CHARTING THE FUTURE

ClassNK

Guidelines for Safety Operation for Ammonia-Fueled Vessels (ver1.0)

[English]

Introduction

Decarbonization of the shipping industry is one of the significant challenges the industry is facing toward its sustainable development. The International Maritime Organization (IMO) adopted the “Initial IMO Strategy” in April 2018 for reduction of GHG emissions from shipping and set out the clear numerical targets for GHG reduction and concrete implementation plan. Amidst an urgent need for further climate actions, this initial strategy was reviewed in 2023 with enhanced targets of 70-80% reduction in GHG emissions by 2040 and zero emissions by 2050. In this regard, the entire industry is required to commit to the challenges for the achievement of the ultimate goal of this strategy of zero emissions by around 2050.

As the GHG emissions from the onboard consumption of conventional fuels, mainly dependent on fossil fuels, are estimated to occupy about 3% of the global emissions, introduction of clean energy and low- or zero-carbon alternative fuels is considered to be one of the effective countermeasures for GHG reduction. Synthesized fuels such as ammonia and hydrogen, methanol, methane, rechargeable batteries, and biofuels are globally considered as the possible alternative fuels and there are high expectations for them toward the achievement of decarbonization, even with advantages and disadvantages associated with each of them.

Commercialization of ammonia as maritime fuel is expected to be in 2026 or later, while careful handling will be necessary due to the risks unique to ammonia, including its high toxicity, corrosiveness and hydrophilicity. While there still exist many challenges to be solved for further popularization in terms of safety, infrastructure readiness, technology development and regulations, the industry stakeholders, research institutes, and regulation authorities are striving for solutions in collaboration through day-to-day effort for the development of technologies and rules.

Operation of ships using alternative fuels is broadly categorized into four modes, namely: “normal operation,” “inspection and maintenance,” “bunkering[1],” and “emergency.”

The purpose of this Guidelines is to provide shipowners and ship management companies operating ships using ammonia as fuel with guiding principles to minimize the risks associated with ammonia bunkering and to reduce the impact on seafarers, ships and environment.

1 : Bunkering means the transfer of fuel from land-based or floating facilities to the ship’s permanent tanks, or the connection of portable tanks to the fuel supply system.

This Guidelines assumes scenarios focusing on ammonia bunkering to identify the items to be considered and sort them out in a matrix. ClassNK is convinced that this Guidelines assists each company in establishing the safety management system (SMS) and contributes to the safe operation of alternative fueled ships. It would be the greatest pleasure for us if this Guidelines also contributes to the mitigation of environmental impact and the sustainable development of the entire industry, serving as a step toward the future.

This Guidelines is subject to continuous reviews and revisions to reflect future discussions among the stakeholders, research outcomes and newly obtained insights. ClassNK is determined to keep on providing appropriate guidance based on the latest information and technologies related to the operation of ammonia-fueled vessels.

Revision History

No.	Revision Date	Category	Description
1.0	*2025. 3.31*	*New*	*Newly issued.*

Contents

Chapter 1 General Rules

1.1 Objectives of this Guidelines

The objective of this Guidelines is to provide shipowners and ship management companies operating ships using ammonia as fuel with guiding principles to minimize the risks associated with ammonia bunkering and to ensure the safety of personnel engaged in bunkering.

1.1.1 Target

This Guidelines has been developed for ships receiving a supply of ammonia fuels. Ammonia used for bunkering is assumed to be stored in a frozen state of -33 ˚C or below at atmospheric pressure.

1.2 International initiatives for ammonia-fueled vessels

International initiatives for ammonia-fueled vessels are mainly aiming to promote environmental regulations and sustainable energies. Ammonia has a huge potential for the future of the shipping industry especially as fuel of great significance to achieve the decarbonization targets by the IMO (International Maritime Organization).

On the other hand, overcoming technical challenges and ensuring safety are essential to use ammonia as fuel. Therefore, international organizations and companies, including IACS (International Association of Classification Societies), SGMF (Society for Gas as a Marine Fuel), SIGTTO (Society of International Gas Tanker and Terminal Operators), OCIMF (Oil Companies International Marine Forum), EMSA (European Maritime Safety Agency), MESD (Maritime Energy & Sustainable Development) as well as each country, with the IMO at the center, are jointly working on the research and development of technologies to establish the technical standards for the entire industry and to develop and update the rules specific to ships using ammonia as fuel.

Ammonia has a potential to serve as a significant step toward decarbonization of the shipping industry as a carbon free fuel with no CO_2 emission, while there still exist many challenges to be solved for commercialization, such as technical barriers, securement of safety, and supply infrastructure readiness. Therefore, international initiatives are ongoing to tackle these issues.

Considerations at the IMO to develop the Interim Guidelines for the Safety of Ships Using Ammonia as Fuel are scheduled as shown in Table 1.

Table 1) Scheduled considerations for the development of the
Interim Guidelines for the Safety of Ships Using Ammonia as Fuel

Name of committee	Schedule	Objectives
The 109th Maritime Safety Committee (MSC109)	Dec 2024	**Approval of the Interim Guidelines for the Safety of Ships Using Ammonia as Fuel**
Correspondence Group (CG)[2]	2024-2025	Collection of information on usage of ammonia and methanol fuels
The 12th Sub-Committee on Carriage of Cargoes and Containers (CCC12)	2026	Review of the Interim Guidelines for the Safety of Ships Using Ammonia as Fuel (if time permits)
The 13th Sub-Committee on Carriage of Cargoes and Containers (CCC13)	2027	**Review of the Interim Guidelines for the Safety of Ships Using Ammonia as Fuel**

The 10th Sub-Committee on Carriage of Cargoes and Containers (CCC10) in October 2024 adopted the amendments to the IGC Code regarding ships using ammonia cargo as fuel, which are expected to come into force on 1 July 2026. With this, ammonia is permitted to be used as fuel by ships carrying ammonia.

Furthermore, with the introduction of ships using materials **other than** low-flashpoint fuels stipulated by the IGF Code as fuel, the 109th Maritime Safety Committee (MSC109) in December 2024 considered and approved the draft amendments to SOLAS to make the IGF Code applicable to gas fuels. It has been agreed that the amendments will become effective on 1 January 2027 if they are adopted at the next Maritime Safety Committee (MSC).

1.3 Abbreviations and Terms related to alternative fuels

ABMP	Ammonia Bunkering Management Plan
ABS	American Bureau of Shipping
ABV	Ammonia Bunker Vessel
AEGL	Acute Exposure Guideline Level: Developed by the NAC/AEGL Committee
AFV	Ammonia-Fueled Vessel
ARMS	Ammonia Release Management System
BAC	Breakaway Coupling: Coupling to secure the safety by automatically separating in case of unexpected external force on hoses and pipes, designed to prevent leakage of fluid from the hose.
BDN	Bunker Delivery Note
BIMCO	The Baltic and International Maritime Council

[2] : A group to continue detailed deliberations on specific agendas through opinion exchange among the states and stakeholders via emails or other means of correspondence during the intersessional period.

BMP	Bunker Management Plan
BOG	Boil-Off Gas
BSL	Bunkering Safety Link: Link connecting the ammonia fuel suppliers' and receivers' emergency shutdown (ESD) systems, which may be pneumatic, electric, fiber-optic or wireless.
CAS NO	CAS Registry Numbers® or CASRNs®: Identification number assigned by the Chemical Abstracts Service (CAS), a division of the American Chemical Society, to every chemical substance
CCC	Sub-Committee on Carriage of Cargoes and Containers: One of the IMO Sub-Committees
CII	Carbon Intensity Indicator (IMO): Measure mainly used to evaluate the environmental impact, representing the amount of CO_2 emissions from fuel or energy consumption.
CPS	Chemical Protective Suit
DD/CC	Dry-Disconnect/Connect Coupling
DF	Dual Fuel: System that can switch between two types of fuels
ECA	Emission Control Area: Specific sea area designated to control the emission of harmful substances (e.g. sulfur oxides, nitrogen oxides) from ships to prevent air pollution.
EEBD	Emergency Escape Breathing Devices
EEDI	Energy Efficiency Design Indicator
EEOI	Energy Efficiency Operational Index
EEXI	Energy Efficiency Existing Ship Index
EMSA	European Maritime Safety Agency
EPA	Environmental Protection Agency (US)
ERC	Emergency Release Coupler: Safety device that automatically releases in case of emergency
ERS	Emergency Release System
ESDS	Emergency ShutDown System
ESD-1	Emergency ShutDown-1: Safety device that automatically shuts down the transfer of ammonia (pumps stopped and valves closed)
ESD-2	Emergency ShutDown-2: Signal to activate ERS and disconnect ERC.
GCU	Gas Combustion Unit
GHG	Green House Gas
GVU	Gas Valve Unit
HAZID	HAZard IDentification
HAZOP	HAZard and OPerability study
HSE	Health, Safety and Environment
IACS	International Association of Classification Societies
IBC CODE	International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk
IGC CODE	International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
IGF CODE	International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels

IMDG CODE	International Maritime Dangerous Goods Code
INTERTANKO	International Association of Independent Tanker Owners
ISGOTT	International Safety Guide for Oil Tankers and Terminals
ISM CODE	International Safety Management Code
LEL/UEL	Lower Explosive Limit/Upper Explosive Limit
MARPOL	International Convention for the Prevention of Pollution from Ships
MARVS	Maximum Allowable Relief Valve Setting
MEPC	IMO's Marine Environment Protection Committee
MESD	Maritime Energy & Sustainable Development: Organization for maritime energy and sustainable development
MOC	Management of Change: Methods to appropriately assess and manage risks and impacts caused by changes
MSC	IMO's Maritime Safety Committee
NAC/AEGL Committee	National Advisory Committee for Acute Exposure Guideline Levels for Hazardous Substances: Committee of the U.S. Federal Government
NOx	Nitrogen Oxides
OCIMF	Oil Companies International Maritime Forum
PPE	Personal Protective Equipment
PPM	Parts Per Million: Unit mainly used to express concentration, meaning one millionth
PRV	Pressure-Relief Valve
QC/DC	Quick Connect/Disconnect Coupler: Device for quick connection or disconnection of the hose system and the manifold of the ship, designed to minimize the spills of ammonia, enabling quick and safe disconnection in case of emergency.
RSO	Receiving Ship Operator
SCBA	Self-Contained Breathing Apparatus
SECA	Sulphur Emission Control Area: Specific Sea area designated to control the emission of sulphur oxides (SO_x) in maritime fuels
SGMF	The Society for Gas as a Marine Fuel
SIMOPs	Simultaneous Operations
SMS	Safety Management System
SOLAS	International Convention for the Safety of Life at Sea
Sox	Sulphur Oxides
SSL	Ship-to-Shore Link: To be fitted to the bunkering source for automatic and manual ESD communication
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
Toxic area	Designated for area on the open deck of the ship, where ammonia at a concentration that may be harmful to health exists or is expected to exist.
Toxic space	Designated for enclosed space in the ship, representing a confined or semi-confined space where ammonia at a concentration that may be harmful to health exists or is expected to exist (not applicable to gas-free machinery spaces).
Zero Emission	State where no greenhouse gas (GHG) is emitted from the specific activities and processes
Zero Greenhouse Gas Emission	To reduce greenhouse gas (GHG) emissions completely to zero.

Chapter 2 General

2.1 Objectives

The objective of this chapter is to ensure that the characteristics of ammonia are well understood. Characteristics specific to ammonia, especially its physical and chemical properties of toxicity, are hugely different from those of conventional maritime fuels, which results in safety risks for seafarers, ships and environment when handled and used onboard. It is necessary for its safe handling to understand the characteristics of ammonia and appropriately address them.

2.2 General requirements

2.2.1 Characteristics of ammonia

Ammonia is registered as ammonia (anhydrous) in the International Chemical Safety Cards (ICSCs) as shown below.

CAS Number	7664-41-7
United Nations Number	1005 (anhydrous)
ELINCS Number (European List of Notified Chemical Substances)	231-635-3

Ammonia is a chemical substance widely used in various industries and has a variety of characteristics. Major characteristics are shown in Table 2.

Table 2) Major characteristics of ammonia (not exhaustive)

Chemical formula	NH_3 (compound of nitrogen and hydrogen)
Physical properties	Colorless and transparent gas at room temperature and pressure with a strongly irritating odor.
Boiling point	-33.34 ˚C (at atmospheric pressure)
Melting point	-77.73 ˚C
Critical temperature	133.4 ˚C
Critical pressure	111.3 atmospheres
Natural ignition point	651 ˚C/537 ˚C for methane, 450 ˚C for propane
Vapor pressure	100 kPa (-33 ˚C, liquid), 1 kPa (-94.5 ˚C, solid), 1 Pa (-139 ˚C)
Relative vapor density	0.6 kg/m^3 (0 ˚C, 0.1 MPa)/Air=1
Liquid density	0.7 kg/L (-33.34 ˚C)/Water=1
Specific gravity	0.597/Air=1

Explosive limits	Lower explosive limit 15vol%/Upper explosive limit 28vol%
Solubility	Soluble in water (approx. 70 g of ammonia can dissolve in 100 g of water at normal temperature (20 ˚C))
Viscosity (cps)	0.25 (-33 ˚C)/water 0.282 (100 ˚C)
Odor threshold (minimum concentration level of an odorant a human can detect)	5 ppm or below *possible to be detected at lower concentration (2-3 ppm)

2.2.2 Physical properties

-1. Appearance: Colorless and transparent gas at room temperature and pressure; colorless and transparent in liquid form as well.

-2. Odor: Having a highly irritating, sharp and pungent odor, which is one of the characteristics of ammonia, making it detectable even at the lower concentration level (2-3 ppm).

-3. Density: Density of ammonia gas is lighter than air with specific gravity of 0.6 (Air=1), causing it to ascend when released into the air.

-4. Solubility: Strongly interacting with water and highly soluble in water, reacting with water to form ammonium hydroxide (NH_4OH).

2.2.3 Chemical properties

-1. High alkalinity: Showing alkalinity with pH of 11-12 when dissolved in water, causing it to be neutralized with most acids.

-2. Properties as reducing agent: Acting as reducing agent capable of causing reduction in many chemical reactions.

-3. Reaction with acidic materials: Reacting with acids to form salt (e.g. ammonium chloride NH_4Cl).

2.2.4 Physical states and temperature characteristics

-1. Liquefaction temperature: Ammonia is liquefied at approximately -33 ˚C at normal pressure (1 atmosphere). Refrigeration system is necessary to store and transport liquefied ammonia. Compression vessel (compression tank) is used to maintain the liquid form by pressurization, in case where refrigeration is difficult or temperature control is impracticable. Liquefaction of ammonia is closely related with pressure and temperature, and the liquefaction temperature rises by adding more pressure.

-2. Vapor pressure curve[3] showing the relation of ammonia's temperature and pressure is provided in Figure 1. Ammonia is transported/stored in the following three states.

[3] : A graph to show the vapor pressure of liquids at certain temperatures by visualizing the changes in vapor density depending on temperature.

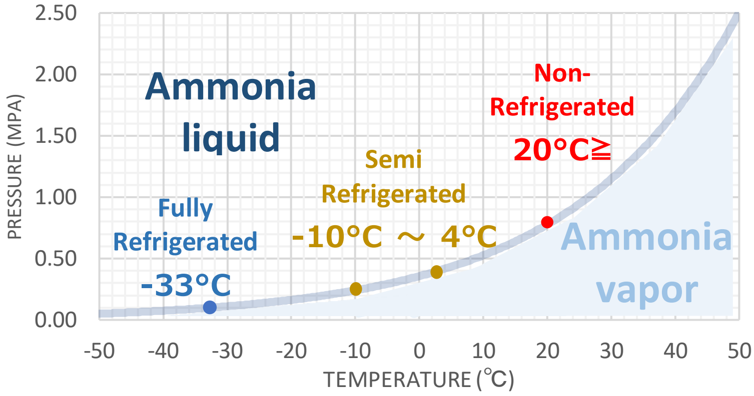

Figure 1) Ammonia vapor pressure at gas-liquid equilibrium (boiling point)

2.3 Risks of ammonia

2.3.1 Toxicity

Ammonia is a chemical compound that may show toxicity to humans and animals at certain concentrations and is classified as Class 2 (gas) [4] and Division 2.3 (toxic gas) [5] by the United Nations Recommendations on the Transport of Dangerous Goods. Ammonia can be harmful to health when inhaled and categorized as a toxic gas for the following reasons:

(1) Ammonia, when inhaled at high concentrations, can cause strong irritation of the respiratory system, resulting in coughing, sore throat and breathing difficulty.

(2) High concentrations of ammonia gas may cause serious damage to the lungs, which could be fatal in an extreme case.

-1. Effects on human health

Even low concentrations of ammonia can give irritation to the respiratory system and mucous membranes (the eyes, nose, mouth, respiratory tract, lungs, etc.) when it enters the body. Also ammonia on the skin can cause pain and inflammation, which may result in serious irritations or burns, and ammonia in the eyes may cause pains, excessive tears, bloodshot eyes, swelling in the conjunctivas, damages to the iris and cornea, glaucoma, and cataract.

Direct inhalation of high concentrations of ammonia may cause serios damages to the respiratory system, which could be life-threatening immediately. Breathing difficulty, chest pain, pneumonia, bronchia spasm, pulmonary edema and other symptoms may appear.

It is recommended to wash the affected area with running water at least for 15 minutes in case of exposure to ammonia. In case of frostbite, it is desirable to wash the affected area with running water and then transport the affected person to a medical institution without removing

[4] : One of the classifications for the transportation of dangerous goods by the United Nations in terms of gas, applicable to goods transported in gas form. As ammonia is in gas form at normal temperature and pressure, it is classified as Class 2 (gas). This classification is further divided based on type of gases, and ammonia is treated as a toxic gas due to its chemical properties.

[5] ：Referring to the materials classified into the category of toxic gases.

the clothes. In case of ammonia in the eyes, it is necessary to wash the eyes with running water for a couple of minutes and immediately transport the affected person to a medical institution.

The exposure limit of ammonia can be identified based on the AEGL (Acute Exposure Guideline Levels) defined by the US Environmental Protection Agency (EPA). AEGLs were developed for the appropriate response and preparation in case of emergency. The Guidelines indicates the typical threshold exposure levels at which health effects start to appear in case of exposure to harmful chemical substances for a certain period of time (i.e. the exposure level below which harmful effects to health are unlikely to be posed). AEGLs are developed for each of five exposure periods (10, 30, and 60 minutes, 4 and 8 hours) with consideration of ammonia concentration and exposure duration, and categorized based on the severity of toxic effects.

Table 3) AEGLs (Acute Exposure Guideline Levels)

Classification	*10 minutes*	*30 minutes*	*60 minutes*	*4 hours*	*8 hours*
AEGL-1 (nondisabling)	*30 ppm*	*30 ppm*	*30 ppm*	*30 ppm*	*30 ppm*
AEGL-2 (disabling)	*220 ppm*	*220 ppm*	*160 ppm*	*110 ppm*	*110 ppm*
AEGL-3 (lethal)	*2,700 ppm*	*1,600 ppm*	*1,100 ppm*	*550 ppm*	*390 ppm*

- **Below AEGL-1 “sensible level”:** Unpleasant odors, tastes and sensory irritations, or slight asymptomatic or non-sensory effects may be caused. These effects are transient and non-disabling.
- **AEGL-1 “Unpleasant level”:** Notable discomfort, irritations, or certain asymptomatic non-sensory effects may be caused. These effects are not disabling and are transient and reversible upon cessation of exposure.
- **AEGL-2 “disabling level”:** Irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape may be caused.
- **AEGL-3 “lethal level”:** Life-threatening health effects or the increase of death may be caused.

-2. Effects on environment

Ammonia reacts with acidic substances in the air (e.g. nitric acid (HNO_3), sulphuric acid (H_2SO_4)) to form micro-particulate matter (PM2.5: particulate matter with a diameter of 2.5 μm or less) such as ammonium sulphate ($(NH_4)_2SO_4$) and ammonium nitrate (NH_4NO_3). If ammonia in the air increases, the formation of PM2.5 also increases, which causes air pollution.

Furthermore, the increased PM2.5 level indirectly contributes to air acidification, making acid rain more likely to occur. Acid rain not only lowers the pH of the soil and hampers the growth of plants but also degrades the water quality and dissolves harmful substances in water to negatively affect the fish and aquatic life.

2.3.2 Flammability and explosibility

Ammonia is a flammable gas, while its flammable limits are narrow compared to other fuels (natural gas, hydrogen, etc.). The flammable concentration limits of ammonia range from 15% to 28% in the air, and when it is mixed with the air within this concentration range, it may cause combustion and explosion if a source of ignition exists. Meanwhile, the probability of autoignition is low with high autoignition temperature of 651 °C under the atmospheric conditions.

Ammonia's explosive risk may occur under the following situations:

- where high concentrations of ammonia are released in an enclosed space;
- where there exists a source of ignition (sparks, heat sources, electric sparks, etc.); and
- where oxidant (chlorine, hydrogen, etc.) and ammonia get mixed and the chemical reaction is accelerated by external stimulus, such as heating or pressurization.

Supposing liquid ammonia is stored in a pressurized container (e.g. tank) as a saturated liquid, if the pressurized container ruptures and the saturated liquid ammonia is released into the air, this may cause a sudden boiling and vaporization, resulting in the expansion by 710 times at maximum. This expansion may lead to a boiling liquid expanding vapor explosion (BLEVE) [6*].

2.3.3 Corrosiveness

Ammonia may cause corrosion or other harmful effects on various materials including metals, plastics and rubbers. Especially when ammonia touches these materials in form of liquid or gas, the corrosiveness becomes evident.

As moisture promotes the ammonia's corrosiveness, metal corrosion is likely to happen when moisture exists. Especially, copper (Cu), iron (Fe), aluminum (Al), zinc (Z), mercury (Hg) and copper alloys are easy to react with ammonia and vulnerable to corrosion.

When ammonia is liquefied for storage or maritime shipping, the liquefied ammonia may cause a stress corrosion cracking (SCC) [7*]. The reinforced carbon steel makes SCC more likely to happen in the liquefied ammonia. Purging to eliminate moisture and oxygen by applying non-condensable gas including inert gas (e.g. N_2) into the hose or pipes can mitigate the risk of SCC existing in the liquefied ammonia.

Note: Ammonia's stress corrosion cracking

Rules for the Survey and Construction of Steel Ships,
Part N "Ships Carrying Liquefied Gases in Bulk," 17.12 Ammonia (IGC Code 17.12)

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[6] : Typically referring to a phenomena caused by the sudden release of pressurized material. The rupture of a pressurized container (e.g. tank) and sudden vaporization of the liquid, resulting in the release of explosive energy due to the expansion.

[7] :A phenomenon where cracks are formed in a metal material by tensile stress under the corrosive environment.

Chapter 3 Handling of Ammonia Fuels

3.1 Objectives

The objective of this chapter is to provide the basic knowledge related to storage, transportation and transfer of ammonia.

3.2 Storage and transfer of ammonia

Liquid ammonia can be stored and transported either in pressurized or refrigerated form, or in a combination of both forms, to ensure the cost-effectiveness. Ammonia can be stored and transferred in the conditions shown in Table 4 below.

Table 4) Typical storage conditions of ammonia

	Fully Refrigerated (FR)	Semi-Refrigerated (SR)/ Semi-Pressurized	Non-Refrigerated (NR)/ Fully Pressurized
IMO Type [8]	Independent Type-A Non-pressurized	Independent Type-B Semi-pressurized	Independent Type-C Normal temperature pressurized (cylindrical)
Temperature	-33 ˚C	-10 ˚C to 4 ˚C	20 ˚C to 45 ˚C (normal temperature)
Pressure	0 bar (atmospheric pressure)	3 bars to 4 bars	7 bars to 17 bars
Secondary barrier	Complete secondary barrier	Partial secondary barrier	No secondary barrier

1) Fully-refrigerated (FR)

Ammonia is stored in liquid form at a low temperature under this storage condition. Ammonia is refrigerated to freezing point for liquefaction and maintained at a pressure close to atmospheric pressure. Boil-off gas (BOG) [9] vaporized from the tanks is liquefied again by the re-liquefaction system and sent back to the tanks. This prevents the release of ammonia from

[8] : IMO Type: IGC Code - Chapter4 - Cargo Containment/Part E - Tank Types

[9] : BOG (Boil-Off Gas) – Gas that occurs by vaporization of liquefied gas (typically liquefied natural gas (LNG), liquefied ammonia, etc.) during storage and transportation. BOG here means a gas that has turned into gas form from liquefied ammonia in the low temperature tanks due to vaporization caused by changes in temperature or pressure, or by operations during transfer. BOG may increase pressure in the tanks or pipes leading to the rupture of equipment and safety risk, and thus appropriate management is necessary.

the pressure relief valves of the tanks into the air in case of pressure increase in the tanks, and enables the efficient storage.

2) Non-refrigerated/Fully-pressurized (NR)

Under this storage condition, liquid ammonia is stored as a liquid by being pressurized at normal temperature. Liquid form can be maintained at ambient temperature and BOG can be contained within the tanks. As the tank is thick and heavy to endure high pressure, it is subject to size restrictions.

3) Semi-refrigerated/semi-pressurized (SR)

This storage condition refers to the combination of refrigeration and pressurization. It is flexibly applicable to various cases by balancing refrigeration and pressurization, and thus it is highly versatile, enabling the large-scale storage.

The 10th Sub-Committee on Carriage of Cargoes and Containers (CCC10) decided that fuel tanks installed on ammonia-fueled vessels are to store ammonia in a fully refrigerated state (FR) at atmospheric pressures, with consideration of the safety of ammonia fuels. Most ammonia carriers used as inland vessels are installed with pressurized tanks to carry liquefied ammonia. Usage of non-refrigerated (NR) tanks or semi-refrigerated (SR) tanks requires to prove their safety equivalent to refrigerated storage for approval from the vessel's Flag Administration.

Transfer of ammonia fuels is expected to be conducted under the following conditions:

-1 Transfer to the tanks under the same condition

In case where the storage temperature and pressure are the same, transfer of ammonia is relatively easy. In case of transfer from a non-refrigerated (NR) tank to a non-refrigerated (NR) tank, the storage tanks and transfer system designed to endure high pressure are necessary.

-2 Transfer from a non-refrigerated (NR) tank to a fully-refrigerated (FR) tank

The system to control temperature and pressure and to maintain the gas or liquid form is necessary. It is essential to pay due consideration to the measures for leakage prevention and safety securement to ensure the appropriate transfer process.

(1) Temperature and pressure control

Temperature and pressure control is most important. Ammonia is in liquid form at high pressure in a non-refrigerated (NR) tank, while it is stored as a liquid at a low temperature (around -33 ˚C) in a fully-refrigerated (FR) tanks. Thus, it is necessary to control the temperature so that the temperature on the side of the FR tank does not excessively rise to prevent the vaporization of liquid ammonia, and to adjust the difference in pressure by pressure regulating valves and pressure relief valves.

(2) Handling of vaporization and gas

Temperature rise in a fully-refrigerated (FR) tank during transfer causes the vaporization of liquefied ammonia, resulting in the accumulation of gas (BOG) and the increased pressure in the tank, and thus the pressure monitoring and control systems are necessary. It is also important to use gastight joints and valves for leakage prevention and to monitor leakage by using a gas detector or other devices.

(3) Heat exchange and temperature fluctuation

Heat exchange system is necessary to suppress the temperature fluctuation during transfer and to stabilize the liquid form in a refrigerated tank.

3.3 Overview and characteristics of fuel transfer modes

There are four possible modes for transfer of ammonia fuels:

(1) Shore/terminal pipeline to ship (ShTS)
(2) Ship to Ship (STS)
(3) Truck to Ship (TTS)
(4) Cassette Bunkering

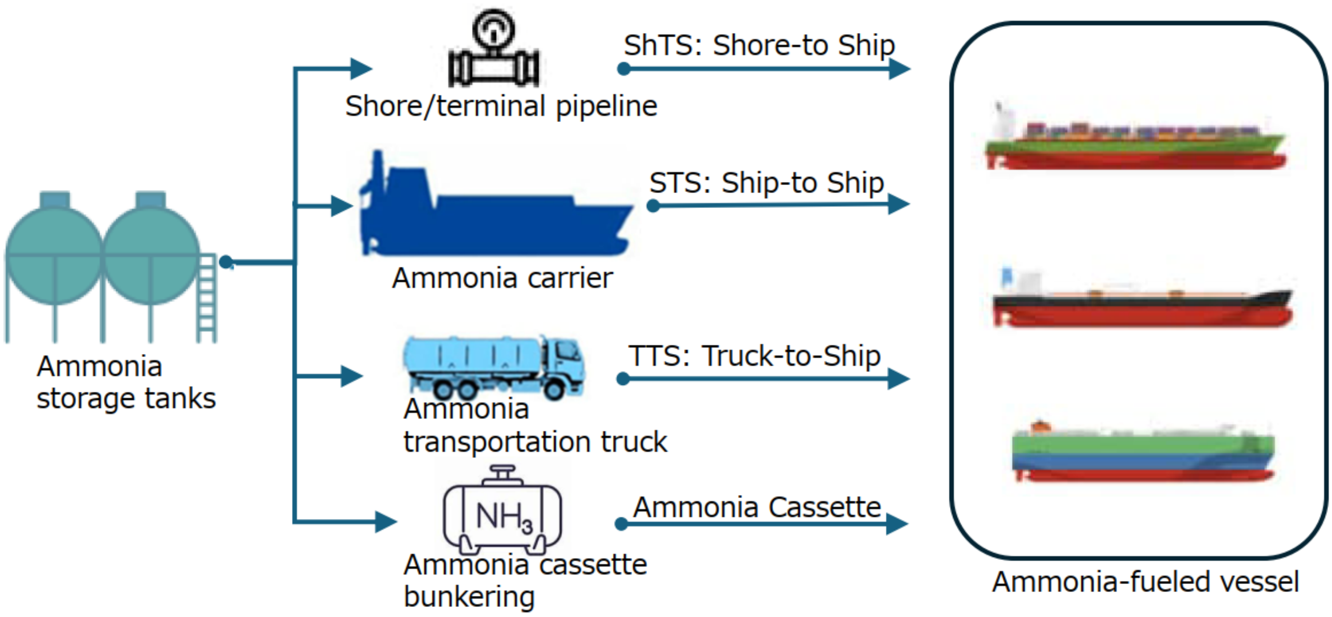


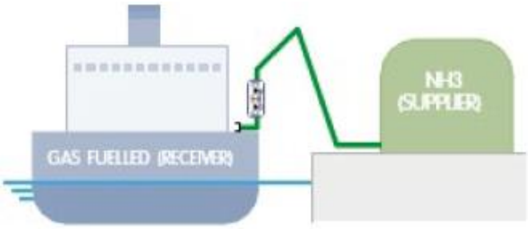
Figure 1) Ammonia transfer modes

3.3.1 Shore facility (terminal or pipeline) to ship (ShTS)

Transfer is conducted via a hose or a dedicated loading arm.

-1. Advantages:

- Ship’s stability is maintained after berthing or docking, resulting in the less danger of the ship swaying or moving away.
- Bunkering volume can be flexibly adjusted, enabling the efficient transfer.



- Appropriate safety equipment can be easily set up in a dedicated terminal.
- It is suitable for the large-scale transfer.
- It is suitable for ships which have a regular route calling at the same port.

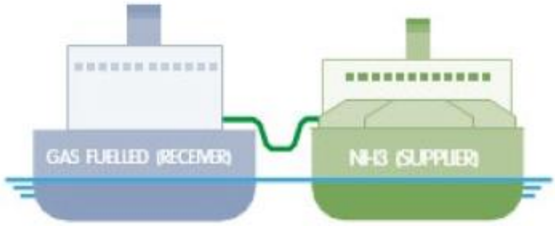
-2. Disadvantages:

- Capital investment and operational cost are expensive.
- Flexibility is limited as ships are required to dock at a pier or quay having a dedicated terminal or pipeline.

3.3.2 Ship to ship (STS)

Transfer is conducted via a hose or a dedicated loading arm.

-1. Advantages:



- Bunkering location and bunkering volume can be flexibly adjusted.
- It is suitable for the large-scale transfer.
- Initial investment and capital investment are small.

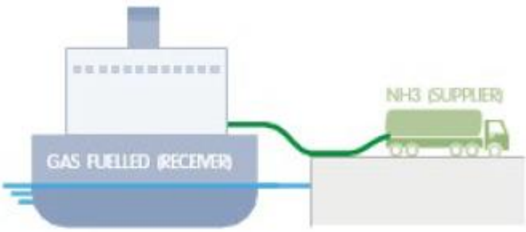
-2. Disadvantages:

- Position keeping of both two ships is important.
- Compliance with the regulatory requirements, such as permission and approval, applicable to the location (waters) where bunkering takes place may be required.
- In case where people or facilities are concentrated around the bunkering location (berthing or docking point), the influence of accidents could be far-reaching.

3.3.3 Truck to ship (TTS)

Transfer is conducted via a hose. ISO tank container[10] on the truck is pressurized.

-1. Advantages:



- It is the most common method at the present time.
- Truck moves to the ship's berthing/docking point for transfer, which is convenient for transfer.
- Multiple trucks can be simultaneously connected and bunkering volume can be flexibly adjusted, enabling the efficient transfer.
- It is suitable for small ships and tug boats.

-2. Disadvantages:

- Limited transfer volume and small capacity of transfer pump make the transfer time-

10 : Tank manufactured in accordance with the standards set by the International Organization for Standardization (ISO) and standardized to transport liquids and gases.

consuming.

- Compliance with the regulatory requirements, such as permission and approval, applicable to the bunkering location (berthing or docking point) may be required.

3.3.4 Cassette Bunkering

This is described for reference purposes as a potential transfer method for the specific ports.

-1. Advantages:

- Putting ammonia in a cassette (container) makes it relatively compact in form and easily loaded on the ship.
- Risks of overpressure and leakage can be mitigated as the transportation in liquid form makes it relatively easy to control the gas pressure.
- Zoning of area and installation of the appropriate safety equipment are easy.
- Time required for bunkering can be shortened.

-2. Disadvantages:

- Initial investment and operational costs are expensive with the refrigerating equipment, cassettes for transportation, dedicated storage system, etc.
- Transfer volume is limited.
- Careful consideration is required in handling and refilling the cassette.

Chapter 4 Safety Measures

4.1 Objectives

Given the toxicity of ammonia, avoidance of ammonia leakage incidents is the top priority, while it is also necessary to prioritize the protection of the lives of the seafarers and workers and consider the actions to be taken to minimize the casualty.

The objective of this chapter is to ensure that the structure of safety measures of ammonia-fueled vessels is well understood.

4.2 Classification of hazardous areas

The IGF Code classifies "hazardous areas" [11] for the purpose of taking safety measures by identifying the areas where explosive gases may occur and selecting the appropriate electric equipment based on the risk. Hazardous areas (IGF Code 12.4) are classified into the following three zones:

(1) Hazardous area zone 0: Area where explosive gas atmosphere is always present (e.g. the interiors of fuel tanks and their pipes, venting systems)

(2) Hazardous area zone 1: Area where explosive gas atmosphere is likely to be present (e.g. fuel tank outlets, fuel preparation spaces, spaces in which fuel pipes are located)

(3) Hazardous area zone 2: Area where explosive gas atmosphere may accidentally be present (e.g. areas surrounding spaces of zone 1, areas on the specific exposed deck)

On the other hand, regulations or standards for zoning with consideration of the toxicity of ammonia have not yet been established.

Given the toxicity of ammonia, it is assumed that areas where toxic gas is or may be expected to present are to be considered as hazardous areas, and special attention is required in installing and using equipment in such areas. It is also necessary to designate a wide area as hazardous for leakage prevention.

Furthermore, it is considered to be necessary to set up safety zones around hazardous areas during ammonia bunkering to implement safety measures such as to limit entry only to personnel who have received safety education and necessary training.

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[11] : Definition of hazardous areas in the IGF Code: 2.2

2.2.21. "Hazardous area" means an area in which an explosive gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of electric apparatus.

2.2.33. "Non-hazardous area" means an area in which an explosive gas atmosphere is not expected to be present, in quantities such as to require special precautions for the construction, installation and use of equipment.

Concepts by some of the related organizations about zoning of areas to be used in bunkering (e.g. hazardous areas, toxic zones, safety zones) are summarized as shown in Table 5, for reference purposes.

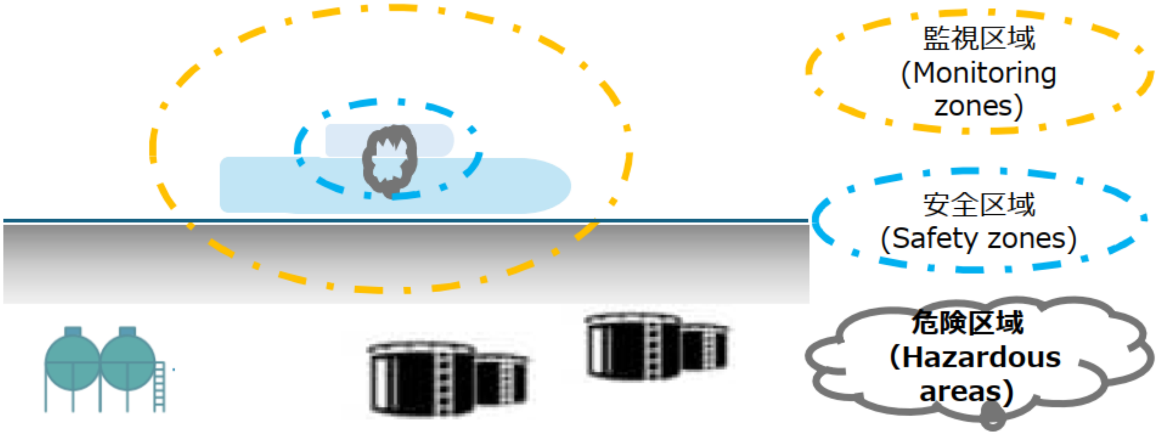

Figure 2) Examples of hazardous areas, safety zones and monitoring zones in ammonia bunkering (STS)

Table 5) Concepts of zoning of areas to be used in bunkering

	ABS	BV	DNV	SGMF
Controlled Zones	Controlled zones are defined based on the results of the gas dispersion analysis, risk assessments, relevant international requirements, and determined by the local authorities.		Controlled area is to include the following four zones, which is to be proposed based on the relevant international requirements (e.g. ISPS Code) and decided by the local authorities.	SGMF defines five controlled areas or zones during bunkering.
Hazardous areas	Only essential personnel are allowed in these areas during bunkering operation. Hazardous areas associated with ammonia are typically limited to enclosed and semi-enclosed areas.	This means an area in which an explosive gas is or may be expected to be present in sufficient quantities to require special precautions for the installation and use of equipment.	This means an area in which an explosive gas atmosphere is or may be expected to be present in quantities such as to require special precautions for the construction, installation and use of equipment. This needs to be set wider to prevent the leaked ammonia from reaching a manned area in case of ammonia leakage.	Hazardous zone is a space in which a combustible, explosive or toxic atmosphere can be expected to be present frequently enough to require special precautions for the control of potential ignition sources and/or personnel access. It is recommended that the hazardous zone is defined as an area where the concentration of ammonia vapor may be expected to be at or greater than the AEGL-3 level of 2,700 ppm.
Safety zones	Safety zones are zones where ignition sources are adequately controlled with limited access to only authorized persons. Safety zones are generally determined based on the bunker characteristics, potential leak rate, weather conditions (especially winds), and surrounding circumstances.		This means an area extending beyond the hazardous area, which requires special precautions to address the risk of ammonia leakage during bunkering. Ignition sources are to be adequately controlled with limited access to only personnel capable of addressing an accidental release of ammonia.	Safety zone can be defined as the space of distances where there is a recognized potential for a leak of ammonia to harm life or damage equipment/infrastructure. This area will be larger than the hazardous zone for the purpose of minimizing harm to people and damage to equipment by excluding non-essential people. It is recommended that the safety zone is defined as the area where the concentration of ammonia vapor may be expected to be between 220 ppm and 2,700 ppm, which is the AEGL-2.
Toxic zones	Toxic zones are areas where toxic fumes could be harmful to personnel during bunkering. Toxic zones are determined by the class requirements.	This means an area in which a toxic gas that may be harmful to health is or may be present in quantities such as to require special precautions.	This means an area in which personnel maybe harmed during bunkering. This is to be designated based on the requirements by the local authorities.	
Security zones	Security zones are to be established around the ammonia bunkering activity area.			

	ABS	BV	DNV	SGMF
Monitoring zones			Monitoring zones are to be established around the ammonia bunkering activity area, which is to be monitored to prevent the breach of safety zone.	
Monitoring &security area				Monitoring and security area is defined as the space to monitor the safety zone during bunkering, which will be larger than the safety zone.
Marine exclusion zones				Marine exclusion zone is decided by port rules, which aims to protect the bunkering vessel from other marine traffic.
Assessment zones				Assessment zone is larger than the marine exclusion zone. This is defined by the level of risk general members of the public can be exposed to, in case where people and facilities are concentrated around the bunkering activity area.

4.3 Setting values of ammonia concentration levels in relation to control, monitoring and safety systems

Given the impact on health of seafarers and workers, the threshold values[12] of the ammonia leakage detector for the concentration level are to be set as follows:

-1. Activation of a local alarm: 25 ppm
-2. Activation of an audible and visual alarm in a manned location[13]: 110 ppm
-3. Activation of the safety systems: 220 ppm (to be activated regardless of concentration level when liquid leakage is detected)
-4. Activation of a visual alarm at the entrance of the toxic space: ammonia concentration level within the space of 25 ppm is to be set as the alarming value.
-5. Activation of automatic shutdown valves: Shutdown valves are activated (i) when 220 ppm is detected by two gas detectors or (ii) when liquid leakage is detected.

> Note: Gas detection
> Guidelines for Ships Using Alternative Fuels, Part C-1 Guidelines for the Safety of Ships Using Ammonia as Fuels (Edition 3.0.2) - 15.8 Gas Detection

4.4 Personnel protection

For the purpose of ensuring the safety of personnel engaged in works related to the ammonia fuel systems, it is important to provide them with the appropriate protective equipment with consideration of both daily works and emergency responses as well as the short-term and long-term impacts of exposure to ammonia. It is also required to take the appropriate safety measures corresponding to the type of work and work environment. This includes the selection of protective equipment based on the risk assessment and the preparation for emergency responses. Specific requirements are provided as follows:

-1. Personal equipment
- Personnel engaged in regular works related to the ammonia fuel systems are to be provided with the appropriate protection equipment including eye protections.
- Personal protective equipment and safety equipment are to be stored in a locker clearly marked and located in an easily accessible location.

-2. Emergency equipment
- Decontamination showers and eyewashes are required to be operable in all conditions. Temperature control system is necessary if they are exposed to the freezing conditions. It is also to be capable of supplying water to the equipment in two locations simultaneously.

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12 : Decided at the 109th Maritime safety Committee (MSC109).

13 : Bridge, central control room, the interior and exterior of the leakage area.

- Decontamination showers and eyewashes are to be arranged: (i) in tank connection spaces (TCS), (ii) in fuel preparation rooms (FPRs), (iii) near each exit of bunkering stations, (iv) in machinery spaces where ammonia fuel consumers are installed, and (v) near lifeboat embarkation stations.
- Stretchers and onboard medical first-aid equipment based on the “Medical First Aid Guide (MFAG)” for ammonia are to be provided.
- Emergency escape breathing apparatus and eye protections are to be provided to all personnel onboard.
- Breathing apparatus for escape is to be self-contained with a duration of at least 15 minutes (filter type breathing apparatus is not accepted).

-3. Safety equipment

- At least three sets of safety equipment adequate for work in the gas environment with consideration of the characteristics of ammonia are to be provided, in addition to the firefighter outfits required by SOLAS regulation II-2/10.10.
- Interactive mobile radio telephone with handsfree earphones and a Push-to-Talk unit is to be provided as equipment operable in spaces filled with ammonia gas.
- A full-face mask equipped with a self-contained positive pressure air-breathing apparatus, gastight protective clothing, boots, gloves, a steel-core rescue line with belt, and an explosion-proof lamp are to be provided.
- Spare bottles and a compressed air supply system are to be provided.

-4. Personal protective equipment (PPE)

Overview of personal protective equipment applicable to personnel engaged in ammonia bunkering is shown in Table 6.

Table 6) Overview of personal protective equipment

Protective equipment	Overview	
Normal protective equipment	Workwear, helmet, safety shoes, gloves	 
Protective glasses	With chemical-resistant lenses or coatings	
Gas mask	Face piece and absorption canister	
Chemical gloves	Chemical protective gloves to prevent chemical substances from permeating and/or penetrating	
Self-contained breathing apparatus (SCBA)	- Apparatus capable of supplying air for breathing without relying on external air supplies. - Composed of compressed air cylinder, regulator and breathing mask (full-face mask)	

Protective equipment	Overview	
Self-contained positive pressure air-breathing apparatus	Breathing apparatus to push air into the respiratory tract by positive pressure within the breathing apparatus and supply the compressed air to the lungs, as a self-contained positive pressure air-breathing apparatus having a free air capacity of 1,200 liters or more, equipped with a full-face mask	
Chemical protective suit (CPS)	Fully equipped protective clothing consisting of the combination of a gas mask, protective gloves, boots and other gears, which is airtight for complete protection from external harmful chemical substances	
Fully enclosed chemical protective suit	Special protective suit designed to fully protect personnel from chemical substances and harmful chemicals, gases, steams and liquids, with extremely high airtightness and chemical resistance to prevent harmful substances from entering the body. These suits are composed of the following equipment: ・ Interactive radio telephone with handsfree earphones and a Push-to-Talk unit ・ Gastight protective clothing (e.g. gas suit) ・ Boots and gloves ・ Steel-core rescue line with belt ・ Explosion-proof lamp	

4.5 Representative safety systems

4.5.1 Emergency shutdown system (ESDS)

ESDS is a system installed on both the ammonia fuels supply side and the receiving ship and mutually linked so that transfer of ammonia (and vapor, if applicable) can be shut down in case of emergency or abnormal situation. This is activated manually and automatically, with the following two phases:

(1) ESD-1: First phase of emergency shutdown of bunkering

Sending out a signal during transfer of ammonia to stop the transfer to secure the safety, leading to the closure of emergency shutdown valves (ESD valves) and stoppage of the transfer pump. Operation test is required before transfer starts.

(2) ESD-2: Second phase of emergency shutdown of bunkering

Activating the emergency release system (ERS) [14] to send a signal to automatically disconnect the ammonia-fueled vessel from the ammonia fuels supply side for prevention of damages to the transfer systems, in case where both vessels drifted apart or where an urgent unberthing/departure is necessary due to emergency such as fire or tsunami. Sealing is provided to prevent the release of ammonia and the emergency release coupler (ERC) is disconnected.

4.5.2 Ammonia release mitigation system (ARMS)

Ammonia release mitigation system (ARMS) is a system to consume, collect or disperse ammonia by thermal oxidation/decomposition, catalytic oxidation/decomposition, dissolution in water or air dilution.

Release of ammonia directly into the air is not permitted in the normal operating condition. If any situation arises where the release is unavoidable, the concentration level is to be lowered to 110 ppm by the ammonia release mitigation system (ARMS).

ARMS is an effective means to prevent ammonia leakage in purging before bunkering.

4.5.3 Ammonia leakage detection system

Ammonia leakage detection system is a system to activate alarms or safety systems based on the toxic level or flammability of ammonia detected by multiple gas detectors. In case of leakage, safety systems are activated when the leakage is confirmed by more than a certain number of detectors to prevent false alarms.

For the purpose of leakage detection, gas detectors are to be installed in the following locations in addition to the locations required by the IGF Code.

- Bunkering stations;
- Access spaces to tank connection spaces (TCS);
- Air inlets of evacuation stations;
- Tank vent outlets;
- Liquid leakage detectors are to be installed in annular spaces[15] of fuel pipes; and
- Liquid leakage detectors are to be installed in tank connection spaces (TCS), fuel preparation rooms (FPR) and bunkering stations to issue a high liquid level alarm and activate the safety systems when detecting low temperatures.

4.5.4 Electric insulation

Safety measures are necessary to prevent the accumulation of static electricity and the

[14] : Safety system to quickly disconnect the transfer systems such as transfer hoses in case of emergency, enabling disconnection without letting ammonia in the transfer hoses leak to the outside.

[15] : Ring-shaped voids or spaces outside of pipes or equipment.

occurrence of arc discharge[16] during connection and disconnection due to a difference in electric potential.

Electric insulation is provided by the following methods:

- To use the appropriate insulated flanges and bonding cables; or
- To prevent the contact of conductive surfaces.

It is required to confirm that the connections (mooring lines, accommodation ladders, gangplanks, cranes, and other physical connections) between the ammonia fuels supply side and the ammonia-fueled vessel are appropriately insulated prior to bunkering.

The following are the items to be noted for each fuel transfer mode.

(1) Shore/terminal pipeline to ship (ShTS)

As a loading arm is made of metal and conductive, electric arc discharge may occur during connection and disconnection. This risk can be mitigated by appropriately earthing equipment and using electric insulation systems.

(2) Ship to ship (STS)

It is recommended to use insulated flanges to shut down the consecutive electric routes for the prevention of arcs. Another option is to use short insulated hoses and maintain the rest to be electrically connected.

(3) Truck to ship (TTS)

Trucks are to be electrically earthed. Tires are to be fixed to prevent unintentional movements.

[16] : Electric discharge with high temperature and energy, generating sparks, light and heat.

Chapter 5 Development of Bunkering Manuals

5.1 Objectives

The objective of this chapter is to ensure that the development of bunkering manuals for ammonia-fueled vessels is well understood.

5.2 Preparation to develop manuals

5.2.1 Considerations

-1. Items to be considered in advance by the shipowner and the ship management company for the safe handling of ammonia are provided in the following sections.

-2. Items listed as follows (though not limited to) are considered to be the standard elements to achieve the safe operation of ammonia.

5.2.2 Procedures

-1. Before bunkering

(1) To make an arrangement and agree on the measures to be taken in case of emergency with all the relevant parties.

(2) To agree on the following conditions for transfer of ammonia:

(i) Transfer time, temperature and pressure of the transferred ammonia, pressure in the tanks, measurement of the transfer lines and vapor return lines;

(ii) Confirmation of the volumes of the initial rate, rate-up and rate-down; and

(iii) Liquid level, temperature and pressure in the tanks on the ammonia fuels supply side.

(3) To confirm the soundness of the inerting system and the nitrogen pressure

(4) To confirm how the vapor return system and vapors are managed (if applicable)

(5) To connect the bunker lines

(6) To connect and test ESDS

(7) To confirm the soundness and operation of ESDS

(8) To inert and purge the bunkering lines

(9) To carry out the leakage test of the bunkering lines

(10) To install insulation or bonding cables

(11) To cool down the bunkering lines

(12) To install the drip tray (pay attention to rain water or dew condensation)

(13) To sign the bunkering contract and checklists

-2. During transfer

(1) To consider the restrictions and simultaneous operations (SIMOPS)

(2) To monitor the tank level and transfer rate as needed and reduce the transfer rate when

necessary

(3) To ensure the monitoring during transfer (flow rate measurement, pressure monitoring, temperature control, leakage check)

(4) To carefully monitor the status of position keeping, especially the relative positions of the own ship and the ammonia fuels supply side

(5) To manage BOG

(6) To address alarms

(7) To respond in case of the activation of ESD

-3. After bunkering

(1) To give an instruction to stop the transfer pump upon reaching the predetermined transfer volume

(2) To push out the remained liquid in the bunker lines by nitrogen

(3) To inert the vapor return hoses and bunker lines (including the usage of the onboard ARMS)

(4) To check the remaining ammonia in the bunkering systems (check the status of pressure decrease in the bunker hoses/manifolds)

(5) To disconnect the bunker lines

(6) To collect and store the bunker systems

(7) To check the bunker volume

(8) To keep a record of bunkering this time as a document

5.2.3 Execution Framework

(1) Personnel assignment and each role

(2) Items to be noted during monitoring

(3) Qualifications required for all workers (seafarers of the own ship and workers on the bunkering side (bunkering vessel, terminal, carriers of the lorries, etc.))

(4) Emergency response

5.2.4 Human and environmental safety measures

5.2.4-1 Human

(1) Development of safety management system

(2) Assignment of manager and his/her location

(3) Education and training for seafarers and all workers

(4) Personal protective equipment (PPE)

(5) Emergency alarms and response to them

(6) Items related to the emergency release of ammonia into the air

(7) Firefighting/watering system

(8) Monitoring system (CCTV)

5.2.4-2 Environment

(1) Arrangement of decontamination showers and eyewashes

(2) Medical first-aid equipment (including oxygen resuscitation equipment)
(3) Detectors (designation of hazardous areas)
(4) Preventive measures to avoid the accumulation of static electricity (electrical earthing, electric insulation)
(5) Marking of safety areas and controlled areas
(6) Applicability, management and storage of the bunkering systems (fuel transfer systems and material/tools)
(7) Setting of hazardous areas (segregation distances) and zones
(8) Equipment for safety measures (ARMS, ESDS, ERS, ERC, QCDC, etc.)
(9) Setting of Safety Haven
(10) Ventilation
(11) Lighting
(12) Firefighting systems

5.2.5 Communication & Contact methods

(1) Ship Shore Link (SSL)
(2) Languages
(3) Internal and external communication systems
(4) Normal and emergency communication systems

5.3 Development of procedures, etc.

Ship specific equipment and technologies, methods of storage and transfer, and trades are to be taken into account in developing specific operation procedures of ammonia bunkering to ensure that the procedures are suitable to the individual ship. Procedures are grouped by four stages and the items to be considered in each stage are listed out, though not limited to.

-1. Planning Stage

(1) Risk assessment of bunkering
(2) Confirmation of the conformity assessment results
(3) Procedures involving the relevant parties and the regulatory bodies and approval from them
(4) Confirmation of overall schedule including docking/berthing and bunkering locations
(5) Planning and risk assessment specific to each of the simultaneous operations (SIMOPS)
(6) Confirmation of the communication methods

-2. Pre-transfer Stage

(1) Safety instructions
(2) Check of the ammonia tank systems, mooring equipment and major bunkering systems including bunker hoses
(3) Mooring

(4) Installation of the gangways
(5) Pre-transfer meeting and keeping the meeting record as a document
(6) Cables and wires connections
(7) Check the connection with the fuel transfer systems
(8) Nitrogen purging and leakage test
(9) Collection of ammonia transfer data
(10) ESDS test (Hot)
(11) Line cool down (if applicable)

-3. Transfer Stage

(1) Check on a constant basis
(2) BOG management
(3) Control of ammonia flow
(4) Ballasting and de-ballasting

-4. Post-transfer Stage

(1) Water discharge and purging of the transfer lines and the vapor return systems
(2) Disconnection of the fuel transfer systems
(3) Disconnection of all cables and wires
(4) Post-transfer meeting
(5) Removal of the gangways
(6) Undocking, unberthing/departure

5.4 Overview of scenarios of ammonia bunkering

Overview of scenarios of typical ammonia bunkering is provided as follows.

Bunkering modes adopted by the ammonia-fueled vessel and the ammonia fuels supply side, and differences among tanks are not taken into account.

Operation Scenario	Procedures	Execution Framework	Human and Environmental safety measures	Communication & Contact methods
Corresponding sections of the ISM Code	*SEC7, 8, 10*	*SEC6, 7, 8, 10*	*SEC6, 7, 8, 10*	*SEC7,8*
1 Bunkering plan	●	●	●	●
2 Preparation prior to fuels transfer (initial pre-cooling)	●	●	●	●
3 Bunker lines connection	●		●	
4 Connection and test of the cables for communication and ESDS signals	●		●	●
5 Inerting, N_2 purging	●		●	

Operation Scenario	Procedures	Execution Framework	Human and Environmental safety measures	Communication & Contact methods
Corresponding sections of the ISM Code	*SEC7, 8, 10*	*SEC6, 7, 8, 10*	*SEC6, 7, 8, 10*	*SEC7,8*
6 Leakage test	●		●	
7 Pre-transfer measurement (Pre MTG)	●	●	●	●
8 Initial transfer (NH_3 gas)	●		●	
9 ESDS test (Hot)	●	●	●	●
10 Start of transfer	●	●	●	●
11 Normal transfer	●	●	●	●
12 Completion of transfer	●	●	●	●
13 Stripping	●		●	
14 Inerting (final), N_2 purging	●		●	
15 Post-transfer measurement (Post MTG)	●	●	●	
16 Disconnection of bunker lines	●		●	
17 ESDS Off	●	●	●	●
18 Disconnection of the cables for communication and ESDS signals	●		●	●
19 Completion of bunkering	●	●	●	●
20 Completion of necessary documents	●	●		
＊BOG Control	●		●	
＊＊Emergency response	●	●	●	●

APPENDIX-1 Relevance with the ISM Code

1.1 Items to be considered in the ISM Code when using ammonia fuels

ISM Code (International Safety Management Code) is a set of rules developed with the aim to setting the safety standards for the ship's operation and management and improving navigational safety. Table 8 below summarizes the impacts from the handling of ammonia as fuel in relation to each section of the ISM Code.

Table 8) Overview of the impacts from the handling of ammonia as fuel in relation to each section of the ISM Code

Section	Title	Notes
1	**General**	Rules and guidelines related to ammonia-fueled vessels are to be well understood and complied with. Clear policy for safety management is to be developed to address the risks associated with new technical challenge posed by the usage of ammonia fuels.
2	**Safety and Environmental Protection Policy**	Policies, with due consideration of dangers that may newly be caused, are required.
3	**Company Responsibility and Authority**	Scope of the usage of ammonia as fuel is to be sufficiently covered.
4	**Designated Person(s)**	(No major changes from the conventional contents.)
5	**Master's Responsibility and Authority**	(No major changes from the conventional contents. Responsibility of the ship navigation is still attributed to the master.)
6	**Resources and Personnel**	Personnel with knowledge and techniques different from the conventional ones may be necessary, which necessitates the new procedures and the relevant trainings, as ammonia specific risks (toxicity, explosiveness, etc.) increase when handling ammonia fuels. For this purpose, stipulations of qualifications, education and trainings in accordance with the Flag administration's requirements are necessary, based on which the seafarers are to be well educated and trained.
7	**Shipboard Operations**	It is necessary to develop new manuals, plans, and instructions (including checklists) on ammonia fuels.
8	**Emergency Preparedness**	Emergency responses may be changed when new risks associated with ammonia and the corresponding measures are added. It is necessary to identify the emergencies resulted from ammonia fuels, and the corresponding manuals are to be included into the trainings and drills.

Section	Title	Notes
9	**Reports and Analysis of Non-conformities, Accidents and Hazardous Occurrences**	(No major changes from the conventional contents. Meanwhile, events related to ammonia may require the addition of new requirements or revision of existing ones.)
10	**Maintenance of the Ship and Equipment**	Maintenance structure for prevention, correction and emergency responses are required for the ammonia fuels related facilities. New equipment and systems are to be incorporated into the maintenance program in addition to the existing structures. Given the characteristics of ammonia, new skills are required for maintenance works, which is important to ensure the safe operation. It is also necessary to use metals, materials, special tools and technologies, for which the compatibility with ammonia is taken into account.
11	**Documentation**	(No major changes from the conventional contents)
12	**Company Verification, Review and Evaluation**	New operations, equipment, systems, etc. are to be reviewed on a regular basis as a part of the entire operation plan, while the requirements for the periodical review are to be maintained.

1.2 Considerations in using alternative fuels

It is important to take the following into account upon the introduction of alternative fuels to establish the systems to achieve the ship's safe and efficient operations.

1.2.1 SMS (Safety Management System)

It is required to review and update the safety management system (SMS) based on the characteristics of the alternative fuels to be introduced.

The ship operator is required to establish and implement the appropriate safety management system. It is necessary to take the following into account to address new risks and safety requirements associated with the usage of the alternative fuels.

(1) Handling instructions of the alternative fuels
(2) Confirmation of the conformity of equipment/systems
(3) Review of emergency procedures
(4) Compliance with the laws and regulations
(5) Reinforcement of the safety monitoring systems
(6) Record and analysis of accidents/incidents
(7) Reinforcement of the maintenance and inspection systems
(8) Assessment of new risks and the corresponding countermeasures
(9) Update of training and education programs
(10) Ensuring the safety of the fuel supply chain (supply, transportation and storage of fuels)

1.2.2 Risk assessment and management

Alternative fuels are associated with new risks due to their characteristics different from the conventional petroleum fuels. Therefore, it is necessary to assess the relevant risks based on the ISM Code and implement the appropriate safety measures. Specifically speaking, the potential risks may include the following.

(1) Risks of fire and explosions
(2) Risks of leakage and environmental pollution
(3) Impacts on health (e.g. health risks caused by the inhalation of ammonia)

1.2.3 Training of seafarers and qualifications

The ISM Code puts emphasis on the training and certification of seafarers, and thus new trainings and qualifications corresponding to the characteristics of the alternative fuels to be introduced are required for them. The items listed out as follows are to be taken into account based on knowledge and skills specific to the alternative fuels.

The company is also required to establish and provide training programs suitable to the fuels to be introduced and the relevant equipment.

(1) Education on characteristics and hazards of the alternative fuels
(2) Training in measures to prevent accidents and incidents
(3) Technical training in operation and maintenance of the new fuel systems

1.2.4 Emergency response plan

It is required to develop the emergency response plan in accordance with the ISM Code to address emergencies specific to the alternative fuels, with the following items taken into account.

(1) Anticipation of emergencies related to the alternative fuels and the corresponding countermeasures
(2) Communication flow during emergencies and response manuals
(3) Evacuation plan and first-aid procedures to address new risks
(4) Periodical drills and trainings to ensure the seafarer’s capability to address emergencies swiftly and appropriately

1.2.5 Maintenance and inspections

The ISM Code requires the periodical inspections and maintenance of the onboard equipment and systems. As the introduction of alternative fuels requires special handling, acquisition of new procedures and technical knowledge corresponding to it and arrangement of maintenance for the equipment and systems are necessary.

1.2.6 Compliance with the laws and regulations

As the ISM Code emphasizes the observance of the legal requirements, the international and national laws, regulations, guidelines and others related to the usage of alternative fuels are to be complied with.

APPENDIX-2 Emergency Procedures and Safety

Establishment of emergency procedures for ammonia bunkering is highly important to mitigate the risks of accidents and disasters and ensure the safety of the personnel and the environment. Emergency procedures for bunkering operations are provided in a specific manner in the following sections.

1.1. Establishment of emergency procedures based on the risk assessment

As the risks in bunkering vary widely, the risk assessment in advance is important. Risk assessment includes the identification of the potential hazards, assessment using risk assessment technologies, and development of risk mitigation measures, which enables the prevention of accidents and disasters as well as achieves the preparedness against emergencies.

1.1.1 Identification of the potential hazards

To identify the risks and accidents that may occur during bunkering, such as leakage, equipment failures, fire and collision.

1.1.2 Application of risk assessment technologies

To assess the impact of the risks and consider countermeasures with prioritization. Examples include the impact of ammonia leakage and hose failures, risk of fire spread, and probability of ship collision.

1.1.3 Development of risk mitigation measures

To develop specific countermeasures (procedures for emergency shutdown, firefighting equipment, evacuation plan, arrangement of means of communication, etc.) to ensure the readiness for their implementation.

1.2. Key components of emergency procedures

Emergency procedures provide specific guidelines for actions against the possible risks. Procedures to be followed in a situation requiring swift action are especially important. Examples of key components to be included in emergency procedures are provided as follows.

1.2.1 Ammonia leakage

To immediately identify the source of leakage and take the appropriate containment measures. Halt of operation or evacuation order may be necessary in case of emergency.

1.2.2 Failures in the hoses and connections

In case of fractures or failures in the bunkering hoses and connections, actions such as the immediate suspension of supply, repair arrangement and replacement with the substitute hoses are necessary.

1.2.3 Failures in ERS

Failures in ERS may cause fuel leakage or abnormal pressure. Procedures for swift action are to be developed with preparation of alternative means.

1.2.4 Failures in the mooring lines

In case where the mooring lines get ruptured, entangled or loosened, resulting in unexpected movements of the ship, confirm the ship’s position immediately and consider receiving assistance from tug boats or taking other means of mooring.

1.2.5 Communication failure

Back-up plan in case of communication interruption (radio communication, hand flag signaling, etc.) is to be prepared in advance.

1.2.6 Human casualties

Rescue of the injured and first aid to them are to be prioritized in case of accidents and disasters.

1.2.7 Fire

Procedures for swift firefighting and evacuation are to be established. Locations of firefighting equipment and fire hydrants are to be checked in advance. In carrying out firefighting activities in case of ammonia leakage, it is important to stop the leakage first, as the initiation of firefighting activities before the leakage is stopped increases the risks of fire and explosions.

1.2.8 Blackout (loss of electric power)

Back-up procedures by using the emergency generators or manual operations are to be prepared as countermeasures against a loss of electric power during bunkering.

1.2.9 Ruptured fenders

To consider alternative means in case of the impact or leakage caused by rupture of the fenders.

1.3. Cooperation from the personnel concerned in emergency responses

Swift cooperation among the personnel concerned are required for emergency responses. It is important to clearly divide the roles in advance to ensure that the communication flow during emergencies and each responsibility are clarified.

1.4. Trainings and drills

Periodical trainings and drills are essential to have emergency procedures work effectively. Key to minimize accidents and disasters is to ensure that all the personnel concerned are capable of taking actions swiftly and accurately through trainings and drills.

APPENDIX-3 Ammonia Bunkering Management Plan (ABMP)

Key points of the Ammonia Bunkering Management Plan (ABMP) to use ammonia as fuel in a safe and efficient manner are provided as follows.

It is desirable to design this plan in a way to provide a framework for the execution of operations in accordance with the procedures and appropriately manage the bunkering operations. It also aims to ensure the compliance with the regulations by the relevant authorities and the industry standards and implement the necessary safety measures.

This plan is to be kept as a document subject to regular reviews and necessary updates corresponding to changes in the regulations and operation procedures.

(1) Objectives

To define the clear objectives and goals to carry out the ammonia bunkering processes in a safe and efficient manner. Basic policies for the appropriate handling of ammonia, safety management and environmental protection are included.

(2) Safety policies

To clarify the specific safety policies to avoid accidents and hazards and set the norm to be observed by the personnel concerned.

(3) Evaluation of compatibility of equipment/systems

To evaluate the appropriateness of equipment and systems to be used for the ammonia bunkering systems to ensure the compatibility of equipment between the ammonia fuels supply side and the ammonia-fueled vessel.

(4) Risk assessment and management

To identify and assess all the risks related to the ammonia bunkering operations. Measures to eliminate or mitigate the risks (e.g. development of emergency procedures) are to be implemented, subject to regular risk reviews.

(5) Definition of roles and responsibilities

To clearly define roles and responsibilities in each phase of bunkering. This is applicable to all the relevant parties, including the captain and other seafarers, personnel relevant to the ammonia fuels supply side, and operation teams.

(6) Communication (means and procedures)

To secure two or more independent communication channels and specify the methods of information sharing during bunkering in order to ensure clear communication among the personnel concerned. Substitute means of communication is also to be prepared to enable swift action in case of emergencies.

(7) Management of change (MOC)

To define how to manage changes in equipment, procedures and operation methods. Risk assessment results are to be reviewed, and the plan is to be updated to adapt to the new situation in case of changes.

(8) Emergency responses

To specify response procedures against the expected emergencies, such as ammonia leakage, failures in hoses and equipment, communication interruption, fire, and blackout.

(9) Safety education

All the relevant parties engaged in ammonia bunkering are to be those who have received safety education, and, in case of seafarers, they are required to be educated and trained on ammonia bunkering, possessing the appropriate qualifications.

(10) Documentation of operations, procedures and checklists (including SIMOPS)

To document the detailed operations and procedures in each phase of bunkering to develop checklists. Special procedures are to be set up to avoid the interference with each other, if SIMOPS (simultaneous operations) are carried out.

Examples of SIMOPS:

- Loading and handling of marine supplies;
- Embarkment/disembarkment of the personnel concerned and seafarers
- Unloading of dangerous goods and management of other supplies (stored items, food, wastes, etc.);
- Handling of chemical products and other low flashpoint products;
- Bunkering of ammonia and fuels other than lubricants;
- Inspections, maintenance, repairs and surveys of the onboard equipment and systems;
- Cargo handling at the port facilities and terminals; and
- Responses against the unforeseen circumstances including failures.

(11) Management and maintenance of equipment

To set up the methods for handling and maintenance of the bunkering systems, equipment and pipes for confirmation that inspections and maintenance are provided on a regular basis. This includes inspections of the ammonia transfer systems and maintenance of the boil-off gas (BOG) management systems.

(12) Identification of areas

Appropriate identification and management of areas, such as hazardous areas, controlled areas, and toxic areas, are required for bunkering operations.

(13) Preventive measures (monitoring and controlling)

Monitoring systems and controlling systems for bunkering operations are to be introduced to establish the alert systems to ensure the safety.

(14) Mitigation measures (as shown below)

- Personal protective equipment (PPE): Application of the appropriate PPE (gas mask, cold-resistant clothing, etc.) to protect personnel from the exposure to ammonia;
- Leakage detection systems: Introduction of the leakage detection systems to enable the early detection of ammonia leakage and swift action against it; and
- Any other critical elements to provide the safe work environment, including water spray, emergency shutdown (ESD) systems, electrical earthing, and access restrictions.

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Acknowledgments

We would like to express our sincerest appreciations to Mr. Tada and everyone involved for their significant guidance and valuable advice for the development of this Guidelines.

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Guidelines for Safety Operation
for Ammonia-Fueled Vessels

Ver. 1.0

[English]

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April 2025