Part C "Guidelines for the Safety of Ships Using Ammonia as Fuel" of Guidelines for Ships Using Alternative Fuels

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1. INTRODUCTION

In the international shipping field, regulations for the prevention of air pollution and global warming have been strengthened in recent years, and the use of global environment-friendly alternative fuels instead of petroleum fuels has been actively studied, considering their potential as next-generation marine fuels. As a response to SOx and NOx regulations, introduction of ships using LNG, LPG, methanol/ethanol, and other alternative fuels is progressing. Use of these fuels in place of fuel oil makes it possible to reduce carbon dioxide (CO_2) emissions from ships by 10% to 20%, and ammonia and hydrogen fuels, which do not contain carbon, are expected to be used to achieve zero GHG emissions. Ships that carry ammonia as cargo are equipped with storage and process systems which make it possible to transport ammonia in an appropriate state, and some refrigerated cargo carriers are equipped with systems that use ammonia as a refrigerant. Thus, although ammonia is not yet used as a fuel, ammonia is already handled in the shipping field. Since ammonia also has a higher energy density and is more easily liquefied than hydrogen, it has attracted considerable attention as a decarbonization fuel for ships. Ships using ammonia as a fuel are being developed in various countries and are expected to be commissioned around 2024. To promote widespread use of ammonia as a fuel in ships including oceangoing vessels in the future, development projects for ammonia bunkering vessels are underway at major ports, including Singapore among others. While preparations for the future use of ammonia fuel in ships engaged in international voyages are progressing steadily, international regulations for the use of ammonia as a fuel have not yet been established. In particular, adequate safety measures are required, as ammonia is highly toxic, and contact with the human body, even in trace amounts, can cause serious health damage. To contribute to the development of ammonia-fueled ships, ClassNK (hereinafter, "the Society") specified the requirements for ensuring the safety of ships using ammonia fuel in Part C of its "Guidelines for Ships Using Alternative Fuels."

This report presents an outline of the safety requirements for ammonia-fueled ships in the Guidelines.

2. CURRENT STATE OF DEVELOPMENT OF AMMONIA-FUELED SHIPS

2.1 Background of Development of Ammonia-Fueled Ships

The relevant regulations of MARPOL Annex VI which provide for reduction of CO_2 emissions from ships have been in effect since January 1, 2013, and regulations utilizing the Energy Efficiency Design Index (EEDI) for new ships, requiring retention of a Ship Energy Efficiency Management Plan (SEEMP) on board ships and requiring use of the Data Collection System (DCS) for fuel oil consumption of ships have been introduced.

In April 2018, a GHG reduction strategy was adopted by the IMO at MEPC72, requiring a 40% improvement in transport efficiency across the entire international shipping industry by 2030 compared to 2008 as a short-term measure for reduction of GHG emissions. Toward achievement of this short-term target, amendments to MARPOL Annex VI and the relevant guidelines for introduction of the Energy Efficiency Existing Ship Index (EEXI) regulations and Carbon Intensity Indicator (CII) rating system were adopted, and the relevant guidelines for implementation of the CII rating system are being prepared. The IMO GHG reduction strategy sets a mid-term target of improving the transport efficiency by at least 70% and reducing GHG emissions by 50% by 2050 compared to 2008, and a long-term target of achieving zero GHG emissions by the end of this century. As mid- and long-term measures for achievement of these targets, a scheme that would impose charges on the use of fuel oil, an emissions trading system, etc. are also under study.

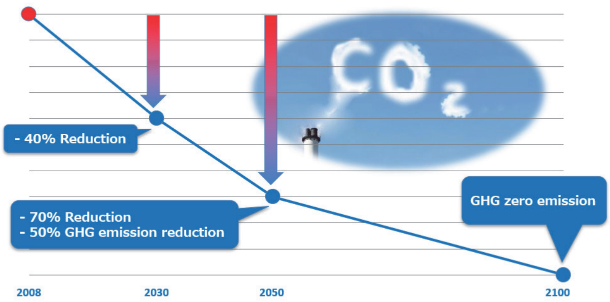

Fig. 1　CO_2 emissions reduction per transport volume of ships in international shipping

The Paris Agreement adopted in 2015 aimed at holding the increase in the global average temperature to below 2 °C above pre-industrial levels, and also included efforts to limit the temperature increase to 1.5 °C. The Inter-Governmental Panel on Climate Change (IPCC) reported that it will be necessary to reduce GHG emissions to net zero by 2050 in order to limit the temperature increase to 1.5 °C, and it has been agreed that the IMO GHG reduction strategy should be reviewed to enhance the targets for reduction of GHG emissions from international shipping specified in the IMO GHG reduction strategy.

With the above background, the use of ammonia as a fuel which does not emit CO_2 when burned is receiving attention as a technology that can realize a substantial reduction of GHG emissions. On land, ammonia is generally used in fertilizers and feedstocks for industrial products. This means that it will be possible to utilize existing technologies in each stage of the supply chain of production, transportation and storage. Ammonia is classified in terms of the production process and the degree of CO_2 reduction as “green” ammonia (ammonia produced from renewable energy), “blue” ammonia (ammonia produced from natural gas and coal materials, with the CO_2 generated in the production process recovered by carbon recycling or CCS) or “gray” ammonia (ammonia produced from natural gas and coal without CO_2 recovery). The current mainstream is gray ammonia, which is available at a cheap price, but emits CO_2 in the production process. Therefore, production of green ammonia and blue ammonia are also expected.

As outlined above, the use of ammonia as a fuel can substantially reduce CO_2 emissions from ships, and in addition, the supply chain for ammonia has already been established throughout the world. In view of these advantages, ammonia is a leading option as an alternative fuel, and the development of ammonia-fueled ships is being actively studied.

2.2　Status of Development of Ammonia-Fueled Ships

As one initiative in connection with ammonia-fueled ships at the world level, multiple ship classification societies issue Approval in Principle (AiP) certification for ammonia-fueled bulk carriers and container ships developed by shipyards, engine manufacturers, etc.

Development of engines is essential for constructing ammonia-fueled ships. MAN Energy Solutions has announced plans for their first delivery of a two-stroke engine in 2024. As an actual ammonia-fueled ship construction project, the development of an ammonia-fueled tanker equipped with Wärtilä Corporation's four-stroke engine, which is to be commissioned in 2024, has also been announced.

Actual construction projects are also underway in Japan, where the development of various ships using ammonia fuel has been announced. These include an ammonia-fueled tugboat equipped with a four-stroke engine developed by IHI Power Systems Co., Ltd., which will be commissioned in 2024, an ammonia-fueled ammonia transport ship with a two-stroke engine developed by Japan Engine Corporation to be commissioned in 2026 and an ammonia-fueled bulk carrier equipped with a two-stroke engine developed by the above-mentioned MAN Energy Solutions.

Fig. 2 Ammonia-fueled ammonia transport ship

2.3 Ammonia Fuel Supply System

The fuel supply systems adopted by ammonia-fueled ships are broadly divided into the following two types.

(1) System for supply of fuel to a high-pressure two-stroke engine (See Fig. 3): Supplies the required amount of fuel to the engine while circulating liquefied ammonia at the designated temperature and pressure.

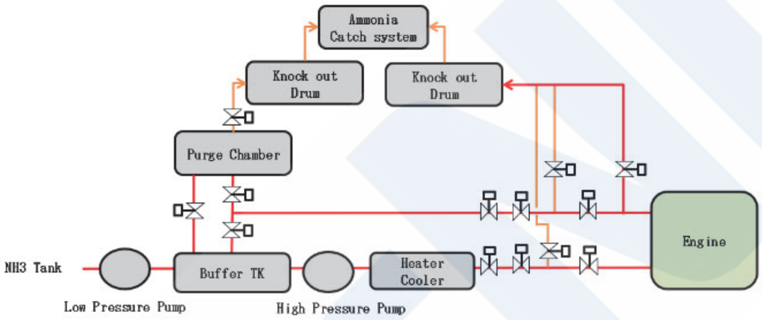

Fig. 3 Fuel supply system for two-stroke engine

(2) System for supply of fuel to a low-pressure four-stroke engine (See Fig. 4): Gasifies liquefied ammonia and supplies the gasified ammonia to the engine at the designated temperature and pressure.

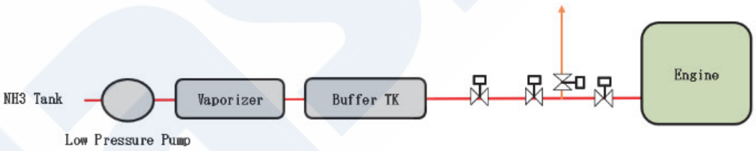

Fig. 4 Fuel supply system for four-stroke engine

2.4 Types and Characteristics of Gas-Fired Engines

Two types of ammonia-fueled engines are currently under study, as follows:

(1) Low-pressure four-stroke dual-fuel engine

Low-pressure four-stroke dual-fuel engines use a premixing lean burn system in which a gas fuel is mixed with the air supplied to the engine, and after this lean mixture is compressed, the mixture is ignited by pilot oil. This system has the advantage of a relatively low supply gas pressure because the gas is premixed with the supply air. As disadvantages, a trace amount of unburned gas called "ammonia slip" is emitted, and knocking resulting from abnormal combustion may occur. Control measures to reduce these undesirable effects are required (See Fig. 5).

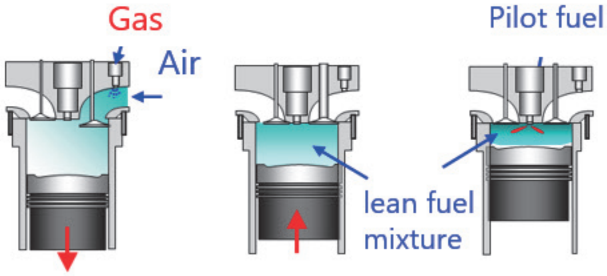

Fig. 5　Combustion system of four-stroke dual-fuel engine

(2)　High-pressure two-stroke dual-fuel engine

High-pressure two-stroke dual-fuel engines use a diffusion combustion system of the type used in oil-fired diesel engines. In this system, after the scavenging process is completed, the ammonia fuel is injected directly into the compressed air and ignited by pilot oil. This system does not cause ammonia slip or knocking and has the advantage of relatively stable combustion. However, as high-pressure ammonia at about 8 bar in a liquid state is supplied to the engine, safety in handling high-pressure gas on board must be considered (See Fig. 6).

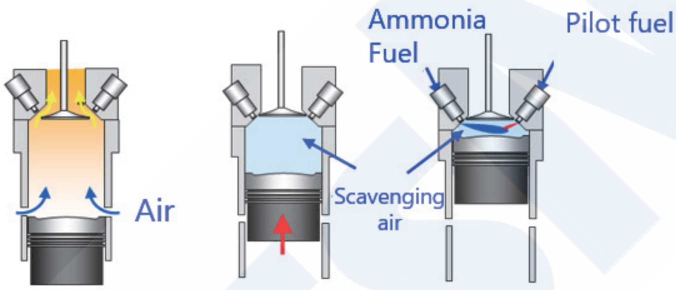

Fig. 6　Combustion system of two-stroke dual-fuel engine

2.5　Ammonia Fuel Tanks

As cargo tanks of ammonia carrier ships, independent tanks as specified in the IGC Code have a record of actual use, and it is thought that similar tanks can also be used for ammonia fuel. The types and characteristics of ammonia fuel tanks are shown in Table 1, and the characteristics of cargo tanks according to the ammonia liquefaction method are shown in Table 2.

Type C independent tanks, which are used as ammonia cargo tanks of the normal temperature pressurized type (in which ammonia is pressurized and carried in a liquid state) and the semi-refrigerated type (in which ammonia is pressurized while being cooled, and ammonia is transported in liquefied form), have a pressure vessel structure. They can be used at high pressure and require no secondary barrier, and they have the advantage of having relatively simple structures and systems. However, their cylindrical shape results in much dead space in the surrounding area when they are installed in spaces in ships. Especially when large ammonia fuel tanks are installed in a large cargo ship, the effect on the cargo carrying capacity and ship size must be minimized. For this reason, it is considered likely that square-shaped Type A and Type B independent tanks, which are used as fully-refrigerated ammonia cargo tanks (in which ammonia is transported at the saturation temperature at atmospheric pressure), will be studied in the future.

Table 1 Types and characteristics of ammonia fuel tanks

Type	Type A Independent tank	Type B Independent tank	Type C Independent tank
Configuration			
Design pressure	<0.07MPa	<0.07MPa	High Pressure
Track record (Gas carrier)	MGC, VLGC	LNGC	LPG/LNG carrier (small size)
Track record (LNG fueled ship)	Nil	Nil	○
Remarks	・Prismatic tank ・Complete secondary barrier	・Prismatic tank ・Partial secondary barrier ・Detail fatigue analysis	・Simple design and structure (Pressure vessel) ・Highly flexible in pressure ・No secondary barrier required

Table 2 Specifications of general ammonia cargo tanks

	Full pressure tank	Semi-pressurized tank	Fully refrigerated tank
Type of tanks	Type C	Type C	Type A, Type B
Design Temp	0°C	Abt.-33°C	Abt.-33°C
Design Pressure	Abt.1.8MPa	0.65MPa～0.85MPa	0.025MPa 0.045Mpa(In harbor)
Tank Volume	～800m^3	3,000m^3～4,000m^3	---
Material	KD500	KL37-M	KL33, KL27

3. PART C OF GUIDELINES FOR SHIPS USING ALTERNATIVE FUELS

3.1 Overview

In August 2021, the Society published "Guidelines for the Safety of Ships Using Ammonia as Fuel" of Part C of the Guidelines for Ships Using Alternative Fuels. Part C-1 of the Guidelines specifies the requirements for the safety of ships using ammonia as fuel except for liquefied gas carriers. The safety requirements for liquefied gas carriers using ammonia fuel are specified in Part C-2 of the Guidelines.

3.2 Process of Developing the Guidelines

The Guidelines for the Safety of Ships Using Ammonia as Fuel were developed in the following three steps:

Step 1 The physical properties of ammonia were investigated, and a gap analysis of conventional fuel oil and liquefied gas fuels was conducted.

Step 2 Based on the provisions for ships using methane as a fuel specified in the IGF Code in Part C-1 of the Guidelines for Ships Using Alternative Fuels, and in Chapter 16 of the IGC Code in Part C-2 of the Guidelines for Ships Using Alternative Fuels, the safety requirements that ammonia-fueled ships should satisfy to ensure safety equivalent to that of methane-fueled ships were provided, considering the investigation results of Step 1.

The IGF Code provides detailed requirements for the use of methane fuel, which is a liquefied gas fuel. As ammonia is also a liquefied gas fuel, the IGF Code was used as a basis for providing the requirements for the use of ammonia as fuel.

Matters requiring special consideration in ammonia-fueled ships were also identified. For example, ammonia has lower flammability and explosion risks than methane, but a higher toxicity risk.

Step 3 The following existing rules and guidelines were investigated and incorporated in the safety requirements as needed.

- IGF Code: Requirements for use of liquefied gas (methane) as fuel
- IGC Code: Requirements for transport of ammonia as cargo

- IBC Code: Requirements for transport of aqueous ammonia as cargo
- Rules for refrigeration installation: Requirements for use of ammonia as a refrigerant
- Part A “Guidelines for the Safety of Ships Using Methyl/Ethyl Alcohol as Fuels” of the Guidelines for Ships Using Alternative Fuels: Requirements for toxic fuel
- Part B “Guidelines for the Safety of Ships Using LPG as Fuel” of the Guidelines for Ships Using Alternative Fuels: Requirements for use of liquefied gas fuel

3.3 Concept of Part C of Guidelines for Ships Using Alternative Fuels

3.3.1 Basic Policy of General Safety Measures for Liquefied Gas Fuels

As the basic policy of general safety measures for liquefied gas fuels, the underlying concept of the IGF Code was analyzed and the areas of ships where safety measures should be taken were classified into four areas based on the presence or absences of fuels.

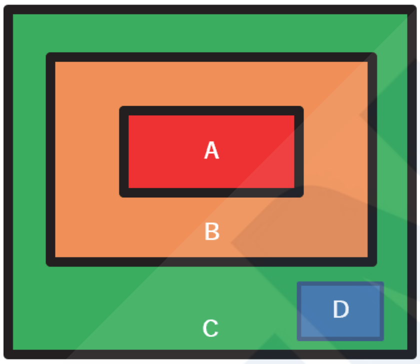

Fig. 7 Classification based on presence/absence of liquefied gas fuels

Area A is an area where fuel is always present (e.g., fuel tanks, piping equipment), and safe containment of the gas fuels inside is required. In this type of area, measures to secure the soundness of the equipment and isolation from any external damage are required. Personnel are not allowed to enter this type of area.

Area B is an area where fuel is not normally present, but is present when leakage occurs (e.g., tank connection spaces, fuel preparation rooms, double-walled pipes and ducts). In this type of area, measures to minimize the effects of fuel leakage are required, including detection of gas leaks, shutting off the fuel supply, containing and removing the leaked fuel and minimizing damage. Personnel may only enter this type of area in case of operational necessity.

Area C is an area where fuel is not present. Area C must be isolated from Area A by two boundaries and from Area B by one boundary. If this type of area cannot be physically isolated, it must be isolated by distance.

Area D is an area in Area C that requires special consideration to ensure that no fuel is present (e.g., accommodation spaces). This type of area must not be in direct contact with Area B.

The physical properties of ammonia that require special consideration in these areas are corrosiveness in Area A and flammability and toxicity in Area B.

3.3.2 Basic Policy of Safety Measures in Consideration of Characteristics of Ammonia

Table 3 shows the differences in the physical properties of methane and ammonia obtained by the gap analysis in Step 1 of the process of developing Part C of the Guidelines for Ships Using Alternative Fuels.

Table 3 Comparison of physical property values of Ammonia and methane

	Ammonia	Methane
Normal boiling point (°C)	-33.4	-161.5
Liquid density (kg/m^3)	682.3	422.5
Gas density (kg/ m^3) @boiling point	0.876	1.820
Gas density (kg/ m^3) @ 20 °C	0.707	0.659
Heat of vaporization (kJ/kg)		510.4
Lower flammability limit (% vol)	15	5.3

Upper detonation limit (% vol)	59.0	13.5
Minimum ignition energy (mJ)	45	0.274
Maximum burning rate (cm/s)	7	37
Quenching distance (cm)	0.064	0.22
Lower heating value (MJ/kg)	18.8	48.0
Self-ignition temperature (℃)	630	537
Toxicity	Yes	No
Corrosiveness	Yes	No
Stress corrosion cracking	Yes	No
Water-solubility (g/100 ml) @20℃	54	2.3

The hazards of ammonia that should be taken into account, as identified by the gap analysis, are described below:

- Toxicity (health hazard)

The typical effects of ammonia on humans include acute toxicity, skin corrosion, severe eye damage and respiratory sensitization. The effects of ammonia on humans by ammonia concentration are as shown in Table 4.

Table 4 Ammonia concentration and effects on humans

Ammonia concentration (ppm)	Effects on humans
5 to 10	Detectable by smell
50	Feeling of discomfort
100	Feeling of irritation
200 to 300	Irritation of eyes and throat
300 to 500	Bearable only for short time (20 to 60 minutes)
2 500 to 5 000	Life threatening in short time (about 30 minutes)
5 000 to 10 000	Respiratory arrest, fatal in short time

- Corrosiveness

Corrosive to copper, copper alloys, mercury, zinc and cadmium.

- Stress corrosion cracking

Causes stress corrosion cracking in carbon manganese steel and nickel steel.

- Low flammability

The lower explosion limit of ammonia is about 15%, which is higher than the limits of existing fuels (1 to 6%), and its minimum ignition energy is 8 mJ to 680 mJ, which is higher than that of methane (0.274 mJ). Accordingly, ammonia is considered to be less flammable than existing fuels such as methane. However, it may generate a flammable gas mixture in semi-closed and closed spaces, and may cause fire or explosion in those spaces.

- Hazard in event of fire

There is doubt about the continuity of combustion of ammonia. In addition, even if ammonia ignites, its calorific value is relatively low compared to those of existing fuels. Therefore, the effect of a fire caused by ammonia on the equipment is expected to be small.

The above-mentioned characteristics of ammonia that should be considered are classified as A) toxicity, B) flammability and C) corrosiveness. The basic policy on safety measures for these characteristics is described below:

A) Toxicity

Ammonia has serious effects on human health, even in small amounts. Therefore, new toxic hazardous areas were set and the safety requirements in the event of a release or leakage of ammonia were defined as follows:

A-1) Isolation of ammonia

Spaces where ammonia is present (Area A and Area B) and spaces where ammonia should not be present (Area C and Area B) are to be separated by physical enclosures or the like, and spaces on open decks where no physical enclosure can be provided are to be separated by distance.

A-2) Control of leaked ammonia

In case ammonia leaks in Area B, the provisions specify that it is to be immediately detected, the ammonia fuel supply to the point where the leakage occurred is to be shut off and the leaked ammonia is to be removed from the space. As in the IGF Code and IGC Code, no special regulations are provided for the release of liquefied gas in an emergency such as leakage into the ship or vent discharge from the pressure relief valves of fuel tanks.

A-3) Response to human exposure to ammonia

To prevent human contact with ammonia, in spaces where ammonia may be present in the event of an abnormality (i.e., Area B), the fact that no ammonia is detected shall be confirmed. If ammonia is detected, personnel wearing proper protective equipment are allowed access to the space. If contact with ammonia occurs, measures to mitigate the effects are to be taken.

A-4) Ensuring Safe Operation

If ammonia is released into the atmosphere in an emergency, places necessary for maneuvering and propulsion of the ship so as to maintain the minimum operation for the ship’s safety, and places for performing emergency operations such as fire extinguishing and evacuation, shall be in safe locations.

B) Flammability

Because the lower explosion limit and minimum ignition energy of ammonia are high, ammonia is more difficult to ignite than other fuels. Therefore, there is a comparatively low probability of fires caused by ammonia. The former version of the IGC Code specified that “Because high concentrations of ammonia in confined spaces can be flammable, the provisions of Chapter 10 for flammable products should be applied except in zones on the open deck.” Based on these points, no requirements for flammable hazard areas on open decks were provided, and the requirements for thermal insulation, etc. were reduced compared to those for methane fuel.

C) Corrosiveness

Ammonia is corrosive for certain materials and has a risk of causing stress corrosion cracking in carbon manganese steel and Ni steel. Therefore, based on the special requirements for ammonia in Chapter 17 of the IGC Code, the related requirements were provided.

3.3.3 Basic Policy on Release of Ammonia

Ammonia release scenarios were set for emergency conditions and normal conditions. The handling of ammonia in each scenario is described below.

(1) Under emergency situations

The following events are regarded as emergencies, and the release of ammonia into the atmosphere or sea is allowed.

① Retaining ammonia fuel may result in the worst-case situation.

(Example) A fire occurs around an ammonia fuel tank, the pressure in the tank increases and the pressure relief valve operates.

② Events in which it is impossible to retain ammonia fuel.

(Example 1) In closed and semi-closed spaces, the piping system, etc. is damaged and ammonia is to be removed from the space where it leaked.

(Example 2) Leaked ammonia is adsorbed by water from the water spray system at a bunkering station, etc. and released into the sea.

(2) Under normal situations

In normal operation, outboard release of highly concentrated ammonia from spaces where ammonia is present (Area A (tanks, piping systems, etc.)) is not allowed.

(Example 1) Purging and gas freeing of the ammonia fuel supply system or bunkering lines

(Example 2) Gas freeing of tanks and pipes during docking or undocking

3.4 Major Requirements of Part C of Guidelines for Ships Using Alternative Fuels

3.4.1 Functional Requirements (Chapter 3 of Part C-1)

Part C-1 of the Guidelines for Ships Using Alternative Fuels provides guidelines for design, construction and operation by specifying goals and functional requirements using the goal based approach, which is the basic philosophy of the IGF Code. Chapter 3 of Part C-1 of the Guidelines for Ships Using Alternative Fuels provides the goal and functional requirements of the entire Guidelines. The goal of the chapter is “to provide for the safe and environmentally friendly design, construction and operation of ships and their installation of systems for propulsion machinery, auxiliary power generation machinery and/or other purpose machinery using ammonia as fuel." As functional requirements, 19 items are provided. The main functional requirements are as follows:

- Ships using alternative fuels shall ensure safety and reliability equivalent to those of conventional ships (oil-fueled engine).
- Hazards related to the use of ammonia as fuel shall be minimized.
- Adequate safety measures to prevent a single failure in the fuel systems shall be provided.
- Hazardous areas shall be minimized.
- Unexpected accumulation of fuel shall be avoided.
- Fuel shall not be discharged other than when necessary for safety reasons.
- Measures shall be taken to minimize human health hazards associated with the toxicity of the fuel.

3.4.2 Risk Assessment (Chapter 4 of Part C-1)

In the design of ammonia-fueled ships, a risk assessment is required in order to eliminate or mitigate any adverse effects on passengers and personnel on board, the environment or the ship. Although the scope of risk assessments for ships using natural gas as fuel is limited in the IGF Code, the scope of risk assessment for ammonia-fueled ships is not limited and includes all items related to the use of ammonia as fuel.

3.4.3 Arrangement of Gas Safe Machinery Spaces (Chapter 5, 9 and 10 of Part C-1)

In addition to the concept of gas safe machinery spaces, the concept of ESD-protected machinery spaces is also introduced in the IGF Code. Because ammonia has serious human health effects, even in small amounts, the provisions for ammonia-fueled ships do not permit an ESD-protected machinery space where a single failure may cause a gas fuel release into the space.

Gas safe machinery spaces are defined as spaces that are considered gas safe not only under normal conditions but also under abnormal conditions. Double-walled pipes are to be provided for the ammonia fuel piping in machinery spaces so that a single failure will not lead to a leakage of gas fuel into the machinery spaces.

3.4.4 Material Arrangement (Chapter 7 of Part C-1)

In consideration of the corrosive nature of ammonia, use of mercury, copper, copper alloys and zinc in materials that may be exposed to ammonia fuels under normal use conditions is prohibited. In the future, use of cadmium will also be prohibited.

Because ammonia may also cause stress corrosion cracking in tanks and piping systems made of carbon manganese steel or nickel steel, additional measures were provided based on 17.12 Special requirements for ammonia in the IGC Code. The main requirements are as follows:

- When carbon manganese steel is used for fuel tanks or other pressure vessels, piping systems, etc., it shall have a specified minimum yield point not exceeding 355 N/mm^2 and an actual yield value not exceeding 440 N/mm^2, and is to satisfy any one of the following requirements ① to ④:
  ① Specified minimum tensile strength < 410 N/mm^2
  ② Post-weld stress relief heat treatment
  ③ Carriage temperature of -33°C (less than -20°C in any case).
  ④ Only ammonia containing not less than 0.1% of water shall be carried.
- If materials with a high yield point exceeding the above yield point are used, post-weld stress relief heat treatment is to be applied.
- Carbon manganese steel and nickel steel used for process pressure vessels and pipes are to be given post-weld stress relief heat treatment.
- Use of nickel steel with a nickel content exceeding 5% is prohibited. As Part K of the Rules for the Survey and Construction of Steel Ships specifies that the content of nickel in 5% Ni steel shall be 4.75% to 6.00%, the applicable range in these Guidelines is 4.75% to 5%.

3.4.5 Bunkering (Chapter 8 of Part C)

Since ammonia is highly toxic and has serious human health effects, even in small amounts, ammonia fuel supply piping systems on open decks are to be surrounded with secondary enclosures. However, secondary enclosures are not required for ammonia fuel bunkering pipes, as gas freeing is conducted at times other than during bunkering and the frequency of ammonia in the pipes is low. (In this case, single-walled pipes may be provided.)

In connections at bunkering stations, devices which enable safe disconnection by use of BAC (Break Away Coupling) or ERC

(Emergency Release Coupling) are required in order to prevent bunkering hoses from breaking due to excessive load. If a disconnecting device is activated, a small amount of fuel remaining at the coupling may scatter, and human contact is possible. To reduce this risk, a water spray system is required at bunkering stations.

3.4.6 Hazardous Areas (Chapter 12 of Part C-1)

Because the LEL and minimum ignition energy of ammonia are high, ammonia is considered to have a low risk of causing fire or explosive atmospheres on open decks. Therefore, no flammable hazardous areas are set for open decks. However, there is a risk of ammonia producing a flammable atmosphere in closed and semi-closed spaces, and hazardous areas are set for those spaces, as in the conventional IGC Code and IGF Code. In Part C of the Guidelines C (Ver1.1), hazardous areas are classified as flammable hazardous areas and toxic hazardous areas. In the future, the classification will be changed so that toxic hazardous areas are included in flammable hazardous areas, as in the IGC Code.

3.4.7 Fire Safety (Chapter 11 of Part C)

(1) Open decks

Ammonia fuel tanks must be protected from heat input due to external fire by cooling and fire prevention. Therefore, the exposed parts of fuel tanks located on open decks are covered with water spray systems.

As noted above, it is assumed that ammonia will not cause fires or explosive atmospheres on open decks. Therefore, unlike the requirements of the IGF Code, installation of water spray systems in spaces (accommodation spaces, etc.) that should be protected from fuel tank fires is not required.

(2) Under open deck

Since there is a risk of fire or explosion caused by ammonia in closed and semi-closed spaces, it is necessary to protect ammonia fuel storage systems from machinery spaces of category A and spaces with a high risk of fire by the following methods:

- Installation of A-60 class heat insulation
- Separation by a cofferdam of 900 mm or longer (If Type C independent tanks are not located directly in a category A machinery space or a high fire risk space, the fuel storage hold space may be regarded as a cofferdam.)

3.4.8 Measures Against Toxicity (Chapters 6, 12, 13 and 14 of Part C)

As in the case of flammable hazardous areas, toxic hazardous areas are set for closed and semi-closed spaces but are not set for open decks. However, as safety measures against toxicity on open decks, requirements for distance for separation from places that should be protected, such as places where ammonia release is possible, where personnel are normally present, openings of non-hazardous spaces and inlets/outlets of ventilation systems in non-hazardous spaces, were specified as follows:

① Vent post

Height of vent exits:

- Not less than B'/3 or 6 m, whichever is greater, above the weather deck
- Not less than 6 m from working areas and walkways

Separation distance of vent exits:

- Not less than B or 25 m from air inlets/outlets and openings of non-hazardous spaces, whichever is lower

② Outlets of ventilation systems

Height of outlets of ventilation systems in enclosed hazardous areas

- Not less than 4 m from the weather deck, working areas and walkways

Separation distance of outlets of ventilation systems in enclosed hazardous areas

- Not less than 10 m from air inlets/outlets and openings of non-hazardous spaces

③ Protected areas

The following protected areas (A) to (C), which are defined as areas that should be protected, are to be separated by the distances (a) to (d) specified for the respective places where ammonia may be released.

Protected areas:

(A) Ventilation inlets/outlets and openings of non-hazardous spaces

(B) Escape routes from spaces where personnel are normally present, such as accommodation spaces, control spaces and electrical equipment rooms

(C) Lifeboats

Places where ammonia may be released and separation distances:

(a) A spherical distance of 4.5 m (3 m + 1.5 m) from any fuel tank outlet, gas or vapor outlet, bunker manifold valve, other fuel valve, fuel pipe flange, fuel preparation room ventilation outlet and fuel tank opening for release of a small amount of gas or vapor caused by temperature variation to regulate the pressure in the fuel tank
(b) A spherical distance of 3.0 m (1.5 m + 1.5 m) from any fuel preparation room entrance, fuel preparation room ventilation inlet and other openings of places where fuel may leak
(c) A distance of 4.5 m (3 m + 1.5 m) around and 3.9 m (2.4 m + 1.5 m) above coamings installed around fuel bunker manifold valves to prevent fuel leakage
(d) For fuel storage systems with an exposed external surface except for Type C tanks, a distance of 3.9 m (2.4 m + 1.5 m) from the external surface

3.4.9 Ventilation System (Chapter 13 of Part C)

Ventilation systems are required in the following spaces where gas may accumulate.

- Tank connection spaces
- Fuel preparation rooms
- Double-walled pipes and ducts

In these spaces, exhaust-type mechanical ventilation systems of non-sparking construction having a ventilation capacity of at least 30 air changes/hour are to be installed. In spaces where ammonia-related equipment is installed and personnel enter during operation, an additional ventilation system that can immediately remove leaked ammonia is to be installed and is to satisfy the following requirements:

- The ventilation system shall have a minimum capacity of at least 45 air changes/hour (which may include the ventilation capacity of at least 30 air changes/hour in normal operation).
- When the ammonia gas concentration detected in such spaces exceeds 3 000 ppm, the ventilation system shall start automatically.

Where a bunkering station is not located on an open deck with sufficient natural ventilation, a risk assessment must be conducted to evaluate its safety. At that time, a study of the necessity of installing an appropriate mechanical ventilation system must be conducted, considering the risk of gas leakage especially during bunkering operation.

Ventilation systems for spaces where ammonia may leak shall be independent of ventilation systems for other spaces, and closing appliances are to be installed at air inlets/outlets of spaces where personnel are normally present.

3.4.10 Automatic Shutdown of Ammonia Supply (Chapter 15 of Part C)

In case of abnormal conditions such as leakage of ammonia fuel or stoppage of ventilation system operation, automatic shutoff valves (master valves) for stopping the fuel supply into machinery spaces shall be provided, and in case of abnormality of an engine using gas fuel, double block and bleed valves for stopping the gas fuel supply to the engine must be installed in each engine. Considering the effects of ammonia on the human body, an alarm is given when the concentration of leaked ammonia detected in a space reaches 25 ppm, and when the concentration reaches 300 ppm, the master valves and double block and bleed valves shut off.

3.5 Future Deliberation and Development

International deliberation has been conducted to develop requirements for ships using ammonia as fuel. In September 2021, 27 member states of the EU and the EC submitted a document (CCC7/3/9) proposing the development of safety requirements for ammonia to the Sub-Committee on Carriage of Cargoes and Containers (CCC), 7th session at the IMO. In October 2021, the Japanese government made a proposal on the development of guidelines for ships using ammonia as fuel at the Maritime Safety Committee (MSC), 104th session. In both committees, no deliberation on these proposals was conducted because of time constraints. If the proposal is deliberated and approved at the next MSC 105 (April 2022), study of specific safety requirements for ammonia-fueled ships is expected to start in the Sub-Committee CCC8 (September 2022).

The Society published the Guidelines of safety requirements in order to contribute to the recent demand for the development of ammonia-fueled ships. In the future, we will contribute to discussions on the development of international regulations by using the investigation results, etc. obtained through the development of the Guidelines, and will review the Guidelines at regular intervals in consideration of the most recent status of deliberations in the IMO and the rapid development of new technologies in order to develop guidelines that will be useful for developers.