FAST Track to Clean and Carbon-Neutral WATERborne Transport

Deliverable 7.2

Feasibility study on ship to ship bunkering

Deliverable data

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CONTENTS

List of symbols and abbreviations

ADN	European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways
AR-AFFF	Alcohol Resistant Aqueous Film Forming Foam
CEVNI	European Code for Inland Waterways
IAPH	International Association of Ports and Harbors
IBC	International Code for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk
IWW	Inland Waterway
WP	Work Package

1 EXECUTIVE SUMMARY

The FASTWATER (FAST Track to Clean and Carbon-Neutral WATERborne Transport through Gradual Introduction of Methanol Fuel) project aims to start a fast transitionary path to move waterborne transport away from fossil fuels, and reduce its pollutant emissions to zero impact, through the use of methanol fuel. FASTWATER will develop and demonstrate a path for marine methanol technology, both for retrofit and next generation systems. Specifically, the project will demonstrate feasibility of three vessels running on methanol fuel: a harbour tug, a pilot boat, and a coast guard vessel. A conversion concept for a river cruise ship using methanol-driven propulsion will also be developed and a universal, scalable retrofit kit for converting diesel fuelled ships to methanol use for a wide power range (200 kW-4 MW) will be validated.

This study shall focus on the ship to ship bunkering of a river cruise ship, where an adapted chemical tanker shall be used as a bunker ship.

1.1 Purpose

The purpose of this document is to provide a summary of recommendations to make ship to ship bunkering of methanol a safe and acceptable operation. It was assumed that reducing the risk to an acceptable level would represent the greatest challenge for passenger ships.

1.2 Problem definition

Although the IWW chemical tankers fulfil the requirements of the ADN and are generally considered very safe, there are restrictions which would not allow Ship to Ship bunkering via IWW chemical tankers.

IWW vessels transporting dangerous goods like methanol must be recognisable. If methanol is stored, in accordance with CEVNI; European Code for Navigation on Inland Waterways, the vessels must be marked with two blue cones or two blue lights. This leads to the following restrictions:

- 150 m distance when waiting before a lock or a bridge
- Not allowed to pass through a lock together with a passenger ship
- Dedicated berthing area, 100 m from civil engineering structures and storage tanks; and 300 m from residential areas
- Loading or unloading of methanol is only permitted in designated areas approved by the authorities

In the past, there was no need for a chemical tanker to go alongside a passenger ship to deliver methanol. Therefore, restrictions described before were reasonable.

1.3 Scope and Approach

Methanol ship to ship bunkering had already been carried out previously. Examples include Stena Germanica at the Port of Gothenburg in January 2024, Maersk's container vessel bunkered green methanol in Singapore in July 2023 and Waterfront Shipping demonstrated methanol ship to ship bunkering at the Port of Rotterdam in May 2021. These three examples show that methanol bunkering is technically feasible and safe. The focus of the FASTWATER project was on ship to ship bunkering of a river cruise ship. In WP 5, the project partner MEYER WERFT worked on the conversion concept for a river cruise ship of the "Viking Longship Class". This concept was used as a reference ship. The operational requirements for the bunkering process were discussed together with MEYER WERFT and the associated partner Viking Cruises. With this in mind, the following scenario was defined to specify the Ship to Ship bunkering:

- A river cruise ship shall be refueled with methanol via an IWW chemical tanker
- Methanol bunkering takes place wherever a river cruise ship can today be refueled with conventional fuel via ship-to-ship bunkering
- During bunkering, passengers are allowed to stay on board the river cruise ship, with a minimum of restrictions, e.g. keeping windows closed, staying on the balcony is prohibited, smoking and naked lights are prohibited on the upper deck.

Each port is organized differently, responsibilities and approval procedures may differ. However, it is assumed that authorities expect the applicant to provide evidence that the bunkering of alternative fuels meets the highest possible safety requirements.

This document provides an overview on how the safety level of an IWW chemical tanker can be increased to allow ship to ship bunkering with a river cruise ship.

2 Properties of Methanol

Methanol, a simple alcohol with the chemical formula CH3OH, has several special properties that make it suitable for various industrial applications, including its potential as an alternative marine fuel. Understanding these properties is crucial for the safe handling, storage and use of methanol as a marine fuel. Some important properties of methanol compared to conventional marine diesel are listed in table 1.

Table 1 Properties of methanol compared to conventional marine diesel

	Methanol	Marine Diesel Oil
Flash Point	12°C	>=60°C
Ignition Temperature	440°C	>=225°C
Boiling Point	65°C	141 - 650°C
Explosive limits in air	6% - 36%	0.6% - 6,5
Specific Gravity (20°C)	0.79 g/cm³	0.84-0,91 g/cm³
Solubility in Water	completely miscible with water	practically insoluble in water
Maximum explosion pressure	8.5 bar	
Flame	Burns with a faint blue, almost invisible flame	Burns with yellow flame, black smoke
Hazard symbols		

Effect of methanol in water

The effect of methanol in water is an important issue, particularly in the marine environment where leakages can occur during handling, transport or use. Although methanol is biodegradable and can be utilised by certain microorganisms as a food and energy source, excessive concentrations can pose risks to aquatic organisms and ecosystems.

Aquatic toxicity testing assesses the impact of substances like methanol on various aquatic organisms, including fish, daphnia (small planktonic crustaceans), and algae. Figure 1 illustrates the effects of methanol on these organisms at specific concentrations and exposure durations. The LC50 for fish indicates the concentration and duration of exposure required to cause mortality in 50% of the test population. Similarly, the EC50 for daphnia represents the concentration and exposure time leading to immobilization of 50% of the tested organisms.

Additionally, the EC50 for other aquatic organisms denotes the concentration and exposure duration at which the growth or growth rate of algae is reduced by 50%. These parameters provide valuable insights into the potential toxicity of methanol to different aquatic species and guide regulatory assessments and environmental management practices.

Methanol (67-56-1)	
LC50 fish 1	15400 - 29400 mg/l 96 h - Fish
EC50 Daphnia 1	> 10000 mg/l 48 h - Daphnia
EC50 other aquatic organisms 1	22000 mg/l 72h - Selenastrum carpricornutum (Pseudokichnerela subcapitata)

Figure 1 Excerpt from section 12: Ecological information Methanol Safety Data Sheet Methanex 2016

To illustrate the effects of methanol on aquatic life, consider the following: A spill of 1000 litres could contaminate around 50 cubic metres of water with a methanol concentration of up to 15400 mg/l, as indicated by the LC50 value for fish. However, it should be noted that natural currents in rivers or seaports generally allow methanol to dilute rapidly. Consequently, the exposure times shown in Figure 1 would probably not be achieved.

3 Involved Parties

A bunker operation typically involves the transfer of fuel from a storage facility to a ship's tanks. This process requires coordination between the bunker supplier, the ship's crew, and often port authorities. The bunker location, the type of the bunker ship and the receiving ship makes every bunker operation unique. A typical berth for river cruise ships is shown in Figure 2. The limits of truck to ship bunkering are clearly visible. The jetty often cannot be used by trucks and is also used by passengers.

Figure 2 Viking Bela: press photo Neptun Werft

Port authority

Every port is governed by a port authority. A port authority is responsible for the sustainable development, management and operation of the port and ensures the safe and smooth handling of all shipping. A methanol bunker operation would also be under their responsibility. Every port is different, the port authorities are organised differently, and responsibilities are distributed variously. However, it is assumed that the authorisation process will be similar everywhere. The ports are very well networked and organised in the International Association of Ports and Harbors (IAPH). The following information were captured by talks with members of staff of the Port of Antwerp-Bruges.

- First, the Port of Antwerp-Bruges consults with other ports, information is exchanged, and a standardised regulation is aimed for.
- The Port of Antwerp-Bruges expects the parties involved in the bunkering process to comply with the bunker checklists published by the IAPH.
- The Port of Antwerp-Bruges has produced a map showing where the bunkering of methanol and other new fuels is permitted. Areas with a higher risk to the public are excluded.
- At the moment, Port of Antwerp-Bruges is drafting a licensing system for bunkering alternative fuels. The licensing system is currently still under review. In the meantime, it's possible to bunker on a case-by-case approach, based on criteria defined by the Harbour Master's office, IAPH and international guidelines.
- Bunker vessels must fulfil the statutory requirements for chemical tankers with either an IBC code for seagoing tankers or an ADN code for inland tankers.
- The Port of Antwerp-Bruges does not impose any additional requirements on tankers that go beyond the provisions of the ADN code and the IBC code.

Bunker checklists published by IAPH

The IAPH has published checklists for bunker operations of alternative marine fuels. For methanol bunkers, checklists for Ship to Ship or Truck to Ship are available.
The Ship to Ship checklist is available in three versions.

- Version A has been developed specifically for project-based bunkering of vessels alongside a quay where the site operator is fully engaged in, and has a shared responsibility for, the safety of the Ship to Ship bunkering.
- Version B has been developed specifically for the bunkering of vessels alongside a "Bunker Ready Terminal".
- Version C has been developed specifically for the Ship to Ship bunkering of vessels on buoys, dolphins or at sea, without a person in overall advisory control.

The three versions are in the same way structured. They are divided into six main parts:

- Part A – Preparation phase
  This phase focuses on preparing for the bunkering operation, including equipment inspection, safety checks, and environmental considerations.
- Part B – Pre-operation phase
  The bunker vessel operator, receiving vessel operator, and site operator complete

specific tasks related to vessel readiness, mooring arrangements, and checklist exchange.

- Part C – Alignment and agreement phase
  A pre-transfer conference is conducted to align all parties on the operation plan, safety measures, and emergency procedures. Agreements are formalized, and connection testing is performed.
- Part D – Connection testing phase
  Prior to fuel transfer, comprehensive testing of connections, emergency shutdown systems, and safety measures is conducted to ensure readiness.
- Part E – Transfer phase
  Fuel transfer begins under the supervision of designated personnel, with periodic checks to monitor progress and ensure compliance with safety protocols.
- Part F – Post-operation phase
  After completion of fuel transfer, post-operation checks are performed to confirm successful disconnection, assess any issues, and ensure compliance with safety standards.

The main parts are further divided into sub-parts. The schematic of version A of the bunker process is shown in Annex A. By working through the preparation phase with all parties involved, and looking for safe solutions, a safe bunker operation should be achieved. It is necessary to conduct further studies to better understand the risks. For the safety of each bunker operation, it is crucial that every checklist is completed with care and that deviations are reported to all parties involved.

River Cruise Ship

A ship of the "Viking Longship class" was used as an example ship. This ship type was used by MEYER WERFT for their "methanol river cruise ship conversion concept", which is part of FASTWATER project WP 5. Table 2 summarises some information about the ship.

Table 2: Key information Viking Longship class

Length	135 m
Breadth moulded	11.45 m
Speed	20 km/h
Passenger cabins	95
Passengers	190
Crew	49
Methanol volume (MeOH only conversion)	150m³

Bunker Ship

The idea was to use an existing IWW chemical tanker and to convert it so that it could be used as a bunker ship. According to the company VARO Energy Netherlands B.V. is the smallest size 85 m long. Smaller sizes are not available because most tank terminals would not accept those for loading methanol or other chemicals, and they are not economically feasible because the market and the distribution network do not yet exist. The distribution network for diesel oil for the IWW market can be described as following: A tanker barge loads diesel on a terminal and delivers this to a bunker station. From there, smaller bunker boats with a tank capacity between 150 to 300 m³, obtain diesel oil and deliver it to IWW ships. VARO Energy choose a type C tanker as a possible ship to be converted to a bunker ship. Among other things, a bunker-boom would have to be installed for hose handling.

Table 3 summarises some information about the type C tanker, which is used as an example ship.

Table 3: Key information type C tanker

Length	84.71 m
Breadth moulded	9.5 m
Depth	3.3 m
Air draft	5.1 m
Deadweight	1686 mt
Crew	3
Tank volume 97%	1733 m³

The ADN describes the minimum requirements for a IWW chemical tanker, when carrying methanol. The table in Figure 3 shows special requirements that must be met when transporting methanol.

UN No. or substance identification No.	Name and description	Class	Classification code	Packing group	Dangers	Type of tank vessel	Cargo tank design	Cargo tank type	Cargo tank equipment	Opening pressure of the pressure relief valve/high velocity vent valve in kPa	Maximum degree of filling in %	Relative density at 20 °C	Type of sampling device	Pump room below deck permitted	Temperature class	Explosion group	Anti-explosion protection required	Equipment required	Number of cones/blue lights	Additional requirements/Remarks
(1)	(2)	(3a)	(3b)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
	3.1.2	2.2	2.2	2.1.1.3	5.2.2 / 3.2.3.1	1.2.1 / 7.2.2.0.1	3.2.3.1 / 1.2.1	3.2.3.1 / 1.2.1	3.2.3.1 / 1.2.1	3.2.3.1 / 1.2.1	7.2.4.21	3.2.3.1	3.2.3.1 / 1.2.1	3.2.3.1 / 1.2.1	1.2.1	1.2.1 / 3.2.3.3	1.2.1 / 3.2.3.3	8.1.5	7.2.5	3.2.3.1
1230	METHANOL	3	FT1	II	3+6.1	N	2	2	3	50	95	0.79	2	yes	T2 [12)]	II A	yes	PP, EP, EX, TOX, A	2	23

Figure 3 Extract from ADN Table C: List of dangerous goods accepted for carriage in tank vessels

4 Hazards and recommendations

While this list is not exhaustive, many hazards can be sufficiently minimized by complying with rules and regulations. The recommendations provided, aim to enhance safety levels to facilitate methanol bunker operations.

Tank Explosion

Safety standards for chemical tankers, whether inland waterway or seagoing, are stringent. While tank explosions are infrequent, their impact is severe. Since chemical tankers are typically berthed away from public areas, casualties usually involve only crew members. An illustrative case is the explosion and subsequent loss of the chemical tanker VICUÑA in 2004, with further information available in the conclusive investigation report.

The tanker VICUÑA exploded while discharging methanol at a terminal. The explosion killed 4 people, resulted in the total loss of the ship and cargo, and caused severe damage to the quay and terminal facilities and to boats moored nearby. It is assumed that the explosion started in tank CS7 and then spread to tanks CP7, CP8 and the neighbouring wing tanks and reached the remaining tanks after a wave of explosions in the direction of the bow. A defective cargo pump is assumed to be the probable cause.

The report made the following safety recommendations, among others:

"All ships, independently of their tonnage, that transport potentially explosive or inflammable cargoes, to be equipped with systems that permit maintaining these cargoes inert during the transport, the loading/discharge or even render impossible the formation of an inadequate atmosphere with the empty tanks."

Recommendation 1: Methanol bunker ships operating in the immediate vicinity of public areas or next to passenger ships should have inerted methanol tanks.

Methanol Spill

Chapter 2 outlines methanol's minimal impact on aquatic organisms, indicating that a methanol spill is primarily a fire hazard rather than an environmental concern due to its low flashpoint. To mitigate the risk of fire in the event of a spill, three crucial measures should be implemented:

- The primary focus should be on preventing the spill through technical and operational measures. This includes immediately stopping pumps or closing valves to limit the volume of the spill. To contain the impact, it's essential to minimize the affected area by swiftly directing spilled methanol overboard using coamings.
- If methanol is spilt, it must be washed off the deck immediately and efficiently.
- If a fire occurs, it must be extinguished quickly and effectively.

Prevention and containing spills

Listed below are potential causes of spills and corresponding recommendations to prevent or mitigate them.

Tank overflowing

By conventional fuels, overflowing of tanks is a common cause of spills during bunkering. This can happen, for example, if tanks are not monitored correctly. Tanks that were thought to be closed are still open and continue to fill. If there is no more space in the tanks the fuel will be discharged over the vent heads on to the deck. This overflowing of tanks can also happen on the bunker ship due to incorrect valve position.

Recommendation 2: Methanol tanks on the bunker ship and the receiving ship shall be equipped with an audible high-level alarm and an independent high-high-level alarm that safely stops the bunkering process via an ESD connection. The high-high alarm setting shall be selected so that the methanol tank is prevented from overflowing.

Recommendation 3: The vent outlet must be designed in a way that overflowing methanol is discharged directly overboard into the water.

Failure of bunker hose

Hose failures are unlikely when the bunker hose is type tested, suitable for methanol, regularly inspected, maintained and tested, correctly stored, only used in the allowed parameter and visually examined before each use. All this is known by bunker operators, how well this is carried out often depends on the knowledge and attitude of the crew.

If the valves in the bunker system are closed too quickly or the valves are still closed at the start of the pumping process, pressure surges can occur. Those pressure surges can be sufficient to damage pipework or the bunker hose.

Recommendation 4: Regular audits should be carried out to ensure that the bunker hose fulfils all requirements, that it is stored correctly and that the crew knows how to carry out a visual inspection.

Recommendation 5: Bunker hoses should be type tested accordingly to MSC.1/Circ.1621 INTERIM GUIDELINES FOR THE SAFETY OF SHIPS USING METHYL/ETHYL ALCOHOL AS FUEL, 8.3.2 Ships' bunker hoses. *"Each type of bunker hose, complete with end-fittings, should be prototype-tested at a normal ambient temperature, with 200 pressure cycles from zero to at least twice the specified maximum working pressure. After this cycle pressure test has been carried out, the prototype test should demonstrate a bursting pressure of at least 5 times its specified maximum working pressure at the upper and lower extreme service temperature."*

Recommendation 6: The crew of the receiving vessel should be knowledgeable about pressure surges. It's crucial that the flow to the tank remains uninterrupted while the pump is in operation. Before closing a filled tank, a new tank should be opened to prevent any disruptions in the flow.

Recommendation 7: The receiving ship and bunker ship should be equipped with pressure relief systems to manage overpressure in the methanol bunker system effectively. The closing time should be verified with a pressure surge calculation.

Recommendation 8: The closing time of motorised valves should be slowed down to avoid excessive pressure surges.

Connection

The connection between the bunker hose and the manifold can be a source of leakage. A leakage will be mostly discovered when the bunker process starts, and the pressure and flow rate are slowly ramped up. To keep the bunker line and bunker hose closed before and after connecting, it is advisable to use a dry-disconnect coupling in combination with a safety dry break-away coupling.

Recommendation 9: For the use of dry disconnect couplings in combination with a safety dry break-away coupling

- Use only (for methanol) approved couplings
- Follow operating manual
- Operation only by skilled and qualified staff
- Maintenance and testing only by skilled and qualified staff
- Use only original spare parts for maintenance
- Ensure that both coupling halves are compatible with each other
- Couplings are connected direct to bunker line and bunker hose, no unnecessary connectors inbetween
- After bunker hose is connected to bunker line, a leakage test with nitrogen should be performed

Reduction of spill size

Because the bunker ship and the receiving ship have to provide a bunker watch, it is assumed that a leak would be quickly discovered, and the bunker process would be stopped immediately. However, it is possible that the bunker watch is distracted, and a methanol leak gets discovered much later.

Recommendation 10: Installation of an attention emergency stop system (dead man's switch). If the bunker watch does not press the button within 30 seconds, an acoustic signal reminds them to do so. If no action is taken within 40 seconds, the bunker process is stopped automatically. There are also systems that require continuous actuation.

Recommendation 11: Installation of leak detection systems that automatically stop the bunkering process as soon as methanol is detected in the form of vapour or liquid.

Recommendation 12: The design of the deck should ensure that any spillage is minimised and can be safely drained into the water.

Removal of spills

Any methanol spill is a fire risk, which is why it is important to remove the methanol from the deck quickly. By using the water spray system, the methanol can be effectively flushed overboard while preventing ignition sources from coming into contact with it. In addition, the bunker watch can maintain a sufficient distance to the spill.

Recommendation 13: A fire hose should be ready for use to wash small spills off the deck immediately. For larger spills, the sprinkler system should additionally be activated.

Methanol fire

A fire on a methanol bunker ship is a big risk for their crew and for the crew and passengers on the river cruise ship. IWW chemical tankers have only limited firefighting equipment on deck. The ADN requires a water main fitted with at least three hydrants in the cargo area above deck. It shall be possible to reach any point of the deck in the cargo area simultaneously with at least two jets of water which do not emanate from the same hydrant. Additionally, two hand fire-extinguishers shall be located in the cargo area. In addition, the tank deck is equipped with a water spray system. The purpose is to cool the top of the tanks to avoid an increase in pressure in the tanks due to solar radiation. However, the required 50 $L/h/m^2$ is not adequate for firefighting or wash away purpose.

The above-mentioned firefighting equipment is adequate for the transport of chemicals. During loading and unloading where the risk for spills, fire and explosion is higher, the tank terminal provides additional equipment and personnel to deal with incidents. The crew on a chemical tanker is with two to three people rather small. In the event of a spill, the bunker watch may also be injured or have methanol in their eyes, making it difficult to deal with a spill or fire. A fixed fire extinguishing system that can be activated nearby or at the same device where the bunker process can be stopped manually would be ideal.

Additional fire extinguishing systems such as foam systems with alcohol-resistant, aqueous, film-forming foam (AR-AFFF) or water spray systems, including those in which AR-AFFF can be injected, are viable options. In this study, however, the effectiveness of water spray systems is mainly investigated. The reason for this choice is the environmental friendliness of water, as it has no negative impact on the environment, and its ease of use.

To prove the effectiveness of a water spray system, the following scenario was assumed: A bunker hose DN65 rupture at a maximum bunker rate of $60m^3/h$. The bunker pump will be stopped after 30 seconds. This would result in a spill size of 500 l. It should be noted that stopping the pump later has little effect on the extent of the spillage, as the methanol is discharged into the water.

Any methanol spill requires a quick response to avoid the risk of fire. Immediate activation of the water spray system could flush the methanol from the deck into the water and shield potential ignition sources from it.

It is worth noting that fire extinguishing tests carried out as part of the proFLASH project have shown that a methanol pool fire cannot be effectively extinguished with a water spray system. It turned out that the fire was extinguished when the methanol was diluted to almost 90% with water. The extinguishment by water dilution can require nine times more water than the methanol spill. However, this disadvantage is more a problem for compartment fire, where a methanol pool in the bilge can be several cm deep.

Assuming the scenario, a spill of 500 l with a size of 10 x 10 m and a depth of 5mm and a water spray system with a discharge rate of 5 $l/min/m^2$, the pool fire would be extinguished (by dilution) after 10 minutes at the latest. During this time the heat from the fire will be effectively suppressed.

Furthermore, the effects of a pool fire during bunkering were analysed. This has been done in cooperation with the RISE Research Institutes of Sweden AB. The report from RISE can be found in annex B. The water spray system on the bunker vessel was not considered in the calculations. In summary, the following can be said:

The construction of the river cruise vessel can be expected to protect passengers inside. However, balconies directed towards the bunker vessel should be closed and forbidden to enter during bunkering. Passengers on upper deck should have time to back off to a safe distance from the methanol pool fire before suffering from second degree burns. Given the limited risk of fire spread, passengers should have enough time to safely evacuate the river cruise vessel. Additionally, methanol burns with little, or no soot and passengers are not expected to suffer from inhalation of toxic smoke during evacuation.

Recommendation 14: Installation of a fixed water spray system with a discharge rate of 5 l/min/m² or more (to compensate the effects of wind). The bunker watch should be able to activate it immediately.

Recommendation 15: A fire hose should be placed on the sun deck of the river cruise ship ready for use in the event of spill or fire on the bunker ship.

Recommendation 16: Spill and fire scenarios should be discussed, strategies planned, and the crews should carry out regular fire drills, preferably together.

Recommendation 17: Providing thermal imaging cameras to determine the extinguishing success.

Recommendation 18: Balconies directed towards the bunker ship should be closed and forbidden to enter during bunkering.

Recommendation 19: Open decks directed towards the bunker ship should be blocked off for passengers.

Methanol Health Risk

Methanol is toxic and presents a considerable health risk if it is inhaled, ingested or comes into contact with the skin. Its effects on the eyes can be serious. Exposure to methanol can lead to poisoning, which can result in symptoms such as headaches, nausea and visual disturbances and, in extreme cases, death.

Recommendation 20: Personal Protective Equipment (PPE) for handling methanol should be worn to minimize the risk of exposure and potential harm.

Recommendation 21: The bunker watch should be equipped with portable gas monitors to effectively monitor methanol concentrations.

Recommendation 22: The crew should be trained on the health risks of methanol and the appropriate first aid measures.

Recommendation 23: The extent to which a methanol spill would create a toxic environment should be calculated or modulated.

Hazardous Area Zones

In accordance with IEC 60079-10-1:2021 is a hazardous area, an area in which an explosive gas atmosphere is present or can be expected to be present, in quantities such that special precautions for the construction, installation and use of equipment are required.

For the safety of ship and persons, hazardous areas should be reduced as far as practical. It should be noted that the hazardous areas of the bunker vessel may extend to the receiving vessel and that the equipment must be certified for this zone or isolated while the bunker vessel is alongside. The classification of zones for tank vessels can be seen in figure 4. It can also be seen that the high velocity vent valve is responsible for a large hazardous area. The valve usually opens only when the tanks are filled, or the tank pressure rises due to solar radiation. The methanol tanks on the river cruise ship are also protected for overpressure. All vents from methanol storage tanks and day tanks are directed to vent boxes (FWD and AFT) through non-return valves and flame arrestors. It is also equipped with a vapour return line. Vapour return has the advantage that the displaced inerted atmosphere in the tanks of the receiving vessel is fed back into the tanks of the bunker ship. The tanks of the bunker ship stay inerted and the hazardous area on the river cruise ship near the vent box is not unnecessarily extended.

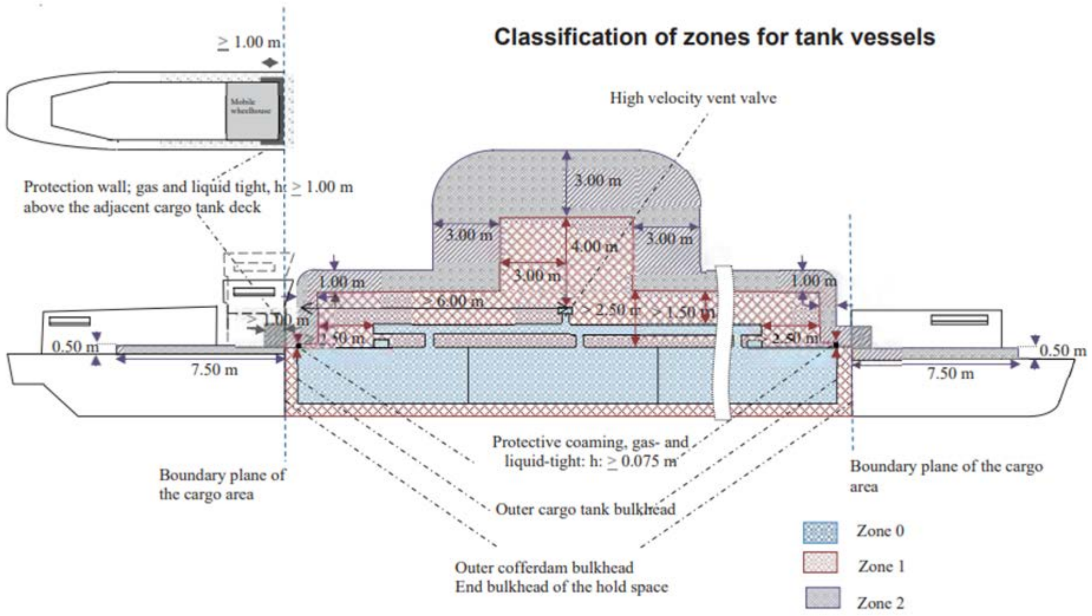


Figure 4 Classification of zones for tank vessels AD 2021

Recommendation 24: Tank vents shall not release methanol vapor when located adjacent to the receiving vessel. The tank pressure should be maintained within a pressure range that prevents the high velocity vent valve from operating.

Recommendation 25: A vapour return system should be used during bunkering.

Recommendation 26: On the river cruise ship in areas that only become hazardous zones during bunkering, it should be possible to isolate electrical systems and equipment that do not meet the requirements for this zone from a central safe location on board.

Recommendation 27: On the river cruise ship a safety zone should be defined that is larger than the hazardous area and inaccessible to passengers and unauthorised crew members during bunkering.

5 Useful documents

Below documents which were useful for this study are listed and briefly described. This list does not claim to be complete, but rather should be seen as a starting point for future projects.

European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN)
This Agreement applies to the international carriage of dangerous goods by vessels on inland waterways. Among other things, the ADN describes the minimum requirements for a IWW chemical tanker when carrying methanol.

International Code for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk (IBC code)
The purpose of the IBC Code is to provide an international standard for the safe carriage, in bulk by sea, of dangerous chemicals and noxious liquid substances. The code prescribes the design, construction and equipment standards of ships, especially of chemical tankers. The IBC Code was not considered in this study as it was assumed that seagoing chemical tankers are too large to be used as a bunker vessel for a river cruise ship.

Guidelines for the Handling, Storage, Use, Maintenance and Testing of STS Hoses
The guide was published by the Oil Companies International Marine Forum (OCIMF) and provides an overview of bunker hose-related topics.

CWA 17540 Ships and marine technology – Specification for bunkering of methanol fuelled vessels
The CEN workshop agreement sets requirements for bunkering methanol to vessels.

IAPH Bunker Checklist Alcohol Based Series & IAPH tool for auditing LNG Bunker Facility Operators
The International Association of Ports and Harbors (IAPH) has developed bunker checklists for methanol and also developed an LNG bunker supplier's accreditation model which ports can use as a base for their accreditation system. It is assumed that ports in which methanol bunkering takes place will use those as the basis for their checklist and accreditation system.
IAPH Clean Marine Fuels WG | IAPH (iaphworldports.org)

ISO 13571:2012 Life-threatening components of fire
Guidelines for the estimation of time to compromised tenability in fires.

proFLASH: Methanol fire detection and extinguishment Franz Evegren SP Rapport 2017:22
The research report outlines the findings from methanol fire tests, assessing different extinguishing agents, detection techniques, and heat radiation effects.

CCC 9/3/6 Submission to the Sub-Committee on Carriage of Cargoes and Containers
The document focuses on Singapore's efforts to address technical challenges in implementing the Interim Guidelines for the safety of ships using methyl/ethyl alcohol as fuel (MSC.1/Circ.1621) within the framework of the IGF Code. It includes a detailed report, beginning on page 4, regarding the preparations for methanol bunkering operations in Singapore.

Methanol Bunker Operation Regulations rev.1, 23/0172023
This publication describes the regulations for the handling and bunkering of methanol in the Port of Gothenburg and neighbouring anchorages.

6 Conclusion and Recommendation

Today, ship-to-ship bunkering is the preferred choice for river cruise ships. To implement methanol as ship fuel, availability and a functional distribution network are essential. Existing chemical IWW tankers which could be converted to methanol bunker ships are much larger than the bunker boats which supply river cruise ships with diesel today.

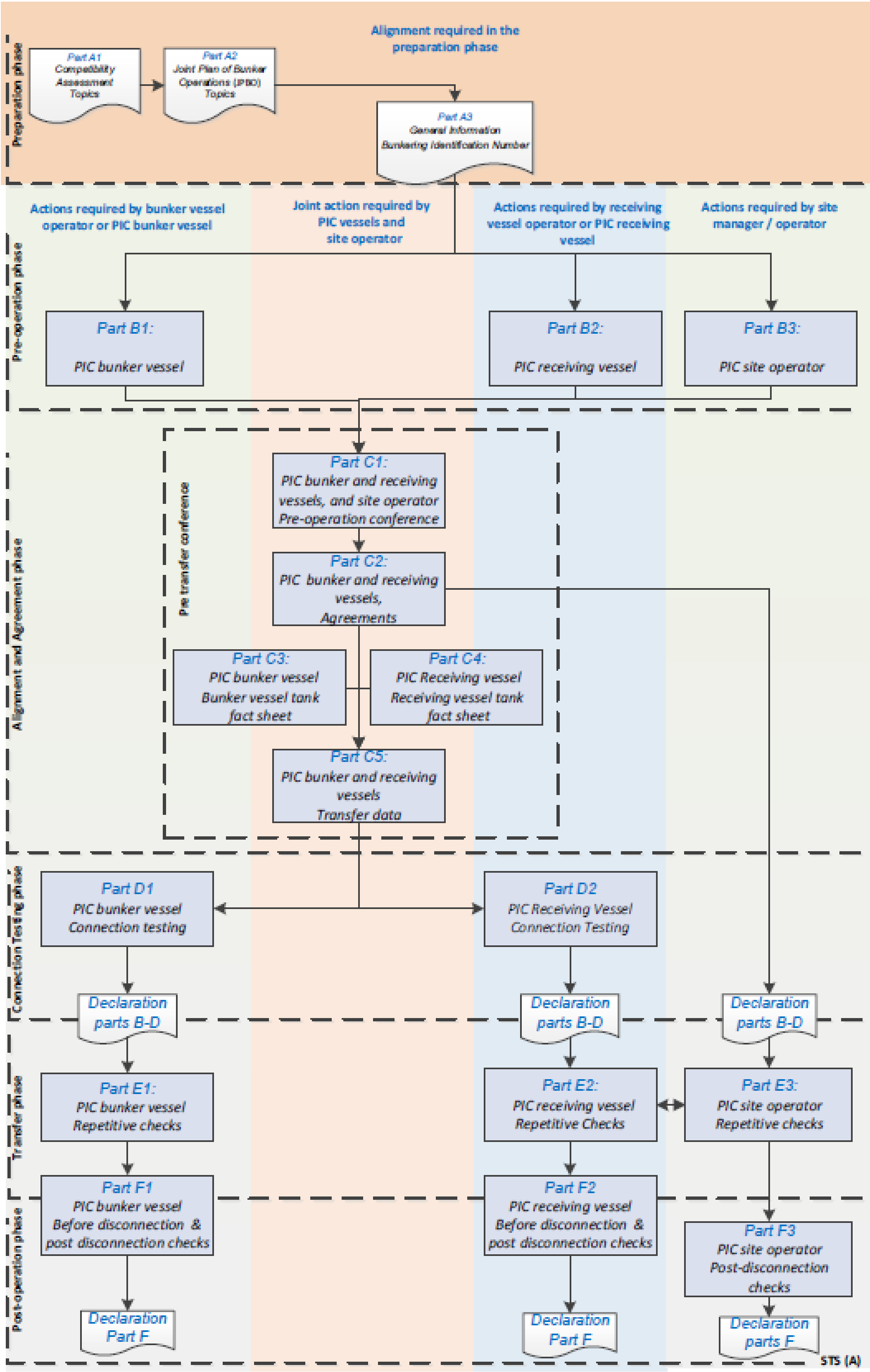
The report made 27 recommendations to further increase the high safety level of chemical tankers to use those as bunker ships at any location where ship to ship bunkering is possible today with conventional fuel. The focus is on tank explosion, spill prevention and removal, and methanol fire. It could be shown that a larger methanol pool fire would not have serious consequences for passengers and give adequate time for evacuation.

Further analysis is required when more details about the bunker vessel and river cruise ship are known to continue reducing the risk and consequences of unplanned events.

7 ANNEXES

7.1 Annex A: Schematic overview of the bunker process

The scheme is taken from the document Ship to Ship bunker operations, Version A, Project-based bunker operations, published by the International Association of Ports and Harbours.



7.2 Annex B: Report FASTWATER – Radiation from pool fires during bunkering

REPORT

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FASTWATER – Radiation from pool fires during bunkering

Based on the results from fire tests conducted by SP (previous RISE) (Holmstedt, Ryderman, Carlsson, Lennmalm, 1980) it was shown that a 50 m² methanol pool fire induces incident radiation of 10 kW/m² at a 2 m distance. An estimation by the looks of the smaller bunkering vessel in the feasibility study, a larger pool fire than 50 m² is not to be expected due to the limited deck area. The shortest distance between a potential pool fire and the river cruise vessel is approximately 1.5 m. Unfortunately, measurements closer than 2 m were not conducted in the study. By looking at the trends of the graph in figure 1, incident radiation from 1.5 m can be estimated to 12.5 kW/m² but to be cautious, the radiative heat flux is chosen to 15 kW/m² in the upcoming calculations.

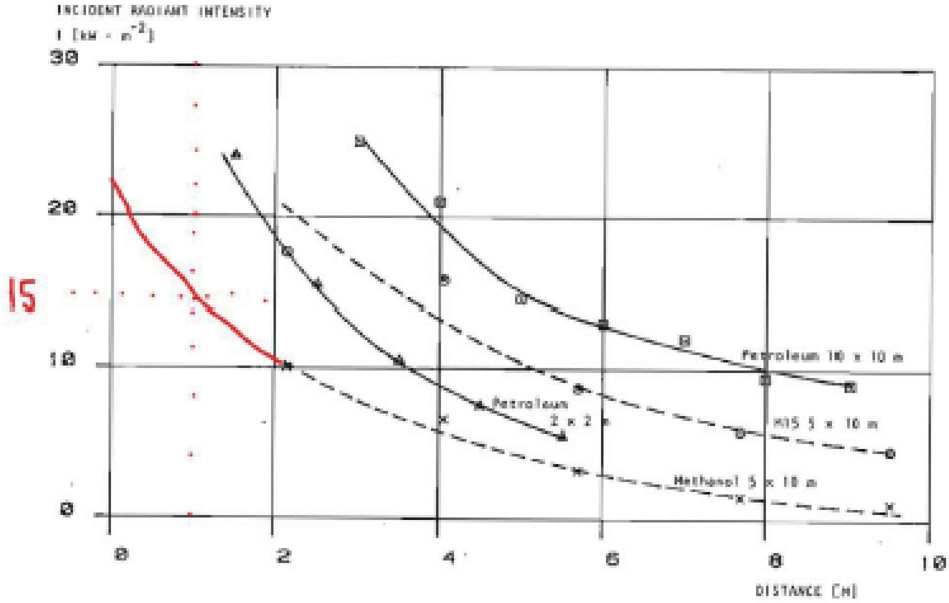

Figure 1. Expected incident radiation from a 50 m² methanol pool fire (the red line is the estimated trendline) from Holmstedt et al.

To put the radiation of 15 kW/m² in context; Swedish building regulations states that buildings should be designed with a safety distance such that incident radiation from a fire does not exceed 15 kW/m² for 30 min. In other words, if incident radiation is less than 15 kW/m² for 30 min, fire spread between buildings is not expected.

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When looking at the criteria for evacuation according to MSC.1 Circ. 1552, 2.5 kW/m² is considered a safe level of exposure to bare skin. From figure 1; 2.5 kW/m² was measured at a distance of 7 m and this distance can therefore be considered a safe distance for passengers.

For higher doses, the Circ. Instead refers to ISO 13571:2012 for assessment of temporarily increased doses. ISO: 13571:2012 states the following:

The time until to second degree burning of bare skin due to radiant heat can be calculated with the following equation:

$t = 6.9 * q^{-1.56}$, where q is incident radiation (kW/m²)

With a radiative heat flux based on the report from SP, the time until second degree burn for passengers on the balconies (approx. 1.5 m safety distance) is 6 s according to ISO 13571:2012.

$t_{15kW/m2}$ = 0,1 min = 6 s

With the assumption of a 4 m safety distance between the pool fire and passengers on upper deck and a radiative heat flux from figure 1, the incident radiation induced by the 50 m² methanol pool fire is expected to be 6 kW/m².

The time until second degree burn of bare skin at 4 m (6 kW/m²) is 25 s according to ISO 13571:2012.

$t_{6kW/m2}$= 0,4 min = 25 s

Results from the SP report also shows that the time from ignition until steady state and the peak of radiative heat flux was 5 min. 2 min after fire ignition, the radiative heat flux only reached half of the peak value.

With the conservative assumption that the radiative heat flux started at half the peak value (3 kW/m²) and was consistent for 2 min, the time until second degree burn of bare skin from 4 m would be 72 s according to ISO 13571:2012.

$t_{3kW/m2}$= 1,2 minutes = 72 s.

The results can be summarised as follows:

Safety distance	Radiative heat flux	Time until second degree burn
1.5 m	15 kW/m²	6 s
4.0 m	6 kW/m²	25 s
4.0 m	3 kW/m² (first 2 min of burning)	72 s
7.0 m	2,5 kW/m²	N/A (safe)

In the results presented in the table above, effects of the water spray system on the deck of the bunker vessel have not been considered. Although it was shown in the proFLASH report (Evegren, 2017) that water spray systems are not very effective on full extinguishment of methanol pool fires (unless an alcohol resistant foam agent is used), radiative heat flux was reduced to an insignificant amount from 2 m distance as a result of activating the water spray system (from 5 kW/m² down to below 1 kW/m²). It should be noted that pools larger than 7m² were not tested in proFLASH and the effect on larger methanol pool fires without additives has not been studied. Additionally, the tests were conducted indoors with no wind, which could limit the effects of a water spray system further.

Discussion

Given that the radiative heat flux is expected to be lower than the critical limit for fire spread between buildings in the building codes, and that the vessel is mainly made of steel, the construction of the river cruise vessel should be able to withstand the heat radiation from a 50 m^2 methanol pool fire. Windows will be the weak points and consideration should be taken to the fact that heavy wind may cause direct impact from the flames. However, the radiative heat flux was chosen to be conservative and the effects of the water spray system on the bunker vessel was not considered in the calculations. If assumed that the water spray system works, it will reduce a significant amount of the radiation towards the river cruise vessel. Additionally, the river cruise vessel is also provided with a water mist system inside accommodation areas which would suppress any small fires spreading to cabins if the windows would burst, as well as water hoses on both vessels which could be used to cool the construction of the river cruise vessel to limit the fire spread.

The construction of the river cruise vessel can be expected to protect passengers inside. However, balconies directed towards the bunker vessel should be closed and forbidden to enter during bunkering. Passengers on upper deck should have time to back off to a safe distance from the methanol pool fire before suffering from second degree burns. Given the limited risk of fire spread, passengers should have enough time to safely evacuate the river cruise vessel. Additionally, methanol burns with little, or no soot and passengers are not expected to suffer from inhalation of toxic smoke during evacuation.

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Annex B: Report FASTWATER – Radiation from pool fires during bunkering

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