probability that a system will produce correct outputs up to some given time. Reliability measures the ability of a system to function correctly, and is enhanced by features that help to avoid, detect and repair hardware faults. Reliability can be characterized in terms of mean time between failures (MTBF).
- ***Availability*** is the probability that a system is operational at a given time, i.e. the amount of time a device is actually operating as the percentage of total time it should be operating. Availability measures how often the system is available for use, even though it may not be functioning correctly. Availability features allow the system to stay operational even when faults do occur. A highly available system would disable the malfunctioning portion and continue operating at a reduced capacity.
- ***Serviceability or maintainability*** is the simplicity and speed with which a system can be repaired or maintained.

5.2 Regulatory compliance – energy efficiency

The most relevant IMO document addressing the performance of innovative energy efficiency technologies is MEPC.1/Circ.896 "*2021 Guidance on treatment of innovative energy efficiency technologies for calculation and verification of the attained EEDI and EEXI".*
This circular supersedes MEPC.1/Circ.815

The purpose of this Guidance is "to assist manufacturers, shipbuilders, shipowners, verifiers and other interested parties relating to Energy Efficiency Design Index (EEDI) and Energy Efficiency Existing Ship Index (EEXI) of ships to treat innovative energy efficiency technologies for calculation and verification of the attained EEDI, in accordance with regulations 5, 6, 7, 8, 9 and 20 of Annex VI to MARPOL.

Although the term EEDI only is used through the whole guidance, it applies to both the EEDI and the EEXI calculations, as applicable.

As for other IMO instruments, this Guidance also should be reviewed, after accumulating the experiences of each innovative technology, to make it more robust and effective, using the feedback from actual operating data.
Therefore, it is advisable that the effect of each innovative technology in actual operating conditions should be monitored and collected for future improvement of this guidance document.

This guidance can be broadly applied to a variety of energy saving technologies, such as hull air lubrication systems, wind assisted sail propulsion systems.
Its Annex 2 contains the provisions which are applicable to the ENGIMMONIA technologies:

- Guidance on calculation and verification of effects of category (c) innovative technologies
  - Waste heat recovery system for generation of electricity (category (c-1))
  - Photovoltaic power generation system (category (c-2))

These provisions are self-explanatory and have been attached in Appendix 2 to this deliverable.

6. Conclusions and Future Plans

Based upon the information provided in the previous sections, it can be seen that the final technical developments and installation and integration on board of all proposed technologies in ENGIMMONIA can progress unaffected and be successfully used on a variety of new or existing ships,

As anticipated in D8.1, the key part of the approval process is the identification of the novel elements and/or novel application of known technology, on which to focus the assessment (= analysis + evaluation).
In this context, TQP and AIP remain the general methodologies to be applied when some aspects of the novel technology are not adequately covered by currently established codes and procedures.

It is concluded that the development of the Interim Guidelines on ammonia are already focused, and work is in progress at the IMO.

The lessons learnt and the results from the other innovative clean energy technologies have evidenced that there is no need of updating any IMO or IACS rule or regulation to facilitate the uptake and scale-up of these carbon-free, environmentally friendly solutions in the maritime sector.

In any case, RINA is involved in all international and European working groups developing new regulations and standards and will keep monitoring the progress and provide input as needed in mutual synergy with the project activities.

Appendix 1

DRAFT INTERIM GUIDELINES FOR SHIPS USING AMMONIA AS FUEL

Note: Already considered by CCC 9 were sections 1, 2 , 3, 4.1 and 4.2, and 12bis

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1 Introduction

1.1 The purpose of these Interim guidelines for the safety of ships using Ammonia as fuel (Interim Guidelines) is to provide an international standard for ships using Ammonia 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 Ammonia as fuel to minimize the risk to the ship, its crew and the environment, having regard to the nature of the fuels involved.

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 available of current operational experience, field data and research and development. These Interim Guidelines address all areas that need special consideration for the use of Ammonia as fuel.

1.4 These Interim Guidelines follow the Generic guidelines for developing IMO goal-based standards (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 Ammonia as fuel.

1.5 The current version of these Interim Guidelines includes provisions to meet the functional requirements for Ammonia 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 section 3 which is mainly text taken from chapter 3 of the IGF Code, albeit modified to reflect the recommendatory nature of these Interim Guidelines.

1.7 Wherever in these Interim Guidelines, reference is made to "gas supply" as contained in the IGF Code, it should be read as "Ammonia supply".

2 GENERAL

2.1 Application

Unless expressly provided otherwise these Interim Guidelines apply to ships using ammonia as fuel. These Guidelines do not address ships using ammonia cargo as fuel.

2.2 Definitions

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.

2.2.1 *Ammonia* means an inorganic compound represented by the chemical formula NH_3. In these Interim Guidelines, Ammonia either in its liquefied or gaseous state is referred to as Ammonia.

2.2.2 *Fuel* means Ammonia, either in its liquefied or gaseous state.

2.2.5 *Fuel consumer* means any unit within the ship using ammonia as a fuel.

[2.2.6 *Ammonia only engine* means an engine ~~capable of operating [only] on ammonia,~~ and not able to changeover to operation on any other type of fuel.]

[2.2.7 *Fuel pipes* means a bunkering pipes and fuel supply pipes. However, in applying chapter 9, bunkering pipes are not included.]

[2.2.10 *Non-hazardous area* means the following:

.1 Area where there is no risk of an explosive atmosphere requiring special attention to the structure, installation and use of the equipment.

.2 Area where there is no risk of the generation of ammonia gas that is hazardous to human health.]

[2.2.12 *Safety Concept* is a document describing the safety philosophy with regard to fuel. It identifies potential sources of ammonia and describes how risks associated with this type of fuel are [mitigated][controlled] under reasonably foreseeable abnormal conditions as well as possible failure scenarios and their control measures. [~~A detailed evaluation regarding the hazard potential of injury from a possible explosion or leakage of ammonia is to be carried out and reflected in the safety concept of the engine [and auxiliary systems].~~]]

[2.2.13 Secondary barrier is the liquid/gas-resisting outer element ~~of a fuel containment system~~ designed to afford temporary containment of any envisaged leakage ~~of liquid and gas fuel through the primary barrier and to prevent the lowering of the temperature of the ship's structure to an unsafe level~~.]

[2.2.14 Secondary enclosure means a ~~gas/liquid-tight ventilated [or inerted] duct or a gas/liquid-tight double wall piping system enclosing fuel piping~~ systems to prevent spreading ammonia leakage.]

[2.2.15 *Source of release* means a point or location from which a gas, vapour, mist or liquid may be released into the atmosphere so that an explosive atmosphere or ammonia concentration atmosphere that affects the human health could be formed.]

[

2.2.16 Toxic area means an area in which [health-affecting] concentrations of ammonia vapour is or may be expected to be present. An ammonia vapour concentration above [300 ppm] [50 ppm]is considered toxic.

2.xxx *Refrigerated ammonia* means …
2.yyy *Semi-refrigerated ammonia* means …
[2.zzz *Pressurized ammonia* means …]

2.3 Alternative design

2.3.1 These Interim Guidelines contain functional requirements for all appliances and arrangements related to the usage of ammonia as fuel.

2.3.2 Appliances and arrangements of ammonia 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 and in particular their installations of systems for propulsion machinery, auxiliary power generation machinery and/or other purpose machinery using ammonia as fuel.

[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 ammonia-related hazards should be limited to a minimum through arrangement and system design, such as ventilation, detection[, containment] and safety actions. In the event of ammonia 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 ~~gas~~ fuel installation do not lead to an unacceptable loss of power.

3.2.4 Hazardous [and toxic] 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 [and/or toxic] 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 toxic gas concentrations should be prevented.

3.2.7 System components should be protected against external damage.

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

3.2.8*bis* Sources of ammonia release should be minimized to reduce the probability of ammonia exposure to humans and the environment.

3.2.19 Measures to minimize the health hazards associated with the toxicity of ammonia should be provided.

[3.2.20 Direct release of ammonia into the atmosphere should be minimized]
[3.2.21 The source of release shall not release ammonia fuel at a concentration that might affect the safety of persons.]

[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 [in emergency situations], the system should be designed to prevent venting under all normal operating conditions including idle periods. [When necessary for safety reasons under [foreseeable] [normal] operation (e.g. venting of fuel supply systems), the system should be designed to prevent direct release to air.]]

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

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

3.2.12 Fuel containment system and machinery spaces containing source that might release gas into the space should be arranged and located such that a fire, 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 Fixed fuel vapour and/or leakage detection 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. **]**

4 GENERAL PROVISIONS

4.1 Goal

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

4.2 Risk assessment

4.2.1 A holistic risk assessment should be conducted to ensure that risks arising from the use of ammonia as fuel affecting persons on board, the environment, the structural strength, or the integrity of the ship and its sub-systems 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 ammonia system integrity with focus on its ability to prevent and isolate leakages and also evaluate potential toxicity hazards, ignition mechanisms and consequences of ignition. Special consideration should be given, but not limited to, the following specific ammonia-related hazards and topics:

- loss of function;
- component damage;
- fire;
- explosion;
- toxicity; and
- electric shock.

4.2.3 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 fire, explosion or toxic consequences

An fire, explosion or toxic effect on human health in any space containing any potential sources of release and potential ignition sources should not:

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

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

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

.4 damage ship personnel normally present in work or accommodation spaces under normal operating conditions;

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

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

.7 disrupt the proper functioning of fire-fighting equipment located outside the explosion-damaged space and fire-fighting activities by toxicity;

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

.9 prevent persons access to life-saving appliances or impede escape routes.

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, fuel storage systems, fuel 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 to 3.2.8, 3.2.12 to 3.2.15, 3.2.17 and 3.2.19. In particular the following apply:

.1 the fuel tank(s) should be located in such a way that the probability for the tank(s) to be damaged following a collision or grounding is reduced to a minimum taking into account the safe operation of the ship and other hazards that may be relevant to the ship;

.2 fuel containment systems, fuel piping and other fuel sources of release should be so located and arranged that released ammonia gas is led to a safe location in the open air or to ammonia treatment system;

.3 the access or other openings to spaces containing fuel sources of release should be so arranged that flammable, asphyxiating or toxic gas cannot escape to spaces that are not designed for the presence of such gases taking into account the specific gravity and dispersion characteristics of ammonia gas;

.4 fuel piping and fuel supply system should be protected against mechanical damage;

.5 the propulsion and fuel supply system should be so designed that safety actions after any ammonia leakage do not lead to an unacceptable loss of power; and

.6 the space where fuel containing machinery and equipment are installed should be designed to minimize the probability of the fire and explosion and exposure of ship personnel to leaked ammonia.

5.3 General provisions

5.3.1 Fuel storage tanks should be protected against mechanical damage.

5.3.2 Fuel storage tanks and or equipment located on open deck should be located ensure sufficient natural ventilation to prevent accumulation of escaped

5.3.3 Mustering stations and lifesaving equipment and access to such stations equipment should not be located in toxic areas as specified in 12.7.

5.3*bis* Provisions for protection of tanks from collision and grounding

5.3*bis*.1 Unless expressly provided otherwise, the requirements of 5.3.3, 5.3.4 and 5.3.5 the IGF Code Part A-1 should apply to ships using ammonia as fuel.

5.4 Machinery space concepts

5.4.1 In order to minimize the probability of an ammonia exposure to ship personnel in a machinery space with ammonia-fuelled machinery should be gas-safe machinery spaces.

5.4.2 Arrangements in gas-safe machinery spaces should be such that the spaces are considered ammonia safe under all conditions, normal as well as abnormal conditions, i.e. inherently ammonia gas safe. In gas-safe machinery spaces, a single failure cannot lead to release of fuel into the machinery space.

5.5 Regulations for gas-safe machinery space

5.5.1 A single failure within the fuel system should not lead to an ammonia release into the machinery space.

5.5.2 All fuel piping within machinery space boundaries should be enclosed by secondary enclosures complying with 9.6.

ALTERNATIVE for 5.4 and 5.5:

5.4 Provisions for machinery space arrangement

5.4.1 Machinery spaces containing ammonia fuel systems should be arranged such the spaces may be considered gas safe under all conditions. A gas-safe machinery space be arranged as a conventional machinery space.

5.4.2 A single failure within the fuel system should not lead to a gas release into machinery space.

5.4.3 All fuel piping within machinery space boundaries should be enclosed in a gas tight enclosure in accordance with 9.5.

5.4.4 Access to machinery spaces should not be arranged from toxic areas.

5.6

Regulations for location and protection of fuel piping

5.6.1 Fuel pipes and fuel supply system should not be located less than 800 mm from the ship's side.

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 should be designed to enable draining to be led to suitable tanks under heel and trim conditions during voyage.

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

5.7 Regulations for fuel preparation room design

5.7.1 Fuel preparation rooms should be gastight towards adjacent spaces, and they should not be adjacent to accommodation spaces, service spaces, electrical equipment rooms or control stations. The term "adjacent" means surface contact, linear contact, and point contact.

5.7.2 Fuel preparation rooms should be designed to minimize the accumulation of gases or formation of gas pockets.

5.7.3 Materials used for the boundaries of fuel preparation rooms should have a design temperature corresponding with the lowest temperature it can be subjected to in a probable maximum leakage scenario unless the boundaries of the space (i.e. bulkheads and decks) are provided with suitable thermal protection. In addition, fuel preparation rooms should be arranged to prevent surrounding hull structures from being exposed to unacceptable cooling.

5.7.4 Fuel preparation rooms should be designed to withstand the maximum pressures that build up during a probable maximum leakage scenario. Alternatively, pressure relief venting to a safe location may be provided.

5.8 Regulations for bilge systems

5.8.1 Bilge systems installed in areas where fuel covered by these Guidelines can be present should be segregated from the bilge system of spaces where fuel cannot be present.

5.8.2 Where fuel is carried in a fuel containment system requiring a secondary barrier, suitable drainage arrangements for dealing with any leakage into the hold or insulation spaces through the adjacent ship structure should be provided. The bilge system should not lead to pumps in spaces having no risks of ammonia. Means of detecting such leakage should be provided.

5.8.3 The hold or inter-barrier spaces of type A independent tanks for liquid gas should be provided with a drainage system suitable for handling liquid fuel in the event of fuel tank leakage or rupture.

5.9 Regulations for drip trays

5.9.1 Drip trays should be fitted where leakage may occur which can cause damage to the ship structure or where limitation of the area which is effected from a spill is necessary.

5.9.2 Drip trays should be made of suitable material.

5.9.3 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, in case of leakage of liquid fuel.

5.9.4 Each tray should be fitted with a drain valve to enable rainwater to be drained over the ship's side where the tray is installed in a location where rainwater may be retained.

5.9.5 Each tray should have a sufficient capacity to ensure that the assumed maximum amount of spill according to the risk assessment can be handled.

5.10 Regulations for arrangement of entrances and other openings in enclosed spaces

5.10.1 Direct access should not be permitted from a non-hazardous area to a hazardous area. Where such openings are necessary for operational reasons, an airlock which complies with 5.11 should be provided.

5.10.2 Fuel preparation room should, as far as practicable, have an independent access direct from the open deck. Where a separate access from deck is not practicable, an airlock which complies with 5.11 should be provided.

5.10.3 Tank connections space should be independently and directly accessible from open decks, as far as practicable. Where separate access from decks is not practicable, airlocks which comply with 5.11 or bolted hatches are to be provided.

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

5.10.5 Arrangements for fuel storage hold spaces, void space, fuel tanks and other spaces classified as hazardous areas, should be such as to allow entry and inspection of any such space by ship personnel wearing protective clothing and breathing apparatus as well as to allow for the evacuation of injured or unconscious ship personnel. Such arrangements should comply with the following:

.1 Access should be provided as follows:

.1 access to all fuel tanks. Access should be directly from open decks as far as practicable;

.2 access through horizontal openings, hatches or manholes. The size should be sufficient to allow a person wearing a breathing apparatus to ascend or descend any ladder without obstruction, and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening is to be not less than 600 mm × 600 mm;

.3 Access through vertical openings or manholes providing passage through the length and breadth of the space The minimum clear opening should be not less than 600 mm × 800 mm at a height of not more than 600 mm from the bottom plating unless gratings or other footholds are provided; and

.4 Circular access openings to type C tanks are to have a diameter of not less than 600 mm.

.2 The sizes referred to in 5.10.5.1.2 and 5.10.5.1.3 may be decreased, if 5.10.5 can be met to the satisfaction of the Administration.

.3 Where fuel is carried in containment systems requiring secondary barriers, 5.10.5.1.2 and 5.10.5.1.3 do not apply to spaces separated from hold spaces by a single gastight steel boundary. Such spaces are to be provided only with direct or indirect access from open decks, excluding any enclosed non-hazardous areas.

5.11 Regulations for airlocks

5.11.1 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 door sill should not be less than 300 mm in height. The doors should be self-closing without any holding back arrangements.

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

5.11.3 The airlock should be designed in a way that no gas can be released to safe spaces in case of the most critical event in the gas dangerous space separated by the airlock. The events should be evaluated in the risk analysis according to 4.2.

5.11.4 Airlocks should have a simple geometrical form. They should provide free and easy passage, 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.

5.11.5 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.

5.11.6 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 is to be restricted until the ventilation has been reinstated. Audible and visual alarms should be given at the navigation bridge or a continuously manned centre control station to indicate both loss of pressure and opening of the airlock doors when pressure is lost.

5.11.7 Essential equipment required for safety should not be de-energized and should be of a certified safe type. This may include lighting, fire detection, public address, general alarms systems.

6 FUEL CONTAINMENT SYSTEM

6.1 Goal

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

6.2 Functional requirements

This chapter relates to functional requirements in 3.2.1, 3.2.2, 3.2.5, 3.2.7 and 3.2.8 to 3.2.17. In particular the following apply:

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

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

  .2 flammable fuels spreading to locations with ignition sources;

  .3 toxicity potential and risk of oxygen deficiency due to fuels and inert gases;

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

.5 reduction in availability of LSA.

.2 the pressure and temperature in the fuel tank should be kept within the design limits of the containment system and possible carriage requirements of the fuel;

.3 the fuel containment arrangement should be so designed that safety actions after any gas leakage do not lead to an unacceptable loss of power; and

.4 if portable tanks are used for fuel storage, the design of the fuel containment system should be equivalent to permanent installed tanks as described in this chapter.

.5 the fuel containment system should be designed considering various characteristics of all possible compositions of the Ammonia.

6.3 General Provisions

6.3.1 The Maximum Allowable Working Pressure (MAWP) of the fuel tank should not exceed 90% of the Maximum Allowable Relief Valve Setting (MARVS).

6.3.2 Tank connection spaces and fuel storage hold spaces other than for tank type C should be gastight towards adjacent spaces. These spaces should not be adjacent to accommodation spaces, service spaces, electrical equipment room and control stations by a single bulkhead or deck. “Adjacent” means liner contact and point contact.

6.3.3 All tank connections, fittings, flanges and tank valves should be enclosed in gastight tank connection spaces. The space is to be able to safely contain leakage from the tank in case of leakage from the tank connections.

6.3.4 Pipe connections to the fuel storage tank should be mounted above the highest liquid level in the tanks, except for type C fuel storage tanks. Connections below the highest liquid level may however also be accepted for other tank types after special consideration by the Administration.

6.3.5 Piping between the tank and the first valve which release liquid in case of pipe failure should have safety equivalent to a type C tank, with dynamic stress not exceeding the values given in 6.4.15.3.1.2.

6.3.6 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 in a probable maximum leakage scenario. The tank connection space is to be designed to withstand the maximum pressure build up during such a leakage. Alternatively, pressure relief venting to a safe location (mast) can be provided.

6.3.7 The probable maximum leakage into the tank connection space should be determined based on detail design, detection and shutdown systems.

6.3.8 If piping is connected below the liquid level of the tank it has to be protected by a secondary barrier up to the first valve.

6.3.9 Means should be provided whereby liquefied gas in the storage tanks can be safely emptied.

6.3.10 It should be possible to empty, purge and vent fuel storage tanks with fuel piping systems. Instructions for carrying out these procedures must 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. For further information, see the detailed requirements specified in 6.9.

6.4 Provisions for liquefied gas fuel containment

6.4.1 Unless expressly provided otherwise, the requirements of the IGF Code Part-A1 Chapter 6.4 should apply to ships using ammonia as fuel.

6.4.2 The provision of 6.4.1.3 of the IGF Code Part A-1 related to portable tanks should not apply to ships using ammonia as fuel.

6.5 Provisions for portable liquefied gas fuel tanks

6.5.1 The provisions of 6.5 of the IGF Code should not apply to ships using ammonia as fuel.

6.6 Provisions for compressed fuel containment

6.6.1 The provisions of 6.6 of the IGF Code should not apply to ships using ammonia as fuel

6.7 Provisions for pressure relief system

6.7.1 General

6.7.1.1 All fuel storage tanks should be provided with a pressure relief system appropriate the design of the fuel containment system and the fuel being carried. Fuel storage hold inter-barrier spaces and tank connection spaces, which may be subject to pressures beyond their design capabilities, should also be provided with a suitable pressure relief system. Pressure control systems specified in 6.9 should be independent of the pressure systems.

6.7.1.2 Fuel storage tanks which may be subject to external pressures above their design pressure should be fitted with vacuum protection systems.

6.7.2 Pressure relief systems for liquefied gas fuel tanks.

6.7.2.1 Liquefied gas fuel tanks should be fitted with a minimum of 2 pressure relief valves (PRVs) allowing for disconnection of one PRV in case of malfunction or leakage.

6.7.2.2 Inter-barrier spaces should be provided with pressure relief devices[1]. For membrane systems, the designer should demonstrate adequate sizing of inter-barrier space PRVs.

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[1] Refer to IACS Unified Interpretation GC9 entitled Guidance for sizing pressure relief systems for inter-barrier spaces, 1988.

6.7.2.3 The opening pressure of the pressure relief valves (PRVs) should not be higher the vapour pressure that has been used in the design of the tank. Valves comprising not more than 50% of the total relieving capacity may be set at a pressure up to 5% above MARVS to allow sequential lifting, minimizing unnecessary release of vapour.

6.7.2.4 The following temperature provisions apply to PRVs fitted to pressure relief systems:

.1 PRVs on fuel tanks with a design temperature below 0◦C should be designed and arranged to prevent their becoming inoperative due to ice formation;

.2 the effects of ice formation due to ambient temperatures should be considered in the construction and arrangement of PRVs;

.3 PRVs should be constructed of materials with a melting point above 925°C. Lower melting point materials for internal parts and seals may be accepted provided that fail-safe operation of the PRV is not compromised; and

.4 sensing and exhaust lines on pilot operated relief valves should be of suitably robust construction to prevent damage.

6.7.2.5 In the event of a failure of a fuel tank PRV a safe means of emergency isolation should be available.

.1 procedures should be provided and included in the operation manual (refer chapter 18);

2 the procedures should allow only one of the installed PRVs for the gas fuel tanks to be isolated, physical interlocks should be included to this effect; and

3 isolation of the PRV should be carried out under the supervision of master. This action should be recorded in the ship's log, and at the PRV.

6.7.2.6 Each pressure relief valve installed on a liquefied gas fuel tank should be connected a venting system, which should be:

1 so constructed that the discharge will be unimpeded and normally be vertically upwards at the

2 arranged to minimize the possibility of water or snow entering the system; and

3 arranged such that the height of vent exits should not be less than B/3 6 m, whichever is the greater, above the weather deck and 6 m above working areas and walkways. However, vent mast height could be limited lower value according to special consideration by the Administration.

6.7.2.7 The outlet from the pressure relief valves should normally be located at least B (greatest moulded breadth) or 25 m, whichever is less, from the nearest:

1 air intake, air outlet or opening to accommodation, service and control spaces, or other non-hazardous area[; and

2 exhaust outlet from machinery installations]

6.7.2.8 All other fuel gas vent outlets should also be arranged in accordance with 6.7.2.6 and 6.7.2.7. Means should be provided to prevent liquid overflow from gas vent outlets, due to hydrostatic pressure from spaces to which they are connected.

6.7.2.9 In the vent piping system, means for draining liquid from places where it may accumulate should be provided. The PRVs and piping should be arranged so that liquid can, under no circumstances, accumulate in or near the PRVs.

6.7.2.10 Suitable protection screens of not more than 13 mm square mesh should be fitted on vent outlets to prevent the ingress of foreign objects without adversely affecting the flow.

6.7.2.11 All vent piping should be designed and arranged not to be damaged by the temperature variations to which it may be exposed, forces due to flow or the ship's motions.

6.7.2.12 PRVs should be connected to the highest part of the fuel tank. PRVs should be positioned on the fuel tank so that they will remain in the vapour phase at the filling limit (FL) as given in 6.8, under conditions of 15° list and 0.015L trim, where L is defined in 2.2.25 of the IGF Code.

6.7.3 Sizing of pressure relieving system

6.7.3.1 *Sizing of pressure relief valves*

6.7.3.1.1 PRVs should have a combined relieving capacity for each liquefied gas fuel tank to discharge the greater of the following, with not more than a 20% rise in liquefied gas fuel tank pressure above the MARVS:

1 the maximum capacity of the liquefied gas fuel tank inerting system if the maximum attainable working pressure of the liquefied gas fuel tank inerting system exceeds the MARVS of the liquefied gas fuel tanks; or

.2 vapours generated under fire exposure computed using the formula:

(Formula of IGF Code 6.7.3.1.1.2 to be included)

6.7.3.1.2 For tanks in fuel storage hold spaces separated from potential fire loads cofferdams or surrounded by ship spaces with no fire load the following should apply:

If the pressure relief valves have to be sized for fire loads the fire factors may reduced to the following

F=0.5 to F=0.25

F=0.2 to F=0.1

6.7.3.1.3 The required mass flow of air at relieving conditions is given by:

$M_{air} = Q * \rho_{air}$ (kg/s)

where density of air (ρ_{air}) = 1.293 kg/m3 (air at 273.15 K, 0.1013 MPa).

6.7.3.2 *Sizing of vent pipe system*

6.7.3.2.1 Pressure losses upstream and downstream of the PRVs, should be taken into account when determining their size to ensure the flow capacity required by 6.7.3.1.

6.7.3.2.2 Upstream pressure losses

1 the pressure drop in the vent line from the tank to the PRV inlet should not exceed 3% of the valve set pressure at the calculated flow rate, in accordance with 6.7.3.1;

2 pilot operated PRVs should be unaffected by inlet pipe pressure losses when the pilot senses directly from the tank dome; and

3 pressure losses in remotely sensed pilot lines should be considered for flowing type pilots.

6.7.3.2.3 Downstream pressure losses

1 Where common vent headers and vent masts are fitted, calculations should include flow from all attached PRVs.

2 The built-up back pressure in the vent piping from the PRV outlet to the location of discharge to the atmosphere, and including any vent pipe interconnections that join other tanks, should not exceed the following values:

1 for unbalanced PRVs: 10% of MARVS;

2 for balanced PRVs: 30% of MARVS; and

3 for pilot operated PRVs: 50% of MARVS.

Alternative values provided by the PRV manufacturer may be accepted.

6.7.3.2.4 To ensure stable PRV operation, the blow-down should not be less than the sum of the inlet pressure loss and 0.02 MARVS at the rated capacity.

6.8 Regulations on loading limit for fuel tanks

6.8.1 Storage tanks for liquefied gas should not be filled to more than a volume equivalent to 98% full at the reference temperature as defined in 2.2.36 of the IGF Code.

A loading limit curve for actual fuel loading temperatures should be prepared from the following formula:

$LL = FL\ \rho_R/\rho_L$ where:

LL = loading limit as defined in 2.2.27 of the IGF Code, expressed in per cent;

FL = filling limit as defined in 2.2.16 of the IGF Code expressed in per cent, here 98%;

ρ_R = relative density of fuel at the reference temperature; and

ρ_L = relative density of fuel at the loading temperature.

6.8.2 In cases where the tank insulation and tank location make the probability very small for the tank contents to be heated up due to an external fire, special considerations may be made to allow a higher loading limit than calculated using the reference temperature, but never above 95%. This also applies in cases where a second system for pressure maintenance is installed, (refer to 6.8). However, if the pressure can only be maintained / controlled by fuel consumers, the loading limit as calculated in 6.7.1 should be used.

6.8.3 For ships constructed on or after 1 January 2024, in cases where the tank insulation and tank location make the probability very small for the tank contents to be heated up due to an external fire, special considerations may be made to allow a higher loading limit than calculated using the reference temperature, but never above 95%.

6.9 Provisions for maintaining fuel storage condition

6.9.1 Control of tank pressure and temperature

6.9.1.1 With the exception of liquefied gas fuel tanks designed to withstand the full gauge vapour pressure of the fuel under conditions of the upper ambient design temperature, liquefied gas fuel tanks' pressure and temperature should be maintained at all times within their design range by means acceptable to the Administration. Systems and arrangements to be used for this purpose may include one, or a combination of, the following methods:

.1 reliquefaction of vapours;

.2 thermal oxidation of vapours;

.3 pressure accumulation; or

.4 liquefied gas fuel cooling.

The method chosen should be capable of maintaining tank pressure below the set pressure of the tank pressure relief valves assuming no consumption for propulsion or power generation.

6.9.1.2 Venting of fuel vapour for control of the tank pressure is not acceptable except in emergency situations.

6.9.2 Design of Systems

6.9.2.1 For worldwide service, the upper ambient design temperature should be sea 32°C and air 45°C. For service in particularly hot or cold zones, these design temperatures should be increased or decreased, to the satisfaction of the Administration.

6.9.2.2 The overall capacity of the system should be such that it can control the pressure within the design conditions without venting to atmosphere.

6.9.3 Reliquefaction systems

6.9.3.1 The reliquefaction system should be arranged in one of the following ways:

.1 a direct system where evaporated fuel is compressed, condensed, and returned to the fuel tanks;

.2 an indirect system where fuel or evaporated fuel is cooled or condensed by refrigerant without being compressed;

.3 a combined system where evaporated fuel is compressed and condensed in a fuel/refrigerant heat exchanger and returned to the fuel tanks; or

.4 if the reliquefaction system produces a waste stream containing ammonia during pressure control operations within the design conditions, these waste gases should, as far as reasonably practicable, be disposed of without venting to atmosphere.

6.9.4 Thermal Oxidation Systems

6.9.4.1 Thermal oxidation can be done by either consumption of the vapours according to the provisions for consumers described in these Interim Guidelines or in a dedicated gas combustion unit (GCU). It should be demonstrated that the capacity of the oxidation system is sufficient to consume the required quantity of vapours.

6.9.5 Compatibility

6.9.5.1 Refrigerants or auxiliary agents used for refrigeration or cooling of fuel should be compatible with the fuel they may come in contact with (not causing any hazardous reaction or excessively corrosive products). In addition, when several refrigerants or agents are used, these should be compatible with each other.

6.9.6 Availability of Systems

6.9.6.1 The availability of the system and its supporting auxiliary services should be such that in case of a single failure (of mechanical non-static component or a component of the control systems) the fuel tank pressure and temperature can be maintained by another service/system.

6.9.6.2 Heat exchangers that are solely necessary for maintaining the pressure and temperature of the fuel tanks within their design ranges should have a standby heat exchanger unless they have a capacity in excess of 25% of the largest required capacity for pressure control and they can be repaired on board without external sources.

6.10 Provisions for atmospheric control within the fuel containment system

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

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

6.10.3 Gas sampling points should be provided for each fuel tank to monitor the progress of atmosphere change.

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

6.10.5 The composition of the inert gas used to purge ammonia from the tank should be compatible with ammonia.

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

[6.11.1 Inter-barrier and fuel storage hold spaces associated with liquefied gas fuel containment systems requiring full or partial secondary barriers should be inerted with a suitable dry inert gas and kept inerted with make-up gas provided by a shipboard inert gas generation system, or by shipboard storage, which should be sufficient for normal consumption for at least 30 days. Shorter periods may be considered by the Administration depending on the ship's service.]

6.11.2 Alternatively, the spaces referred to in 6.11.1 requiring only a partial secondary barrier may be filled with dry air provided that the ship maintains a stored charge of inert gas or is fitted with an inert gas generation system sufficient to inert the largest of these spaces, and provided that the configuration of the spaces and the relevant vapour detection systems, together with the capability of the inerting arrangements, ensures that any leakage from the liquefied gas fuel tanks will be rapidly detected and inerting effected before a dangerous condition can develop. Equipment for the provision of sufficient dry air of suitable quality to satisfy the expected demand should be provided.

6.12 Provisions for environmental control of spaces surrounding type C independent tanks

6.12.1 Spaces surrounding type C independent tanks should be filled with suitable dry air and be maintained in this condition with dry air provided by suitable air-drying equipment. This is only applicable for liquefied gas fuel tanks where condensation and icing due to cold surfaces is an issue.

6.13 Provisions for 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 ammonia to any non-hazardous spaces via an inert gas system connected to ammonia fuel tanks or piping systems, 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). In addition, a closable non-return valve should be installed between the double block and bleed arrangement and the fuel system. These valves should be located in a toxic space or on open deck to ensure safe segregation.

6.13.3 Where inert gas connections to the fuel piping systems are non-permanent, one non-return valve and one shut-off valve in series may replace the valves required in 6.13.2. The two valves should be arranged on the fuel piping side of the non-permanent connection to the inert gas system.

6.13.4 The inert gas system should be such that each space being inerted can be isolated and the necessary arrangements should be provided for controlling pressure in these spaces.

6.13.5 Where insulation spaces are continually supplied with an inert gas as part of a leak detection system, means should be provided to monitor the quantity of gas being supplied to individual spaces.

6.14 Provisions for inert gas production and storage on board

6.14.1 The equipment should be capable of producing inert gas with oxygen content at no time greater than 5% by volume. A continuous-reading oxygen content meter should be fitted to the inert gas supply from the equipment and should be fitted with an alarm set at a maximum of 5% oxygen content by volume.

6.14.2 An inert gas system should have pressure controls and monitoring arrangements appropriate to the fuel containment system.

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

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

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

7 Material and general pipe design

7.1 Goal

The goal of this section is to ensure the safe handling of fuel, under all operating conditions, to minimize the risk to the ship, personnel and to 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 to 3.2.10 and 3.2.10. In particular the following apply:

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

7.2.1.2 Provision should be made to protect the piping, piping system and components and fuel tanks from excessive stresses due to thermal movement and from movements of the fuel tank and hull structure.

7.2.1.3 If the fuel gas contains heavier constituents that may condense in the system, means for safely removing the liquid should be fitted.

7.2.1.4 Low temperature piping 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.

7.2.1.5 Materials should be selected in consideration of the corrosiveness of the fuel according to the relevant environment conditions.

7.2.1.6 Fuel piping should be designed to prevent fuel from accumulating in piping in consideration of the characteristics of ammonia. In addition, fuel piping should be arranged for inerting and gas freeing.

7.3 Regulations for general pipe design

7.3.1 General

7.3.1.1 Fuel pipes and all the other piping needed for a safe and reliable operation and maintenance should be colour marked in accordance with a standard at least equivalent to those acceptable to the Organization.[2]

7.3.1.2 Where tanks or piping are separated from the ship's structure by thermal isolation, 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.

7.3.1.3 All pipelines or components which may be isolated in a liquid full condition should be provided with relief valves.

7.3.1.4 Pipework, which may contain low temperature fuel, should be thermally insulated where necessary to the extent which will minimize condensation of moisture in consideration of leakage confirmation and maintenance.

7.3.1.5 Piping other than fuel supply piping and cabling may be arranged in the double wall piping or duct provided that they do not create a source of ignition or compromise the integrity of the double pipe or duct. The double wall piping or duct should only contain piping or cabling necessary for operational purposes.

7.3.2 Wall thickness

7.3.2.1 The minimum wall thickness should be calculated as follows:

$$t = (t_0 + b + c) / (1 - a/100) \text{ (mm)}$$

where:

t_0 = theoretical thickness

t_0 = $PD / (2.0Ke + P)$ (mm)

with:

P = design pressure (MPa) referred to in 7.3.3;

D = outside diameter (mm);

K = allowable stress (N/mm²) referred to in 7.3.4; and

e = efficiency factor equal to 1.0 for seamless pipes and for longitudinally or spirally welded pipes, delivered by approved manufacturers of welded pipes, that are considered equivalent to seamless pipes when non-destructive testing on welds is carried out in accordance with recognized standards. In other cases an efficiency factor of less than 1.0, in accordance with recognized standards, may be required depending on the manufacturing process;

2 Refer to EN ISO 14726:2008 Ships and marine technology – Identification colours for the content of piping systems.

b = allowance for bending (mm). The value of b should be chosen so that the calculated stress in the bend, due to internal pressure only, does not exceed the allowable stress. Where such justification is not given, b should be:

$b = D \cdot t_0 / 2.5r$ (mm)

with:

r = mean radius of the bend (mm);

c = corrosion allowance (mm). If corrosion or erosion is expected the wall thickness of the piping should be increased over that required by other design regulations. This allowance should be consistent with the expected life of the piping; and

a = negative manufacturing tolerance for thickness (%).

7.3.2.2 The absolute minimum wall thickness should be in accordance with a standard acceptable to the Administration.

7.3.3 Design condition

7.3.3.1 The greater of the following design conditions should be used for piping, piping system and components as appropriate:[3,4]

.1 for systems or components which may be separated from their relief valves and which contain only vapour at all times, vapour pressure at 45°C assuming an initial condition of saturated vapour in the system at the system operating pressure and temperature; or

.2 the MARVS of the fuel tanks and fuel processing systems; or

.3 the pressure setting of the associated pump or compressor discharge relief valve; or

.4 the maximum total discharge or loading head of the fuel piping system; or

.5 the relief valve setting on a pipeline system.

7.3.3.2 Piping, piping systems and components should have a minimum design pressure of 1.0 MPa except for open ended lines where it is not to be less than 0.5 MPa.

7.3.4 Allowable stress

7.3.4.1 For pipes made of steel including stainless steel, the allowable stress to be considered in the formula of the strength thickness in 7.3.2.1 should be the lower of the following values:

14 Lower values of ambient temperature regarding design condition in 7.3.3.1.1 may be accepted by the Administration for ships operating in restricted areas. Conversely, higher values of ambient temperature may be required.

15 For ships on voyages of restricted duration, P0 may be calculated based on the actual pressure rise during the voyage and account may be taken of any thermal insulation of the tank. Reference is made to the Application of amendments to gas carrier codes concerning type C tank loading limits (SIGTTO/IACS).

$R_m/2.7$ or $R_e/1.8$

where:

R_m = specified minimum tensile strength at room temperature (N/mm²); and

R_e = specified minimum yield stress at room temperature (N/mm²). If the stress strain curve does not show a defined yield stress, the 0.2% proof stress applies.

7.3.4.2 Where necessary for mechanical strength to prevent damage, collapse, excessive sag or buckling of pipes due to superimposed loads, the wall thickness should be increased over that required by 7.3.2 or, if this is impracticable or would cause excessive local stresses, these loads should be reduced, protected against or eliminated by other design methods. Such superimposed loads may be due to; supports, ship deflections, liquid pressure surge during transfer operations, the weight of suspended valves, reaction to loading arm connections, or otherwise.

7.3.4.3 For pipes made of materials other than steel, the allowable stress should be considered by the Administration.

7.3.4.4 High pressure fuel piping systems should have sufficient constructive strength. This should be confirmed by carrying out stress analysis and taking into account:

.1 stresses due to the weight of the piping system;

.2 acceleration loads when significant; and

.3 internal pressure and loads induced by hog and sag of the ship.

7.3.5 Flexibility of piping

7.3.5.1 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 potential for fatigue into account.

7.3.6 Piping fabrication and joining details

7.3.6.1 Flanges, valves and other fittings should comply with a standard acceptable to the Administration, taking into account the design pressure defined in 7.3.3.1. For bellows and expansion joints used in vapour service, a lower minimum design pressure than defined in 7.3.3.1 may be accepted.

7.3.6.2 All valves and expansion joints used in high pressure fuel piping systems should be approved according to a standard acceptable to the Administration.

7.3.6.3 The piping system should be joined by welding with a minimum of flange connections. Gaskets should be protected against blow-out.

7.3.6.4 Piping fabrication and joining details should comply with the following:

7.3.6.4.1 Direct connections

.1 Butt-welded joints with complete penetration at the root may be used in all applications. For design temperatures colder than minus 10°C, butt welds should be either double welded or equivalent to a double welded butt joint. This may be accomplished by use of a backing ring, consumable insert or inert gas back-up on the first pass. For design pressures in excess of 1.0 MPa and design temperatures of minus 10°C or colder, backing rings should be removed.

.2 Slip-on welded joints with sleeves and related welding, having dimensions in accordance with recognized standards, should only be used for instrument lines and open-ended lines with an external diameter of 50 mm or less.

.3 Screwed couplings complying with recognized standards should only be used for accessory lines and instrumentation lines with external diameters of 25 mm or less.

7.3.6.4.2 *Flanged connections*

.1 Flanges in flange connections should be of the welded neck, slip-on or socket welded type; and

.2 For all piping except open ended, the following restrictions apply:

  .2 For design temperatures colder than minus 10°C, slip-on flanges should not be used in nominal sizes above 100 mm and socket welded flanges should not be used in nominal sizes above 50 mm.

7.3.6.4.3 *Expansion joints*

Where bellows and expansion joints are provided in accordance with 7.3.6.1 the following apply:

.1 if necessary, bellows should be protected against icing;

.2 slip joints should not be used except within the fuel storage tanks; and

.3 bellows should normally not be arranged in enclosed spaces.

7.3.6.4.4 Other connections

Piping connections should be joined in accordance with 7.3.6.4.1 to 7.3.6.4.3 but for other exceptional cases the Administration may consider alternative arrangements.

7.4 Regulations for materials

7.4.1 Metallic materials

7.4.1.1 Materials for fuel containment and piping systems should comply with the minimum regulations given in the following tables:

Table 7.1: Plates, pipes (seamless and welded), sections and forgings for fuel tanks and process pressure vessels for design temperatures not lower than 0°C.

Table 7.2: Plates, sections and forgings for fuel tanks, secondary barriers and process pressure vessels for design temperatures below 0°C.

Table 7.3: Pipes (seamless and welded), forgings and castings for fuel and process piping for design temperatures below 0°C.

Table 7.4: Plates and sections for hull structures required by 6.4.13.1.1.2.

7.4.1.2 Materials having a melting point below 925°C should not be used for piping outside the fuel tanks.

7.4.1.3 Where required the outer pipe or duct containing high pressure gas in the inner pipe should as a minimum fulfil the material regulations for pipe materials in table 7.3.

7.4.1.4 The outer pipe or duct around liquefied gas fuel pipes should as a minimum fulfil the material regulations for pipe materials in table 7.3.

Note: tables not changed so not copied here

7.4.2 Material Requirements for Corrosion

Materials which may be exposed to fuel during normal operations should be resistant to the corrosive action of ammonia. In addition, mercury, copper, copper alloys, zinc and cadmium should not be used for the construction of fuel tanks as well as associated pipelines, valves, fittings and other items of equipment normally in direct contact with the fuel liquid or vapour.

7.4.3 Requirements for Stress Corrosion Cracking

7.4.3.1 Anhydrous ammonia may cause stress corrosion cracking in containment and process systems made of carbon manganese steel or nickel steel. To minimize the risk of this occurring, measures detained in 7.4.3.2 to 7.4.3.8 should be taken as appropriate to minimize the risk of this occurring.

7.4.3.2 Requirements for Using Carbon Manganese Steel

Where carbon manganese steel is used, fuel tanks, process pressure vessels and fuel piping should be made of fine-grained steel with a specified minimum yield strength not exceeding 355 N/mm2 and with an actual yield strength not exceeding 440 N/mm2. One of the following constructional or operational measures should be taken:

.1 lower strength material with a specified minimum tensile strength not exceeding 410 N/mm2 should be used; or

.2 fuel tanks, etc. should be post weld stress relief heat treated; or

.3 carriage temperature is to be maintained preferably at a temperature close to the product boiling point of −33°C but in no case at a temperature above −20°C; or

.4 the ammonia is not to contain less than 0.1% w/w water.

7.4.3.3 Heat Treatment for Carbon Manganese Steels with Higher Yield Properties

If carbon manganese steels with higher yield properties are used other than those specified in 7.4.3.2, the completed fuel tanks and piping, etc. should be given a post weld stress relief heat treatment.

7.4.3.4 Heat Treatment for Process Pressure Vessels
Process pressure vessels and piping for the condensate parts of refrigeration systems are to be given a post-weld stress relief heat treatment when made of materials referred to in this 7.4.3.1

7.4.3.5 Mechanical Properties of the Welding Consumables
The tensile and yield properties of welding consumables should, in principle, not be less than those of the tank or piping material.

7.4.3.6 Unsuitable Materials to Use
Nickel steel containing more than 5% nickel, and carbon manganese steel not complying with 7.4.3.2 and 7.4.3.3 are particularly susceptible to ammonia stress corrosion cracking and should not be used for containment and piping systems for the carriage of this product.

7.4.3.7 Requirements for Using Nickel Steel Containing Not More Than 5% Nickel
Nickel steel containing not more than 5% nickel may be used, provided that the carriage temperature complies with the requirements specified in 7.4.3.2.3

7.4.3.8 Dissolved Oxygen Content
To minimize the risk of ammonia stress corrosion cracking, it is advisable to keep the dissolved oxygen content below 2.5 ppm w/w. This can best be achieved by reducing the average oxygen content in the tanks prior to the introduction of liquid ammonia to less than the values given as a function of the carriage temperature T in the table below:

T(%)	**O2 (% v/v)**
-30 and	0. below
-20	9
-10	0.5
0	0.2
10	8
20	0.1
30	6
Note: Oxygen percentages for intermediate temperatures may be obtained by direct interpolation.	

8 BUNKERING

8.1 Goal

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

8.3 Regulations for bunkering station

8.3.1 General

8.3.1.1 The bunkering station should be located on open deck so that sufficient natural ventilation is provided. Closed or semi-enclosed bunkering stations should be subject to special consideration within the risk assessment.

8.3.1.2 Closed or semi-enclosed bunkering stations should be gastight towards adjacent spaces. The term "adjacent" includes linear contact and point contact.

8.3.1.3 Air intakes and openings in accommodation spaces, service spaces, engine rooms and control stations should not be located in hazardous areas and toxic zone associated with bunkering stations.

8.3.1.4 Connections and piping should be so positioned and arranged that any damage to the bunkering piping does not cause damage to the ship's fuel containment system resulting in an uncontrolled fuel discharge.

8.3.1.5 Bunkering piping should not be led through accommodation spaces, service spaces, electrical equipment rooms or control stations. Where bunkering piping is arranged in other enclosed spaces, bunkering piping should pass through a secondary enclosure

8.3.1.6 Arrangements should be made for safe management of any spilled fuel.

8.3.1.7 Suitable means should be provided to relieve the pressure and remove ammonia contents from pump suctions and bunker lines. Ammonia is to be discharged to the fuel tanks or other suitable location.

8.3.1.8 The surrounding hull or deck structures should not be exposed to unacceptable cooling, in case of leakage of fuel.

8.3.2 Ships' fuel hoses

8.3.2.1 Liquid and vapour hoses used for fuel transfer should be compatible with the fuel and suitable for the fuel temperature.

8.3.2.2 Hoses subject to tank pressure, or the discharge pressure of pumps or vapour compressors, should be designed for a bursting pressure not less than five times the maximum pressure the hose can be subjected to during bunkering.

8.3.2.3 Where fuel hosed are stored on the open deck or in a storage room, arrangements should be made for safe storage of the hoses.

8.4 Regulations for manifold

8.4.1 The bunkering manifold should be designed to withstand the external loads during bunkering. The connections at the bunkering station should be of dry-disconnect type equipped with additional safety dry break-away coupling/-self-sealing quick release. The couplings should be of a standard type.

8.4.2 Effective equipment should be arranged at bunkering manifolds and all possible leakage points to prevent any diffusion of ammonia in a leakage scenario.

8.5 Regulations for bunkering system

8.5.1 An arrangement for purging fuel bunkering lines with inert gas should be provided.

8.5.2 The bunkering system should be so arranged that no gas is discharged to the atmosphere during filling of storage tanks.

8.5.3 A manually operated stop valve and a remote operated shutdown valve in series, or a combined manually operated and remote valve should be fitted in every bunkering line close to the connecting point. It should be possible to operate the remote valve in the control location for bunkering operations and/or from another safe location.

8.5.4 Means should be provided for draining any fuel from the bunkering pipes upon completion of operation.

8.5.5 Bunkering lines should be arranged for inerting and gas freeing. When not engaged in bunkering, the bunkering pipes should be free of gas, unless the consequences of not gas freeing are evaluated and approved.

8.5.6 In case bunkering lines are arranged with a cross-over it should be ensured by suitable isolation arrangements that no fuel is transferred inadvertently to the ship side not in use for bunkering.

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

8.5.8 If not demonstrated to be required at a higher value due to pressure surge considerations a default time as calculated in accordance with 16.7.3.7 from the trigger of the alarm to full closure of the remote operated valve required by 8.5.3 should be adjusted.

9 FUEL SUPPLY TO CONSUMERS

9.1 Goal

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

9.2 Functional requirements

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. In particular the following apply:

.1 the fuel supply system should be so arranged that the consequences of any release of fuel will be minimized, while providing safe access for operation and inspection. Unless otherwise approved by the Administration, the fuel supply system should not release ammonia gas into the atmosphere in concentrations exceeding 25 ppm during normal operation. The causes and consequences of ammonia gas release should be given special consideration when carrying out the risk assessment required by 4.2.;

.2 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; and

.3 fuel lines outside the machinery spaces should be installed and protected so as to minimize the risk of injury to personnel and damage to the ship in case of leakage.

.4 the fuel supply system should be designed and arranged not to cause unintentional phase changes within the fuel supply system.

.5 All fuel piping should be suitably arranged for inerting and gas freeing. Inerting system should be in accordance with 6.12.

.6 new FR regarding [.9 Ammonia mitigation system] (move to Chapter 9).

9.3 Regulations on redundancy of fuel supply

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

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

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

9.4 Regulations on safety functions of fuel supply system

9.4.1 Fuel storage tank inlets and outlets should be provided with valves located as close to the tank as possible. Valves required to be operated during normal operation[5] which are not accessible should be remotely operated. Tank valves whether accessible or not should be automatically operated when the safety system required in 15.2.2 is activated.

9.4.2 The main fuel supply line to each fuel consumer or set of consumers should be equipped with a manually operated stop valve and an automatically operated "master fuel valve" coupled in series or a combined manually and automatically operated valve. The valves should be situated in the part of the piping that is outside the machinery space containing fuel consumers, and placed as near as possible to the installation for heating the fuel, if fitted. The master fuel valve should automatically cut off the fuel supply when activated by the safety system required in 15.2.2.

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

9.4.4 Each fuel consumer should be provided with "double block and bleed" valves arrangement. These valves should be arranged as outlined in .1 or .2 so that when the safety system required in 15.2.2 is activated this will cause the shut-off valves that are in series to close automatically and the bleed valve to open automatically and:

.1 the two shut-off valves should be in series in the fuel pipe to the fuel consuming equipment. The bleed valve should be in a pipe that vents to a safe location in the open air that portion of the fuel piping that is between the two valves in series; or

.2 the function of one of the shut-off valves in series and the bleed valve can be incorporated into one valve body, so arranged that the flow to the fuel utilization unit will be blocked and the ventilation opened.

9.4.5 The two valves should be of the fail-to-close type, while the ventilation valve should be fail-to-open.

9.4.6 The double block and bleed valves should also be used for normal stop of the engine.

[5] Normal operation in this context is when fuel is supplied to consumers and during bunkering operations.

9.4.7 In cases where the master fuel valve is automatically shutdown when the safety system as required in 15.2.2 is activated, the complete fuel supply branch downstream of the double block and bleed valve should be automatically purged ammonia. Ammonia release into the atmosphere from inner fuel pipes discharged by the purging operation should meet the requirement of 12B.6.1 as far as practicable. However, in the case where the ammonia treatment system is powered by electric power and the system is shutdown due to the loss of electric power, such automatic purging may be not required until the ammonia treatment system is restored (Refer to 12B.6.4).

9.4.8 There should be one manually operated shutdown valve in the fuel supply line to each engine upstream of the double block and bleed valves to assure safe isolation during maintenance on the engine. Where fuel is recirculated from each engine to the fuel supply piping, one manually operated shut-off valve should also be provided downstream of the double block bleed valve in the fuel return piping for each engine.

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

9.5 Regulations for fuel distribution outside of machinery space

9.5.1 Fuel pipes should be protected by a secondary enclosure. This enclosure can be a ventilated duct or a double wall piping system. The duct or double wall piping system should be mechanically underpressure ventilated with 30 air changes per hour in accordance with 13.8, and gas detection as required in 15.8 should be provided. Other solutions providing an equivalent safety level may also be accepted by the Administration.

9.5.2 The provision in 9.5.1 need not to be applied for fuel pipes located in a fuel preparation room or tank connection space.

9.5.3 Where the gas detection required by 15.8.1.2 is not fit for purpose cannot detect ammonia liquid leakage in a suitable duration, the secondary enclosures around liquefied fuel pipes should be provided with leakage detection by means of pressure or temperature monitoring systems, or any combination thereof.

9.5.4 The provision in 9.5.1 need not be applied for fully welded fuel gas vent pipes led through mechanically ventilated spaces.

9.6 Regulations for fuel supply to consumers in gas-safe machinery spaces

9.6.1 Fuel piping in gas-safe machinery spaces should be completely enclosed by a double pipe or duct fulfilling one of the following conditions:

.1 the fuel piping should be a double wall piping system with the fuel contained in the inner pipe. The space between the concentric pipes should be pressurized with inert gas at a pressure greater than the fuel pressure. Suitable alarms should be provided to indicate a loss of inert gas pressure between the pipes. When the inner pipe contains high pressure fuel, the system should be so arranged that the pipe between the master fuel valve and the engine is automatically purged with inert gas when the master fuel valve is closed; or

.2 the fuel piping should be installed within a ventilated pipe or duct. The airspace between the fuel piping and the wall of the outer pipe or duct should be equipped with mechanical underpressure ventilation having a capacity of at least 30 air changes per hour. This ventilation capacity may be reduced to 10 air changes per hour provided automatic filling of the duct with nitrogen upon detection of gas is arranged for. The fan motors should comply with the required explosion protection in the installation area. The ventilation outlet should be arranged in accordance with 13.3.10.; or

.3 other solutions providing an equivalent safety level may also be accepted by the Administration.

9.6.2 The connecting of fuel piping and ducting to the fuel injection valves should be completely covered by the ducting. The arrangement should facilitate replacement and/or overhaul of injection valves and cylinder covers. The double ducting is also required for all gas pipes on the engine itself, until gas is injected into the chamber.[6]

[1] If gas is supplied into the air inlet directly on each individual cylinder during air intake to the cylinder on a low pressure engine, such that a single failure will not lead to release of fuel gas into the machinery space, double ducting may be omitted on the air inlet pipe

9.7 Regulations for the design of ventilated duct, outer pipe against inner pipe gas leakage

9.7.1 The design pressure of the outer pipe or duct of fuel systems should not be less than the maximum working pressure of the inner pipe. Alternatively for fuel piping systems with a working pressure greater than 1.0 MPa, the design pressure of the outer pipe or duct should not be less than the maximum built-up pressure arising in the annular space considering the local instantaneous peak pressure in way of any rupture and the ventilation arrangements.

9.7.2 Double wall pipes and ducts should be gas tight towards adjacent spaces.

9.7.3 For high-pressure fuel piping the design pressure of the ducting should be taken as the higher of the following:

.1 the maximum built-up pressure: static pressure in way of the rupture resulting from the gas flowing in the annular space;

.2 local instantaneous peak pressure in way of the rupture: this pressure should be taken as the ~~critical~~ pressure given by the following expression:

$$p = p_0 \left(\frac{2}{k+1}\right)^{\frac{k}{k-1}}$$

where:

p_0 = maximum working pressure of the inner pipe

k = C_p/C_v constant pressure specific heat divided by the constant volume specific heat

[6] If gas is supplied into the air inlet directly on each individual cylinder during air intake to the cylinder on a low pressure engine, such that a single failure will not lead to release of fuel gas into the machinery space, double ducting may be omitted on the air inlet pipe.

The tangential membrane stress of a straight pipe should not exceed the tensile strength divided by 1.5 (R_m/1.5) when subjected to the above pressures. The pressure ratings of all other piping components should reflect the same level of strength as straight pipes.

As an alternative to using the peak pressure from the above formula, the peak pressure found from representative tests can be used. Test reports should then be submitted.

9.7.4 Verification of the strength should be based on calculations demonstrating the duct or pipe integrity. As an alternative to calculations, the strength can be verified by representative tests.

9.7.5 For low pressure fuel piping the duct should be dimensioned for a design pressure not less than the maximum working pressure of the fuel pipes. The duct should be pressure tested to show that it can withstand the expected maximum pressure at fuel pipe rupture.

9.8 Regulations for compressors and pumps

9.8.1 If compressors or pumps are driven by shafting passing through a bulkhead or deck, the bulkhead penetration should be of gastight type.

9.8.2 Compressors and pumps should be suitable for their intended purpose. All equipment and machinery should be such as to be adequately tested to ensure suitability for use within a marine environment. Such items to be considered would include, but not be limited to:

.1 environmental;

.2 shipboard vibrations and accelerations;

.3 effects of pitch, heave and roll motions, etc.; and

.4 gas composition.

9.8.3 Arrangements should be made to ensure that under no circumstances liquefied gas can be introduced in the gas control section or gas-fuelled machinery, unless the machinery is designed to operate with gas in liquid state.

9.8.4 Compressors and pumps should be fitted with accessories and instrumentation necessary for efficient and reliable function.

10 POWER GENERATION INCLUDING PROPULSION AND OTHER FUEL CONSUMERS

10.1 Goal

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

10.2 Functional requirements

This chapter is related to functional requirements in 3.2.1, 3.2.11, 3.2.13, 3.2.16 and 3.2.17. In particular the following apply:

.1 the exhaust systems should be configured to prevent any accumulation of un-burnt fuel;

.2 unless designed with the strength to withstand the worst case over pressure due to ignited fuel leaks, engine components or systems containing or likely to contain an ignitable ammonia gas and air mixture should be fitted with suitable pressure relief systems. Dependent on the particular engine design this may include the air inlet manifolds and scavenge spaces;

.3 the explosion venting should be led away from where personnel may normally be present;

.4 all fuel consumers should have a separate exhaust system; and

.5 the possibility of ammonia leakage from fuel consumers into the space or auxiliary system such as cooling water systems and its effects should be minimized.

10.3 Regulations for internal combustion engines of piston type

10.3.1 General

10.3.1.1 The exhaust system should be equipped with explosion relief ventilation sufficiently dimensioned to prevent excessive explosion pressures in the event of ignition failure of one cylinder followed by ignition of the unburned fuel in the system.

10.3.1.1.1 For ships constructed on or after 1 January 2024, the exhaust system should be equipped with explosion relief systems unless designed to accommodate the worst case overpressure due to ignited gas leaks or justified by the safety concept of the engine. A detailed evaluation of the potential for unburnt gas in the exhaust system is to be undertaken covering the complete system from the cylinders up to the open end. This detailed evaluation should be reflected in the safety concept of the engine.

10.3.1.2 For engines where the space below the piston is in direct communication with the crankcase a detailed evaluation regarding the hazard potential of fuel gas accumulation in the crankcase should be carried out and reflected in the safety concept of the engine.

10.3.1.3 Each engine other than two-stroke crosshead diesel engines should be fitted with vent systems independent of other engines for crankcases and sumps.

10.3.1.4 Where gas can leak directly into the auxiliary system medium (lubricating oil, cooling water), an appropriate means should be fitted after the engine outlet to extract gas in order to prevent gas dispersion. The gas extracted from auxiliary systems media should be vented to a safe location in the atmosphere.

10.3.1.5 For engines fitted with ignition systems, prior to admission of gas fuel, correct operation of the ignition system on each unit should be verified.

10.3.1.6 A means should be provided to monitor and detect poor combustion or misfiring. In the event that it is detected, gas operation may be allowed provided that the gas supply to the concerned cylinder is shut off and provided that the operation of the engine with one cylinder cut-off is acceptable with respects to torsional vibrations.

10.3.1.7 For engines starting on fuels covered by these Guidelines, if combustion has not been detected by the engine monitoring system within an engine specific time after the opening of the fuel supply valve, the fuel supply valve should be automatically shut off. Means to ensure that any unburnt fuel mixture is purged away from the exhaust system should be provided.

10.3.1.8 The following events should be analysed and evaluated in detail, and the safety devices for each of them, if necessary, should be reflected in the Safety Concept of ammonia fuelled engines.

.1 Ammonia accumulation in the ammonia fuelled engines;

.2 Ammonia release from the ammonia fuel consumers such as exhaust gases, release from pressure relief valves, etc.; and

.3 Ammonia leakage into auxiliary systems such as cooling water system, lubricating oil systems, etc.

10.3.1.9 Consideration should be given to the following with respect to ammonia fuel injection valves.

.1 Ammonia fuel injection valves should possess satisfactory operating characteristics and durability for the assumed service period;

.2 Ammonia fuel valves should be provided with sealing systems to effectively to effectively prevent fuel from leaking through spaces around valve spindles; and

.3 Appropriate means should be provided in cases where fuel injection valve actuating oil is required to be kept clean.

10.3.2 Regulations for dual fuel engines

10.3.2.1 In case of shut-off of the fuel supply, the engines should be capable of continuous operation by oil fuel only without interruption.

10.3.2.2 An automatic system should be fitted to change over from fuel operation to oil fuel operation and vice versa with minimum fluctuation of the engine power. Acceptable reliability should be demonstrated through testing. In the case of unstable operation on engines when ammonia fuel firing, the engine should automatically change to oil fuel mode. Manual activation of fuel system shutdown should always be possible.

10.3.2.3 In case of a normal stop or an emergency shutdown, the fuel supply should be shut off not later than the ignition source. It should not be possible to shut off the ignition source without first or simultaneously closing the fuel supply to each cylinder or to the complete engine.

10.3.3 Regulations for ammonia-only engines

In case of a normal stop or an emergency shutdown, the fuel supply should be shut off not later than the ignition source. It should not be possible to shut off the ignition source without first or simultaneously closing the fuel supply to each cylinder or to the complete engine.

10.3.4 Regulations for multi-fuel engines

10.3.4.1 In case of shut-off of one fuel supply, the engines should be capable of continuous operation by an alternative fuel with minimum fluctuation of the engine power.

10.3.4.2 An automatic system should be fitted to change over from one fuel operation to an alternative fuel operation with minimum fluctuation of the engine power. Acceptable reliability should be demonstrated through testing. In the case of unstable operation on an engine when using a particular fuel, the engine should automatically change to an alternative fuel mode. Manual activation should always be possible.

	AMMONIA ONLY		DUAL FUEL	MULTI FUEL
IGNITION	Spark	Pilot fuel	Pilot fuel	N/A
MAIN FUEL	Ammonia	Ammonia	Ammonia and/ or Oil fuel	Ammonia and/ or Liquid

10.4 Regulations for main and auxiliary boilers

10.4.1 Each boiler should have a dedicated forced draught system. A crossover between boiler force draught systems may be fitted for emergency use providing that any relevant safety functions are maintained.

10.4.2 Combustion chambers and uptakes of boilers should be designed to prevent any accumulation of fuel.

10.4.3 Burners should be designed to maintain stable combustion under all firing conditions.

10.4.4 On main/propulsion boilers an automatic system should be provided to change from fuel operation to oil fuel operation without interruption of boiler firing.

10.4.5 Fuel nozzles and the burner control system should be configured such that fuel can only be ignited by an established oil fuel flame, unless the boiler and combustion equipment is designed and approved by the Administration to light on fuel.

10.4.6 There should be arrangements to ensure that fuel flow to the burner is automatically cut off unless satisfactory ignition has been established and maintained.

10.4.7 On the fuel pipe of each fuel burner a manually operated shut-off valve should be fitted.

10.4.8 Provisions should be made for automatically purging the fuel supply piping to the burners, by means of an inert gas, after the extinguishing of these burners.

10.4.9 The automatic fuel changeover system required by 10.4.4 should be monitored with alarms to ensure continuous availability.

10.4.10 Arrangements should be made that, in case of flame failure of all operating burners, the combustion chambers of the boilers are automatically purged before relighting.

10.4.11 Arrangements should be made to enable the boilers purging sequence to be manually activated.

10.4.12 The possibility of ammonia accumulation in the combustion chamber or the exhaust system should be analysed and evaluated in detail, and the safety devices for each of them, if necessary, should be reflected in the Safety Concept of ammonia fuelled boilers.

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 ammonia as ship fuel.

11.2 Functional requirements

This chapter is related to functional requirements in 3.2.2, 3.2.4, 3.2.5, 3.2.7, 3.2.12, 3.2.14, 3.2.15 and 3.2.17.

11.3 Regulations for fire protection

11.3.1 Fuel preparation rooms should, for the purpose of the application of SOLAS regulation II-2/9, be regarded as a machinery space of category A.

11.3.2 The space containing the fuel containment system should be separated from the machinery spaces of category A or other rooms with high fire risks. The separation should be done by a cofferdam of at least 900 mm with insulation of A-60 class. The fuel storage hold space may be considered as a cofferdam provided that:

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

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

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

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

11.3.5 The enclosed or semi-enclosed bunkering station should be separated by A-60 class divisions towards machinery spaces of category A, accommodation, control stations and high fire risk spaces, except for spaces such as tanks, voids, auxiliary machinery spaces of little or no fire risk, sanitary and similar spaces where the insulation standard may be reduced to class A-0.

11.4 Regulations for fire main

11.4.1 The water spray system required below may be part of the fire main system provided that the required fire pump capacity and working pressure are sufficient for the operation of both the required numbers of hydrants and hoses and the water spray system simultaneously.

11.5 Regulations for water spray system

11.5.1 A water spray system should be installed for cooling and fire prevention to cover exposed parts of fuel storage tank(s) located on open deck.

11.5.2 The system should be designed to cover all areas as specified above with an application rate of 10 l/min/m² for the largest horizontal projected surfaces and 4 l/min/m² for vertical surfaces. For structures having no clearly defined horizontal or vertical surfaces, the capacity of the water spray systems should not be less than the projected horizontal surface multiplied by 10 l/min/m².

11.5.3 Stop valves should be fitted in the water spray application main supply line(s), at intervals not exceeding 40 metres, for the purpose of isolating damaged sections. Alternatively, the system may be divided into two or more sections that may be operated independently, provided the necessary controls are located together in a readily accessible position not likely to be inaccessible in case of fire in the areas protected.

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 as specified above in the areas 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 Remote start of pumps supplying the water spray system and remote operation of any normally closed valves to the system should be located in a readily accessible position which is not likely to be inaccessible in case of fire in the areas protected.

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 space being protected.

11.6 Regulations for dry chemical powder fire-extinguishing system

11.6.1 A permanently installed dry chemical powder fire-extinguishing system should be installed in the enclosed or semi-enclosed bunkering station area to cover all possible leak points. The capacity should be at least 3.5 kg/s for a minimum of 45 s. The system should be arranged for easy manual release from a safe location outside the protected area.

11.6.2 In addition to any other portable fire extinguishers that may be required elsewhere in IMO instruments, one portable dry powder extinguisher of at least 5 kg capacity should be located near the enclosed or semi-enclosed bunkering station.

11.7 Regulation for fuel preparation room fire-extinguishing systems

Fuel preparation rooms containing pumps, compressors or other potential ignition sources should be provided with a fixed fire-extinguishing system complying with the provisions of SOLAS regulation II-2/10.4.1.1 and taking into account the necessary concentrations/application rate required for extinguishing ammonia fires.

11.8 Regulations for fire detection and alarm system

11.8.1 A fixed fire detection and fire alarm system complying with the Fire Safety Systems Code should be provided for machinery spaces containing ammonia fuelled engines, fuel preparation space containing equipment considered to be ignition sources, enclosed or semi-enclosed bunkering stations and all other rooms of the fuel system where fire cannot be excluded.

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

12 Explosion ~~and toxic exposure~~ protection

12.1 Goal

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

12.2 Functional requirements

This chapter is related to functional requirements in 3.2.2 to 3.2.5, 3.2.7, 3.2.8, 3.2.12, 3.2.13 and 3.2.16. In particular the following apply:

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

.1 reducing number of sources of ignition; and

.2 reducing the probability of formation of ignitable mixtures.

12.3 General provisions for explosion protection

12.3.1 Hazardous areas on open deck and other spaces not addressed in this chapter should be decided based on a recognized standard[7]. The electrical equipment fitted within hazardous areas should be according to the same standard.

12.3.2 Electrical equipment and wiring should in general not be installed in hazardous areas unless essential for operational purposes based on a recognized standard[8].

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[9]. See also 12.5 below.

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

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.

7 Refer to IEC standard 60092-502, part 4.4: Tankers carrying flammable liquefied gases as applicable.

8 Refer to IEC standard 60092-502: IEC 60092-502:1999 Electrical Installations in Ships-Tankers-Special Features and IEC 60079-10-1:2008 Explosive atmospheres-Part 10-1: Classification of areas – Explosive gas atmospheres, according to the area classification.

9 Refer to standards IEC 60079-10-1:2008 Explosive atmospheres part 10-1: Classification of areas – Explosive gas atmospheres and guidance and informative examples given in IEC 60092-502:1999, Electrical Installations in Ships – Tankers – Special Features for tankers.

12.5.2 Hazardous area zone 1

This zone includes, but is not limited to:

.1 tank connection spaces, fuel storage hold spaces[10] and inter-barrier spaces;

.2 fuel preparation rooms;

.3 other enclosed or semi-enclosed spaces in which single-walled piping containing fuel are located (e.g., bunkering station); and

.4 annular spaces of secondary enclosures around fuel pipes.

12.5.3 Hazardous area zone 2

This zone includes, but is not limited to:

.1 airlocks; and

.2 space containing bolted hatch to tank connection space.

12*bis* Provisions addressing toxicity

12*bis*.1 Goal

The goal of this section is to provide for the prevention of exposure to toxic gases

12*bis*.2 Functional Requirements

12*bis*.2.1 This chapter is related to functional requirements in 3.2.2 to 3.2.5, 3.2.7, 3.2.8, 3.2.8*bis*, 3.2.12, 3.2.13 and 3.2.16. In particular the following apply:

The [risk/probability] of exposure to toxic gases should be reduced to a minimum by considering arrangement and location

.2 ~~arrangement and location of~~ potential sources of ammonia release such as from valves flanges and fittings ~~should be minimized to reduce the probability of ammonia exposure to humans and the environment.~~

.3 ~~arrangement and location of~~ outlet from [~~tank and other fuel system~~] relief valves [~~not discharging to a safely contained~~

.4 openings from spaces where ammonia leakages may occur;

.5 ~~arrangement and location of~~ openings to the vessel interior needing to protected from intake of toxic gas;

.6 ~~arrangement and location of~~ [safe havens], lifesaving appliances emergency

.7 ~~safe~~

~~arrangement and location of~~ bunker stations

[.8 Active or passive systems to prevent ammonia propagation to adjacent spaces]

10 fuel storage hold spaces for type C tanks are normally not considered as zone 1

[.9 Ammonia mitigation system] (move to Chapter 9)

12.*bis*.3 General provisions for toxic exposure protection

12*bis*.3.1 Toxic area classification is a method of analysing and classifying the areas where health-affecting concentrations of ammonia vapour may be expected to be present.

The objective of the classification is to limit the risk of direct exposure to ammonia for persons on board.

12*bis*.3.2 To allow for a safe arrangement preventing cross-contamination from ammonia discharges, and to facilitate safe arrangement of lifesaving appliances and emergency escapes, toxic areas are defined.

12.*bis*.4 Provisions for toxic area classification

12*bis*.4.1 Toxic areas include, but are not limited to:

.1 the interiors of fuel tanks, any pipework for pressure-relief or other venting systems for fuel tanks, pipes and equipment containing fuel;

.2 tank connection spaces, inter-barrier spaces and fuel storage hold spaces for tank containment systems requiring secondary barriers;

.3 fuel preparation rooms;

.5 annular space of secondary enclosures around fuel pipes;

.4 [enclosed and semi-enclosed] bunkering stations and other enclosed and semi-enclosed spaces in which [potential sources of release] [such as single-walled piping containing fuel] are located;

.6 areas on open deck [including bunkering stations] within [10 m] of any flanges, valves, and other potential leakage sources in ammonia fuel systems;

.7 areas on open deck within B or 25 m, whichever is less, from outlets from the pressure relief valves installed on a liquefied fuel gas tank and all other fuel gas vent outlets

.8. areas on open deck within B or 25 m, whichever is less, from outlets from inter-barrier spaces for tanks of IMO type A;

.9 areas on open deck within 10 m from outlets from inter-barrier spaces for tanks of IMO type B;

.10 areas on open deck within 10 m from outlets from secondary enclosures around ammonia piping, ventilation outlets from tank connection spaces and fuel preparation rooms and other spaces containing ammonia leakage sources; and

.11 areas on open deck within [5 m] from inlets to secondary enclosures around ammonia piping, ventilation inlets to tank connection spaces and fuel preparation rooms and other spaces containing ammonia leakage sources; and

.12 areas on open deck within 5 m from entrance openings to spaces containing ammonia leakage sources.

[12bis.4.2 In addition to the toxic area requirements in this section, [a dispersion analysis should be carried out in order to][the Administration may require a dispersion analysis to] demonstrate that ammonia gas concentrations exceeding [300 ppm] does not reach air intakes, outlets and other openings into the accommodation, service and machinery spaces, control stations[, the navigation bridge] and other non-hazardous spaces in the ship.

The dispersion analysis boundary conditions should be approved by the Administration. The analysis should include, but not be limited to, discharges from the pressure relief valves protecting the tank containment system, discharges from secondary barriers around fuel and discharges from secondary enclosures around ammonia leakage

13 Ventilation

13.1 Goal

The goal of this section is to provide for the ventilation required for safe operation of gas fuelled machinery and equipment where ammonia is used as fuel.

13.2 Functional requirements

This chapter is related to functional requirements in 3.2.2, 3.2.5, 3.2.8, 3.2.10, 3.2.12, 3.2.13 and 3.2.16.

13.3 Provisions for ventilation of spaces

13.3.1 Each toxic space should have independent ventilation systems to eliminate the possibility of toxic gases spreading to other spaces. The ventilation should function at all temperatures and environmental conditions the ship will be operating in.

13.3.2 All toxic spaces should be continuously ventilated. Consequently, ventilation inlets and outlets for such spaces should be located at sufficient height above deck to avoid requirements for closing appliances according to the International Load Line Convention.

13.3.3 All toxic spaces should be provided with an effective mechanical ventilation system of the extraction type, enabling a ventilation rate of at least 30 air changes per hour. The ventilation system should ensure a negative differential pressure between toxic spaces and surrounding spaces.

13.3.4 All toxic spaces should additionally be equipped with effective mechanical emergency ventilation. The capacity should be 300 m3/h for each m^2 deck area that can be wetted in an ammonia leakage scenario, but not less than 45 air-changes per hour. The normal ventilation capacity may be included in the ventilation capacity for emergency ventilation.

13.3.5 The required capacity of the ventilation plant should be based on the total volume of the room. An increase in ventilation capacity may be required for rooms having a complicated form.

13.3.6 The ventilation system should be arranged for efficient extraction of ammonia leakages in the space.

13.3.7 Regular and emergency ventilation should be arranged such that a failure of an active component or a failure in the power supply system to the fans cannot cause loss of both fans.

13.4 Provisions for ducting

13.4.1 Electric motors for ventilation fans should not be located in ventilation ducts for hazardous spaces unless the motors are certified for the same hazard zone as the space served.

13.4.2 Design of ventilation fans serving spaces containing gas sources should fulfil the following:

.1 Ventilation fans should not produce a source of vapour ignition in either the ventilated space or the ventilation system associated with the space. Ventilation fans and fan ducts, in way of fans only, should be of non-sparking construction defined as:

.1 impellers or housings of non-metallic material, due regard being paid to the elimination of static electricity;

.2 impellers and housings of non-ferrous metals;

.3 impellers and housings of austenitic stainless steel;

.4 impellers of aluminium alloys or magnesium alloys and a ferrous (including austenitic stainless steel) housing on which a ring of suitable thickness of non-ferrous materials is fitted in way of the impeller, due regard being paid to static electricity and corrosion between ring and housing; or

.5 any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm tip design clearance.

.2 In no case should the radial air gap between the impeller and the casing be less than 0.1 of the diameter of the impeller shaft in way of the bearing but not less than 2 mm. The gap need not be more than 13 mm.

.3 Any combination of an aluminium or magnesium alloy fixed or rotating component and a ferrous fixed or rotating component, regardless of tip clearance, is considered a sparking hazard and should not be used in these places.

13.4.3 Where a ventilation duct passes through a space with a different toxic zone classification, possible leakages to the non-toxic zone should be prevented. This shall be obtained by ensuring that the non-toxic space or duct has an over-pressure relative to the toxic space or duct. Such ventilation ducts should be of a gastight construction.

13.5 Provisions for location of ventilation openings

13.5.1 Air intakes and outlets for ventilation systems serving accommodation, service and machinery spaces, control stations and other non-hazardous spaces should be arranged outside toxic areas.

Closing devices capable of being operated from inside the space should be arranged for air intakes and outlets. Such closing devices need not be arranged in machinery spaces and spaces not normally manned, such as deck stores, forecastle stores, workshops.

13.5.2 Air inlets for ventilation systems serving toxic spaces should be taken from areas that, in the absence of the considered inlet, would not be defined as a toxic area.

Air outlets for ventilation systems serving toxic spaces may be located in toxic areas and can be grouped together to limit the extent of toxic areas on open deck.

13.5.3 Air inlets for toxic spaces should be arranged to prevent recycling of ventilation air from the outlet.

13.5.4 Non-hazardous spaces with entry openings to a hazardous enclosed space should be arranged with an airlock and the hazardous space should be maintained at underpressure relative to the non-hazardous space. Operation of the extraction ventilation in the hazardous space should be monitored and in the event of failure of the extraction ventilation:

.1 an audible and visual alarm should be given at a manned location; and

.2 if underpressure cannot be immediately restored, automatic or programmed, disconnection of electrical installations according to a recognized standard in the non-hazardous space should be required.

[13.6 Provisions for tank connection spaces

Approved automatic fail-safe fire dampers should be fitted in the ventilation trunk for the tank connection space.]

13.7 Provisions for machinery spaces

The ventilation system for machinery spaces containing gas-fuelled consumers should be independent of all other ventilation systems.

13.8 Provisions for bunkering station

Bunkering stations that are not located on open deck should be suitably ventilated to ensure that any vapour being released during bunkering operations will be removed outside. If the natural ventilation is not sufficient, mechanical ventilation should be provided in accordance with the risk assessment required by 4.2.

13.9 Provisions for ducts and double pipes

13.9.1 If fitted, the ventilation systems for double wall piping and for gas valve unit spaces in gas-safe engine-rooms should be independent of all other ventilation systems.

13.9.2 If fitted, the ventilation inlets for double wall piping or duct should be fitted with a suitable wire mesh guard and protected from ingress of water.

14 Electrical installations

14.1 Goal

The goal of this section is to provide for electrical installations that minimize the risk of ignition in the presence of a flammable atmosphere.

14.2 Functional requirements:

This chapter is related to functional requirements in 3.2.1, 3.2.2, 3.2.4, 3.2.7, 3.2.8, 3.2.11, 3.2.12 and 3.2.15 to 3.2.17. In particular the following apply:
Electrical generation and distribution systems, and associated control systems, should be designed such that a single fault will not result in the loss of ability to maintain fuel tank pressures and hull structure temperature within normal operating limits.

14.3 Provisions – General

14.3.1 Electrical installations should comply with a standard at least equivalent to those acceptable to the Organization[11].

14.3.2 Electrical equipment or wiring should not be installed in hazardous areas unless essential for operational purposes or safety enhancement.

14.3.3 Where electrical equipment is installed in hazardous areas as provided in 14.3.2 it should be selected, installed, and maintained in accordance with standards at least equivalent to those acceptable to the Organization[12]. Equipment for hazardous areas should be evaluated and certified or listed by an accredited testing authority or notified body recognized by the Administration.

14.3.4 Failure modes and effects of single failure for electrical generation and distribution systems in 14.2 should be analysed and documented to be at least equivalent to those acceptable to the Organization[13].

14.3.5 The lighting system in hazardous areas should be divided between at least two branch circuits. All switches and protective devices should interrupt all poles or phases and should be located in a non-hazardous area.

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

14.3.7 Submerged fuel pump motors and their supply cables may be fitted in liquefied gas fuel containment systems. Fuel pump motors should be capable of being isolated from their electrical supply during gas-freeing operations.

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11 Refer to IEC 60092 series standards, as applicable.

12 Refer to the recommendation published by the International Electrotechnical Commission, in particular to publication IEC 60092-502:1999.

13 Refer to IEC 60812.

15 Control, monitoring and safety systems

15.1 Goal

The goal of this section is to provide for the arrangement of control, monitoring and safety systems that support an efficient and safe operation of the ammonia fuelled installation as covered in the other sections of these Interim Guidelines.

15.2 Functional requirements

This section is related to functional requirements in 3.2.1, 3.2.2, 3.2.11, 3.2.12 to 3.2.14, 3.2.16 and 3.2.17 of these Interim Guidelines. In particular, the following applies:

.1 the control, monitoring and safety systems of the ammonia fuelled installation should be so arranged that the remaining power for propulsion and power generation is in accordance with 9.3.1 in the event of single failure;

.2 an ammonia safety system should be arranged to close down the fuel 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;

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

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

.5 where two or more fuel supply systems are required to meet the provisions, each system should be fitted with its own set of independent fuel control and fuel safety systems.

15.3 General provisions

15.3.1 Suitable instrumentation devices should be fitted to allow a local and a remote reading of essential parameters to ensure a safe management of the whole fuel-gas equipment including bunkering.

15.4 Provisions for bunkering and fuel tank monitoring

15.4.1 *Level indicators for fuel tanks*

.1 Each fuel tank should be fitted with liquid level gauging device(s), arranged to ensure a level reading is always obtainable whenever the fuel tank is operational. The device(s) should be designed to operate throughout the design pressure range of the liquefied gas fuel tank and at temperatures within the fuel operating temperature range.

.2 Where only one liquid level gauge is fitted it should be arranged so that it can be maintained in an operational condition without the need to empty or gas-free the tank.

.3 Fuel tank liquid level gauges may be of the following types:

.1 indirect devices, which determine the amount of fuel by means such as weighing or in-line flow metering; or

.2 closed devices, which do not penetrate the fuel tank, such as devices using radioisotopes or ultrasonic devices.

15.4.2 *Overflow control*

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

.2 An additional sensor operating independently of the high liquid level alarm should automatically actuate a shut-off valve in a manner that will both avoid excessive liquid pressure in the bunkering line and prevent the fuel tank from becoming liquid full.

.3 The position of the sensors in the fuel tank should be capable of being verified before commissioning. At the first occasion of full loading after delivery and after each dry-docking, testing of high-level alarms should be conducted by raising the fuel liquid level in the fuel tank to the alarm point.

.4 All elements of the level alarms, including the electrical circuit and the sensor(s), of the high, and overfill alarms, should be capable of being functionally tested. Systems should be tested prior to fuel operation in accordance with 18.4.3.

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

15.4.4 The pressure indicators should be clearly marked with the highest and lowest pressure permitted in the 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 a continuously manned central control station or onboard safety centre. Alarms should be activated before the set pressures of the safety valves are reached.

15.4.6 Each fuel pump discharge line and each liquid and vapour bunker manifold should be provided with at least one local pressure indicator.

15.4.7 The local pressure indicators should be provided to indicate the pressure between ship's bunker manifold valves and hose connections to the bunkering facility.

15.4.8 Fuel storage hold spaces and inter-barrier spaces without open connection to the atmosphere should be provided with pressure indicator.

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

15.4.10 Each fuel tank should be provided with devices to measure and indicate the temperature of the fuel.

15.5 Provisions for bunkering control

15.5.1 Control of the bunkering should be possible from a safe location remote from the bunkering station. At this location the tank pressure, tank temperature, and tank level should be monitored. Remotely controlled valves required by 8.5.3 and 11.5.6 should be capable of being operated from this location. Overfill alarm and automatic shutdown should also be indicated at this location.

15.5.2 If ammonia leakage is detected in the secondary enclosure around the bunkering lines, an audible and visual alarm should be provided at the bunkering control location. The bunker valve and other valves required to isolate the leakage should be automatically closed by the safety system in accordance with Table 1.

15.6 Provisions for gas compressor monitoring

15.6.1 Gas compressors should be fitted with audible and visual alarms both on the navigation bridge and in the engine control room. As a minimum the alarms should include low gas input pressure, low gas output pressure, high gas output pressure and compressor operation.

15.6.2 Where bulkhead penetrations are used to separate the drive from a hazardous space, temperature monitoring for the bulkhead shaft glands and bearings should be provided, which automatically give a continuous audible and visual alarm on the navigation bridge or in a continuously manned central control station.

15.7 Provisions for gas engine monitoring

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

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

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

15.8 Provisions for leakage detection

15.8.1 Where gas detection should cause shutdown in accordance with Table 1, detector voting should be applied where two units should detect gas to activate shutdown. A failed detector should be considered as an active detection.

15.8.2 Permanently installed gas detectors should be fitted in:

.1 tank connection spaces;

.2 all secondary enclosures around fuel pipes;

.3 machinery spaces containing gas piping, gas equipment or gas consumers;

.4 fuel preparation rooms;

.5 bunkering stations and other enclosed spaces containing fuel piping or other fuel equipment not protected by a secondary enclosure;

.6 other enclosed or semi-enclosed spaces where fuel vapours may accumulate including inter-barrier spaces and fuel storage hold spaces of independent tanks other than type C;

.7 airlocks and entry spaces to tank connection spaces;

.8 gas heating circuit expansion tanks;

.9 motor rooms for compressors as specified in 15.6.2 (if fitted);

.10 at ventilation inlets to accommodation and machinery spaces where required based on the risk assessment in 4.2;

.11 at ventilation inlets for safe haven; and

.12 at outlet from tank pressure relief valves.

15.8.3 The number of detectors in each space should be considered taking into account the size, layout and ventilation of the space, and each space shall be covered by sufficient number of detectors to allow for voting in accordance with Table 1.

15.8.4 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 location of gas detectors.

15.8.5 Gas detection equipment should be designed, installed, and tested in accordance with a recognized standard.

15.8.6 Fuel piping should also be arranged with detection of liquid leakages in the secondary enclosure at the lowest point.

15.8.7 Each tank connection space, fuel preparation room and bunker station should be provided with liquid leakage detection. Alarm should be given at high liquid level and low temperature indication should activate the safety system.

15.8.8 An audible and visible alarm should be activated at an ammonia vapour concentration of 150 ppm as specified in Table 1. The safety system should be activated at an ammonia vapour concentration of 350 ppm with actions as specified in Table 1.

15.8.9 Audible and visible alarms from the leakage detection equipment should be located on the navigation bridge, in the continuously manned central control station and inside and outside the space where the leakage is detected.

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

15.9 Provisions for prevention of condensation in fuel supply line

15.9.1 Where gaseous ammonia fuel is supplied to a consumer, the following should be monitored:

- fuel pipe wall temperature; and
- fuel pressure.

The control system should be capable of calculating the dynamic dew point based on measurements of fuel pressure and fuel pipe wall temperature. If fuel pipe wall temperature falls within 10°C of the calculated dew point of the fuel, the fuel system should shut down and fuel system should be purged of ammonia fuel.

15.10 Provisions for ventilation

15.10.1 Any reduction of the required ventilating capacity in tank connection spaces, fuel preparation rooms or other enclosed spaces containing fuel piping or other fuel equipment not protected by a secondary enclosure should give an audible and visual alarm on the navigation bridge or in a continuously manned central control station or safety centre. Loss of ventilation should result in automatic closing of valves as specified in table 1.

15.11 Provisions for safety functions of fuel supply systems

15.11.1 If the fuel supply is shut off due to activation of an automatic valve, the fuel supply should not be opened until the reason for the disconnection is ascertained and the necessary precautions taken. A readily visible notice giving instruction to this effect should be placed at the operating station for the shut-off valves in the fuel supply lines.

15.11.2 A caution placard or signboard should be permanently fitted in the machinery space containing gas fuelled engines stating that heavy lifting, implying danger of damage to the fuel pipes, should not be done unless the fuel supply lines are free from ammonia.

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

.1 navigation bridge;

.2 cargo control room;

.3 onboard safety centre;

.4 engine control room;

.5 fire control station; and

.6 adjacent to the exit of fuel preparation rooms.

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

Table 1 Monitoring of ammonia fuel installation

Parameter	Alarm	Automatic shutdown of bunker valve	Automatic shutdown of tank valve(s)	Automatic shutdown of fuel preparation room valve(s)	Automatic shutdown of master valve(s)	Comments
High-level fuel tank	X					See 15.4.2.1
High-high level fuel tank	X	X	X			See 15.4.2.2
Submerged fuel pumps, low level in tank	X					See 15.4.9 Stop fuel pumps at low-low liquid level
Gas detection in bunker station at 150 ppm	X					See 15.8.7
Gas detection in bunker station at 350 ppm		X				See 15.8.7
Liquid leakage detection in bunker station	X	X				See 15.8.6 Close valve at low temperature
Gas detection in in secondary enclosure around bunkering lines at 150 ppm	X					See 15.5.2
Gas detection in		X	X			See 15.5.2

Parameter	Alarm	Automatic shutdown of bunker valve	Automatic shutdown of tank valve(s)	Automatic shutdown of fuel preparation room valve(s)	Automatic shutdown of master valve(s)	Comments
in secondary enclosure around bunkering lines at 350 ppm						
Liquid leakage detection in secondary enclosure around bunkering lines	X	X	X			See 15.5.2
Gas detection in tank connection space at 150 ppm	X					15.8.7
Gas detection on two detectors in tank connection space at 350 ppm	X		X			15.8.7
Liquid leakage detection in tank connection space	X		X			See 15.8.6 Close valve at low temperature
Gas detection in fuel preparation room at 150 ppm	X					15.8.7

Parameter	Alarm	Automatic shutdown of bunker valve	Automatic shutdown of tank valve(s)	Automatic shutdown of fuel preparation room valve(s)	Automatic shutdown of master valve(s)	Comments
Gas detection on two detectors in fuel preparation room at 350 ppm	X			X		15.8.7
Liquid leakage detection in Fuel preparation room	X			X		See 15.8.6 Close valve at low temperature
Gas detection in secondary enclosure of fuel supply piping at 150 ppm	X					15.8.7
Gas detection on two detectors in secondary enclosure of fuel supply piping at 350 ppm	X		X	X	X	See 15.8.7 All valves required to isolate the leakage should close
Liquid leakage detection in secondary enclosure of fuel supply pipes	X		X	X	X	See 15.8.5 All valves required to isolate the leakage should close
Reduced ventilation in tank	X					See 15.10.1

Parameter	Alarm	Automatic shutdown of bunker valve	Automatic shutdown of tank valve(s)	Automatic shutdown of fuel preparation room valve(s)	Automatic shutdown of master valve(s)	Comments
connection space						
Loss of ventilation in tank connection space			X			See 15.10.1
Reduced ventilation in fuel preparation room	X					See 15.10.1
Loss of ventilation in fuel preparation room				X		See 15.10.1
Manually activated emergency shutdown of master fuel valve(s) engine	X				X	See 9.4.5

16 Manufacture, Workmanship and Testing

16.1 General

16.1.1 The manufacture, testing, inspection, and documentation should be in accordance with recognized standards and the provisions given in these Interim Guidelines.

16.1.2 Where post-weld heat treatment is specified or required, the properties of the base material should be determined in the heat-treated condition, in accordance with the applicable tables of chapter 7, and the weld properties should be determined in the heat-treated condition in accordance with 16.3. In cases where a post-weld heat treatment is applied, the test provisions may be modified at the discretion of the Administration.

16.2 General test provisions and specifications

Unless expressly provided otherwise, the requirements of the IGF Code Part-A1 Chapter 16.2 should apply to ships using ammonia as fuel.

16.3 Welding of metallic materials and non-destructive testing for the fuel containment system

Unless expressly provided otherwise, the requirements of the IGF Code Part-A1 Chapter 16.3 should apply to ships using ammonia as fuel.

16.4 Other provisions for construction in metallic materials

Unless expressly provided otherwise, the requirements of the IGF Code Part-A1 Chapter 16.4 should apply to ships using ammonia as fuel.

16.5 Fuel containment system testing

Unless expressly provided otherwise, the requirements of the IGF Code Part-A1 Chapter 16.5 should apply to ships using ammonia as fuel.

16.6 Welding, post-weld heat treatment and non-destructive testing

16.6.1 General

Welding should be carried out in accordance with 16.3.

16.6.2 Post-weld heat treatment

Post-weld heat treatment should be required for all butt welds of pipes made with carbon, carbon manganese and low alloy steels. The Administration may waive the provisions for thermal stress relieving of pipes with wall thickness less than 10 mm in relation to the design temperature and pressure of the piping system concerned, observing the requirements in 7.4.1.

16.6.3 Non-destructive testing

In addition to normal controls before and during the welding, and to the visual inspection of the finished welds, as necessary for proving that the welding has been carried out correctly and according to the provisions in this paragraph, the following tests should be required:

.1 100% radiographic or ultrasonic inspection of butt-welded joints for piping systems with;

  .1 design temperatures colder than minus 10°C; or

  .2 design pressure greater than 1.0 MPa; or

  .3 inside diameters of more than 75 mm; or

  .4 wall thicknesses greater than 10 mm.

.2 When such butt-welded joints of piping sections are made by automatic welding procedures approved by the Administration, then a progressive reduction in the extent of radiographic or ultrasonic inspection can be agreed, but in no case to less than 10% of each joint. If defects are revealed the extent of examination should be increased to 100% and should include inspection of previously accepted welds. This approval can only be granted if well-documented quality assurance procedures and records are available to assess the ability of the manufacturer to produce satisfactory welds consistently.

.3 The radiographic or ultrasonic inspection regulation may be reduced to 10% for butt-welded joints in the outer pipe of double-walled fuel piping.

.4 For other butt-welded joints of pipes not covered by 16.6.3.1 and 16.6.3.3, spot radiographic or ultrasonic inspection or other non-destructive tests should be carried out depending upon service, position, and materials. In general, at least 10% of butt-welded joints of pipes should be subjected to radiographic or ultrasonic inspection.

16.7 Testing provisions

16.7.1 Type testing of piping components

Valves

Each type of piping component intended to be used in ammonia fuel systems should be subject to the following type tests:

.1 Each size and type of valve should be subjected to seat tightness testing over the full range of operating pressures and temperatures, at intervals, up to the rated design pressure of the valve. Allowable leakage rates should be to the requirements of the Administration During the testing satisfactory operation of the valve should be verified.

.2 The flow or capacity should be certified to a recognized standard for each size and type of valve.

.3 Pressurized components should be pressure tested to at least 1.5 times the design pressure.

.4 For emergency shutdown valves, with materials having melting temperatures lower than 925°C, the type testing should include a fire test to a standard at least equivalent to those acceptable to the Organization[14].

16.7.2 System testing provisions

16.7.2.1 The provisions for testing in this section apply to fuel piping inside and outside the fuel tanks. However, relaxation from these provisions for piping inside fuel tanks and open-ended piping may be accepted by the Administration.

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[14] Refer to the recommendations by the International Organization for Standardization, in particular publications:
ISO 19921:2005, Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Test methods
ISO 19922:2005, Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Requirements imposed on the test bench

.3 the ship should be provided with operational procedures including a suitably detailed fuel handling manual, such that trained qualified personnel can safely operate the fuel bunkering, storage, and transfer systems; and

.4 the ship should be provided with suitable emergency procedures.

16.7.2.2 After assembly, all fuel piping should be subjected to a strength test with a suitable fluid. The test pressure should be at least 1.5 times the design pressure for liquid lines and 1.5 times the maximum system working pressure for vapour lines. When piping systems or parts of systems are completely manufactured and equipped with all fittings, the test may be conducted prior to installation on board the ship. Joints welded on board should be tested to at least 1.5 times the design pressure.

16.7.2.3 After assembly on board, the fuel piping system should be subjected to a leak test using air, or other suitable medium to a pressure depending on the leak detection method applied.

16.7.2.4 In double wall fuel piping systems the outer pipe or duct should also be pressure tested to show that it can withstand the expected maximum pressure at pipe rupture.

16.7.2.5 All piping systems, including valves, fittings and associated equipment for handling fuel or vapours, should be tested under normal operating conditions not later than at the first bunkering operation, in accordance with the requirements of the Administration.

16.7.2.6 Emergency shutdown valves in liquefied gas piping systems should close fully and smoothly within 30 s of actuation. Information about the closure time of the valves and their operating characteristics should be available on board, and the closing time should be verifiable and repeatable.

16.7.2.7 The closing time of the valve referred to in 8.5.8 and 15.4.2.2 (i.e., time from shutdown signal initiation to complete valve closure) should not be greater than:

$$3600U/BR \text{ (second)}$$

where:

U = ullage volume at operating signal level (m3);

BR = maximum bunkering rate agreed between ship and shore facility (m3/h); or 5 seconds, whichever is the least.
The bunkering rate should be adjusted to limit surge pressure on valve closure to an acceptable level, taking into account the bunkering hose or arm, the ship and the shore piping systems, where relevant.

17 Drills and emergency exercises

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

Such gas-related exercises could include for example:

.1 tabletop exercise;

.2 review of fuelling procedures based in the fuel handling manual required by 18.2.3;

.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.

Gas related exercises may be incorporated into periodical drills required by SOLAS.

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

Article I.

1 Operation

18.1 Goal

The goal of this section is to ensure that operational procedures for the loading, storage, operation, maintenance, and inspection of systems for ammonia fuel minimize the risk to personnel, the ship, and the environment, and that are consistent with practices for a conventional oil-fuelled ship whilst taking into account the nature of ammonia.

18.2 Functional requirements

This section 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 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 ammonia related installations should be available on board;

18.3 Provisions for maintenance and inspection

18.3.1 Maintenance and repair procedures should include considerations with respect to the fuel containment systems and adjacent spaces. Special consideration should be given to the toxicity of fuel.

18.3.2 In-service survey, maintenance and testing of the fuel containment system are to be carried out in accordance with the inspection/survey plan required by 6.4.1.8 of the IGF Code Part A-1.

18.3.3 The procedures and information should include maintenance of electrical equipment that is installed in explosion hazardous spaces and areas. The inspection and maintenance of electrical installations in explosion hazardous spaces should be performed in accordance with a recognized standard[15].

18.4 Provisions for bunkering operations

18.4.1 Responsibilities

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

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

.1 agree in writing on the transfer procedure, including cooling down and if necessary, gassing up; the maximum transfer rate at all stages and volume to be transferred;

.2 agree in writing action to be taken in an emergency; and

.3 complete and sign the bunker safety checklist.

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

18.4.2 Overview of control, automation, and safety systems

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

18.4.3 Pre-bunkering verification

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

.1 all communications methods, including ship shore link (SSL), if fitted;

.2 operation of fixed gas and fire detection equipment;

.3 operation of portable gas detection equipment;

.4 operation of remote-controlled valves;

.5 inspection of hoses and couplings;

.6 operation of water spray system; and

.7 function testing of tank level alarms.

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

18.4.4 Ship bunkering source communications

18.4.4.1 Communications should always be maintained between the ship PIC and the bunkering source PIC during the bunkering operation. If communications cannot be maintained, bunkering should stop and not resume until communications are restored.

18.4.4.2 Communication devices used in bunkering should comply with recognized standards for such devices acceptable to the Administration.

18.4.4.3 PICs should have direct and immediate communication with all personnel involved in the bunkering operation.

18.4.4.4 The ship-shore link (SSL) or equivalent means to a bunkering source provided for automatic ESD communications should be compatible with the receiving ship and the delivering facility ESD system[16].

18.4.5 Electrical bonding

Hoses, transfer arms, piping and fittings provided by the delivering facility used for bunkering should be electrically continuous, suitably insulated and should provide a level of safety compliant with recognized standards[17].

18.4.6 Conditions for transfer

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

18.4.6.2 During the transfer operation, personnel in the bunkering manifold area should be limited to essential staff only. All staff engaged in duties or working in the vicinity of the operations should wear appropriate personal protective equipment (PPE). A failure to maintain the required conditions for transfer should be a cause to stop operations. Transfer should not be resumed until all required conditions are met.

18.5 Provisions for enclosed space entry

18.5.1 Under normal operational circumstances, personnel should not enter fuel tanks, fuel storage hold spaces, void spaces, tank connection spaces or other enclosed spaces where gas or flammable vapours may accumulate, unless the gas content of the atmosphere in such space is determined by means of fixed or portable equipment to ensure oxygen sufficiency and absence of a toxic and explosive atmosphere[18].

18.5.2 Personnel entering any space designated as a hazardous area should not introduce any potential source of ignition into the space unless it has been certified gas-free and maintained in that condition.

18.5.3 Personnel entering any space designated as a toxic area should wear appropriate personal protective equipment (PPE).

18.6 Provisions for inerting and purging of fuel systems

18.6.1 The primary objective of inerting and purging fuel systems is to prevent the formation of a toxic and combustible atmosphere in, near or around fuel system piping, tanks, equipment, and adjacent spaces.

18.6.2 Procedures for inerting and purging of fuel systems should ensure that air is not introduced into piping or a tank containing ammonia, and that ammonia is not introduced into enclosures or spaces adjacent to fuel systems.

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16 Refer to ISO 28460:2010, Petroleum and natural gas industries – installation and equipment for liquefied natural gas – Ship-to-shore interface and port operations.

17 Refer to API RP 2003, ISGOTT: International Safety Guide for Oil Tankers and Terminals.

18 Refer to the Revised recommendations for entering enclosed spaces aboard ships (A.1050(27)).

18.7 Fuel handling manual

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

.1 Overall operation of the ship related to the ammonia installation from dry-dock to dry-dock.

.2 Arrangement and lay-out of the ammonia fuel supply system, including:
- a description of main components in the fuel supply system;
- a general description of how the fuel system is intended to work; and
- a toxic area plan.

.3 Description of the safety system and automatic safety actions for the ammonia fuel supply system, including:

.1 Procedures for handling leakages:
- in the fuel system;
- in the tank connection spaces;
- in the fuel preparation rooms;
- in the bunkering station; and
- from a fuel tank pressure relief valve (ref. 6.7.2.6).

.2 Procedures for how to respond to substantial discharges from the outlet from fuel tank pressure relief valves or ventilation openings from toxic spaces, including:
- evacuation to safe haven;
- closing of ventilation inlets; and
- operation of water spray systems to limit extent of toxic vapours.

.3 Procedures for how to respond to loss of ventilation in:
- tank connection spaces; and
- fuel preparation rooms.

.4 Procedures for how to respond to a fire in:
- the machinery space;
- on deck; or
- fuel preparation room

in relation to operation of the ammonia fuel system.

.4 Description of hazards in connection with exposure to ammonia and procedures for how to avoid exposure to ammonia during:
- bunkering operations;
- normal operation;
- entry of toxic spaces; or
- when performing maintenance on the ammonia fuel system.

.5 Description of hazards in connection with exposure to inert gas and procedures for how to avoid exposure.

.6 Description of entry procedures for:
- tank connection spaces;
- fuel preparation rooms;
- bunkering stations;

- hold spaces; and
- other spaces where entry may constitute a hazard to the ship or personnel.

.7 Description of bunkering operations, including procedures to:

- ensure system readiness (fire, water spray, gas detection automatic valves, inert gas, pre-bunkering procedures, communication procedures);
- prevent overfilling of tanks (transfer rates, filling limits, high-level alarms);
- control the tank pressure when bunkering (vs. tank design temperature and pressure, spraying, vapour return);
- prevent release of fuel gases to atmosphere;
- purge the bunkering system at termination of bunkering operation; and
- ensure proper use of PPE.

.8 Procedures for purging and gas freeing of ammonia fuel systems to ensure safe maintenance.

.9 Procedure for operation of fuel containment systems including:

- cool down and warm up procedures;
- procedures for emptying tanks to shore;
- inerting and gas freeing.

19 Training

19.1 Goal

The goal of this section is to ensure that seafarers on board ships to which these Interim Guidelines apply are adequately qualified, trained, and experienced.

19.2 Functional requirements

19.2.1 The company should ensure that seafarers on board ships using ammonia fuel should have completed training to attain the abilities that are appropriate to the capacity to be filled, and duties and responsibilities to be taken up.

19.2.2 The master, officers, ratings and other personnel on ships using ammonia fuel should be trained and qualified in accordance with regulation V/3 of the STCW Convention and section A-V/3 of the STCW Code, taking into account the specific hazards of ammonia used as fuel.

20 Personnel protection

20.1 Goal

The goal of this section is to ensure that protective equipment is provided for persons on board, considering both routine operations and emergency situations and possible short- or long-term effects of ammonia exposure.

20.2 Functional requirements

This section relates to functional requirements in 3.2.1, 3.2.11 and 3.2.15. In particular the following apply:

.1 For the protection of crew members who are engaged in operation and maintenance of ammonia fuel systems, the ship should have on board protective equipment suitable for ammonia exposure, taking the exposure risk of different operations into account.

.2 For the protection and treatment of crew members affected by ammonia leakages, the ship should have on board suitable emergency equipment.

20.3 Protective equipment

20.3.1 Suitable protective equipment, including eye protection, to a recognized national or international standard should be provided for protection of crew members engaged in normal operations related to the ammonia fuel system.

20.3.2 Personal protective and safety equipment required in this section should be kept in suitable, clearly marked lockers located in readily accessible places.

20.4 Emergency equipment

20.4.1 Suitably marked decontamination showers and eyewashes should be available in convenient locations:

- close to bunkering stations;
- close to exit from tank connection spaces;
- close to exit from fuel preparation rooms; and
- in machinery spaces for ammonia fuelled consumers.

The showers and eyewashes should be operable in all ambient conditions. A heating system with temperature control is required if pipe routeing of the water supply exposes the piping to freezing conditions. Water supply capacity should be sufficient for simultaneous use of at least two units. Thermal insulation is not considered as an alternative to a system with temperature control.

20.4.2 A stretcher that is suitable for hoisting an injured person from spaces such as tank hold spaces should be kept in a readily accessible location.

20.4.3 The ship should have onboard medical first aid equipment, including oxygen resuscitation equipment, based on the requirements of the Medical First Aid Guide (MFAG) for ammonia.

20.4.4 Suitable respiratory and eye protection for emergency escape purposes should be provided for every person on board, subject to the following:

.1 filter-type respiratory protection is unacceptable; and

.2 self-contained breathing apparatus should have at least 15 minutes of service time; and

.3 emergency escape respiratory protection should not be used for fire-fighting or cargo-handling purposes and should be marked to that effect.

20.5 Safety equipment

20.5.1 Sufficient, but not less than three complete sets of safety equipment should be provided in addition to fire-fighter's outfits required by SOLAS regulation II-2/10.10. Each set should provide adequate personal protection to permit entry and work in a gas-filled space. This equipment should consider the nature of ammonia.

20.5.2 Each complete set of safety equipment should consist of:

.1 one self-contained positive pressure air-breathing apparatus incorporating full face mask not using stored oxygen and having a capacity of at least 1,200 litres of free air. Each set should be compatible with that required by SOLAS regulation II-2/10.10;

.2 gastight protective clothing, boots, and gloves to a recognized standard;

.3 steel-cored rescue line with belt; and

.4 explosion-proof lamp.

20.5.3 An adequate supply of compressed air should be provided and should consist of:

.1 at least one fully charged spare air bottle for each breathing apparatus required by 20.5.1;

.2 an air compressor of adequate capacity capable of continuous operation, suitable for the supply of high-pressure air of breathable quality; and

.3 a charging manifold capable of dealing with sufficient spare breathing apparatus air bottles for the breathing apparatus required by 20.5.1.

20.5.4 The compressed air equipment should be inspected at least once a month by a responsible officer and the inspection logged in the ship's records. This equipment should also be inspected and tested by a competent person at least once a year.

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7. Appendix 2

ANNEX 2[6]

GUIDANCE ON CALCULATION AND VERIFICATION OF EFFECTS OF CATEGORY (C) INNOVATIVE TECHNOLOGIES

1 WASTE HEAT RECOVERY SYSTEM FOR GENERATION OF ELECTRICITY (CATEGORY (C-1))

1.1 Summary of innovative energy efficient technology

1.1.1 This chapter provides the guidance on the treatment of high temperature waste heat recovery systems (electric generation type) as innovative energy efficiency technologies related to the reduction of the auxiliary power (concerning $P_{AEeff(i)}$). Mechanical recovered waste energy directly coupled to shafts need not be measured in this category, since the effect of the technology is directly reflected in the V_{ref}.

1.1.2 Waste heat energy technologies increase the efficiency utilization of the energy generated from fuel combustion in the engine through recovery of the thermal energy of exhaust gas, cooling water, etc. thereby generating electricity.

1.1.3 There are the following two methods of generating electricity by the waste heat energy technologies (electric generation type):

.1 (A) method to recover thermal energy by a heat exchanger and to drive the thermal engine which drives an electric generator; and

.2 (B) method to drive directly an electric generator using power turbine, etc. Furthermore, there is a waste heat recovery system which combines both of the above methods.

6 All examples in this chapter are used solely to illustrate the proposed methods of calculation and verification.

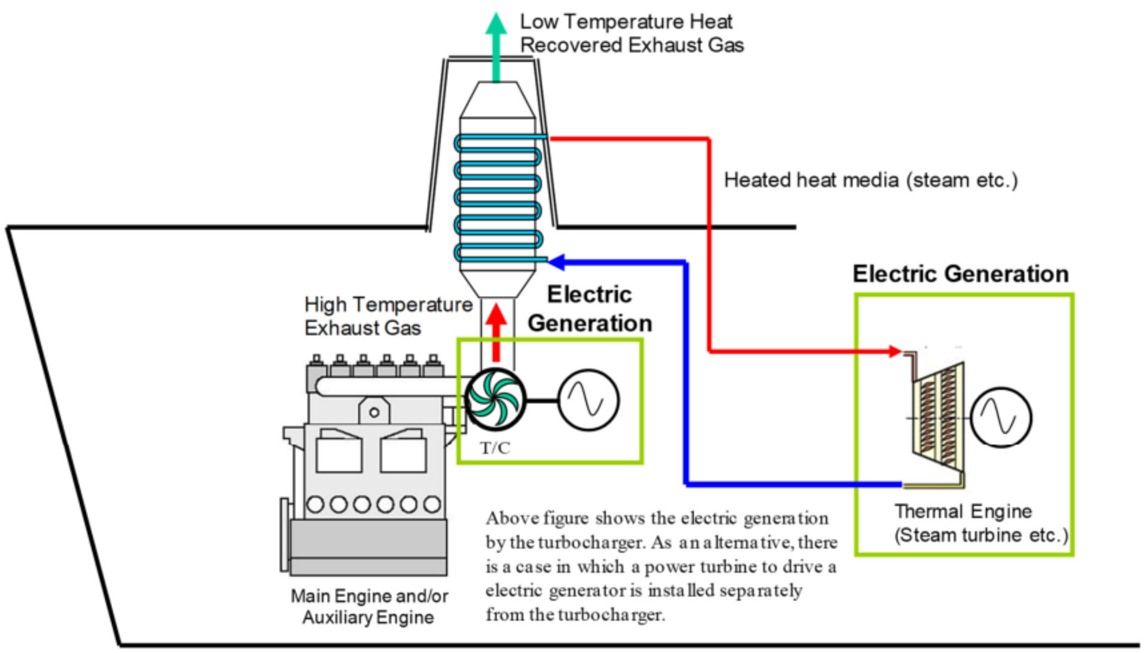

Figure 1 – Schematic illustration of Exhaust Heat Recovery

1.2 Method of calculation

1.2.1 Power reduction due to waste heating recovery system

1.2.1.1 The reduction of power by the waste heat recovery system is calculated by the following equation. For this system, f_{eff} is 1.00 in EEDI formula.

$$P_{AEeff} = P'_{AEeff} - P_{AEeff\_loss} \quad (1)$$

In the above equation, P'_{AEeff} is power produced by the waste heat recovery system. P_{AEeff_Loss} is the necessary power to drive the waste heat recovery system.

1.2.1.2 P_{AEeff} is the reduction of the ship's total auxiliary power (kW) by the waste heat recovery system under the ship performance condition applied for EEDI calculation. The power generated by the system under this condition and fed into the main switch board is to be taken into account, regardless of its application on board the vessel (except for power consumed by machinery as described in paragraph 1.2.1.4 of this chapter).

1.2.1.3 P'_{AEeff} is defined by the following equation.

$$P'_{AEeff} = \frac{W_e}{\eta_g}, \quad (2)$$

where:

W_e : Calculated production of electricity by the waste heat recovery system η_g : Weighted average generator efficiency

1.2.1.4 P_{AEeff} is determined by the following factors:

- .1 temperature and mass flow of exhaust gas of the engines, etc.;
- .2 constitution of the waste heat recovery system; and
- .3 efficiency and performances of the components of the waste heat recovery system.

1.2.1.5 P_{AEeff_Loss} is the power (kW) for the pump, etc. necessary to drive the waste heat recovery system.

1.3 Method of verification

1.3.1 General

1.3.1.1 Verification of EEDI with innovative energy efficient technologies should be conducted according to the EEDI Survey Guidelines. Additional items concerning innovative energy efficient technologies not contained in EEDI Survey Guidelines are described below.

1.3.2 Preliminary verification at the design stage

1.3.2.1 In addition to paragraph 4.2.2 of EEDI Survey Guidelines, the EEDI Technical File which is to be developed by the shipowner or shipbuilder should include:

- .1 diagrams, such as a plant diagram, a process flow diagram, or a piping and instrumentation diagram outlining the waste heat recovery system, and its related information such as specifications of the system components;
- .2 deduction of the saved energy from the auxiliary engine power by the waste heat recovery system; and
- .3 calculation result of EEDI.

1.3.2.2 In addition to paragraph 4.2.7 of the EEDI Survey Guidelines, additional information that the verifier may request the shipbuilder to provide directly to it includes:

- .1 exhaust gas data for the main engine at 75% MCR (and/or the auxiliary engine at the measurement condition of *SFC*) at different ambient air inlet temperatures, e.g. 5°C, 25°C and 35°C; which consist of:
  - .1 exhaust gas mass flow for turbo charger (kg/h);
  - .2 exhaust gas temperatures after turbo charger (C°);
  - .3 exhaust gas bypass mass flow available for power turbine, if any (kg/h);
  - .4 exhaust gas temperature for bypass flow (C°); and
  - .5 exhaust gas pressure for bypass flow (bar).

.2 in the case of system using heat exchanger, expected output steam flows and steam temperatures for the exchanger, based on the exhaust gas data from the main engine;

.3 estimation process of the heat energy recovered by the waste heat recovery system; and

.4 further details of the calculation method of P_{AEeff} defined in paragraph 1.2.1 of this chapter.

1.3.3 Final verification of the attained EEDI at sea trial

1.3.3.1 Deduction of the saved energy from the auxiliary engine power by the waste heat recovery system should be verified by the results of shop tests of the waste heat recovery system's principal components and, where possible, at sea trials.

1.3.3.2 In the case of systems for which shop tests are difficult to be conducted, e.g. in case of the exhaust gas economizer, the performance of the waste heat recovery system should be verified by measuring the amount of the generated steam, its temperature, etc. at the sea trial. In that case, the measured vapour amount, temperature, etc. should be corrected to the value under the exhaust gas condition when they were designed, and at the measurement conditions of *SFC* of the main/auxiliary engine(s). The exhaust gas condition should be corrected based on the atmospheric temperature in the engine-room (Measurement condition of *SFC* of main/auxiliary engine(s); i.e. 25°C), etc.

2 PHOTOVOLTAIC POWER GENERATION SYSTEM (CATEGORY (C-2))

2.1 Summary of innovative energy efficient technology

2.1.1 Photovoltaic (PV) power generation system set on a ship will provide part of the electric power either for propelling the ship or for use inboard. PV power generation system consists of PV modules and other electric equipment. Figure 1 shows a schematic diagram of PV power generation system. The PV module consists of combining solar cells and there are some types of solar cell such as "Crystalline silicon terrestrial photovoltaic" and "Thin-film terrestrial photovoltaic", etc.

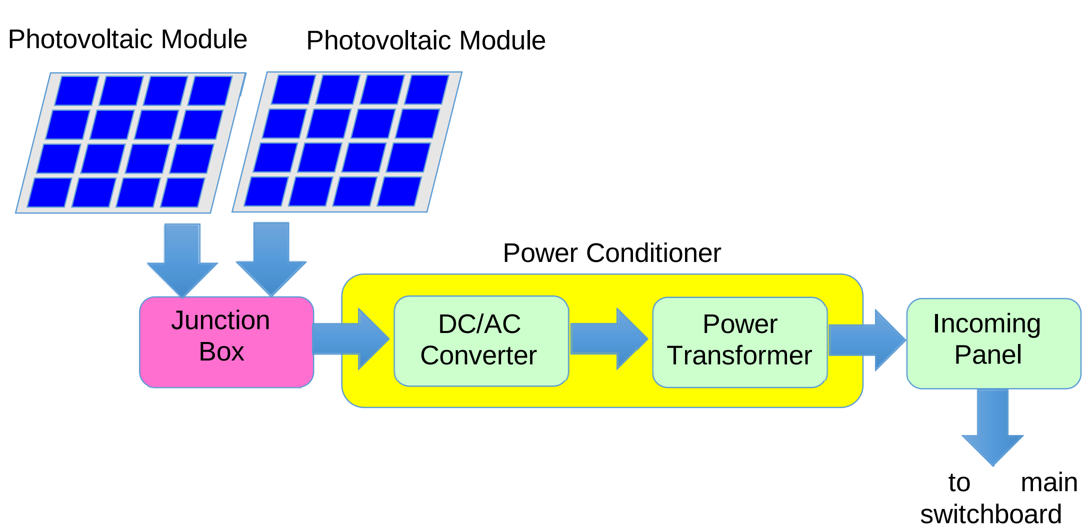

Figure 1 – Schematic diagram of photovoltaic power generation system

2.2 Method of calculation

2.2.1 Electric power due to photovoltaic power generation system

2.2.1.1 The auxiliary power reduction due to the PV power generation system can be calculated as follows:

$$f_{eff} \cdot P_{AEeff} = \{f_{rad} \times (1 + L_{temp} / 100)\} \times \{P_{max} \times (1 - L_{others} / 100) \times N / \eta_{GEN}\} \quad (1)$$

where $f_{eff} \cdot P_{AEeff}$ is the total net electric power (kW) generated by the PV power generation system.

2.2.1.2 Effective coefficient f_{eff} is the ratio of average PV power generation in main global shipping routes to the nominal PV power generation specified by the manufacturer. Effective coefficient can be calculated by the following formula using the solar irradiance and air temperature of main global shipping routes:

$$f_{eff} = f_{rad} \times (1 + L_{temp} / 100) \quad (2)$$

2.2.1.3 f_{rad} is the ratio of the average solar irradiance on main global shipping route to the nominal solar irradiance specified by the manufacturer. Nominal maximum generating power P_{max} is measured under the Standard Test Condition (STC) of IEC standard.[7] STC specified by manufacturer is that: Air Mass (AM) 1.5, the module's temperature is 25°C, and the solar irradiance is 1000 W/m^2. The average solar irradiance on main global shipping route is 200 W/m^2. Therefore, f_{rad} is calculated by the following formula:

$$f_{rad} = 200 \text{ W/m}^2 \div 1000 \text{ W/m}^2 = 0.2 \quad (3)$$

2.2.1.4 L_{temp} is the correction factor, which is usually in minus, and derived from the temperature of PV modules, and the value is expressed in per cent. The average temperature of the modules is deemed 40°C, based on the average air temperature on main global shipping routes. Therefore, L_{temp} is derived from the temperature coefficient f_{temp} (percent/K) specified by the manufacturer (see IEC standard[7]) as follows:

$$L_{temp} = f_{temp} \times (40°C - 25°C) \quad (4)$$

2.2.1.5 P_{AEeff} is the generated PV power divided by the weighted average efficiency of the generator(s) under the condition specified by the manufacturer and expressed as follows:

$$P_{AEeff} = P_{max} \times (1 - L_{others} / 100) \times N / \eta_{GEN}, \quad (5)$$

where η_{GEN} is the weighted average efficiency of the generator(s).

2.2.1.6 P_{max} is the nominal maximum generated PV power generation of a module expressed in kilowatt, specified based on IEC Standards.[7]

7 Refer to IEC 61215 "Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval" for Crystalline silicon terrestrial PV modules, and to IEC 61646 "Thin-film terrestrial photovoltaic (PV) modules – Design qualification and type approval" for Thin-film terrestrial PV modules.

2.2.1.7 L_{others} is the summation of other losses expressed by percent and includes the losses in a power conditioner, at contact, by electrical resistance, etc. Based on experiences, it is estimated that L_{others} is 10% (the loss in the power conditioner: 5% and the sum of other losses: 5%). However, for the loss in the power conditioner, it is practical to apply the value specified based on IEC Standards.[8]

2.2.1.8 *N* is the numbers of modules used in a PV power generation system.

2.3 Method of verification

2.3.1 General

2.3.1.1 Verification of EEDI with innovative energy efficient technologies is conducted according to EEDI Survey Guidelines**.** This section provides additional requirements related to innovative technologies.

2.3.2 Preliminary verification at the design stage

2.3.2.1 In addition to paragraph 4.2.2 of EEDI Survey guidelines, the EEDI Technical File which is to be developed by the shipowner or shipbuilder should include:

.1 outline of the PV power generation system;

.2 power generated by the PV power generation system; and

.3 calculated value of EEDI due to the PV power generation system.

2.3.2.2 In addition to paragraph 4.2.7 of the EEDI survey guidelines, additional information that the verifier may request the shipbuilder to provide directly to it includes:

.1 detailed calculation process of the auxiliary power reduction by the PV power generation system; and

.2 detailed calculation process of the total net electric power ($f_{eff} \cdot P_{AEeff}$) specified in section 2.2 in this guidance.

2.3.3 Final verification of the attained EEDI at sea trial

2.3.3.1 The total net electric power generated by PV power generation system should be confirmed based on the EEDI Technical File. In addition to the confirmation, it should be confirmed whether the configuration of the PV power generation systems on ship is as applied, prior to the final verification.

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8 IEC 61683 "Photovoltaic systems – Power conditioners – Procedure for measuring efficiency".

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