METHANOL BUNKERING: TECHNICAL AND OPERATIONAL ADVISORY

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1. Equatorial Marine Fuel Management
2. Global Centre for Maritime Decarbonisation
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4. Methanol Institute

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INTRODUCTION

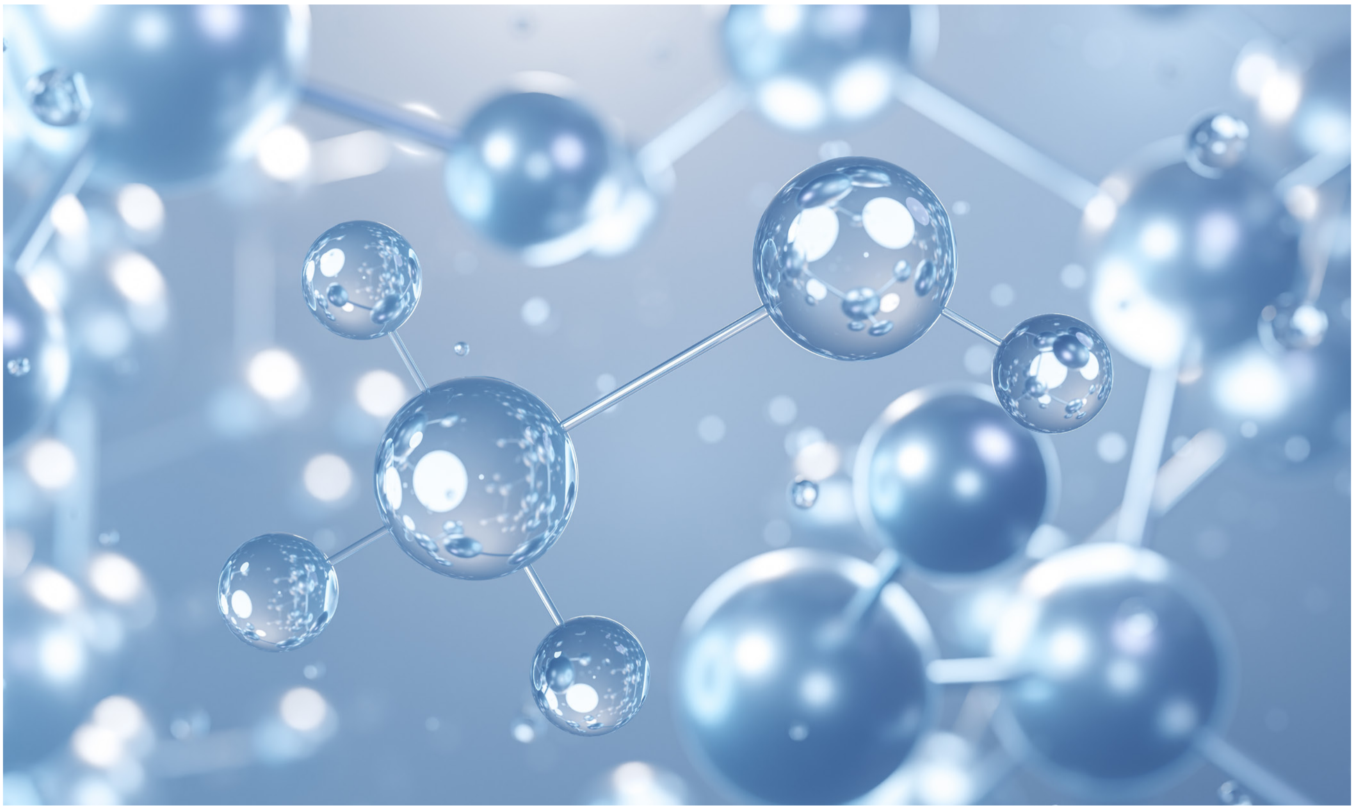
The maritime industry faces several substantive challenges driven by increasingly stricter gaseous air emission legislation and increased efforts by the International Maritime Organization (IMO) to reduce greenhouse gas (GHG) emissions from ships. The adoption of low-flashpoint fuels and gases which can be produced from renewable and sustainable sources, such as methanol, is expected to become one of the means to meet those challenges. Accordingly, owners, operators, designers and shipyards around the world are considering taking advantage of using methanol as marine fuel.

This Advisory has been developed to address the need of the maritime industry to better understand the issues involved with methanol bunkering. It is intended to provide guidance on the technical and operational challenges for both the delivering ship (or land-side sources) and the receiving ship involved in bunkering operations. Critical design issues, viable solutions, compliance with regulations, safe practices, important areas of operational processes, training and safeguards are addressed in this document.

GENERAL

Methanol (methyl or wood alcohol) is a clear, odorless chemical compound that has an additional oxygen atom compared to methane, with the chemical composition CH_3OH (often abbreviated to MeOH). It is water soluble and biodegradable and has a low flashpoint of approximately 12° C and is corrosive to certain materials. Methanol can be produced from renewable sources such as biomass or an electrolysis process. These are also known as bio-methanol and e-methanol and may be delivered on a commercial scale.

Methanol is a liquid at atmospheric pressure, with a boiling point of 65° C. The energy density, at 15.7 megajoules per liter (MJ/L), is significantly lower than that of conventional fuel oils and therefore requires approximately 2 to 2.5 times more storage volume for the same energy content. Methanol has cleaner burning properties enabling reduced exhaust emissions such as Sulfur Oxides (SOx) and particulate matter (PM) and emits less nitrogen oxides



(NOx) than conventional fuel oils. In open air, methanol has a flammable range of approximately 6-36.5 percent and burns with a flame that is nearly invisible in daylight with no smoke. Methyl alcohol is classified as toxic by the IMO's International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code). The United States National Institute for Occupational Safety and Health (NIOSH) Immediately Dangerous to Life or Health Concentrations (IDLH) value is 6,000 parts per million (ppm). The Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit is 200 ppm over an eight hour time-weighted average (TWA).

Refer to the ABS Sustainability Whitepaper: Methanol as Marine Fuel, for additional information on methanol as a marine fuel.

Table 1: Methanol Properties

Methanol Property	Value
Energy Density (MJ/L)	15.7
Heat of Vaporization (kJ/kg)	1098
Autoignition Temperature (° C)	450
Liquid Density (kg/m3)	798
Adiabatic Flame Temperature at 1 Bar (° C)	1980
Molecular Weight (g/mol)	32.04
Melting Point (° C)	-97.8
Boiling Point at 1 Bar (° C)	65
Critical Temperature (° C)	239.4
Critical Pressure (Bar)	80.84
Flammable Range in Dry Air (%)	6-36.5
Cetane Number	< 5
Octane Number	109
Flashpoint (° C)	12
Heavy Fuel Oil (HFO) Equivalent Volume	2.54

METHANOL AS A MARINE FUEL

There are currently no International Organization for Standardization (ISO) standards developed for methanol as a marine fuel. The fuel quality issues of methanol are far less than may be experienced with conventional residual fuel oils or liquefied natural gas (LNG). The ISO/DIS 6583 Specification of methanol as a marine fuel for marine applications is currently indicated as under development stage at the ISO/TC 28/SC 4 Technical Committee. Until this specification is published, the fuel specification and quality should be subject to the minimum statutory requirements for sulfur content and commercial agreements between supplier and purchaser. Agreements for fuel supply should also take into consideration the International Methanol Producers and Consumers Association (IMPCA) Methanol Reference Specifications and the required specifications of the equipment manufacturers, i.e., the engine and fuel supply system designers.

Table 2: Extract from IMPCA Methanol Reference Specifications.

	Unit	Limit	Value	Test Method
Purity on dry basis	% w/w	Min.	>99.785	IMPCA 001
Water	% w/w	Max.	<0.1	ASTM E1064
Acetone	mg/kg	Max.	30	IMPCA 001
Chloride as Cl	mg/kg	Max.	0.5	IMPCA 002
Sulfur	mg/kg	Max.	0.5	ASTM D3961 ASTM D5453

METHANOL FUEL TANKS

A key advantage for methanol as fuel is that it is liquid at atmospheric temperatures and pressures, and thus can be stored in tanks on board in a similar manner as conventional fuels. Sections 5 and 6 of MSC.1/Circ.1621 provide some of the main requirements for the expected integral tanks, although independent and portable tanks may also be acceptable.

Methanol fuel tanks should not be located in accommodation spaces or machinery spaces of Category A. Furthermore, cofferdams are required around methanol fuel tanks, except because methanol mixes readily and is biodegradable in water, methanol tanks can be stored next to the shell plating below the lowest possible waterline. Cofferdams are also not required where methanol fuel tanks are bounded by other methanol fuel tanks or the fuel preparation space (fuel pump room). The cofferdams, where provided, are to have gas and leak detection and be arranged for inerting or filling with water. The methanol tanks are also to have a controlled tank venting system with pressure vacuum (P/V) valves connected to a vent mast, and the vapor space is to be inerted at all times such that the oxygen content does not exceed 8 percent by volume in any part of the tank. For fuel tanks and cofferdams, access is to be arranged from the open deck if possible. However, if this arrangement is challenging, an alternative solution to access these spaces may be through an airlock. Further information on the provisions for airlocks can be found in section 5.12 of MSC.1/Circ.1621. For smaller ships such as harbor craft, tugs, inland waterway ships, etc., it can be a challenge to accommodate the cofferdam requirements, mainly due to the increased volume required due to the lower energy content of methanol. As experience and technology develops, other arrangements may be accepted where justified by demonstrating compliance with the goals and functional requirements of MSC.1/Circ.1621, and that the risks are mitigated to As Low As Reasonably Practicable (ALARP) for equivalency to fuel oil. The basic tank requirements of MSC.1/Circ.1621 are shown in Figure 1.

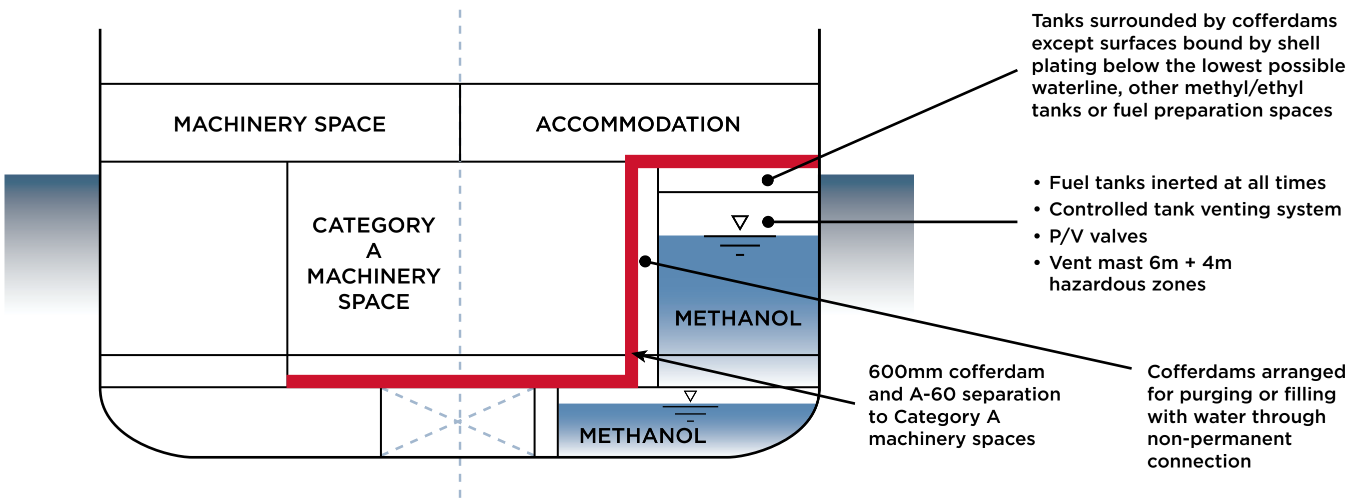


Figure 1: Methanol Fuel Tank Requirements.

REQUIREMENTS FOR METHANOL AS A MARINE FUEL

For international shipping, the carriage of chemicals such as methanol in bulk is regulated by SOLAS Chapter VII – Carriage of dangerous goods and MARPOL Annex II – Regulations for the Control of Pollution by Noxious Liquid Substance in Bulk. Both of those regulations require chemical tankers built after 1 July 1986 to comply with the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code). The safety requirements developed under the IBC Code have provided some of the basis for the IMO developed guidelines for the use of methanol as fuel under the SOLAS framework of the International Code of Safety for Ships Using Gases or other Low-Flashpoint Fuels (IGF Code).

IMO SAFETY – LOW FLASHPOINT FUELS

SOLAS has historically prohibited the use of fuel oils with a flashpoint less than 60° C except for emergency generator use, where the limit is 43° C and subject to additional requirements detailed under SOLAS II-2 Regulation 4.2.1. The adoption of the IGF Code by IMO Resolution MSC.391(95) in June 2015, as implemented from SOLAS II-1, Part G, provided the International Maritime Organization (IMO) regulatory safety requirements and framework for ships using gases or other low-flashpoint fuels, such as methanol, as fuel. The IGF Code is incorporated into Part 5C Chapter 13 of the ABS Marine Vessel Rules. The IGF Code contains goals and functional requirements for the application of low-flashpoint fuels and gases, but only contains detailed prescriptive requirements for natural gas (methane) under Part A-1. Other low-flashpoint fuels should apply the Alternative Design criteria under 2.3 of the IGF Code, and equivalency is to be demonstrated as specified in SOLAS II-1/55, which refers to the engineering analyses submitted for approval to be based on the MSC.1/Circ.1212 and MSC.1/Circ.1455 guidelines.

For methanol (or ethanol) as fuel, IMO has supplemented the IGF Code requirements and the MSC.1/Circ.1621 Interim Guidelines for the Safety of Ships Using Methyl/Ethyl Alcohol as Fuel, adopted November 2020. Based on the IGF Code structure and format, these Interim Guidelines form the basis of the international ship safety requirements for application of methanol as a marine fuel, which is applied in lieu of the Alternative Design process subject to flag Administration agreement. The guidelines also maintain the goals and functional requirements approach of the IGF Code, together with a risk assessment forming a vital part of the ship design approval process. For guidance on risk assessments, refer to the IACS Recommendation No.146 Risk Assessment as Required by the IGF Code and the ABS *Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries*.

IMO ENVIRONMENT – FUEL SULFUR AND QUALITY

MARPOL Annex VI, as amended, details the Regulations for the Prevention of Air Pollution from Ships. Fuel oil under this definition covers any fuel delivered to and intended for use on board a ship. With respect to fuel bunkering, regulation 14.5 requires sulfur content of fuel oils supplied to the ship to be documented by the supplier in the form of a Bunker Delivery Note (BDN) containing the required information in accordance with regulation 18. For low-flashpoint/gas fuels, this required information are updated in the amendments as part of MEPC 81. According to the amendments, the BDN is to at least contain the information specified in items 1 to 6 of Appendix V of MARPOL 73/78, Annex VI, the density as determined by a test method appropriate to the fuel type together with the associated temperature and a declaration signed and certified by the fuel oil supplier's representative that the fuel oil is in conformity with the fuel oil quality requirements in paragraph 3 of Regulation 18. In addition, the sulfur content of a low-flashpoint/gas fuel is still to be documented in the BDN by the supplier either in terms of actual value determined by a suitable test method or with the agreement of the appropriate authority at the port of supply that the sulfur content is less than 0.001% m/m.

The amendments also indicate that the requirements in paragraphs 10 and 11 of Regulation 14 and paragraphs 5.1, 8.1 and 8.2 of Regulation 18 do not apply to a low-flashpoint fuel or a gas fuel meaning that considering the safety and toxicity reasons of methanol fuel, in-use and onboard fuel oil sampling may not be required unless an authority instructs otherwise. Relevant amendment also considered in the Appendix I, Form of International Air Pollution Prevention (IAPP) Certificate as per Regulation 8.

It should be noted that bunker sampling practices may vary from supplier to supplier, country to country and even port to port. In most ports, other than Singapore and Gibraltar which have their own code of practice of bunkering, the legal and binding commercial samples according to supplier terms and condition are usually the samples taken by the supplier and the sampling point of these commercial samples may not be the vessel's manifold.

It is therefore important to review both local requirements as well as the suppliers' terms and conditions/charter party agreements to assess where the legal and binding commercial samples are to be taken during bunkering operations until clear standards have been instituted for the sampling of methanol bunkers.

Until the IMO finalizes work on developing robust life-cycle greenhouse gas (GHG) or Carbon Intensity Indicators (CII) for all types of fuels, the fuel supplier should document the Carbon Factor (CF) applicable to the supplied methanol. This is particularly relevant to methanol produced from non-fossil sources, where the IMO default CF value of 1.375 ton CO_2/ton of fuel, for methanol derived from petroleum or gas refining, will typically be applied through the IMO's Energy Efficiency Design Index (EEDI), Energy Efficiency Existing Ship Index (EEXI), CII or fuel oil Data Collection Scheme (DCS) regulations, and may not be representative of the supplied methanol.

OFF-SPEC METHANOL:

Off-spec methanol refers to methanol that does not meet the established standard specifications for its intended use. These deviations from the expected quality may arise from inaccuracies in the manufacturing process, the introduction of impurities during storage and transportation or other contributing factors. The presence of off-spec methanol can present considerable challenges, potentially leading to performance issues impacting the quality and safety of the crew and the reliability of associated systems. Methanol is hygroscopic and water contamination is the most common type of impurity found across the value chain. Other impurities include the presence of higher alcohols, formaldehyde and sulfur compounds which may become blended because of storage or transfer systems that are either unclean or lack adequate protection. These impurities have the potential to induce corrosion in fuel system components and alter combustion characteristics, eventually deteriorating engine performance. Toxic impurities like formaldehyde and sulfur compounds pose health risks to crew members exposed to the fuel or its emissions. Depending on the concentration and duration, exposure can lead to irritation of the eyes, lungs and skin irritation. Higher alcohols or fusel alcohols, a group of alcohols with more than two carbon atoms in their molecular structure, may release volatile organic compounds (VOCs) and can contribute to air pollution.

Implementing rigorous quality controls is imperative in the production and handling of methanol to ensure adherence to specified standards. The economic repercussions of off-spec methanol, such as potential rejections or the necessity for additional processing to meet desired standards, underscore the importance of robust management practices in its production, storage and transportation. Understanding the specific types of off-spec methanol is crucial to ensure the safe and effective use of methanol so that appropriate corrective action is applied. When encountering off-spec methanol, the following safeguards may be considered:

a. Isolate the off-spec methanol to prevent any cross contamination.
b. Evaluate the potential hazards of the off-spec methanol.
c. Assess the requirement for any additional safety measures for the crew and ship. Availability of BDN, MDS , test reports and other documents should be confirmed.
d. Seek guidance from experts/chemical engineers for safe handling.
e. Local, national and international regulators may be contacted for the safe transport and disposal of off-spec methanol.

REGULATORY ORGANIZATIONS AND REQUIRED APPROVALS

The primary organizations that are involved with reviewing methanol bunkering system designs and arrangements, as well as possibly the fueling procedures, are listed in the following sections.

CLASSIFICATION SOCIETIES

Classification societies such as ABS will have a significant role in reviewing the design and construction of methanol bunkering systems on the receiving ship and any methanol bunker ships (i.e., chemical cargo carriers/ barges). Besides reviewing the design and surveying construction according to its own Rules, class societies may also be the reviewing organization for compliance with national and international requirements such as MSC.1/ Circ.1621 on behalf of the flag Administration in their role as a Recognized Organization (RO). The MSC.1/Circ.1621 requirements have been incorporated in the ABS *Requirements for Methanol and Ethanol Fueled Vessels*.

FLAG ADMINISTRATIONS

Flag Administrations, such as the United States Coast Guard (USCG), the United Kingdom Maritime and Coastguard Agency (UK MCA) and other national maritime agencies, have primary responsibility for enforcing international and national regulations related to the ships under their registry and the associated bunkering systems, processes and procedures. National regulations can be more restrictive than class Rules or international regulations. Some flag Administrations may delegate all or part of their review and approval process to classification societies acting as ROs, while others may carry out the review and approvals themselves.

PORT STATES

Port States will take an active role in the approval, or permitting, of bunkering operations at the locations where the bunkering process will take place as all the risks to life, environment and property will be within their jurisdiction waters. The port State will have primary jurisdiction over land-based facilities or ship to ship transfer within such ports that are a part of the bunkering process. Port State regulations cover more aspects of the bunkering process than either class Rules or flag Administration regulations since they oversee the interface bunkering zones, risk to local area and routine port operations.

For example, port States can include requirements for the actual bunker procedure, permissible bunkering locations, restrictions on bunkering times and due to weather conditions, simultaneous operations, bunkering supply facilities, training, required documentation, acceptability of risk assessments and permits. Since port States

(and local jurisdictions within the port State, such as port authorities, harbor masters, and local and regional governments) can have a broad authority over the bunkering process it is important to determine early on which ones will be involved, particularly at the local or port level.

Bunkering Permit

A fuel transfer/bunkering permit may be required by the port authority prior to bunkering operations. These permits enforce safe and environmentally conscious bunkering operations. Permissions are sought by the supplier at least 24 hours in advance of planned operations. The requirements depend on location and apply to all owners, people in charge and any other associated personnel.

A bunkering permit may include, but is not limited to the following requirements:

- Spill and recovery plan and contingency planning; suitable spill kits available.
- Compliance with all national or international regulatory requirements for fuel transfers.
- Personnel training and training sessions provided.
- Written operational plans and procedures including all activities distributed to all involved parties.
- Safe access between supplier and receiver.
- Emergency and evacuation procedures in place.
- Proper use and display of signages.

REQUIRED APPROVALS

Review and approval of some aspects of the receiving ship and/or the bunker supplier is required by various organizations. Receiving ships are to be approved according to the classification societies' Rules such as the ABS Requirements for Methanol and Ethanol Fueled Vessels and applicable statutory requirements such as the IGF Code and MSC.1/Circ.1621. The bunker supplying ship requires approval to the applicable international (IBC Code) or national requirements depending on the ship type and size. Shoreside bunkering facilities require approval to the applicable national and port requirements. Approval of the bunkering procedures is partially captured by the operational and bunkering-specific document requirements of MSC.1/Circ.1621. In addition, the port States are also likely to require the review and approval of the bunkering procedures, together with assessment of the bunkering interface and port permitting process.

To reduce the risks for major design changes and delays, the approval process is to be initiated early in the development of a project. Design details and operating procedures may be specific to different bunkering scenarios, bunkering ship types and bunkering locations. Detailed consultation and collaboration with the classification society and the regulatory organizations is recommended. All parties involved in the project development should be prepared to submit detailed designs, reports, analyses and procedures to the multiple reviewing organizations covering but not limited to the following:

- Approach and Mooring
- Connection and Testing of Cargo and Vapor Return Hoses
- Bunkering Operations
- Draining, Purging and Disconnection of Hoses
- Unmooring and Departure
- Other Factors (Crew qualifications, training records, records of fire and spill drills, PPE matrix etc.
  - Crew Qualification
  - Methanol-Specific Firefighting training
  - Methanol-Specific Safety Items
    - Thermal Camera
    - Methanol Gas Detector
    - Chemical Suit
    - Lightning protection Rod
    - Antidotes (Ethanol solution)
  - Methanol – Specific PPE Matrix

METHANOL BUNKERING OPERATIONS

BUNKERING METHODS

The main methods of methanol bunkering to ships are:

- Truck-to-ship bunkering using a road tanker – Truck-to-ship bunkering is the most commonly used method of bunkering methanol to date. Methanol is widely used for land-based operations within Europe and is transported according to the International Carriage of Dangerous Goods by Road (ADR) regulation as a Class 3 flammable liquid (UN 1230).
- Ship-to-ship bunkering (delivery by bunker ship) – Ship-to-ship bunkering, also referred to as "barge-to-ship" bunkering, is carried out while a ship is alongside at port or while at anchor. Fuel is provided from a bunker supply ship, tanker or barge to the receiving ship. Most large ships use this method of bunkering, although it may also be appropriate for smaller ships in some cases.
- Land storage tank (or Terminal) to ship bunkering, using a pipe or hose connection – Bunkering from a land storage tank or terminal is a suitable solution for ships operating out of a home port, such as the pilot or tugboat, and ships operating on fixed routes that bunker from compatible ports.

For other ship types or varied ports of operations, the storage tank or terminal pipe sizes and delivery pressures should be considered and be compatible with the ship's equipment. Providing fuel in portable tanks that are transferred to the vessel is another option that could be used particularly for smaller vessel applications, such as for fuel cells.

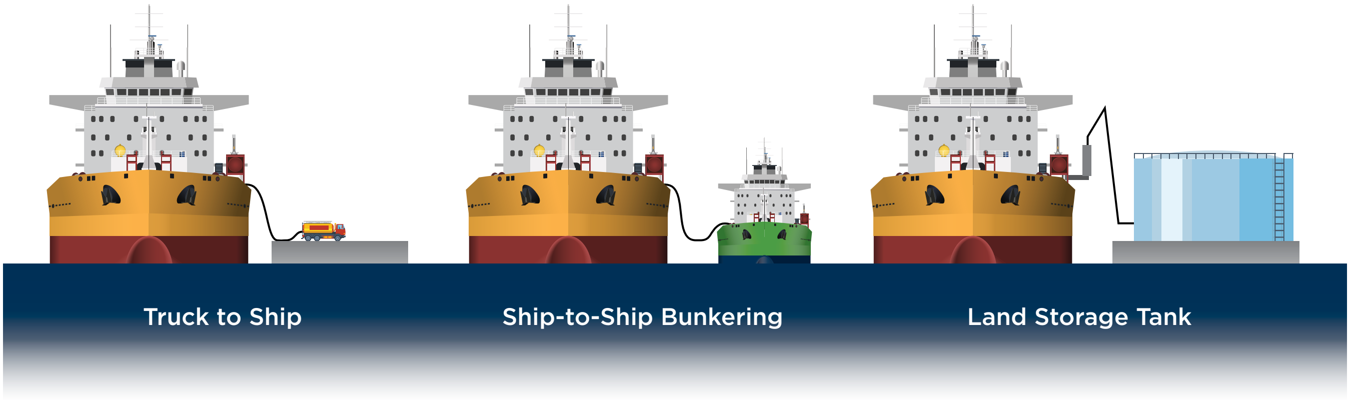


Figure 2: Typical Bunkering Scenarios

The table below lists the advantages and disadvantages of the different bunkering options as covered in this Section.

Table 3: Summary of Advantages and Disadvantages of Different Bunkering Options

	Truck to Ship	Ship to Ship	Terminal to Ship
Advantages	• Bunkering directly at berth • Low investment • Experience in place	• High flexibility • High bunkering rates • High bunkering volume • Bunkering directly at berth or anchor	• High tank capacity • Fast bunkering
Disadvantages	• Low bunkering rates • Low volumes	• High investment	• Fixed location • High investment

BUNKERING INTERFACE AND SHIP COMPATIBILITY

One of the key steps in safe methanol bunkering is verifying compatibility of the supplying ship or facility and the receiving ship. Methanol is liquid at atmospheric temperatures and pressures and hence bunkering is similar to conventional fuel oils, albeit the low-flashpoint and toxic properties require additional equipment and operational procedures. Hoses and connections are to be certified for methanol use and inspected periodically in compliance with the latest version of MSC.1-Circ. 1621. The fittings are to be cleaned, tight-fitting and leak free with spill protection. Pressure-testing and recertification is to be performed every six months for hoses uniquely identified. Connections should be quick release and self-sealing with seals in new or good condition. Any mobile facilities such as tank trucks, rail cars and portable tanks should conform to meet the International Organization for Standardization (ISO) and other standards for handling methanol fuel. Earthing of road truck/ISO tanks and ship is to be accomplished with a bonding wire to protect from static electricity which may be an ignition source. Depending on the set up of the supplier, there may be extra requirements of port authorities regarding operations. Section 17.4 of MSC.1/Circ.1621 provides the main operational requirements and responsibilities for bunkering methanol. These include verification of compatibility as well as key parameters and functions such as transfer rate, vapor return arrangements, communications, Emergency Shut Down (ESD) and emergency procedures. The responsibilities and procedures are to be agreed upon and confirmed in writing prior to commencing bunkering. Completing a checklist to confirm compatibility before each bunkering operation is an easy way to capture this information. Sample checklists are found in Appendix I.

The compatibility review and pre-bunkering verification should address all relevant shore-to-ship or ship-to-ship considerations, including:

- Confirmation that the receiving ship (and supply ship, if applicable) can be safely moored and that adequate fendering or spacing is provided between the ships or to the facility to prevent damage. Any restrictions on length should be noted. Moorings should be sufficient to keep the ship(s) restrained for anticipated wind, tide and weather conditions, and any expected surges from passing ships. The overhanging of mooring should be avoided as far as practicable.
- The relative freeboard of the ship(s) or facility should allow hoses to reach from the bunker supply connection to the bunker receiving connection with sufficient slack to allow for any expected relative motion between the two. Any restrictions on freeboard should be noted. Saddles or hose supports should be considered.
- The manifold arrangements, spill containment systems and hose connections for the supply source and the receiving ship should be confirmed including emergency release (hose breakaway) arrangements.
- The use of non-sparking material during hose connection and disconnection is to be considered. The means for electrical bonding, insulation and means to prevent electrical arcing are addressed.
- Confirmation that both the supply source and receiving ship have compatible communications, including SSL, and control/monitoring and ESD functions. The required connections and interfaces are provided so that both the bunker supplier and receiver can monitor the bunkering operation, and both can initiate an ESD of the complete transfer operation.
- Confirmation that the size and scope of the hazardous areas on both the supply source and the receiving ship are compatible (i.e., that the size of one is not beyond the size of the other). The goal is to keep any sources of ignition from either the supplier or receiving ship outside of the other's hazardous area.
- When vapor return is required, then confirmation is needed that the supply source can accept returned vapor and that the vapor return systems are compatible. Sufficient space for receipt of the vapor is to be considered. The volume of vapor is 1:1.4 times more than the volume it replaces. When vapor is returned to the same discharge tank of a bunker tanker, the process is to be closely monitored.
- Confirmation that both the supply source and receiving ship possess inerting and purging capabilities.
- Confirmation of firefighting and emergency procedures.

BUNKER STATION INSTALLATION

The bunker station presents obvious risks to the ship due to the possibility of methanol liquid and vapor escape. The location of the bunker station is therefore a critical factor for determining the level of risk associated with the ships bunkering operation. Bunker manifolds are classified as a zone 1 area within 3 m of any valves, and section 8 of MSC.1/Circ.1621 provides the detailed requirements for methanol bunkering. Methanol bunker stations should be located on open decks to provide sufficient natural ventilation. Enclosed or semi-enclosed bunker stations should have mechanical ventilation and gas detection arrangements providing equivalent safety. The design should consider the distance of the bunker station from the openings of any areas with human presence such as living accommodations, service and machinery spaces, and control stations. Depending on the location of the bunker station, additional outfitting may be required. For example, on some ships the bunker station is located below the weather deck. These ships normally require a suitable watertight door in the side shell to prevent waves and weather from entering the space but can be opened to allow the bunkering operation. Furthermore, for such enclosed bunker stations, an airlock should be provided to separate the bunker station hazardous area from adjacent non-hazardous areas. The bunker station design is to account for the collection of spills, with coamings or drip trays and a means of collecting and storing spills, which could be a dedicated holding tank. Eye wash stations are to be located close to areas where the risk of accidental contact with methanol exists.

One of the changes in categorizing methanol as toxic under the IBC Code is that loading and unloading of cargoes requires a vapor return system. Many ports are expected to require vapor return systems for the bunkering of methanol fueled ships. Thus, vapor return piping arrangements should be considered for the design. While MSC.1/Circ.1621 does not mandate a vapor return system, it requires that the fuel tank vents are sized to permit bunkering at a design loading rate that does not over-pressurize the tank. See 6.3.8 of MSC.1/Circ.1621.

The ship's bunkering piping design and materials are to meet the requirements of section 7 of MSC.1/Circ.1621 and be designed so that any leakage does not cause a danger to persons on board, the environment or the ship. Bunkering lines are to be arranged for inerting and gas freeing and are to be free of fuel when not engaged

in bunkering. Bunkering manifolds and piping should be arranged and marked in accordance with recognized industry publications such as the OCIMF Recommendations for Oil and Chemical Tanker Manifolds and Associated Equipment.

The bunkering manifolds are to be designed for the maximum envisaged external loadings and equipped with dry-disconnect couplings with break-away coupling or quick release and self-sealing functions. The ISO is expected to develop standards for these couplings in the longer term in the same way as ISO 21593:2019 was developed for LNG dry-disconnect couplings. However, standard fluid interface couplings based on the NATO STANAG 3756 standard used for kerosene and diesel fuels may be applied subject to seal compatibility with methanol.

MSC.1/Circ.1621 also contains requirements for the ship's bunker hoses. The bunkering couplings are expected to be in the scope of supply of the methanol fuel supplier. Manifolds are recommended to be equipped with standard flanges at new construction or conversion, so that they can be connected to the couplings as required by the IMO and compatible with the fuel supplier's equipment.

SHIP SHORE LINK AND EMERGENCY SHUTDOWN

A ship-to-shore link (SSL) is to be provided to enable automatic and manual ESD of bunkering operations by stopping pumps and closing the manifold valves. The ESD should be capable of activation from both the bunker receiving ship and the bunker supplier, and the signal should simultaneously activate the ESD on both sides of the transfer operation. No release of liquid or vapor is to take place due to ESD activation. Typical reasons for activation of the ESD include:

- Overflow in the receiving tank (high-level alarm activation)
- High tank pressure
- Leak or vapor detection
- Fire detection
- Loss of ventilation in double wall piping, as applicable
- Manual activation from either the supplier or receiver
- Excessive ship movement
- Abnormal pressure in transfer system
- Power failure
- Other causes as determined by system designers and class or regulatory organizations.

At the manifold connection a manually operated stop valve and a remotely operated shutdown valve are to be provided. These functions can be combined but the remote function is to be operable from the bunker control station and arranged for ESD operation. ABS requires that this remote valve be of the fail-close type (close on loss of actuating power), be capable of manual closure and to have indication of the valve position.

The ESD link is to be in accordance with a recognized standard and compatible with the bunker delivery ship. The OCIMF Linked Ship/Shore Emergency Shutdown Systems for Oil and Chemical Tankers or the SIGTTO ESD Systems Recommendations for Emergency Shutdown and Related Safety Systems are examples of relevant industry standards. The Port of Gothenburg Methanol Bunker Operating Regulations also provides further guidance on bunkering operations and bunkering equipment including SSL and ESD requirements.

The ESD functionality is critical for the safety of the bunkering control process and is fitted to stop the flow of fuel in emergencies. The general monitoring, alarm and shutdown parameters required to be monitored on the receiving ship are given under Table 15.1 to MSC.1/Circ.1621 and incorporated into the ABS Requirements for Methanol and Ethanol Fueled Vessels. This table includes some monitoring relevant to the bunkering process, which should trigger automatic closure of the remotely operated bunker manifold ESD valves.

ABS has additional requirements, including that systems are to be designed to accommodate surge pressures that may exist during ESD activation and that manual operation of the ESD system is to be possible by a single control on the bridge, a safe control station and at least two strategic positions around the bunker manifold area. Manual or automatic activation of the ESD system, on either the receiving or bunker ship, is to trigger ESD actions on both ships.

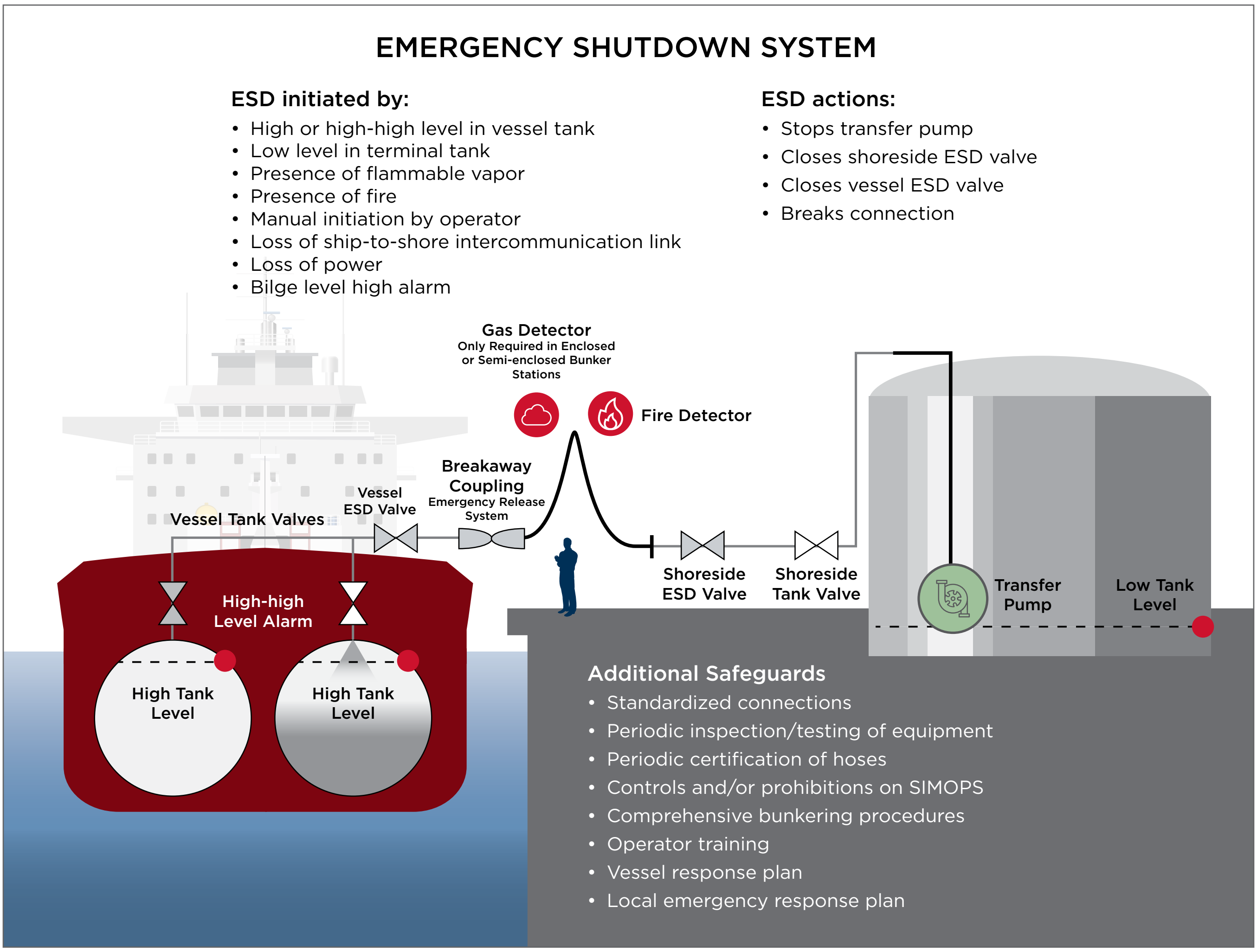


Figure 3: Recommended Safeguards for Methanol Bunkering Operations

FIRE PROTECTION

Section 11 of MSC.1/Circ.1621 details the fire protection requirements for methanol fueled ships and references the low flashpoint and specific flame characteristics of methanol.

These requirements include a cofferdam with A-60 class insulation to separate fuel tanks from the machinery spaces of category A and other rooms with high fire risks, as well as A-60 insulation to separate fuel preparation spaces and bunkering stations from machinery spaces of category A, accommodation, control stations and high fire risk spaces.

Where methanol tanks are located on deck, additional requirements for a fixed water spray system for the exposed parts of the tank and fire main isolation are also applicable. Tanks on the open deck are also to be protected by an alcohol resistant foam fire-fighting system that meets the requirements of the IBC Code and the Fire Safety Systems Code (FSS Code). The bunker station is also to be provided with a fixed alcohol resistant foam type extinguishing system and a portable dry chemical powder, or equivalent, extinguisher located near the entrance to the bunkering station.

Methanol burns with a near invisible flame and thus the fire detection and alarm system are to be suitable for the detection of methanol fires, and MSC.1/Circ.1621 requires smoke detectors to be used in combination with detectors that can effectively detect methanol fires. The 2017 Swedish RI.SE proFLASH: Methanol fire detection and extinguishment report provides several recommendations to be considered when designing and specifying fire detection and extinguishing systems for methanol-fueled ships, including:

- Approved infrared (IR) flame detectors (tested against ethanol) are likely suitable to detect methanol fires.
- CO_2 design concentrations for fire-extinguishing systems should be increased from 40 percent to 55 percent compared to traditional fuels to achieve the same safety margin.

- 90 percent dilution may be necessary for to extinguish methanol fires.
- Higher foam/water application rates are more effective than lower rates.
- A concealed methanol pool fire is difficult to extinguish.
- Water spray systems perform better than water mist systems in extinguishing methanol fires.
- The use of alcohol resistant foam injection with fixed water based extinguishing systems is recommended.

EMERGENCY PROCEDURES

Methanol emergency response is important in preventing incidents that may cause harm to people, the environment and assets. Emergency procedures are needed for the handling and bunkering of methanol. The IGF Code requires specific emergency procedures to be created and implemented. Drills are to be conducted on board regularly per IGF Code sections 17 and 18.2.4 (MVR 5C-13-17 and 5C-13-18/2.4). Emergency procedures cover incidents that include spills, vapor release and fire. All crew personnel must be provided with and be made aware of the emergency procedures and trained in any roles and responsibilities they may have. Training, drills and exercises to prepare the crews for emergencies are to be provided. Lessons learned from past operations should be incorporated to improve the emergency procedures. Procedures should cover all scenarios specific to the ship, type of incident, equipment and associated areas.

ENVIRONMENTAL EFFECTS

Methanol dissolves readily in water and has significantly less impact if spilled or leaked into the environment than conventional hydrocarbon fuels. Only in very high concentrations does it create lethal conditions for marine life. This means that a methanol spill would result in limited damage to the environment. Methanol in the ocean is abundant and common, being produced naturally by phytoplankton and readily consumed by bacteria microbes, making it a fundamental part of the marine food chain.

ROLES AND RESPONSIBILITIES

A person-in-charge (PIC) should be appointed for the methanol supplier's side and the receiving side. These individuals have the responsibility for the methanol delivery on the supplier's side and loading on the ship's side. The PICs should work closely with the ship's master. Typically, the ship PIC is an officer specifically trained in bunkering operations, monitoring and control systems, emergency equipment, spill prevention, spill detection and is assigned to the ship. Each PIC should communicate with each other and share important information pertaining to the emergency response and associated equipment of the operations. Refer also to IGF Code 18.4.1 (MVR 5C-13-18/4.1) for the PIC bunkering operation responsibilities.

Methanol facilities and methanol fueled ships may only require a few people each during a typical bunkering operation, but additional crew may be necessary for normal ship operations and should be available in case of emergency or other circumstances. The number of bunker supplier personnel depends on the method of supply (e.g., truck, barge, ship or fixed facility). Actual manning requirements depend on the bunker procedure, facilities and regulatory requirements. All personnel involved in the bunkering operation should have the necessary training and certification to fulfill their roles.

PROCEDURES AND MANUALS

Manuals and procedures should be readily available during bunker operations. Before beginning any bunker operations, both the supplier and the receiver should ensure that the receiving ship's procedure is compatible with the supplier's transfer procedure and the procedure to be followed is agreed upon by both parties. Port State regulatory requirements will typically require operational procedures and manuals for bunkering ships such as:

- Methanol Fuel Transfer Systems Operation Manual
  - List of personnel qualified to conduct methanol bunkering operations
  - Duties and responsibilities of all personnel involved
  - Emergency contact information
  - Bunkering parameters
  - Limitations on bunkering operations identified in risk assessments or regulatory guidance
- Emergency Manual
- Maintenance Manual

RECEIVING SHIP CONSIDERATIONS

Bunkering procedures for methanol differ by project, ship and bunker facilities. The use of standardized procedures and checklists (sample checklists for before, during and after bunkering operations are given in Appendix 1 of this document) from existing projects may provide helpful guidance. Ship-specific procedures for the bunkering operation should be developed to include any unique aspects to the bunkering facility and receiving ship or location. According to 17.2.3 of MSC.1/Circ.1621, operational procedures including a suitably detailed fuel handling manual are to be provided so that trained staff can safely operate the fuel bunkering, storage and transfer systems. There are further requirements under 17.4 of MSC.1/Circ.1621 regarding operational requirements for bunkering. These requirements form the basis of the operational procedures applicable to a specific ship.

RESPONSIBILITIES

The responsibilities of the appointed representatives and person-in-charge (PIC) of the receiving ship and bunkering source are to agree to the following before any bunkering operations commence:

- The transfer procedure includes maximum transfer rate at all stages and total volumes.
- Emergency actions to be taken in the event an incident occurs.
- A completed and signed bunker safety checklist.

Once bunkering operations have been completed, the ship's appointed representative and PIC should receive and sign documentation with the description of the product and the quantity of fuel delivered. These responsibilities are detailed under 17.4.1 of MSC.1/Circ.1621.

PRE-BUNKERING VERIFICATION

Pre-bunkering verification should be completed prior to the transfer of fuel. It is to include but not limited to the following tasks which are to be carried out and documented in the bunker safety checklist to be signed by both PICs:

- All communications methods are verified including ship shore link (SSL), if fitted
- Fixed fire detection equipment operation
- Portable gas detection equipment operation
- Fixed and portable firefighting systems and appliances readiness
- Remote-controlled valves operation
- Inspection of hoses and couplings

Guidance on pre-bunkering verification items is given under 17.4.3 of MSC.1/Circ.1621. More detailed information on communications/monitoring, inerting/purging and simultaneous operations (SIMOPS) to be considered during bunkering are further detailed in the following sections.

COMMUNICATIONS AND MONITORING

Communications between the receiving ship and bunker supplier are critical for carrying out the bunkering operation safely. Communications should be established before the bunker hoses are connected and end only after the hoses are disconnected. It is important for the supplier and receiver to both speak a common language and fully understand each other. Compatibility of all communication links, including SSL and ESD, between the receiving ship and bunker supplier should be confirmed and tested prior to commencing bunkering. Radio and communication equipment for involved persons should include the following considerations:

- Radio equipment to be used in the safety zone during the operation should be designed for use in hazardous areas and should be intrinsically safe.
- Any radio equipment, cell phones, or portable electronic equipment in the safety zone that are not intrinsically safe should be removed from the area.

INERTING AND PURGING

Methanol tanks are required to have controlled tank venting systems and be maintained with an inert vapor space. The required fuel handling manuals should detail operational requirements from dry-dock to dry-dock and include the practices to be followed for inerting tanks prior to first fill. Similarly, the compatibility and pre-bunkering checks should establish the local arrangements for vapor return. As required by 8.5.2 of MSC.1/Circ.1621, bunkering lines are to be arranged for inerting and gas freeing. When not engaged in bunkering, the bunkering lines are to be free of methanol in its liquid or vapor phase. This necessitates a process to ensure a safe environment in the fixed bunkering lines and bunker hoses (that may typically be part of the fuel suppliers' equipment) prior , during and after bunkering. The ship is to have adequate inert gas storage or generation capability onboard for its operations. Before commencing methanol bunkering, to prevent a flammable gas mixture, the inerting process includes displacing air from the bunker lines with inert gas, typically nitrogen. After the bunker lines have been inerted, the bunkering of methanol can begin. After bunkering, the bunker hoses are to be drained, and any remaining liquid or vapor in the bunkering lines should be purged using the inert gas so that they are free of fuel in operation. If the bunker hoses are part of the receiving ships' equipment, then these are to be stored on the open deck or in a storage room arranged with independent mechanical ventilation.

The methanol tank vapor space is to be inerted at all times and inert gas is required to enable purging of fuel supply and bunkering lines. The fuel supplier may provide inert gas for the bunkering operation functions, but the ship should have onboard sufficient inert gas to achieve at least one trip from port to port considering maximum consumption and to keep tanks inerted for two weeks in harbor with minimum port consumption – see 6.5.1 of MSC.1/Circ.1621.

Ships should therefore be equipped with sufficient capacity for a stored inert gas such as nitrogen. These can be stored in bottles or have a production plant installed onboard. The production plant is to be capable of producing inert gas with a maximum oxygen content of 5 percent and the installed arrangements are to be capable of maintaining an atmosphere in the tank vapor space with an oxygen content not exceeding 8 percent. Additional requirements apply to the spaces where the plant is located to prevent risks to the crew from oxygen deficiency, and also apply to the piping arrangements to prevent unexpected inert gas or low-flashpoint fuel reverse flow. ABS may consider locating inert gas generators within an engine room subject to meeting the requirements given under 5C-13-6/14.5 of the ABS *Marine Vessel Rules*.

SIMULTANEOUS OPERATIONS

Simultaneous operations generally refer to the transfer of cargo on ships while bunkering but can also refer to bunkering with passengers on board or while embarking and/or disembarking, together with bunkering while other general operations are undertaken, such as bunkering conventional fuel oil, taking on stores, and performing maintenance work. Commercially, it may be necessary for the ship operator and facility to perform simultaneous operations while bunkering. During normal methanol bunkering operations, a flammable gas mixture should not be present provided all equipment is operating properly and appropriate procedures are being followed. However, in certain situations fuel or vapor may accidentally discharge to the atmosphere, resulting in a potentially flammable or toxic mixture. The risk of ignition increases substantially when uncontrolled sources of ignition are in the vicinity of the bunkering station. No sources of ignition are permitted in the potentially hazardous areas to reduce the possibility of fire or explosion. Cargo operations can increase uncontrolled sources of ignition. This is particularly of concern for cargo operations located near to or in hazardous areas. Certain cargo operations present a greater chance for sources of ignition than others. Loading operations near a ship's bunker station can introduce sparks or mechanical damage, which can be a source of ignition, compared to loading passengers onto a ferry using a gangway on the opposite side of the ship from the bunker station. However, the presence of passengers approaching the ship during the bunker operation presents a much greater risk of personnel injury from a hazardous event than simple cargo operations with a limited number of trained personnel in the vicinity of the ship. Accordingly, potential SIMOPS need to be measured along with the associated risk levels during the bunkering operations risk assessment process. The assessment of the allowable SIMOPS operations would typically be undertaken as part of the port assessment for a particular ship, fuel supply arrangements and permitted locations.

SUPPLIER CONSIDERATIONS

Much like oil fueled ships, methanol fueled ships have bunkering stations by which the ship refuels using hoses from either a shoreside facility, truck or a methanol bunker ship or barge. The methanol supply method to be developed in a port depends on whether the source of methanol is local to the port or is transported from some distance away. Also, safety considerations, such as simultaneous cargo operations and other activities and hazards that occur on the pier or quay during bunkering, affect whether the methanol bunkering supply is from shore, or from a bunker ship located on the offshore side of the receiving ship or alongside it at anchorage.

BUNKERING FROM ONSHORE FACILITY

In the case of bunkering from an onshore facility, this may be from a fixed installation or a mobile tank or truck. Fixed installations provide a bunker supply connection directly at the quay or pier and the methanol is transferred from the bunker supply connection to the ship through hoses or a moveable arm. Mobile tanks or trucks provide a flexible approach and may be used prior to the provision of dedicated onshore facilities.

The ship's bunkering station provides connections to the ship's fuel tanks to allow the loading of methanol and, as applicable, the return of displaced vapor from the fuel tanks. In all cases, the bunkering operations will be subject to assessment of the bunkering interface and port permitting process.

BUNKER SHIPS

A dedicated methanol bunkering fleet has yet to emerge, but may utilize existing small chemical barges, chemical tankers (complying with the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk [IBC Code]), ships, or offshore support vessels (OSVs) used to handling methanol for offshore purposes. Since methanol is stored at atmospheric temperatures and pressures, it is relatively easy to handle, and bunker ships do not require the additional equipment required for handling liquefied gases. Accordingly, conventional refueling barges may also be adapted to be compatible with the receiving ship.

FLOW RATE AND MANIFOLD CONNECTIONS

The bunker piping systems are sized according to the design flow rates, and in consideration of operator's requirements, methanol fuel tank capacity and other factors such as vapor return capability or availability of a controlled discharge system, flow velocity limits, and bunkering time window. The flow rate is also dependent on the achievable bunkering rate from the bunker ship or shore facility. A vapor return from the receiving tank back to the supplier's tank or installation of a controlled discharge system may help increase flow rate, help to avoid over pressurization of the receiver's fuel tanks, and may also satisfy local requirements regarding the venting of toxic vapors.

ISO standards for methanol bunkering couplings are not yet available. However, precedents from similar applications are available and the provision of compatible couplings meeting the IMO MSC.1/Circ.1621 requirements may be considered as part of the bunkering compatibility assessment and pre-bunkering verification and are typically within the scope of supply of the bunker ship.

BUNKER HOSES

Bunker hoses should be suitable for methanol. Section 8.3.2 of MSC.1/Circ.1621 includes additional requirements, including type approval requirements, even though those hoses may be within the scope of the bunker provider. The type test requirements require that each type of hose is to be prototype tested at ambient conditions with 200 cycles from 0 to at least double the maximum working pressure. Once the cyclic cycle testing is completed a burst test at five times the specified maximum working pressure is also to be demonstrated. The International Maritime Organization (IMO) requirements also indicate that each bunker hose in service needs to be hydrostatically tested at not less than 1.5 times the specified maximum working pressure and to be marked with date of testing, maximum working pressure, and applicable maximum and minimum ambient service conditions. Means to assist bunker hose handling should be part of a bunker supplier's equipment, even though many receiving ships are also equipped with hose handling cranes or davits. Means are to be provided to enable draining any methanol from the bunkering hoses upon completion of the fuel transfer. For bunkering operations with varied height of the hoses, appropriate support should be considered. During an emergency shutdown (ESD) activation, siphon back flow may occur which may cause contamination, equipment damage, environmental spills, and fire hazards. To prevent siphon back flow, installation of check valves or utilizing proper piping configurations such as air gaps or dedicated back flow prevention devices should be considered in the bunkering design. Dedicated black flow prevention devices may include pressure vacuum breakers (PVBs), reduced pressure zone (RPZ) valves and double check valves (DCVs).

ISOLATION FLANGES

Ships transferring or receiving low-flashpoint flammable liquids, such as methanol, should take additional precautions to prevent ignition due to electrical arcing. Two causes of arcing are static electricity buildup in the bunker hose and differences in potential between the receiving ship and bunker supplier's facility, including the quay or pier, trucks, bunker ships, etc.

An effective way of preventing arcing is to isolate the ship and the bunker supplier using an isolating (insulating) flange fitted at one end of the bunker hose only, in addition to an electrically continuous bunker hose. The Society of International Gas and Tanker Operators (SIGTTO) publication, A Justification into the Use of Insulation Flanges (and Electrically Discontinuous Hoses) at the Ship/ Shore and Ship/Ship Interface provides details and background for the use of an isolating (insulating) flange for liquefied natural gas (LNG) applications, but the principles are equally applicable to all such connections.

The isolating flange prevents arcs from passing between the receiving ship and bunkering facility even if there is a difference in potential. Furthermore, because the hose is electrically continuous and one end is grounded to either the ship or the bunker supplier, static electricity will effectively be dissipated. An alternative method is to use one short section of insulating hose without any isolating flange, but with the rest of the bunker hose string electrically continuous. Prior to starting any bunkering operation, the responsible bunkering crew should check that all connections between the receiver and supplier vessels, such as mooring lines, gangways, cranes, and any other physical connections, are properly isolated. This is typically done by using rope tails on mooring lines, insulating rubber feet on the end of gangways, and prohibiting the use of certain equipment that would otherwise pose an unacceptable risk of arcing.

VAPOR HANDLING

Offloading or loading methanol between ships involves specific vapor handling procedures to ensure the safety of the operation. Typically, the operation is conducted using a closed system to prevent the release of methanol vapors. The methanol and nitrogen (or other inert gas) vapor mix is collected by the supplying vessel and is usually discharged back to shore facilities for further processing.

Depending on the quality/concentration of the vapor mix, shore facilities may consider reliquefying the methanol for reuse, or incinerating it using gas combustion units. Some chemical tankers are fitted with reliquefication and/or incineration units for handling the vapors onboard to reduce the reliance on shore facilities. As an alternative to vapor recovery or flaring, a controlled discharge system in accordance with Chapter 5, Regulation 13 of Annex II MARPOL may be considered. This regulation specifically addresses the discharge of vapors during the cleaning of cargo tanks or tank washing operations for chemical tankers. Approval from the ship's flag State Administration may be required to ensure that the discharge is conducted in accordance with established guidelines and meets safety and environmental standards.

A controlled discharge system can be provided to complement or replace the manual pressure relief system. The primary purpose of the system is to take excessive vapor from the tank system and process it such that it can be discharged in another place of form other than as a gas release on deck. Several design possibilities exist, some given below for information, but other novel ideas may also be considered by ABS.

- A seawater driven eductor with underwater discharge attached to the vapor header that premixes the gas with water before discharge.
- A compression system where tank vapor is recycled, and which can be complemented by an underwater overboard line for pressurised gas.
- A distillation system connected to the vapor header which separates the premix vapor with the nitrogen released in a safe place or reused and the recycled methanol returned to the fuel system.

Methanol fuel vapors (above the lower flammability limit) can be prevented from forming by reducing the liquid temperature below the flashpoint. Additional information on vapor control is provided in the Methanol Institute's Methanol Safe Handling Manual in Chapter 6.2.

TRAINING AND CERTIFICATION

Crew training and certification are invaluable for performing safe methanol bunkering operations. Personnel involved in the bunkering and receiving ships are to meet the minimum applicable training requirements outlined in the IGF Code and the Interim Guidelines for the Safety of Ships Using Methyl/Ethyl Alcohol as Fuel or the Seafarers' Training, Certification and Watchkeeping (STCW) Code for IBC Code Vessels. They are to receive formal training that includes basic handling of methanol including scenarios for leakage, spillage, and fire. Courses should cover fundamentals of methanol, technical safety, operational risks and hazards, fire prevention and firefighting, roles and responsibilities, emergency management and operational procedures.

Ship-specific training is to be reviewed and approved by governing regulatory authorities. The IGF Code provides detailed training requirements for ships which use gases or other low-flashpoint fuels. Ships under the jurisdiction of flag Administrations signatory to SOLAS should ensure that seafarers should have the specified certificates of proficiency and the Administration shall approve courses and issue endorsements indicating completion of the qualification.

SAFETY AND RISK ASSESSMENTS

Methanol as a fuel is a hazardous material that has similar characteristics as conventional fuels such as flammability, reactivity and toxicity. Care should be taken during bunkering operations to prevent any spills or release of gas or liquid, limit explosion consequences and prevent or contain any hazardous events. Risk assessments should be conducted to evaluate the hazards of methanol and how they may affect humans, the environment, and any associated assets. Risks are to be analyzed using accepted and recognized methodologies evaluating loss of function, explosion, toxicity and fire. Elimination and mitigation of these risks are to be assessed and documented prior to operation.

Note that IMO has developed Interim Guidelines for the Safety of Ships using Methyl/Ethyl Alcohol as Fuel, which provides general guidance on the safety of using methanol as fuel. The document also contains information on conducting a risk assessment specific to the use of methanol as fuel.

RISKS AND HAZARDS

Explosion and Fire Risk: Methanol liquid and vapor are highly flammable and are easily ignited by heat, sparks or flames. Methanol in enclosed areas such as containers may explode when heated and the fire will produce irritating, corrosive and/or toxic gases. A fire focus area and explosion focus area should be considered when conducting the risk assessment. Methanol fire and explosion can be prevented by controlling the fuel vapor and by removing ignition sources. Measures for managing these strategies are elaborated in Chapter 6 of the Methanol Institute's Methanol Safe Handling Manual. Consideration should be given to bunkering during poor weather due to the risk of lightning.

Vapor Release and Toxicity: Methanol vapors are heavier than air and hazardous concentrations may develop in low lying areas with poor ventilation. Ingestion of methanol may lead to decreased consciousness, vomiting, diarrhea, visual disturbances, and other potentially fatal issues. Caution is to be considered in enclosed areas. Toxic exposure to methanol vapor or liquid can occur by inhalation, ingestion or absorption through the skin. If liquid methanol is present, then methanol vapor in concentrations above toxic limits might also be present. A toxic cloud focus area study should be performed to assess the area of influence.

Corrosivity: The use of methanol compliant equipment for bunkering operations is required. Special attention should be taken for drip-free couplings and spill trays at connections. Additional information about the compatibility of methanol with various materials can be found at Methanol.org.

Table 4: Operational Hazards and Mitigations Summary

Volatile	Flammable	Toxic	Corrosion
Hazards			
Methanol is a low molecular weight (32.04 g/mol), low-boiling (64.7° C, 148° F) organic solvent. Because of its low boiling point, low vapor pressure, it readily evaporates at room temperature and its vapors are always present. In air, methanol remains as a vapor for 18 days, eventually breaking down to other chemicals. It can be carried for long distances. Methanol does not bind well to soil, so it can enter the groundwater. In contrast, its relative vapor density, the density of methanol in vapor form compared to that of air, is 1.11. This implies it is denser than air and so the vapors would sink to lower levels in the air.	Highly flammable liquid The flammable range of methanol vapor to air is between 6% and 36.5% and can create an explosive or flammable environment. A methanol-water mixture of at least 25% methanol is still capable of burning. Water will not cool methanol below its flashpoint. Do not use high-pressure water streams. Because methanol is miscible in water, application of water will spread the fire until the dilution ratio reaches at least 3/1. Water-methanol solutions are flammable to a composition of 76 vol% water. The flame is invisible in daylight hours.	Methanol as a toxic chemical. Exposure to liquid methanol on the skin can cause irritation, dryness, cracking, inflammation or burns. Methanol in the human body (either ingested or skin absorption) oxidizes and produces formic acid and formaldehyde. A minimum of 10 mL of pure methanol ingested can accumulate dangerous levels of formic acid and destroy the optical nerves, causing blurry or indistinct vision, changes in color perception, and eventual blindness. Other symptoms include headache, vertigo, weakness, nausea, vomiting or inebriation, and overexposure will lead to death, where the median ingested lethal dose is approximately 100 ml. Allowable occupational exposure limits 200 ppm (260 mg/m3) TWA for exposure to the skin. Higher values are given for short-term exposure limits alternatively to long-term low exposure amounts. Ingestion of methanol may be life threatening. The onset of symptoms may be delayed for 8 to 36 hours after ingestion.	Methanol is corrosive for certain materials
Mitigating Measures			
Closed loading, delivery and handling of methanol shall be carried out. Methanol is completely soluble in water, plenty of water to spray to dissolved vapors. Use of methanol gas detection equipment.	Closed loading, delivery and handling of methanol shall be carried out. Use of methanol gas detection equipment. Use of (infrared) IR camera to detect methanol fire. Alcohol resistant foam firefighting extinguishers.	Remove to fresh air. If difficulty in breathing develops or if breathing has stopped, administer artificial respiration or cardiopulmonary resuscitation (CPR) immediately and seek medical attention. Proper PPE	Consideration to be given to the tank coatings, pipes, and piping fixtures seals, O-rings, gaskets within the fuel handling system.

RISK ASSESSMENT METHODOLOGY AND REPORTING

Risk assessments are conducted to assess the associated risks and hazards of the bunkering operation. The assessment should be conducted in accordance with relevant standards and regulations. At a minimum, the bunkering operation specific risk assessment should cover preparations before and upon the ship's arrival, approach and mooring; testing and connection of equipment; methanol transfer and boil-off gas management; completion of bunker transfer and disconnection of equipment; and risks to personnel and environment (NP 2120 ISO Document).

More information can be found on risk assessments in the ABS *Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries*.

SIMULTANEOUS OPERATIONS (SIMOPS) STUDY

For any operations performed simultaneously during bunkering operations, a simultaneous operations (SIMOPS) study is to be conducted. This should include any activities such as cargo or passenger loading that may produce potential hazards like dropped objects, accidental spills or vapor release, or cargo operations too close to bunkering locations. The study should also include operations that could introduce risks or hazards to bunkering operations and whether those operations should be prohibited or not. The assessment results should include identification and description of the operations, the SIMOPS risk assessment, and any mitigation measures. Mitigation measures may be incorporated into the standard operating manuals and procedures or used as a stand-alone process.

SAFETY AND SECURITY ZONES

The safety zone is a designated ignition-free area where entry is limited to authorized essential personnel with proper training. The extent of the area is determined by regulation, review of local and national authorities, and analysis of the boundaries of areas where potentially flammable mixtures could enter in the event of an accidental release or spill. These boundaries are to be determined with a risk assessment and typically are set within a combined security zone. To prevent ignition sources, all sources should be eliminated prior to bunkering operations. The following considerations should be taken when creating the boundaries of a safety zone:

- Operational case scenarios for weather conditions during bunkering operations in the event of a spill
- Height and vertical space in areas where people may be working
- Surrounding environments such as buildings, port facilities and topography may affect dispersion
- Properties and spill characteristics of fuel in the event of a release

The security zone is an area around the ship that prevents other ships, equipment, vehicles, and other operations from a minimum distance from the bunkering operation. Only authorized and essential personnel are allowed to be within this zone to minimize any intentional damage or interference. The minimum distance of the zone is determined by the risk assessment analysis which takes all associated risks into consideration and any regulatory requirements. The security zone is typically not smaller than the established safety zone. When establishing the security zone, attention should be given to radio communication activities, traffic movement (ship or road) and simultaneous operations (SIMOPS) work.

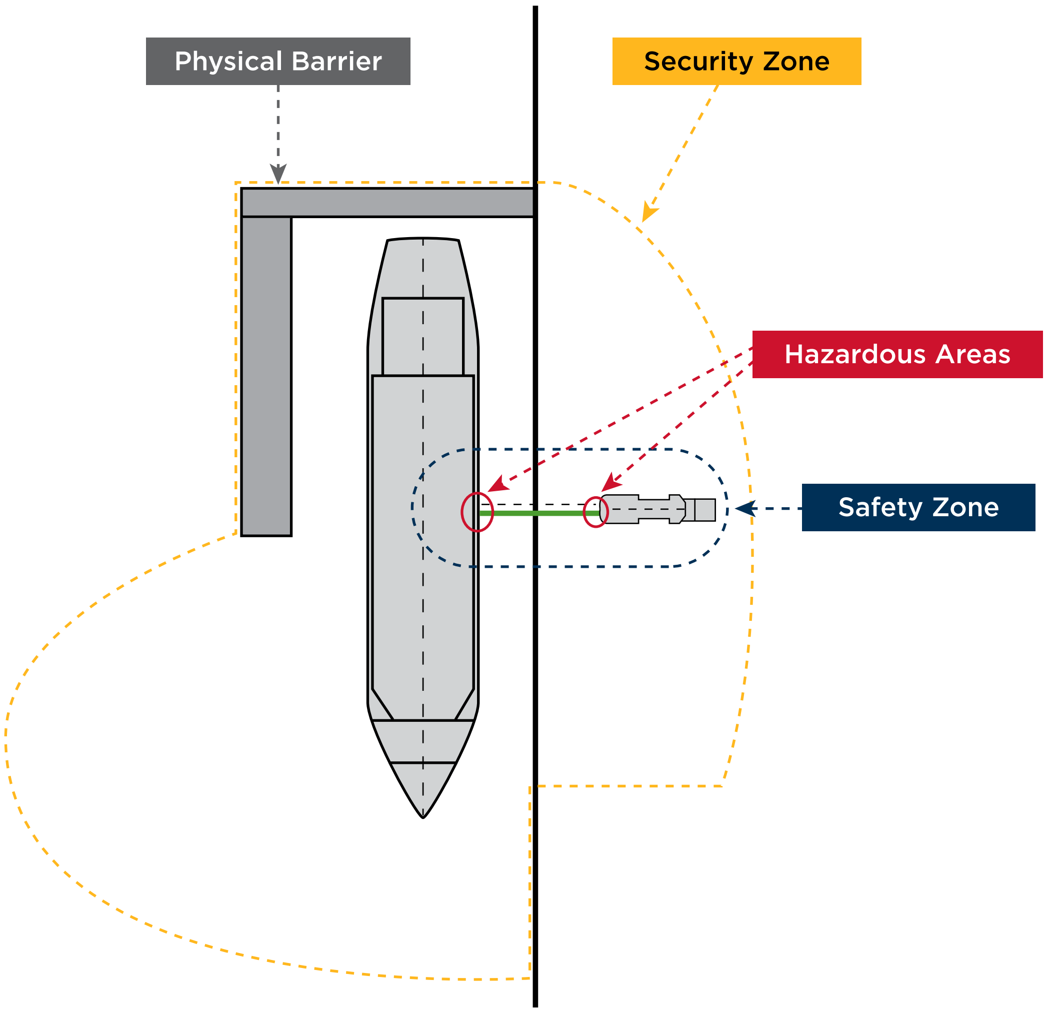


Figure 6: Example of Safety and Security Zones for Bunkering Operation

APPENDIX I CHECKLISTS

Checklists are useful in confirming the completion of all proper steps before and after an operation. These confirm to the person-in-charge and other parties involved that the procedure has been performed correctly, completely and in the proper sequence. The following checklists are guidelines for methanol bunkering operations and can be used as templates to create the actual checklists that should be more detailed with specific information on the ship, bunker supply and location. Additional guidance can be found in MSC.1/Circ. 1621.

BEFORE BUNKERING

Item	Check	Supplier (Truck/ Terminal/ Ship)	Receiving Ship	Remarks
PART I: PLANNED OPERATIONS CHECKLIST (To be completed within 48 hours prior to bunkering operation)				
1	Initiate communication with all involved parties including the port authorities with intent to bunker			
2	Supplier is authorized by relevant port/ authority to bunker methanol			
3	Bunkering location and schedule are agreed upon			
4	Firefighting and emergency response procedures, any applicable limitations and communication protocols are completed and agreed upon			
5	Bunker fuel specification and transfer quantity is agreed upon			
6	Perform mooring compatibility assessment prior to operations			
7	Rigging sequence and hose handling/ securing methods are agreed upon			
8	Perform compatibility assessment of methanol transfer system arrangement			

Item	Check	Supplier (Truck/ Terminal/ Ship)	Receiving Ship	Remarks
9	Method of electrical bonding to earth has been agreed upon and electrical insulation is provided for the bunker			
10	Procedure and time period for testing, purging and blow through operations are established			
11	Nitrogen availability and supply for testing, purging and blow through process are established			
12	Tank vents are free of obstructions			
13	Sampling procedure and quantity of samples to be collected is agreed upon			
14	Sounding procedure is agreed upon			
15	ESD scenarios are established and agreed upon			
16	Persons-in-charge of mooring and bunkering are designated			
17	Crew qualifications, training and records of fire & spill drills are available			
18	Fire control plans are available at readily accessible location.			
19	Firefighting equipment (fixed and portable) is in good working order			
20	Requirements of local and/or national authorities are being observed			

Item	Check	Supplier (Truck/ Terminal/ Ship)	Receiving Ship	Remarks
21	Methanol gas detectors and/or thermal cameras (fixed and portable) are in place and in good working order			
22	PPE matrix for each stage of the operation is established			
23	Spill protection is available at the manifold			
24	Spill transfer arrangement (pump) is ready to use			
25	Review appropriate lighting is provided			
26	Review safety zones and security zones are established and in place			
27	Maintenance records and test certificates of fender and mooring equipment are available			
28	Limits of wind, weather and sea conditions have been agreed upon			
29	Provision to monitor lightning warnings is available			
30	Safe means of access are available between the ships and/or shore			
31	Provision for continuous monitoring of bunkering operation (physical presence/ CCTV) is in place for both the receiver and supplier			

Item	Check	Supplier (Truck/ Terminal/ Ship)	Receiving Ship	Remarks
PART II: PRE-BUNKERING CHECKLIST (To be completed before commencement of the bunkering operation)				
1	Part I of checklist is completed and operations specific requirements (if identified) are available			
2	Wind, weather and sea conditions are within the agreed upon limits			
3	Shore personnel /Crew/onboard fixed or portable system is designated to monitor lightning warnings			
4	Permissions from authorities for methanol bunkering (where applicable) have been received and notifications made			
5	Any simultaneous operation during bunkering is to be agreed upon between the supplier and receiver as necessary			
6	Primary and secondary means of communication is established			
7	Ship is securely moored with sufficient fendering			
8	Initial bunker gauging completed			
9	Receiving ship tank has sufficient volume to receive the specified bunker quantity and subsequent nitrogen blanketing			
10	Safe means to access between supplier and receiver is established			
11	Bunker manifold and operation areas are sufficiently illuminated			
12	Safety shower and eyewash are ready for use			
13	Scupper and save-alls are plugged			
14	Spill trays are empty and drain plugs are closed			

Item	Check	Supplier (Truck/ Terminal/ Ship)	Receiving Ship	Remarks
15	Unused bunker connections are blanked and secured			
16	Bunker hoses or transfer arms together with QCDC, DBC, SSL and ESD links are connected between the supplier's and receiving ship's manifolds			
17	Hoses are adequately supported			
18	Insulation and electrical grounding are set up			
19	Fixed and portable electrical components in the operations area are intrinsically safe			
20	Provision to prevent accidents from falling objects in place			
21	Signage is posted for safety zones and unauthorized access zones			
22	External doors, portholes and accommodation ventilation inlets are closed			
23	Positive pressure maintained inside accommodation			
24	Nitrogen supply for purging and leak testing the hoses is available			
25	Valves and instruments for purging and leak testing the hoses are identified and ready			
26	Crew notified of commencement of hose testing			
27	Methanol and vapor return hoses are purged and leak tested satisfactorily			
28	Receiving ship has been notified facility is ready for transfer			
29	Supplier received confirmation to commence the transfer			

DURING BUNKERING

Item	Check	Supplier (Truck/ Terminal/ Ship)	Receiving Ship	Remarks
1	Pre-bunkering checklist Part I and II completed			
2	Bunkering commences to the specified transfer rate progressively			
3	Safety procedures and mitigation measures for simultaneous activities, as mentioned in the ship's approved operational documentation, are agreed upon and are observed by all parties involved			
4	Monitoring of tank levels, tank conditions (pressure and temperature), leaks and vapors, and pump transfer rates			
5	Monitor mooring lines and bunker hoses and transfer arms occasionally			
6	Quantity of methanol discharged to the receiving ship (10%, 25%, 50% etc.) is continuously relayed to receiving ship			
7	Monitor that the integrity of security and safety zones is maintained			
8	Monitor that weather and sea conditions remain within limits			

AFTER BUNKERING

Item	Check	Supplier (Truck/ Terminal/ Ship)	Receiving Ship	Remarks
1	Receiving ship has been informed that the methanol transfer is completed			
2	Confirm all manifold valves are closed			
3	Nitrogen supply for purging and blow through operation is available			
4	Spill trays are located below the disconnecting flanges			
5	Methanol and vapor return hoses are purged and blown through			
6	Bunker loading arm, hoses, monitoring, ESD and electrical isolation or bonding connections are disconnected from the receiving ship's manifold			
7	Remove all signs after the security zone and safety zone have been deactivated			
8	All parties involved, including the authorities, have been notified that operations have been completed			
9	Documentation and bunker samples are handed over			
10	Unmooring and cast off			
11	Disconnection of communication			
12	Report any near misses and/or incidents to the authorities			

LIST OF REFERENCES AND GUIDANCE DOCUMENTS

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26. UNFCCC. Decision 1/CP.21. Adoption of the Paris Agreement. Conference of the Parties, 21st session held in Paris 30 November to 13 December 2015. Agreement entered into force 4 November 2016.

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LIST OF ACRONYMS AND ABBREVIATIONS

ABS	American Bureau of Shipping
ADR	Agreement concerning the International Carriage of Dangerous Goods by Road
ALARP	As Low As Reasonably Practical
ASTM	American Society for Testing and Materials
BDN	Bunker Delivery Note
CF	Carbon Factor
CII	Carbon Intensity Indicator
CO_2	Carbon Dioxide
DCS	Data Collection System (IMO)
EEDI	Energy Efficiency Design Index
EEXI	Energy Efficiency Existing Ship Index
ESD	Emergency Shutdown
FSS	Fire Safety Systems
GHG	Greenhouse Gas
HFO	Heavy Fuel Oil
IACS	International Association of Classification Societies
IDLH	Immediately Dangerous to Life or Health
IGF	International Code of Safety for Ships Using Gases or other Low-Flashpoint Fuels (IMO)
IMO	International Maritime Organization
IMPCA	International Methanol Producers and Consumers Association
ISO	International Organization for Standardization
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MARPOL	International Convention for the Prevention of Pollution from ships, 1973, as amended (IMO)
MEPC	Marine Environment Protection Committee (IMO)
MSC	Maritime Safety Committee (IMO)
MVR	ABS Rules for Building and Classing Marine Vessels; Marine Vessel Rules
NIOSH	National Institute for Occupational Safety and Health
NOx	Nitrogen Oxides
OCIMF	Oil Companies International Marine Forum
OSHA	Occupational Safety and Health Administration

PM	Particulate Matter
PPM	Parts Per Million
P/V	Pressure/Vacuum
RO	Recognized Organization
SIMOPS	Simultaneous Operations
SOLAS	International Convention for the Safety of Life at Sea, 1974, as amended (IMO)
SOx	Sulfur Oxides
SSL	Ship-Shore Link
STCW	Standards of Training, Certification and Watchkeeping for seafarers
TWA	Time Weighted Average
UK MCA	UK Maritime and Coastguard Agency
UNFCCC	United Nations Framework Convention on Climate Change
USCG	United States Coast Guard

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