MARITIME TECHNOLOGIES FORUM

LEADING THE MARITIME WORLD FORWARD

GUIDELINES FOR DEVELOPING AND IMPLEMENTING A SAFETY MANAGEMENT SYSTEM FOR AMMONIA-FUELLED SHIPS

Abbreviations and Definitions

Abbreviation	Definition
AEGL	Acute Exposure Guideline Levels
ARMS	Ammonia Release Mitigating System
BIMCO	The Baltic and International Maritime Council
DP	Designated Person
EU ETS	EU Emissions Trading System
FuelEU	Fuel EU Maritime Regulation
ICS	International Chamber of Shipping
IGC Code	The International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
IGF Code	The International Code of Safety for Ship Using Gases or Other Low-flashpoint Fuels
IMO	International Maritime Organization
Intertanko	International Association of Independent Tanker Owners
ISM Code	International Safety Management Code
ISO	International Organization for Standardization
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
MEPC	IMO’s Marine Environment Protection Committee
MLC	The Maritime Labour Convention, 2006
MOC	Management of Change
MGO	Marine Gasoil
MSC	IMO’s Maritime Safety Committee
MTF	Maritime Technologies Forum
OCIMF	Oil Companies International Marine Forum
OEM	Original Equipment Manufacturer
PTW	Permit To Work
PMS	Planned Maintenance System
SEP	Safety and Environmental Protection Policy
SGMF	The Society for Gas as a Marine Fuel
SIGTTO	The Society of International Gas Tanker and Terminal Operators
SMS	Safety Management System
SIMOPS	SIMultaneous OPerationS
STCW Convention	The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers,1978
STCW Code	Seafarers’ Training, Certification and Watchkeeping Code
TRA	Task Risk Assessment

Executive Summary

The Maritime Technologies Forum (MTF) is a group of flag States and classification societies which aims to bridge the gap between technological progress and regulatory process. To encourage safe application of alternative fuels for industry wide application, acceptance, and consistent development and implementation; MTF had published "Guidelines to support development of new SMS and/or strengthen the existing SMS for alternative fuels onboard ship/company fleet". Among the broad spectrum of technologies, with some early pilot trials and fuel solutions; ship designers, builders, owners and operators have identified anhydrous ammonia (NH_3) as a potential zero carbon emission solution.

Noting the industry forecasts on the uptake of future fuels with low to zero carbon emissions, ammonia was identified as one of the frontrunners and relatively, on balance, was seen to have newer risks for the maritime industry such as toxicity and corrosiveness. As such MTF took the initiative to develop these guidelines for use by industry as a first step to close identified gaps when using ammonia as fuel. Additional considerations would be needed when ammonia cargo is used as fuel, which are out of the scope of these guidelines.

In these guidelines, MTF members followed a method to assess these gaps by reviewing ISM Code's Part A implementation for each section and identifying areas that may be relevant to when ammonia is used as fuel onboard. Industry stakeholders were consulted during the development of these guidelines to strengthen the document with their different sector experiences. The list of these industry stakeholders can be found at the end of this document.

Proposed guidelines can be used to develop new or strengthen existing SMS:
Companies can use these guidelines to develop new SMS and/or strengthen their existing SMS for ammonia as fuel onboard their fleet. MTF recommends that these guidelines may be used in addition to other similar existing and/or upcoming guidelines (of which some are already referenced within this document) to ensure a safe application of ammonia as fuel on board ships.

Experience from operating with ammonia as fuel will initially be limited:
MTF recognises that the use of ammonia as fuel in the maritime industry has elevated operational and environmental risks relative to fossil fuels. It should be recognised that the lack of data from the operational experience of equipment operating with ammonia as fuel will be a gap that will exist in the initial stages of deployment of ammonia as fuel. A centralized industry database should be established to share lessons learnt from ammonia pilot projects and incident reports; enabling knowledge transfer and faster adaptation of ammonia as fuel.

SMS should learn from hazardous occurrences and accidents with ammonia as fuel:
The application of a structured risk management within the SMS would be beneficial to strengthen the system in managing anticipated risks including risks from the deployment of ammonia as fuel. The strength of the company's SMS should be in the ability to proactively identify improvements in the SMS through learning from non-conformities, accidents, and hazardous occurrences (including near misses) related to ammonia as fuel and facilitate the closing of the gaps. Furthermore, and until operational experience is gained within each organisation, the SMS can be improved based on learnings from additional sources of information, including risk evaluations from the design or retrofit stage, learnings from other companies or pilot projects.

SMS should be versatile to accommodate mixed fuel operations:
In the initial stages, as the fuel-mix onboard likely includes both fossil fuels and ammonia (including pilot fuel), it is essential to implement safe fuel changeover procedures and provide comprehensive dual-fuel engine training programs to ensure safe operations. As such the SMS should be versatile enough to meet various fuel scenarios, as ammonia as fuel is progressively scaled, eventually becoming mainstream.

Training and familiarisation are critical to ensure safe operations with ammonia as fuel:
To ensure safe ammonia-fuelled operations, careful consideration needs to be given to the evaluation of the competency, training, familiarisation and resources relevant to ammonia as fuel. The required level of competence, training and upskilling should be determined by the role, task or responsibility assigned to a person.

Human factors considerations[1] and addressing associated risks to enhance SMS:
The human factors in the operations associated with the handling, storage and utilisation of ammonia is critical, and should be considered to ensure safe operations[2]. Due to ammonia's novelty as a fuel in the maritime industry, it is critical that the various ammonia related risks associated with human factors are understood so that appropriate processes and procedures are put in place to enhance the overall SMS.

Background and Objective

The Maritime Technologies Forum (MTF) has been established to provide technical and regulatory expertise for the maritime industry. MTF's role is to publish research based on its members' expertise and offer unbiased advice to the maritime industry.

To encourage safe application of alternative fuels for industry wide application, acceptance, and consistent development and implementation; MTF had published 'Guidelines to support development of new SMS and/or strengthen the existing SMS for alternative fuels onboard ship/company fleet'[3]. Among the broad spectrum of technologies, as well as the early pilot trials[4], and fuel solutions; ship designers, builders, owners and operators have identified anhydrous ammonia (NH_3) as a potential zero carbon emission solution.

As such, in the next phase to dive deeper into some of the more prominent alternative fuels, MTF decided to develop 'Guidelines for developing and implementing a Safety Management System for ammonia-fuelled ships'. These guidelines could be seen as a progressive step in the interim to identify and fill operational gaps onboard ammonia fuelled ships, encouraging safe application of ammonia as fuel in the maritime industry.

As a fuel, ammonia has the potential to be almost carbon free from production to combustion and in its liquid form is energy denser[5] relatively to Hydrogen or Natural Gas so it may be particularly suitable for longer ship voyages. Ammonia is seen as one of the frontrunners among the future fuels, with estimates putting e-ammonia (also referred to as green ammonia) as fuel at 35% to 50% of the market, with optimistic estimates ranging up to 79% by year 2050[6].

One of the main concerns with using ammonia as fuel in the maritime industry is ensuring its safe handling, operation and maintenance; Toxicity being one of the prominent risks[7], covered later on in the guidelines.

A number of industry stakeholders representing different maritime sectors contributed towards the development of these guidelines. Their contributions were in the form of workshop discussions and document reviews, representing input from different sectors, which helped to strengthen these guidelines. MTF is grateful for their contribution and the full list of these industry stakeholders can be found at the end of this document.

Disclaimer

The guidance and recommendations provided in this report are based along with other sources on the 'Interim Guidelines for the Safety of Ships Using Ammonia as Fuel' (MSC.1/Circ.1687)[8].

The findings and recommendations in this report represent a collaborative effort between participating MTF members. While the advice given in this report has been developed using the best currently available information, it is intended to be used solely as guidance. No responsibility is accepted by MTF or its members for any consequences resulting directly or indirectly from the adoption of any of the recommendations in this report. This report does not stop MTF members from having independent opinions or conclusions.

Characteristics of Ammonia

This guidelines throughout refer to anhydrous ammonia as fuel. While each new fuel is to be treated differently depending on its own characteristics and properties, the key properties of ammonia in comparison to LNG and MGO are shown in Table.1 below[9].Ammonia offers the advantage of containing no carbon in its molecule (unlike LNG or MGO), therefore, the combustion occurs without formation of carbon dioxide. However, there are other exhaust emissions such as nitrogen oxides, which is a local pollutant, and nitrous oxide which is a greenhouse gas. Moreover, ammonia can have unstable combustion and the existing ammonia-fuelled engine designs require a pilot fuel to provide the ignition energy; as such for now, ammonia as fuel, is unlikely to be combusted without a pilot fuel. LNG must be stored at cryogenic conditions of –161.5°C, whereas liquid ammonia can be stored at –33 °C, making its storage much less energy-intensive.

Properties	Ammonia	Methane/LNG	MGO
Chemical Formula	NH_3	CH_4	C10 – C22
Boiling Point @ 1bar (°C)	-33	-161.5	170 to 350
Autoignition Temperature (°C)	651	539	250
Minimum Ignition Energy (mJ)	8	0.28	0.23
Flammable Range in Dry Air (%)	15 to 28	5 to 15	0.7 to 5

Table 1: Key properties of ammonia in comparison to LNG and MGO

Ammonia is considered a less flammable gas compared to LNG and MGO requiring much higher concentrations (15.2% to 27.4%) and minimum ignition energy to ignite. Ammonia gas is lighter than air and will rise, so it generally dissipates quickly in open spaces, reducing the risk of fire and explosion when compared to LNG and MGO. However, ammonia can be potentially dangerous in enclosed space owing to its wider flammability ranges than LNG and MGO. Ammonia also has the ability to auto-ignite at a temperature of 651°C.

Ammonia's reaction with moisture can corrode copper, brass, zinc and other alloys, forming a greenish/ blue colour. Ammonia is an alkaline-reducing agent and reacts with acids, halogens and oxidising agents. Ammonia stress corrosion cracking (SCC) is most prevalent in carbon steels equipment in service or in copper-zinc alloys in aqueous environments. These properties add challenges related to the selection of materials for onboard equipment and tanks. This contrasts with LNG and MGO, which do not have such pronounced corrosive effects on materials.

One of the most effective methods to remove ammonia gas is to dissolve it in water, which removes ammonia gas but generates ammonia effluent onboard. Consideration should be given to safely handle and responsibly dispose ammonia effluent generated onboard ammonia-fuelled ships, mainly from ammonia gas abatement systems (where provided).

In the presence of moisture (such as high relative humidity), the liquefied anhydrous ammonia gas can form vapours that are heavier than air. These vapours may spread along the ground or into low-lying areas with poor airflow where personnel may become exposed. Similar behaviour is exhibited by cold gaseous ammonia. In such areas, ammonia's toxicity becomes a more critical concern compared to LNG, which has different handling protocols. This could potentially affect the design of ventilation systems, necessitating the inclusion of targeted exhaust systems in areas where ammonia is stored or handled, as well as the implementation of clearly marked escape routes and emergency exits to ensure safe evacuation in case of vapour accumulation.

<table>
<tr><th rowspan="2">Hazard</th><th colspan="2">Applies to</th><th rowspan="2">Operators Safety Procedures</th><th rowspan="2">Transversal Control</th></tr>
<tr><th>LNG</th><th>NH_3</th></tr>
<tr><td>Fires and Explosion Gases
Mist and Vapours
Pressure</td><td>X</td><td>X</td><td>• Ventilation (negative pressure)
• Leak detection/Monitoring and Alarm
• Detection (heat detection systems)/Alarm
• Equipment installed/used suitable for intended purpose</td><td rowspan="4">Class Requirements
Training
PTW
TRA
PPE
Emergency Prepardness
STOP
Opening Meeting
Toolbox Talks</td></tr>
<tr><td>Corrosivity</td><td></td><td>X</td><td>• Piping valves and tanks insulation</td></tr>
<tr><td>Hazardous Temperatures - Cold</td><td>X</td><td>X</td><td rowspan="2">• Ventilation (negative pressure)
• Leak detection/Monitoring and Alarm
• Control of all leakage scenarios</td></tr>
<tr><td>Toxicity</td><td></td><td>X</td></tr>
</table>

Table 2: Alternative Fuels Safety Guidance (issue 1.1) – Lloyd's Register

In terms of toxicity, ammonia presents a significant risk, particularly in enclosed or poorly ventilated spaces. The severity of the health effects depends on the concentration of ammonia, duration or frequency of exposure, route of exposure and the individual's vulnerability due to preexisting health conditions. Several global agencies and organisations have established exposure limits and guidelines to ensure the safety of workers and the public who may be exposed to ammonia in various work, industrial, or other settings. The ammonia concentration and the duration of exposure, with corresponding toxic effects[10] are summarised below. The most common exposure being inhalation:

Concentration (ppm)	Effect
5 - 25	Odour perception
20 - 50	Mild discomfort
50 - 80 (2 hour)	Perceptible eye and throat irritation
100 (2 hour)	Nuisance eye and throat irritation
140 (2 hour)	Severe eye, nasal, throat and chest irritation. Leave exposure area
300	No scape-impairing symptoms and no irreversible effect
500 (30 min)	Upper respiratory tract irritation, tearing of the eyes
700 -1,700	Coughing, bronchospasm and chest pain with severe eye irritation and tearing
5,000 -10,000	Rapidly lethal: Chemical bronchitis and chemical burns of the skin
10,000	Promptly lethal

Table 3: Concentration in air of Ammonia and health effects – EMSA

Whilst different agencies from different countries have published various findings regarding ammonia exposure levels, the AEGLs (Acute Exposure Guideline Levels) [11] were referred to by the IMO CCC 10 sub-committee in their discussions when developing the 'interim guidelines for the use of ammonia fuel'.

A simplified table showing AEGL values for Ammonia:

Levels (Exposure)	10 mins	30 mins	1 hr	4 hrs	8 hrs	Signs and Symptoms
AEGL 1 (Non-disabling)	30 ppm	30 ppm	30 ppm	30 ppm	30 ppm	Notable discomfort, irritation, or certain asymptomatic nonsensory effects. **Reversible**.
AEGL 2 (Disabling)	220 ppm	220 ppm	160 ppm	110 ppm	110 ppm	**Irreversible** or other serious, long-lasting adverse health effects or an impaired ability to escape.
AEGL 3 (Lethal)	2,700 ppm	1,600 ppm	1100 ppm	550 ppm	390 ppm	Life-threatening health effects or **fatal**

Table 4: AEGL levels for ammonia – The National Academies

Exposure to ammonia in high concentrations can cause severe irritation to the respiratory system, damage to lung tissue, and, depending on the exposure duration, lead to long-term health effects or death. Therefore minimising exposure, monitoring, and controlling access to, and length of time spent, in spaces containing equipment associated with ammonia should be considered. In open air, ammonia vapours are less of a concern, but in confined spaces or areas with poor ventilation, ammonia vapours can accumulate, posing a greater risk to personnel.

It is crucial for companies to understand the hazards associated with handling ammonia in order to incorporate suitable and adequate measures within the SMS to protect the health of crew and shore-side personnel, minimising the risks associated with ammonia exposure.

Introduction to the Guidelines

These guidelines are developed following a review of each section of the ISM Code's Part A. The structure and section numbers within these guidelines therefore mirror those of the ISM Code to help the reader. The structure of these guidelines is shown below:

1. General,
2. Safety and Environmental Protection Policy,
3. Company Responsibilities and Authority,
4. Designated Person(s),
5. Master's Responsibility and Authority,
6. Resources and Personnel,
7. Shipboard Operations,
8. Emergency Preparedness,
9. Reports and Analysis of Non-conformities, Accidents and Hazardous Occurrences,
10. Maintenance of the Ship and Equipment,
11. Documentation, and
12. Company Verification, Review and Evaluation.

Each section provides assessments and recommendations for implementing SMS when considering the use of ammonia as fuel onboard ships. The reader should note that some sections provide more detailed content due to the specific aspects associated with using ammonia as fuel onboard ships, while others remain high-level to address general considerations in SMS implementation.

It is to be noted that the guidance provided in this document is based on the current state of play of regulatory development as well as early industry experience. As such these guidelines should be seen as a progressive step in the interim to identify and fill operational gaps onboard ammonia fuelled ships; Once the regulatory requirements and industry best practices are published, they should take precedent.

While some content within these guidelines may be considered generic and business as usual, MTF believes that it is crucial to interpret these sections through the lens of ammonia as a fuel. This ensures that safety, environmental, and operational considerations specific to ammonia are emphasised in the context of ship operations.

These guidelines are for ships using ammonia as fuel. Where ammonia cargo is used as fuel, further considerations are needed, which are out of the scope of these guidelines. Also, cargo transfer operations carried out periodically at sea are different from ammonia bunkering operations.

1. General

In an operational environment, it is difficult to achieve a process devoid of risks, especially when dealing with operations that may have inherent elevated risks due to several uncertainties.

The use of ammonia as fuel in the maritime industry involves addressing safety and environmental risks that differ from those associated with fossil fuels. In general, these risks can be considered to be more severe due to uncertainties associated with ammonia, a relatively new fuel for maritime use. These risks may be perceived and mitigated when operational procedures and contingencies are planned, but there may be some adverse unforeseen outcomes as the systems become functional on ships. The lack of operational data, including case studies on ammonia-related incidents, performance metrics for ammonia-fuelled systems, and safety protocol benchmarks, creates a significant gap in understanding and experience with ammonia as fuel.

The regulatory requirements are in their early stages but are being developed, with the "high-level goal based" interim guidelines for the use of ammonia as fuel onboard ships already approved [8], with a view to fully update the guidelines in future. It has been recognised, though, that further development will be required, especially technical details regarding the toxicity of ammonia, once experience in their use has been gained. Given the current lack of fully matured formal requirements for ammonia fuel, the approval process outlined in the IMO guideline MSC.1/Circular.1455 (*Guidelines for the Approval of Alternatives and Equivalents*)[12] should be followed. This necessitates to proactively identify and mitigate the operational risks through a risk-based approach (in accordance with appropriate international standards) rather than relying on a compliance route with formal regulatory requirements.

The practical and pragmatic approach of managing risk in an operational environment can be achieved through risk management i.e. proactive risk assessment, risk mitigation and continual improvement of the operational processes[13]. It is recommended to use risk management tools and methodologies, such as HAZID (Hazard Identification), HAZOP (Hazard and Operability Study), or bowtie analysis for identifying and mitigating risk associated with ammonia fuel handling. The measures that would be beneficial for safe operations when using ammonia as fuel could include:

- Identification of potential safety and environmental risks associated with the use of ammonia as fuel, including the toxic and corrosive properties of ammonia and its environmental impact, particularly on marine life.
- Development of operational procedures for operations involving ammonia as fuel based on assessment of known and anticipated risks, ensuring that ammonia's specific hazards are accounted for.
- Development of contingency plans for addressing unintended operational outcomes, such as ammonia leaks, spills, or combustion-related incidents.
- Proactive risk assessment and implementation of appropriate control measures to mitigate the identified risks prior to operations.
- Diligent reporting of non-conformities, accidents, and hazardous occurrences (including near-misses) noted by personnel in the operational procedures ensuring they are logged, analysed, and addressed appropriately.
- Continuous assessment of operational procedures and contingency plans, incorporating corrective actions and update protocols as required, based on reported gaps, incident reports and lessons learned.
- A scenario-based training for crew members to prepare for potential ammonia-related risks, including leak detection, spill management, and emergency response to ammonia-related incidents.

One key objective of the ISM Code is that all identified risks shall be assessed and mitigated with appropriate control measures put in place. Although the ISM Code is not applicable during the design phase, risk assessments should be conducted during the design and retrofit stages of the vessel. The risk management measures identified during the design phase should be integrated into the operational phase of the vessel's lifecycle, and updated regularly based on operational feedback.

Ammonia's inherent toxicity to both humans and marine life underscores the importance of implementing stringent risk controls at every phase of the vessel's lifecycle. The findings from the design/retrofit phase, particularly regarding safety measures, should be treated as living documents and must be transferred and accessible during the operational phase. These documents should also accompany the vessel if it changes ownership or company.

In addition to addressing risks identified during the design or retrofit stage, procedures should also consider any new operational risks that arise once the vessel is in service. The introduction of ammonia fuel represents new technology and will necessitate updated operational procedures, as well as a shift in organizational mindset and safety management practices.

The strength of the company's SMS lies in its ability to continuously improve the operational processes by proactively identifying any gaps through reporting, analysing and learning from non-conformities, accidents, and hazardous occurrences (including near-misses). It is recommended implementing digital tools for tracking and analysing trends in safety performance. These tools will allow for real-time monitoring of safety performance, improving the ability to identify areas of concern early and make adjustments to prevent unintended outcomes Agility in amending the processes and maintaining a strong safety culture throughout the organisation would show the strength of the SMS in preventing the recurrence of unintended outcomes. Until operational experience is gained within each organisation, the SMS can also consider learnings from additional sources of information, including risk evaluations from the design or retrofit stage, learnings from other companies or pilots.

The deployment of ammonia as fuel is expected on newbuilds as well as existing assets through suitable retrofits. During the early stages of this transition, it is likely that a fuel mix, including both ammonia and fossil fuels, will be used. This mixed-fuel approach should be incorporated into the SMS, with procedures specifically addressing the handling and operation of both fuels. As the industry evolves, the SMS should remain flexible and adaptable to accommodate these changes rapidly at all levels of management. Digital document control has become a widely accepted practice in safety management and will be crucial in managing changes as companies implement ammonia fuel on their vessels.

2. Safety and Environmental Protection Policy

The necessity to achieve high levels of safety remains unchanged; however, the use of ammonia as a marine fuel introduces specific risks, including high toxicity, flammability, and reactivity, that should be explicitly acknowledged within the Safety and Environmental Protection (SEP) policy as per ISM Code Section 1.2.2. This acknowledgment should reflect the unique hazards associated with ammonia and the specific measures required to address these challenges, ensuring that the policy remains robust, fit for purpose and responsive to ammonia's distinct safety and environmental risks.

Given the goal-based approach to designing and certifying ammonia-fuelled vessels, the SEP policy should emphasise continual improvement, such as continuous risk assessments, incorporating feedback from operational incidents and current best-practice. The policy should focus on actively reducing risk levels associated with the vessel's operation and ensuring that both onboard and shore-side personnel are adequately trained, equipped and prepared to manage these risks. The policy should prioritise a proactive approach to risk management, fostering a culture of safety, continuous learning and environmental responsibility across all operational levels.

On a tank to wake basis ammonia is a zero-carbon fuel, therefore produces no CO_2 emissions, but its use can result in emissions such as nitrogen oxides (NO_x) and nitrous oxide (N_2O). N_2O has an atmospheric lifespan of 114 years and a global warming potential of 265, when measured across a 100-year timespan[14]. Emissions of N_2O are currently regulated under EU ETS and FuelEU, with its release resulting in potential financial exposures. Both NO_x and N_2O may be monitored using Continuous Emissions Monitoring Systems (CEMS) and mitigated through technologies such as Selective Catalytic Reduction (SCR) systems. Furthermore, the company should be aware of the emissions associated with ammonia, from both its pilot fuel and any other fuels used onboard ships in the fleet[15].

On a well to tank basis, the production and the transportation of ammonia to a vessel needs to also be considered. Different production pathways of ammonia require differing amounts of energy, resulting in varying levels of CO_2 emissions. The SEP policy should consider the broader environmental impacts of ammonia as a fuel along with its overall emissions, as these emissions go beyond just carbon reduction and are integral to the overall environmental responsibility of the operation.

Ammonia's high toxicity presents significant hazards, and even a limited spill can result in toxic effects on human health and marine ecosystems. Therefore, the emergency response planning should prioritise the use of appropriate personal protective equipment (PPE), effective spill containment measures, and coordination with port state authorities.

Given ammonia's unique chemical properties, the response to ammonia spills and gaseous releases differs significantly from conventional oil-based spills. Ammonia's high toxicity, volatility, and vapour dispersion behaviour require specific procedural measures. These considerations are more akin to incidents involving liquefied natural gas (LNG) rather than conventional oil-based spills. The policy should acknowledge these distinctions and underscore the importance of developing detailed operational procedures for managing ammonia-related risks, including regular spill response simulations and safety drills to ensure crew readiness.

Integrating these considerations into the SEP policy can provide a solid foundation for effectively managing the complexities associated with ammonia-fuelled operations, ensuring that both safety and environmental protection remain at the forefront.

No.	Recommended Actions
1.	The company should update its policy to explicitly acknowledge the unique safety and environmental risks associated with ammonia as fuel and, therefore, stress the importance of adhering to the processes and procedures outlined in the SMS.
2.	The company should ensure environmental protection commitments with focus on minimising ammonia emissions during routine operations, bunkering, and emergencies, and establish and maintain robust spill response and emissions monitoring systems.
3.	The company should be aware of the emissions associated with ammonia and the other fuels used onboard.

3. Company Responsibilities and Authority

The ISM Code requires that companies develop, implement and maintain a SMS that includes the functional requirements listed in section 1.4 of the ISM Code. Active involvement and support from the company's shore based senior management are paramount in the development, implementation, and maintenance of a robust and adaptive SMS. The senior management should lead by ensuring comprehensive safety reviews, appropriate resource allocation, and robust risk management measures tailored to ammonia-fuelled operations. Given the potentially increased operational risk, senior management has a crucial role to play in the safe deployment of using ammonia as fuel within their fleet.

The company holds the overarching responsibility to ensure that processes and procedures within the system are fit for purpose throughout the vessel's lifecycle. This includes the development of comprehensive safety procedures, such as ammonia spill response plans, toxicity mitigation measures, and safety drills covering full range of ships and operational scenarios. While maintaining and implementing the existing SMS, the company should develop appropriate procedures through pilot programs, and close engagement with regulatory and industry stakeholders in anticipation of deployment of ammonia as fuel.

Moreover, a lifecycle approach should be adopted:

- Design/Retrofit Phase: Conduct detailed risk assessments during design or retrofit to anticipate operational hazards, with outcomes used to guide operational procedures.
- Operational Phase: Implement real-time risk monitoring, reporting mechanisms, and updates to address evolving risks.
- Decommissioning Phase: Establish protocols for handling residual ammonia and safely disposing of associated equipment.

These measures ensure that safety, environmental protection, and operational integrity are maintained throughout the vessel's service life.

Given the wide-ranging risks posed by ammonia to ship safety, crew welfare, and the environment, companies should adopt a proactive approach to monitoring and updating safety protocols. This entails addressing specific risks, such as ammonia's toxicity, reactivity, and unique spill behaviour, while staying abreast of industry developments and fostering a culture of continuous improvement. The SMS should be robust enough to streamline processes and procedures, ensuring the safe operation of all vessels in the company's fleet - whether they use ammonia exclusively, a fuel mix, or traditional fuels.

The company should ensure that the SMS has a clear description of roles and allocation of their responsibilities particularly for ammonia-specific tasks such as handling, storage, and emergency response. This prevents ambiguity in process execution, enhances accountability, and determines authority levels and interrelations among personnel. Aligning these roles with ISM Code Section 6.1 ensures the effective allocation of resources and personnel to manage operational risks.

In deploying ammonia as fuel to their fleet, the company's senior management should recognise that the importance of managing the elevated operational risks through comprehensive personnel training (which should be aligned with industry standards, in addition to relevant STCW requirements and IGF Code provisions for alternative fuels), awareness of personnel, and vetted processes is essential. Regular emergency response simulations, third-party audits, and continuous skill assessments are essential for maintaining high competence levels among crew and shore-side personnel.

The company should reassess applicable existing requirements and identify additional provisions (which may not be apparent at first glance) applicable to ammonia as a fuel. This includes revisiting MSC-MEPC.7/Circular.8[16] which provides basic principles for companies for developing and maintaining the SMS to the requirements outlined in the ISM Code. Incorporating industry best practices alongside these frameworks can help the SMS to adequately address the unique challenges posed by ammonia-fuelled operations.

Finally, the strength of the SMS lies in fostering a proactive culture of safety and environmental responsibility. The company should:

- Encourage diligent reporting of non-conformities, accidents, and near-misses.
- Regularly reassess the SMS through third-party audits and feedback loops.
- Implement regular emergency response simulations and training aligned with ammonia-specific risks.
- Use digital tools to track safety performance trends and enable rapid updates to safety protocols.

By continuously improving processes and promoting a safety-first mindset, the company can address operational challenges effectively.

Recommended actions that need to be taken by the company to ensure the adequacy of the SMS (under section 3 of the ISM Code), with a focus on ammonia as fuel are listed below:

No.	Recommended Actions
4.	A fit for purpose SMS should be developed and maintained for addressing the elevated operational risk from using ammonia as fuel.
5.	Adequate resources, which may be more or different with ammonia as fuel, should be provided to ensure safe operations and to execute contingency plans. These may also include port specific plans[16] or general shore-side resources and clearly defined lines of communication.
6.	Procedures should be developed to periodically review and evaluate the SMS, with a specific focus on processes involving ammonia as fuel.
7.	Procedures should be developed to analyse reports of non-conformities, observations, accidents and hazardous occurrences (including near-misses) in operation when using ammonia as fuel, and implement corrective and preventive actions.
8.	Procedures should be developed for carrying out internal audits ensuring that the audit process adequately captures the processes involving ammonia as fuel.

4. Designated Person(s)

The Designated Person (DP) plays a pivotal role in the facilitation of the development, implementation, maintenance, and continual improvement of a company's SMS. However, ammonia as fuel introduces unique safety and operational challenges due to its toxicity, corrosivity, flammability, and the lack of operational data. As such, the DP should also be equipped to address these unique challenges effectively, based on good understanding of ammonia-related operations, equipment and systems.

Moreover, the DP's role is critical in bridging the gap between onboard operations and shore-based management. For ammonia, which is highly toxic and corrosive, this role becomes even more pivotal. Therefore, the DP is responsible for actively promoting a culture of proactive risk management and continuous improvement tailored to ammonia-specific risks, ensuring ammonia-specific hazards are not only mitigated through SMS measures but also internalized by personnel at all operational levels.

This section provides two key recommendations for enhancing the DP's role in the safe adoption of ammonia as fuel, grounded in the ISM Code principles, MSC-MEPC.7/Circ.6[18], and the relevant industry guidelines.

To manage the risks associated with ammonia as fuel, the suitability criteria for the DP role should be expanded beyond traditional qualifications, training, and experience:

Qualifications

- The DP should have a comprehensive understanding of ammonia's key characteristics, including its physical and chemical properties, associated safety hazards, and operational considerations, to effectively oversee its safe use as a marine fuel.
- The qualifications of a DP should be as per the guidance provided in MSC-MEPC.7/Circ.6.
- Noting the emerging regulatory landscape for ammonia fuelled ships, the DP should have knowledge of emerging requirements and familiarity with industry pilot projects using ammonia as fuel, as well as familiarity with risk-based decision-making tools, such as Bowtie Analysis, HAZID, or HAZOP, specifically applied to ammonia operations.

Training

- Completion of specialised training on ammonia as fuel, covering safety management principles, emergency preparedness, and fuel system operations.
- In addition to the guidance on training provided in MSC-MEPC.7/Circ.6, DP training should align with industry recommended frameworks[19] and where relevant the International Convention on Standards of Training, Certification, and Watchkeeping (STCW).
- In addition, simulation-based training to build and enhance skills and knowledge with ammonia-specific scenarios, such as handling leaks, fires, or spills in operational contexts and training on ammonia bunkering procedures and ammonia's interaction with other fuels in mixed-fuel operations.

Experience

- The DP should have prior appropriate involvement in implementing SMS for ammonia or other alternative fuels.
- Having the knowledge or experience to implement a SMS to safely manage toxic fuel is beneficial.

To improve the role effectiveness of the DP, one of the important factors is to have clear lines of communications. This is essential for managing the complexities of ammonia as fuel. The SMS should clearly define communication protocols and ensure comprehensive documentation tailored to ammonia operations.

Internal Communication

- Establish direct and well-defined communication pathways between onboard personnel and the DP to address ammonia-specific concerns such as toxicity, flammability, corrosive nature, environmental risks, and the operational complexities of storage, handling and regulatory compliance.
- It is recommended that effective communication mechanisms are utilised between onboard personnel and the DP, leveraging digital tools or platforms for incident reporting and risk management.
- Lessons learnt from ammonia-related safety considerations to be included in regular crew meetings, safety drills and management meetings; with feedback linked into the company's continuous improvement process to refine the SMS.

Reporting to Management

- Enable the DP to report directly to top management with actionable insights on ammonia-related safety performance and incidents including but not limited to toxic exposure, leaks, fire hazards, material corrosion, and emergency response challenges.
- Include structured feedback mechanisms to refine SMS elements based on operational learnings and incidents.

The DP should engage in ongoing professional development by participating in industry collaborations, conferences, and working groups related to alternative fuels, ensuring up-to-date knowledge and sharing of best practices.

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Continuous Learning and Development

- The DP should integrate lessons learned from ammonia incidents across the industry into training and procedural updates.

Recommended actions that may be considered in expanding the role of the DP(s) for ammonia-fuelled ships are listed below:

No.	Recommended Actions
9.	Integrate ammonia-specific training and qualifications into the DP role, focusing on ammonia's risks (toxicity, corrosivity, storage and handling) and ensuring relevant experience or knowledge of ammonia-related operations, systems and components.
10.	Clear lines of communication to the DP for onboard personnel, and from the DP to the highest level of on-shore management should be developed, ensuring ammonia safety performance is monitored and communicated and timely actions are taken.
11.	Establish structured mechanisms for periodic reviews of ammonia-related safety performance, using digital dashboards and incident-tracking systems to provide actionable insights to management.
12.	Ensure the DP participates in industry-level alternative fuel working groups, staying updated on regulatory changes, incidents, and innovations related to ammonia.
13.	Facilitate regular simulation-based training for DPs and key personnel to address ammonia-specific emergency scenarios, improving preparedness and response effectiveness.

5. Master's Responsibility and Authority

Whilst the Master retains overall responsibility for onboard ammonia management as part of the vessel's safety management system, a 'person with immediate responsibility'[20] may be designated to oversee specific fuel-related operational tasks.

The Master has a critical role in ensuring the ongoing suitability and effectiveness of the SMS in managing ammonia-related risks. This includes conducting periodic reviews of the SMS to assess its performance in addressing the unique hazards associated with ammonia – such as toxicity, reactivity with any onboard elements, equipment/system issues, and spill behaviour –– and identifying and reporting any deficiencies or areas for improvement. Given the risk-based certification nature of ammonia fuelled vessels, this review process will require ongoing attention, particularly in relation to ammonia-related risks, procedures, and the effectiveness of safety measures. Continuous feedback and adaptation of the SMS are essential to ensure it remains responsive to evolving operational and risk management needs, incorporating lessons learned from operations and incidents.

Crew members must be encouraged to proactively report unsafe conditions and participate in continuous improvement efforts.

Building a robust safety culture onboard is essential for managing ammonia as fuel, with the Master playing a key role in fostering awareness and engagement from all crew members. The Master should conduct regular safety meetings, toolbox talks and training sessions to ensure that all crew members understand ammonia-specific risks and their individual responsibilities in managing ammonia risks and preventing accidents. The safety culture onboard should encourage proactive reporting of unsafe conditions and foster continuous improvement. The Master should ensure that all personnel are informed about the hazardous nature of ammonia and equipped to take preventive actions. This includes empowering[21] crew members to respond effectively to emergencies and ensuring they are fully aware of the operational and safety protocols associated with ammonia handling.

Recommended actions that may be considered in re-evaluating the role of the Master within the SMS when ammonia is to be used as fuel on board are listed below:

No.	Recommended Actions
14.	The SMS should define the responsibility and authority of the Master in relation to the management of ammonia onboard, delegating specific duties to certified personnel[19].
15.	Procedures to be developed for the periodical review and evaluation of the SMS by the Master, with a specific focus on processes involving ammonia as fuel to ensure that operational aspects for ammonia are covered within the review.

6. Resources and Personnel

The current regulatory framework, while addressing alternative and/or equivalent design approvals through MSC.1/Circular.1455, does not extend to an equivalent alternative training approval process within STCW to address the specific needs of ammonia-fuelled ships. Although the IMO (in the HTW Sub-Committee) has a plan to develop training provisions for seafarers on ammonia fuelled ships, currently there are limited international standards[22] to establish robust standardised training protocols for ammonia handling operations.

Nonetheless, companies must ensure that all ship's personnel* receive adequate training and familiarisation. This should align with ISM Code requirements and exceed basic STCW standards as necessary, depending on the ship's operational profile and the identified risks. Training should be tailored to the ship-specific equipment and operational scenarios associated with ammonia. In any case, all ship's personnel* and shore-side personnel should have awareness of the risks associated with ammonia.

Considering the novel nature of the technologies that may be involved for safe deployment of ammonia as fuel, the company may consider consulting all relevant stakeholders such as OEMs in providing specific training to personnel. Furthermore, Competence programmes[22] can facilitate the assessment of competence gaps, following which steps can be taken to address the identified gaps.

The ship crew should have the competence, training and familiarisation to:

- Understand ammonia-specific operations: Understand the nature of operations associated with equipment specific to the use of ammonia as fuel and the differences from traditional fossil fuel-operated equipment.
- Identify operational risks: Understand the operational risks in terms of equipment damage and hazards related to ammonia, including human exposure and environmental impact from ammonia-fuelled equipment.
- Perform critical tasks: Perform operational, maintenance and inspection duties on ammonia-fuelled equipment with a focus in safety and efficiency, and appropriate response in case of emergencies.

The personnel training associated with ammonia as fuel should cover hazardous material handling protocols, specifically focusing on the anticipated behaviour of ammonia in case of leaks, spills, and vapour dispersion under different environmental conditions, including the selection and use of appropriate PPE.

The training should be based on various scenarios that could have an immediate impact to ship personnel and surrounding areas due to the rapid dispersion of ammonia[23]. These scenarios should consider the type and design of the vessel and may include bunkering near other vessels or at a terminal, leakage detection, and emergency evacuation of personnel from high-risk areas.

Specific tasks may be designated to 'person with immediate responsibility'. This individual should have decision-making capacity, the necessary competence in ammonia fuel handling and emergency response and operational oversight of tasks such as ammonia system monitoring, storage, and maintenance, as well as emergency management duties. Additional specific tasks may be delegated to certified personnel due to the hazardous nature of ammonia.

The training for deck and engine crew should be tailored as appropriate to focus on their specific responsibilities and address the distinct operational hazards associated with ammonia. For example: Deck crew training should focus on bunkering operations, leak detection, and emergency protocols. Engine crew training should emphasise system integrity, maintenance of ammonia fuel systems, operational readiness and emergency protocols[22].

*Ship's personnel: includes deck crew, engine crew and all support staff onboard.

The consideration of Human element[2] in operational safety is essential too; Companies must proactively address any unintentional mishandling during operations by putting preventive actions in place to eliminate human errors and emphasising:

- Regular drills and refresher courses to maintain familiarity with ammonia systems and emergency procedures.
- Risk-minimization protocols, such as reducing personnel presence in ammonia-related spaces whenever possible.
- Clear communication protocols during normal operations and emergencies.

Recommended actions for appropriate resources and planning to safely manage the operations onboard ships with ammonia as fuels are listed below:

No.	Recommended Actions
16.	Identify gaps in the competencies for personnel outlining required certification, training and experience. Gap assessments and follow ups can be conducted based on competence programmes.
17.	Training procedures should be identified and implemented for personnel on hazards and risks associated with use of ammonia as fuel onboard, and contingency plans for dealing with toxic and hazardous situations. Certification of Basic or advanced training should be provided based on the role and responsibilities associated with using ammonia as fuel, including any assigned roles and responsibilities in case of emergencies [22].
18.	Procedures for familiarisation of personnel on risks associated with ammonia and the relevant equipment should be developed. An aim in the procedures should be to minimise any personnel presence within the spaces that have equipment associated with ammonia.
19.	Implement comprehensive training programs to certify maintenance personnel in ammonia system handling, focusing on properties, risks, and mitigation measures.
20.	Assess the need for additional personnel during ammonia fuelling operations and other critical operations to ensure safe handling and compliance with operational protocols.

7. Shipboard Operations

The shipboard operations associated with ammonia as fuel will need to have documented procedures for the transfer, storage and handling, operation, and maintenance to minimise the risk to the ship, personnel and the environment. Such procedures should explicitly address ammonia's high toxicity, potential corrosiveness, and the need for specialized PPE and emergency protocols.

Due to the use of novel technology, there is limited operational data from the maritime industry to develop robust operational procedures when using ammonia as fuel. However there are procedures that exist in the shore-based ammonia industry, where relevant lessons can be learnt from. This limitation along with the absence of mature regulations and other safety standards in the maritime industry, the procedures will need to be guided by the requirements in the IMO guideline MSC.1/Circular.1455 and any relevant industry guidelines and best-practice associated with ammonia that are available. Additionally, the company should monitor evolving industry practices and incorporate lessons learned from pilot projects or early adopters of ammonia as fuel.

Some of the existing standards and industry guidelines in place associated with ammonia that could be referred to are listed below. Furthermore, for ammonia's similar characteristics with other fuels, it can be beneficial to be guided by relevant part of requirements for established fuels such as LNG when developing operational procedures and contingency plans. These together can inform the development of operational procedures associated with ammonia as fuel.

Although these publications are for cargo transfer systems, some aspects would be relevant to fuel transfer systems:

- Tanker Safety Guide (Liquefied Gas) 4th Edition [24]: The guide provides industry guidance to support gas carrier operators conduct safe and efficient operations.
- Guidelines for the Alleviation of Excessive Surge Pressures on ESD for Liquefied Gas Transfer Systems [25]: This guideline explains the concept of surge pressure and provides practical advice on its associated hazards and risk management.

The following industry guidelines may be used for the handling of ammonia and developing the operational procedures for ammonia as fuel:

- Ammonia – Safety and Operational Guidelines – Bunkering [26]
- Methanol – Safety and Operational Guidelines – Bunkering [27]
- EMSA NH3SAFE Part 1 – Ammonia properties, regulations and accidents review
- EMSA NH3SAFE Part 2 – Safety assessment and reliability analysis of main components, equipment, sub-systems and systems.
- ISO 5771:2024 Rubber hoses and hose assemblies for transferring anhydrous ammonia — Specification.
- Recommendations for a Competency Framework Ensuring Safe Ammonia Bunkering Operations from the "Global Centre for Maritime Decarbonisation' (GCMD)[28].

The ammonia bunkering operational procedure should be customised for each ship, taking into account its distinct design and arrangement, technology, bunkering operations, and trade. The procedure should consider four key stages: planning, pre-transfer, transfer, and post-transfer:

- Planning Stage: Risk and compatibility assessment, regulatory approval, confirm schedule and location, Simultaneous Operations (SIMOPS) assessment
- Pre-transfer Stage: Safety checks, inspect bunkering systems, mooring and access setup, system connection and leak test
- Transfer Stage: Periodic checks, vapour management, ammonia flow control, topping off and ballasting
- Post-transfer Stage: Drain and purge lines, disconnect systems and cables, post-transfer meeting, access removal, unmooring departure.

While the ISM Code does not specify any specific approach in managing risks on board ships, it is for the company to decide on the methods that are most suitable in assessing risks within the context of the company. ISO 31000:2018 [13] can prove beneficial in carrying out a structured identification, analysis and evaluation of the risks associated with alternative fuels. Companies should ensure these risk assessments are frequently revisited and updated as operational experience with ammonia grows.

The hazardous area and toxic area assessments should be done to establish the safety boundaries for ammonia bunkering operations, identifying potential risks and implementing control measures to reduce them. This involves zoning and classifying hazardous areas based on ammonia concentrations, similar to SGMF's BASiL (Bunkering Area Safety information LNG) approach used in LNG bunkering[29].

It is to be noted that toxic areas should be carefully considered, which may cover a larger area than the identified hazardous areas[23]. These toxic areas would have been identified in the design stage, utilising the prescriptive requirements and the results from the gas dispersion analysis.

Consideration should be given to safely handle and responsibly dispose ammonia effluent that is generated onboard ammonia fuelled ships, mainly from ammonia gas abatement systems (where provided).

The hazardous zones (primarily associated to explosion or fire risk) and toxic zones (primarily associated with toxicity exposure risk) include areas with potential toxic, combustible, or explosive atmospheres, necessitating strict safety measures. During ammonia bunkering, a defined safety zone should be established around high-risk areas, with access restricted to trained personnel. A monitoring zone provides additional safety, with emergency response protocols in place. The outer zone informs the public of potential releases and appropriate actions to prevent panic.

The risk assessment for the bunkering operation should address potential risks to both personnel and the environment. The assessment should mitigate risks where applicable and inform the appropriate safety, security and toxic zones around the operation, based on transfer configurations and bunker modes. The assessment should cover key aspects, including preparations before and during the ship's arrival, approach, and mooring; the preparation, testing, and connection of equipment; the ammonia transfer process; boil-off gas (BOG) management; the completion of the bunkering and disconnection of equipment; and Simultaneous Operations (SIMOPS), if applicable.

Management of Change (MOC)
Where ammonia is used as fuel and there is a modification(s) introduced to equipment/system, procedures or personnel, the MOC process should form an integral part of the shipboard procedures and include but not be limited to the following items:

- A risk assessment is conducted in the planning phase of the modification which addresses the full range of hazards and consequences of the implementation of ammonia as fuel.
- The MOC identifies all personnel involved or affected by the change.
- The MOC identifies the training needs arising from the implementation of ammonia as fuel for both shipboard and office personnel.
- The MOC identifies all procedures, documentation, records, manuals, drawings and templates that need to be updated. This includes notifying the relevant authorities (Ship's Flag, Classification Society(s) etc.) and stakeholders.
- Any change in technology should undergo thorough evaluation.
- Any change in Regulatory Compliance either by introduction of new Regulations or by application of local requirements should undergo a review to identify deviations from the original risk assessment.
- Effective communication and coordination among all stakeholders is essential, keeping the impacted parties updated on the resulting changes.
- Key aspects include evaluating equipment changes, reviewing operational protocols, updating emergency response plans, ensuring environmental compliance, and conducting comprehensive risk assessments.

Competence requirements[22] can be utilised as a reference to scope out and describe the content of the handling manual.

Risk Assessment of hazards associated with storage and handling of ammonia:
The risk assessment should be able to identify and assess hazards related to storage and handling of ammonia fuel including spills, fire, explosion, and toxicity. Control measures should be implemented to lower the associated risk to acceptable levels.

The risk assessment should cover all critical aspects of ammonia bunkering and fuel handling including preparation to prior bunkering, mooring procedures, testing of equipment, connection of ammonia transfer systems, ammonia transfer process, management of BOG, completion of ammonia transfer, safe disconnection of transfer equipment, SIMOPS, fuel changeover in normal operation and emergency.

Due to the toxic effects from exposure to ammonia; minimising, monitoring, and controlling access to, and length of time spent in, spaces containing equipment associated with ammonia should be considered.

No.	Recommended Actions
21.	The company should use gas dispersion analysis results to ensure that unacceptable ammonia concentrations do not reach selected sensitive spaces, such as air inlets into accommodations, control stations and other non-toxic spaces or areas. This is in addition to the prescriptive toxic area and space classifications on the ship.
22.	An ammonia fuel handling manual should be developed covering roles and responsibilities, pre-bunkering and bunkering procedures, tank pressure and temperature management, SIMOPS, emergency response and contingency plans.
23.	The introduction of ammonia as fuel should be accompanied by a MOC procedure that identifies all personnel, procedures, documentation, regulations, training requirements and vessel systems that are affected by the change. A plan to mitigate the identified risks should be followed to ensure the safe implementation of ammonia as fuel.
24.	All risk assessment procedures should be updated to consider the hazards deriving from the use of ammonia as fuel.
25.	Both the fuel handling manual and the risk assessment covering shipboard operations should be specific for each vessel and system arrangement.
26.	Safe management of ammonia effluent that is generated onboard from ammonia gas abatement systems (where provided) should be considered.
27.	To improve response times for anticipated situations and the effectiveness of the training procedures, training drills simulating the anticipated scenarios should be carried out helping to familiarise and train the personnel to deal with toxic and hazardous situations associated with ammonia.

8. Emergency Preparedness

Emergency preparedness is critical for ammonia-fuelled ships due to the toxic and hazardous nature of ammonia. While robust design and operational controls can mitigate many risks, it is essential to have comprehensive emergency response measures to manage residual risks effectively and minimize harm to the ship, crew, and environment.

The SMS should identify and prepare for potential emergency shipboard situations associated with ammonia; these may include, but are not limited to:

- Release of toxic liquid or vapour
- Spill or leakage of hazardous substances due to hose or structural failure
- Structural damage to fuel tanks
- Mooring line failure
- Communication failure
- Blackout
- Ship collision or grounding
- Fender burst
- Fire management (internal and external)
- Fire involving ammonia or related systems
- Exposure-related incidents, including cold burns
- Overpressure in tanks or piping systems
- Overfilling of fuel tanks
- Ammonia leakage within the engine room or accommodation spaces
- Exhaust system explosion caused by unburned ammonia
- Activation of Emergency Shutdown Systems (protocols such as ESD-1/ESD-2)

To effectively manage such scenarios, the SMS should incorporate detailed response procedures, tailored to ammonia-specific risks, including but not limited to:

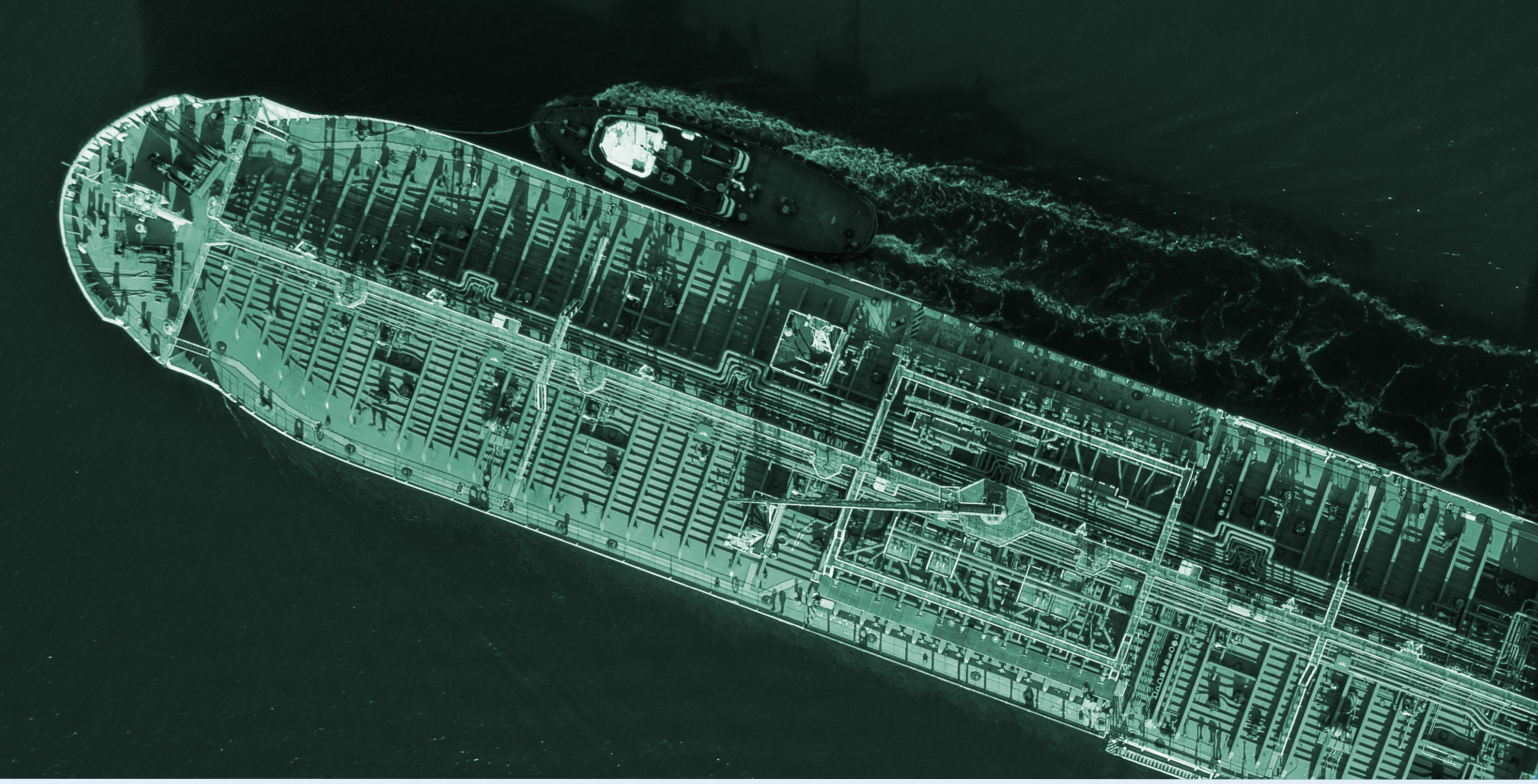
- **Ammonia Spill Response:** Establish immediate evacuation protocols for affected areas. Develop spill containment and neutralization strategies using ammonia-specific agents.
- **Incident Reporting Protocols:** Define clear protocols for reporting ammonia-related incidents with 24/7 communication channels for internal and external emergency responders.
- **Leak Containment:** Outline procedures for isolating and mitigating ammonia leaks using dispersion modelling tools to predict vapour spread and identify safe zones.
- **First Aid for Exposure:** Protocols should include flushing affected areas with water for 15 minutes and seeking medical attention promptly, when in port.
- **Emergency Contacts:** For each port maintain an updated list of medical facilities and poison control centres for swift communication.
- **Emergency Shutdown System (ESDS)**: Regularly test and integrate ESD systems into response drills to ensure rapid and coordinated system shutdown during emergencies. Also test ESDS prior to ammonia fuel transfer to halt operations in emergencies.
- **Ship-to-Ship Bunkering Communication**: Establish protocols for radio, signalling, and emergency procedures.
- **PPE Training**: Train personnel on proper selection use and maintenance of PPE.
- **Fire handling**: Establish procedures, for fire detection, isolation and suppression using extinguishing systems provided.
- **Crew Training**: Offer training on emergency preparedness, equipment familiarization, and fuel handling scenarios, including simulations.

- **Emergency Drills and Exercises**: Conduct regular drills and exercises simulating ammonia-related scenarios, in their established programme, to evaluate response procedures, for leak detection and containment, spill management, firefighting and emergency evacuation scenarios. Consider including coordination with port authorities and shore-based responders to practice aligning ship and onshore emergency services.
- **Port Collaboration**: Collaborate with port authorities to align emergency plans and ensure resource availability, such as specialized response equipment or personnel.
- **Emergency Plan Updates**: Regularly review and update plans based on operational experience, incidents, technological advancements and regulatory changes.
- **Safety Equipment Checks**: Periodically inspect and maintain gas detectors, ventilation systems, and other equipment, including PPE for ammonia handling.
- **Emergency Kit Inventory**: Maintain kits with neutralizing agents and protective suits for ammonia incidents.
- **Ammonia Properties Training**: Educate personnel on ammonia’s toxicity and flammability.
- **Onboard Walkthroughs**: Highlight safety systems and emergency exits specific to ammonia.
- **Ammonia Equipment Training**: Provide detailed instructions for storage tanks and fuel supply systems.
- **First Aid Training**: Educate crew on measures for eye and skin irrigation and managing inhalation injuries.
- **Chain of Command**: Define roles and responsibilities for ammonia emergencies.
- **Company-Level Response**: Incorporate remote guidance and external expertise into emergency procedures.
- **Incident Reporting and Feedback**: Create mechanisms to document drills and actual incidents, gathering crew insights.
- **Continuous Improvement**: Analyse drills outcomes, incidents, and near-misses to refine procedures, identify additional training needs and ensure plans remain effective and relevant. Keep records of procedural enhancements based on feedback and incident analysis.
- **Monitoring and Alert Systems**: Integrate advanced monitoring systems into emergency procedures to detect leaks, overpressure, or operational anomalies in real time, reducing response times.

As part of the emergency response planning the company should incorporate the results from the plume dispersion analysis conducted during the design phase. The dispersion analysis results will enable the company to identify the locations on board ships where ammonia could pool, allowing for safety and mitigation measures to be deployed accordingly. Utilising the results from the plume dispersion model would also enable the ship’s crew and external emergency responders to understand the possible locations that could be dangerous and identify the safe zones and muster points on board ships.

Using the established safe refuge /haven locations to muster will allow the effective zoning within the vessel in an ammonia leak scenario so that ship emergency response coordination with shore-side entities can be executed. The hazardous zones should be clearly demarcated and monitoring and alert systems integrated to enforce restricted access during emergencies. Port authorities would need clear information of the situation onboard ship during the emergency, as the situation emerges. Hence, the ship command team needs to be in a controlled environment to relay the information for coordination.

The operational procedures should ensure that monitoring and alert systems are integrated with emergency response procedures to reduce response time during emergencies. IMO Resolution A.1072(28) [30] provides guidelines to assist in the preparation of an integrated system for shipboard emergencies and will be particularly beneficial in integrating the assessed emergency preparedness with other established procedures.



Recommended actions that may ensure safe emergency preparedness for ships using ammonia as fuel are listed below:

No.	Recommended Actions
28.	The company should develop detailed ammonia-specific response procedures tailored to each foreseeable potential emergency. These protocols should include immediate crew actions, equipment usage, containment methods, and escalation plans to ensure rapid and effective mitigation of hazards. The emergency response procedures should incorporate the results from gas dispersion analysis.
29.	The company should ensure that the SMS incorporates procedures for real-time monitoring of critical areas (e.g., fuel tanks, piping, exhaust systems) and establishes clear actions for responding to system alerts, such as leaks or overpressure conditions. These procedures should ensure that monitoring and alert systems are integrated with emergency response procedures to reduce response time during emergencies.
30.	Emergency drills and exercises, which may incorporate reported incidents and near-misses, should involve shipboard teams and, when relevant, shore personnel and external stakeholders. The company should ensure it is prepared to respond effectively and coordinate with external parties during emergencies.
31.	The company should take into account the external government agencies that could be involved in large scale emergency events in addition to the coastal states when considering emergency plans for coordination.

9. Reports and Analysis of Non-conformities, Accidents and Hazardous Occurrences

The company SMS should include procedures for reporting and investigation of all non-conformities, incidents, accidents and hazardous occurrences including any safeguard failures related to ammonia handling and storage. It should have a broader spectrum of what a reportable incident is, considering the lack of experience in the industry, to include any ammonia-related events (e.g., small leaks, near misses, equipment malfunctions) that could pose a hazard if repeated.

The reporting framework should be adapted to capture ammonia-specific data, such as release location, duration, activation of Ammonia Release Mitigation Systems (ARMS), and environmental factors. Additional fields for toxicity, gas dispersion, material incompatibility, and other ammonia-related risks may be included to ensure thorough documentation. Incident types such as fuel leaks, equipment failures, and operational errors should be clearly defined with unambiguous reporting criteria, ensuring consistent documentation of all relevant events. These enhancements will facilitate better risk analysis and management.

While roles for incident reporting are typically outlined in the SMS, they should explicitly address ammonia-related incidents. Responsibilities must be clearly defined, and individuals completing reports should possess the technical knowledge to provide accurate and relevant information for effective analysis and follow-up.

Relevant incidents should be sent as notifications to Flag State, Port State, Classification Society, Qualified Individual and industry stakeholders, where appropriate related to ammonia handling so that the operational experience is shared and for benchmarking purposes. Notifications should include essential information (anonymised, if needed), such as the nature of the incident, affected systems, and the role of crew involved to facilitate broader learning and industry-wide improvement.

Analyses of the company incidents is crucial to identifying areas of improvement in terms of procedures, training, culture or technology. An action plan should be formulated based on this analysis to improve the company's HSSE performance related to the use of ammonia as fuel. Ammonia incident investigations require expertise in ammonia safety and must address unique risks like toxic exposure and flammability. Investigations should prioritise identifying root causes, gathering data on ammonia concentrations, pressure, temperature, and safety system performance, and documenting findings clearly. Sharing these findings will support ongoing safety improvements.

Ammonia's inherent toxicity and corrosiveness necessitates safety management to protect human health, vessels, and the environment with prompt reporting and analysis of incidents involving ammonia release. The following should be taken into account when investigating ammonia incidents:

Reporting Framework

- Establish a systematic process for reporting all ammonia-related non-conformities, accidents, and hazardous occurrences, including near-misses.
- Define reporting timelines and designate responsible persons for initiating and escalating reports and monitoring follow up actions.
- Include ammonia-specific risks, such as toxicity, gas dispersion, and material incompatibility, in reporting templates.
- The reporting should facilitate the identification of potential safety gaps and the implementation of corrective and/or preventive measures.
- Encourage active participation from the crew in reporting observations, near misses, and potential improvements related to ammonia operations

Feedback Process

- Integrate an effective feedback loop within the SMS to ensure timely analysis of reports from shipboard operations.
- Provide shipboard personnel with a structured mechanism to submit feedback on ammonia-related incidents or procedures.

Comprehensive Investigations

- Ensure investigations for ammonia-related incidents consider the fuel's unique properties, such as high toxicity, reactivity, and low flammability.
- Include root cause analysis methodologies specific to ammonia storage, handling, and usage systems.
- Use risk matrices to assess the severity and probability of recurrence for ammonia-specific hazards.
- The detailed investigation should aid in understanding the specific challenges posed by ammonia fuel and in developing targeted preventive strategies.

Data-Driven Analysis

- Collect and analyse data from reported incidents and maintain a centralised database of ammonia-related non-conformities and hazardous occurrences to identify trends, recurring issues and potential systemic failures in ammonia operations and to inform future risk assessments.
- Compare findings against established safety benchmarks for alternative fuels.

Procedure Updates

- Regularly update SMS procedures and contingency plans based on investigation findings and operational data from ammonia-fuelled operations.
- Develop contingency plans for newly identified risks associated with ammonia usage, ensuring alignment with the ISM Code requirements.
- Analysing incident data helps identify patterns or recurring issues associated with ammonia fuel usage. This analysis will help for refining safety protocols and enhancing overall operational safety.

Preventive Measures

- Introduce specific training modules addressing identified skill or knowledge gaps in ammonia handling and emergency preparedness.
- Enhance onboard and company-level safety practices, such as installing improved ammonia detection systems or updating PPE requirements.
- Develop targeted preventive strategies for newly identified ammonia-related risks.

Learning from Experience

- Use lessons learned from non-conformities, accidents, and hazardous occurrences to refine operational practices continuously.
- Share findings with an intent to apply corrective measures to all vessels in the fleet, thereby promoting a unified and consistent safety culture for ammonia operations.
- Encourage a culture of learning from experience by disseminating analysis and improvement actions throughout the company.

Adaptive Approach

- Allow SMS flexibility to incorporate operational data and industry best practices as ammonia-fuelled operations mature.
- Periodically review the SMS effectiveness in managing ammonia-specific risks and update it as necessary to maintain operational excellence.

In line with risk-based certification, incidents should be assessed against original design acceptance criteria to validate the safety philosophy. Corrective actions should address root causes, whether they are technical, procedural, or human-related factors, and focus on enhancing safety systems, procedures, or equipment.

To ensure effectiveness, corrective actions should be reviewed to confirm their success in preventing recurrence. This continuous improvement approach is critical for adapting to ammonia-related operational challenges. As part of the continuous improvement process any identified corrective actions should be applied to all fleet vessels sharing the same or similar systems.

Recommended actions associated with ammonia as fuel that may be considered relevant to section 9 of the ISM Code are listed below:

No.	Recommended Actions
32.	Establish a comprehensive ammonia-specific incident reporting and analysis framework. This should include clear reporting timelines, designated personnel, escalation protocols, and procedures to ensure the comprehensive capture of all relevant details.
33.	Clearly define roles and responsibilities for reporting ammonia incidents to ensure accountability and prompt action.
34.	Ensure that at least one key individual involved in incident investigations or near-miss analyses is trained in ammonia handling to provide specialised expertise during incident or near-miss analyses.
35.	Enhance investigation processes to account for ammonia-specific factors and ensure thorough analysis of incidents, using data-driven methods. Share findings across the fleet and with industry stakeholders to promote broader safety improvements.
36.	Ensure corrective actions address the root causes of ammonia-related incidents and are implemented effectively and in a timely manner.
37.	Effective feedback process[31] within the SMS should be included to track near-misses and incidents related to ammonia storage and handling, enabling the acceleration of hazard identification and operational learning.

10. Maintenance of the Ship and Equipment

The Company should utilise a PMS that includes all systems and components related to ammonia handling and the associated spare parts inventory management. Reporting of defects should be in place for all components related to ammonia handling to ensure that the root cause of each failure is identified and appropriate corrective actions are implemented to prevent recurrence.

Due to the toxic effects from exposure to ammonia; minimising, monitoring, and controlling access to, and length of time spent, in spaces containing equipment associated with ammonia should be considered.

Procedures should be in place to confirm that maintenance of ammonia related equipment is conducted strictly in accordance with manufacturer's recommendations and instructions, which should be verified during shore-side personnel visits and internal audits.

A critical equipment list should be identified for the ammonia storage and handling systems and the planned maintenance system as well as the spare parts inventory requirements should take it into consideration. Procedures should be in place for testing of critical equipment which is not continually in use. The company is to be promptly notified when critical equipment is out of operation for maintenance or due to failure. A risk assessment and management approval process should be in place when critical equipment requires to be out of operation for maintenance.

In conjunction with manufacturer's maintenance recommendations, the company should utilise condition–based monitoring methods for the ammonia related equipment to be able to assess the operational condition of each piece of equipment and proceed with proactive maintenance. These approaches help timely detect early signs of corrosion, leaks, or wear in ammonia-exposed parts.

Designated personnel should be responsible for specific maintenance tasks of ammonia related equipment. The personnel responsible for such tasks should have the appropriate skills and training to perform them safely.

All maintenance instructions as well as the associated risk assessments, toolbox meetings and work permits should clearly address the toxic nature of ammonia and should include safety considerations for ammonia handling, including ammonia effluent.

1.1 Incorporating Ammonia-Specific Requirements

- Develop maintenance procedures tailored to equipment used for the handling, storage, and utilization of ammonia fuel.
- Perform additional checks and inspections for components exposed to ammonia, focusing on corrosion, material compatibility, and wear.

1.2 Periodic Inspections and Testing

- Establish regular inspection schedules for ammonia storage tanks, fuel supply systems, piping, and valves.
- Double-walled pipes are essential for safely handling ammonia, with the inner pipe carrying ammonia and the outer pipe serving as a secondary containment barrier. The interstitial space is ventilated and equipped with sensors to promptly detect leaks, ensuring safety. To maintain reliability, these sensors should be regularly calibrated using certified calibration gas[32].
- Test ventilation and emergency shutdown systems periodically to confirm operational readiness.
- Perform regular ultrasonic thickness gauging on pipes and valves to detect corrosion or material thinning.

1.3 Integration with OEM and Industry Recommendations

- Follow Original Equipment Manufacturer (OEM) guidelines for maintenance intervals and processes for ammonia-specific equipment.
- Use manufacturer-approved ammonia-resistant materials (e.g., stainless steel or nickel alloys) for all replacements.
- Incorporate recommendations from industry standards and classification societies to address evolving best practices for ammonia as fuel.
- Utilize ammonia-compatible gaskets and packing materials to maintain long-term sealing effectiveness.

2. Critical Equipment Identification

- Identify and document critical equipment and systems related to ammonia handling, storage, and fuel utilization.
- Maintain an inventory of spare parts for critical systems, including ammonia-compatible materials and seals.
- Assign priority levels to critical equipment within the Planned Maintenance System (PMS) based on risk assessments and operational significance.

3. Safety and Competence in Maintenance

- Embed ammonia handling safety procedures into the maintenance plans, ensuring alignment with emergency preparedness protocols.
- Include specific guidelines for decontamination and safe disposal of ammonia-contaminated materials during maintenance.
- Define levels of competence required for performing maintenance on ammonia-related systems within the PMS.
- Ensure senior personnel supervise critical tasks, such as valve replacements, fuel system repairs, and sensor calibrations.
- Perform periodic leak tests using calibrated gas detection equipment with appropriate test gases to ensure system integrity.
- Inspect flanges and joints during routine inspections to identify and address potential leaks.
- Apply ammonia-compatible lubricants to valve stems and moving parts to avoid seizing or operational issues.
- Conduct thorough external and internal inspections of fuel tanks during scheduled maintenance and dry dock intervals.

4. Human Element Consideration

- Train maintenance personnel on ammonia properties, including its toxicity, reactivity, and material compatibility issues.
- Provide certification for personnel handling maintenance of ammonia systems, aligned with IGF Code requirements and industry standards, as appropriate.
- Equip personnel with proper Personal Protective Equipment (PPE) suitable for ammonia exposure.
- Establish emergency protocols for accidental releases during maintenance, including isolation and ventilation procedures.

5. Continuous Improvement and Feedback

- Use feedback from inspections and maintenance activities to refine procedures for ammonia equipment.
- Implement changes in the PMS based on learnings from near-misses, incidents, and evolving regulatory guidance.
- Lessons learnt from experience and continuous improvements should be communicated (information anonymised, if needed) to the relevant industry stakeholders, including equipment manufacturers forming the feedback loop.
- Periodically review and update maintenance procedures to reflect advancements in ammonia handling technologies and best practices.

No.	Recommended Actions
38.	Develop and integrate detailed maintenance procedures for ammonia-related equipment, ensuring alignment with OEM guidelines and industry best practices. Establish a robust inspection and testing program that includes regular checks for corrosion, material compatibility, and leak detection using calibrated ammonia-specific systems.
39.	Incorporate emergency response protocols into maintenance plans, equipping personnel with ammonia-compatible PPE and conducting periodic drills for accidental releases during maintenance tasks.
40.	The company should identify the components of the ammonia handling and storage systems that should be considered as critical and apply the appropriate procedures in terms of maintenance and spare parts inventory.
41.	Shore-side based personnel visiting the vessel(s) should confirm that ammonia related equipment is maintained as per manufacturer's recommendations, while condition-based monitoring methods are implemented for predictive maintenance.
42.	Personnel, both on the ship and shore-side, responsible for maintaining ammonia-related equipment should receive specialised training covering ammonia's toxicity, corrosiveness, and emergency response. It is also important to consider periodic refresher/updated training.
43.	The company should develop templates for the relevant risk assessments, permits to work and toolbox meetings relevant to the maintenance of ammonia handling and storage equipment in such manner that all ammonia hazards are addressed.

11. Documentation

The implementation of ammonia as fuel should be accompanied by a Management of Change (MOC) which should identify all documentation that will need to be either updated or created from scratch to cover the use of ammonia as fuel. Such documents include the certification of equipment and vessel, procedures that cover all aspects of ammonia handling and storage, training of crew and shore-side personnel, operational records, checklists, data sheets and logs related to ammonia, as well as the regulatory framework applicable to ammonia.

The company should have a procedure to ensure that all documents remain relevant and up to date especially as recommendations and requirements related to ammonia are being developed in the industry.

In conjunction with the incidents and near–misses reporting and analysis, the SMS procedures covering the use of ammonia as fuel should be regularly updated to include the preventive actions identified in the investigation analyses. The same applies to industry recommendations and best practices coming, as other stakeholders share their operational experience from using ammonia as fuel. Benchmarking can also be used to identify improvements to the SMS against other industry stakeholders. Ship personnel involved in ammonia handling should be encouraged to review the relevant procedures and contribute to each revision, fostering a stronger safety culture and sense of ownership.

The operational procedures should be vessel-specific, reflecting the characteristics of each fuel system and distinguishing between ammonia-fuelled and conventional fossil-fuelled ships to prevent any procedural ambiguities that could compromise safety or efficiency.

Maintaining up-to-date documentation is critical, given the evolving regulatory landscape for ammonia as fuel. The interim guidelines for the use of ammonia as fuel onboard vessels were approved in December 2024, with a view to update the guidelines in future; highlighting the need for continuous monitoring of regulatory changes to ensure compliance.

Furthermore, the complexity of ammonia-fuelled systems requires detailed records of system designs, safety assessments, and crew training programs. This level of detail in documentation supports effective risk management and facilitates regulatory compliance.

Regular audits should be conducted to remove any obsolete documents, and replace them with revised versions, ensuring that only current and relevant information guides ship operations.

Operational records should be developed to cover the monitoring of all ammonia-related equipment as per manufacturer's recommendations and design. Experience from ammonia handling as cargo would be beneficial when developing these records, as it can provide practical insights into safe and efficient management of ammonia systems. When developing the operational records, the company where possible should streamline the record keeping to minimise undue effect on the ship personnel

No.	Recommended Actions
44.	A MOC list should be maintained that will identify all documentation that needs to be updated or created to cover the implementation of ammonia as fuel. Consultation from equipment manufacturers and the experience of ammonia handling as cargo are beneficial when developing the relevant documentation.
45.	Effective document control and updated information should be available, and obsolete documents should be removed to maintain clarity and relevance.
46.	The Company should have a procedure in place to be able to update all relevant documentation promptly, ensuring it reflects the latest information and best practices available in the industry.
47.	The Company SMS should be regularly updated to incorporate the preventive actions arising from the investigation of incidents and near-misses, ensuring continuous improvement and alignment with ammonia-specific operational experience.
48.	Documentation associated with effective management of ammonia effluent onboard should be maintained.

12. Company Verification, Review and Evaluation

Quarterly management meetings at shore-side and onboard, with the participation of all pertinent departments and functions, should include a dedicated section to the HSSE targets related to ammonia handling. During these meetings, operators, supervisors and managers should be encouraged to submit ideas and suggestions to improve HSSE excellence, particularly focusing on the unique challenges associated with ammonia as a fuel. This includes jointly reviewing ammonia-related performance and risk assessments and specifying a process for documenting feedback, assigning responsibility for follow-up, and providing updates in subsequent meetings. Additionally, a formal feedback system is to be established to capture any input, which records and analyses all the received suggestions/ideas.

The company should preserve a strategic plan focused on ammonia operations that ensures continual improvement in HSSE performance by identifying strengths, weaknesses, opportunities and threats. This plan should include aims and objectives as well as the steps to achieve them and measures progress towards established milestones (e.g. effective tracking such as number of ammonia-related incidents per quarter, near-miss reports, PPE compliance rate) to quantitatively assess improvements and identify areas needing additional attention).

A clear mention or separate section should be dedicated to the handling of ammonia in the following procedures:

- Master's review of SMS
- Management review
- Onboard safety meetings
- Officers' forums

The company should be able to demonstrate that proper training has taken place for onboard and shore-side personnel involved in ammonia handling operations. Proactive feedback should be encouraged between shore-side personnel, vessel personnel and industry third parties, including industry and fleet incidents, alert bulletins, customer and contractors feedback and seminars, to foster a culture of continuous improvement.

All onboard inspections by shore-side personnel should include time dedicated to reviewing the equipment and a dedicated section related to ammonia handling and verifying the ammonia-related procedures including risk assessments and permit to work. This ensures that the operational practices on board are consistent with the unique demands of ammonia storage and handling.

Vessel personnel should be encouraged to identify areas for improvement by reporting incidents, best practices, identified hazards and unsafe acts, and safety suggestions for matters related to the handling and storage of ammonia. This approach supports ongoing operational refinements and heightened awareness of ammonia's potential risks.

Auditor qualifications require re-evaluation to address ammonia's elevated risks. Criteria should prioritise direct experience with ammonia-fuelled vessels or robust ammonia-specific training, ensuring auditors can effectively assess compliance with both the IGF Code requirements and the specialised protocols for ammonia. Incorporating scenario-based evaluations and ammonia-specific hazard reviews within the framework ensures that audits address the elevated risks, confirm practical readiness and verify that shipboard procedures are effectively implemented and aligned with the required standards and best practices for safe ammonia operations. A proactive audit strategy will foster safety and compliance for ships operating with ammonia.

External or third-party audit findings specific to ammonia (e.g., from Classification Societies, Flag States, Port States, or recognized specialist consultants) can supplement internal audit scope. Such an approach reinforces confidence in the robustness of the company's verification and highlights openness to external expertise.

Finally, there should be a formalised process for distributing relevant findings from internal audits across the fleet to ensure that lessons learned on one vessel are quickly shared elsewhere, accelerating knowledge transfer and best-practice adoption.

No.	Recommended Actions
49.	The Company should include dedicated sections covering the handling and storage of ammonia in the quarterly management meetings, Master's review of the SMS, Management Review, onboard safety meetings and Officers' Forums
50.	The Company should be able to demonstrate training records for their personnel onboard and shore-side related to ammonia handling and storage.
51.	Inspections and audits by shore-based personnel should include time dedicated to cover the handling and storage of ammonia; with allocated section(s) within their report.
52.	Internal auditors should be duly trained on aspects associated with ammonia to ensure that internal audits focus on verifying the effective implementation of corrective and preventive actions implemented onboard. Scenario-based evaluations, ammonia-specific hazard reviews, and alignment with IGF Code requirements are recommended.

Conclusions

As companies look to deploy ammonia as fuel ahead of national and international regulatory requirements being developed, they can use their SMS to provide an effective tool for managing the associated risks. Identification of hazards and risks for safe operation and management of ammonia-fuelled systems is essential for the development of SMS, related procedures and safety culture which may differ for each company.

MTF believes that this guidance document may be one way of encouraging safe application of ammonia as fuel for industry wide application; acceptance; and consistent development and implementation. Companies can use this guideline to develop new SMS and/or strengthen their existing SMS for ammonia as fuel onboard their fleet.

MTF recommends that these guidelines may be used in addition to other similar existing and/or upcoming guidelines (some of which are already referenced within this document) to ensure a safe application of ammonia as fuel on board ships.

Based on MTF review, highlights may be drawn and are listed below:

- It is important to recognise that the ultimate responsibility lies with the company's shore based senior management; as such the drive should come from the top level in the company, with active involvement and support in the development, implementation, and maintenance of a robust and adaptive SMS.
- In the initial stages, with the fuel-mix on board still including fossil fuels along with ammonia as fuel, the SMS should be versatile enough to meet the fuel scenarios as ammonia as fuel is progressively scaled, becoming mainstream.
- The lack of data from the operational experience of equipment operating with ammonia as fuel will be a gap that will exist in the initial stages of deployment of ammonia as fuel.
- The strength of the company's SMS shall be in the ability to proactively identify improvements in the SMS through learning from non-conformities, accidents, and hazardous occurrences (including near-misses) related to ammonia as fuel, and facilitate the closing of the gaps that would exist initially due to lack of operational data.
- The IGF Code, IGC Code, relevant interim guidelines, relevant IMO circulars and industry best practices may be consulted in developing the procedures related to ammonia as fuel within the SMS.
- The anticipated changes in the ship operation that are expected to be brought about by ammonia as fuel are set to expand the suitability criteria of the person assuming the role of DP. HAZOP (Hazard and Operability) training, ammonia emergency response certification and experience in ammonia bunkering protocols will help to ensure DPs are adequately prepared for the unique challenges of ammonia operation.
- The SMS should identify the role defined in STCW Code section B-V/3 as "person with immediate responsibility" as a person being in a decision-making capacity for handling of ammonia as fuel and its operations.
- The integration of a structured risk management within the SMS would be beneficial to strengthen the system in managing anticipated risks including risks from the deployment of ammonia as fuel.
- The effective control of documents within the SMS is important, and this can be emphasised further with ammonia as fuel given the associated elevated operational risk.

References

1. OCIMF, "The OCIMF Human Factors Approach". Available: https://www.ocimf.org/document-libary/62-human-factors-approach/file. [Accessed: Feb.5, 2025].
2. MMMZCS, "Human Factors Considerations: Ammonia Fuel End-of Stage Report". Available: https://cms.zerocarbonshipping.com/media/uploads/documents/Human-Factors-Project-Report_Ammonia-Fuel-Operations_report.pdf. [Accessed: Feb.5, 2025].
3. MTF, "Guidelines to support development of new SMS and/or strengthen the existing SMS for alternative fuels onboard ship/company fleet". Available: https://www.maritimetechnologiesforum.com/documents/2024-mtf-ism-guideline-report-April-4-2024.pdf. [Accessed: Feb.14, 2025].
4. MPA Singapore. World's First Use of Ammonia as a Marine Fuel in a Dual-Fuelled Ammonia-Powered Vessel in the Port of Singapore. Available: https://www.mpa.gov.sg/media-centre/details/world-s-first-use-of-ammonia-as-a-marine-fuel-in-a-dual-fuelled-ammonia-powered-vessel-in-the-port-of-singapore Accessed: Mar.3, 2025].
5. AEA, "Ammonia for Power : a literature review". Available: https://ammoniaenergy.org/articles/ammonia-for-power-a-literature-review/. [Accessed: Feb.14, 2025].
6. LR, "The Future of Maritime Fuels". Available: https://maritime.lr.org/l/941163/2023-09-04/86cyj/941163/1693881339KV19NyGO/LR_Fuel_Mix_Report_v1.pdf. [Accessed: Nov.15, 2024].
7. SGMF, "Ammonia as a marine fuel, an introduction (v2.0)". Available: https://sgmf.info/product/fp15-01_ammonia-as-a-marine-fuel-an-introduction/. [Accessed: Jan.10 2025].
8. IMO, MSC.1/Circ.1687 - "Interim Guidelines for the safety of ships using ammonia as fuel".
9. G. Zamboni, et al., "Comparative analysis among different alternative fuels for ship propulsion in a well-to-wake perspective", Vol.10, Issue 4.
10. EMSA, "Study investigating the safety of ammonia as fuel on ships". Available: https://www.emsa.europa.eu/publications/reports/item/5264-safety-of-ammonia-for-use-in-ships-part-1-ammonia-properties,-regulations-and-accidents-review.html. [Accessed: Jan.7, 2025].
11. National Academy of Sciences, "Acute Exposure Guideline Levels for Selected Airborne Chemicals (Vol.6)". Available: https://www.epa.gov/sites/default/files/2014-11/documents/ammonia_final_volume6_2007.pdf. [Accessed: Feb.5, 2025].
12. IMO, MSC.1/Circ.1455 – "Guidelines for the approval of alternatives and equivalents as provided for in various IMO instruments".
13. ISO, "ISO 31000:2018 Risk Management Guidelines".
14. LR, Fuel for Thought AMMONIA. Available: https://www.lr.org/en/knowledge/research-reports/2024/fuel-for-thought-ammonia-report/. [Accessed : 6 Feb.2025].
15. IMO, "2024 Guidelines on Life Cycle GHG Intensity of Marine Fuels". Available: https://www.imo.org/en/OurWork/Environment/Pages/Lifecycle-GHG---carbon-intensity-guidelines.aspx. [Accessed: Dec.30, 2024].
16. IMO, MSC-MEPC.7/Circ.8 – "Revised Guidelines for the Operational Implementation of the International Safety Management (ISM) Code by Companies". [Accessed: Dec.30, 2024].
17. MTF, "Safety Considerations for Establishing Green Shipping Corridors". Available: https://www.maritimetechnologiesforum.com/documents/2024-mtf-safety-considerations-for-establishing-green-shipping-corridors-report.pdf. [Accessed: Feb.1, 2025].
18. IMO, MSC-MEPC.7/Circ.6 - Guidance on the Qualifications, Training and Experience Necessary for Undertaking the Role of the Designated Person Under the Provisions of the International Safety Management (ISM) Code.
19. DNV, Recommended Practice (DNV-RP-0699) – Competence related to the use of ammonia as fuel.
20. IMO, STCW Part B-V/3.1 - Person with immediate responsibility.
21. UK MCA, "Code of Safe Working Practices for Merchant Seafarers". Available : https://assets.publishing.service.gov.uk/media/6604028ff9ab41001aeea37b/1385-WL-12464_MCA_COSWP_BLACK_AND_WHITE_v1_0-ACCESSIBLE_P2.pdf. [Accessed: Jan.1, 2025].

22. MMMCZCS, "Ammonia as Fuel - Competencies and Training". Available: https://www.zerocarbonshipping.com/publications/ammonia-as-fuel-competencies-and-training/. [Accessed : Mar.3, 2025].
23. ABS, Guidance Notes on Gas Dispersion Studies of Gas Fueled Vessels. Available: https://ww2.eagle.org/content/dam/eagle/rules-and-guides/current/design_and_analysis/311guidancenotesgasdispersionstudiesgasfueledvessels/gas-dispersion-guidance-notes-nov19.pdf. [Accessed: Feb.1, 2025].
24. ICS, Tanker Safety Guide (Liquefied Gas). Available: https://www.ics-shipping.org/publications/tanker-safety-guide-liquefied-gas-fourth-edition. [Accessed: Jan.10, 2025].
25. SIGTTO, "Guidelines for the Alleviation of Excessive Surge Pressures on ESD for Liquefied Gas Transfer Systems". Available: https://sigtto.org/publications/guidelines-for-the-alleviation-of-excessive-surge-pressures-on-esd-for-liquefied-gas-transfer-systems/. [Accessed: Jan.10, 2025].
26. SGMF, "FP23-01_Ammonia – Safety and Operational Guidelines – Bunkering". Available: https://sgmf.info/product/fp23-01_ver1-0_ammonia-safety-and-operational-guidelines-bunkering/. [Accessed: Jan.10, 2025].
27. SGMF, "FP22-01_Methanol – Safety and Operational Guidelines – Bunkering". Available: https://sgmf.info/product/coming-soon-fp22-01_methanol-safety-and-operational-guidelines-bunkering/. [Accessed: Jan.10, 2025].
28. GCMD, "Recommendations for a Competency Framework Ensuring Safe Ammonia Bunkering Operations". Available: https://www.gcformd.org/wp-content/uploads/2024/08/Competency-Framework-for-Safe-Ammonia-Bunkering-Ops-FINAL.pdf. Accessed : Jan.20, 2025].
29. SGMF, BASiL (Bunkering Area Safety information LNG) tool.
30. IMO, A.1072(28) – "Revised Guidelines for a Structure of an Integrated System of Contingency Planning for Shipboard Emergencies".
31. BIMCO, Key Performance Indicators. Available: https://ship-pi.bimco.org/documentation/4.0/key-performance-indicators. [Accessed : Jan.27, 2025].
32. IRS, "Guidelines on Ammonia Fueled Vessels". Available: https://www.irclass.org/media/7356/guidelines-on-ammonia-fueled-vessels_december-2022.pdf. [Accessed : Mar.11, 2025].

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