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Co-authors	Oskar Grönlund		
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EXECUTIVE SUMMARY

The FASTWATER (FAST Track to Clean and Carbon-Neutral WATERborne Transport through Gradual Introduction of Methanol Fuel) project aimed 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's overarching goal was to develop and demonstrate a path for marine methanol technology, both for retrofit and next generation systems. Specifically, the project plan was to demonstrate feasibility on 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 was also to 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)validated.

To demonstrate safe operation of the vessels retrofit to run on methanol fuel, the crews of each vessel needed to be trained in the safe handling and use of methanol, according to their duties and responsibilities on board. In addition, shoreside personnel, including maintenance personnel and those working in areas where the methanol-fuelled vessel would be bunkered, needed to receive training as appropriate to their duties. This report is focussed on training activities and experiences from the project.

Purpose

The purpose of this report is to describe the training material developed within the FASTWATER project and to document the training activities that were carried out for the demonstrator vessels that were taken into service.

Approach and scope

The regulatory requirements and upcoming developments regarding training of crews on vessels using low flashpoint fuels were assessed to identify applicable topics and approaches for training on methanol-fuelled vessels. Information on current practice for training on ocean-going methanol-fuelled vessels was collected through literature review and contact with operators.

Recommendations for model course materials on methanol properties, safety, characteristics, hazards, and safe handling on board were developed based on industry literature regarding safe handling, chemical industry publications, research reports, and literature review.

FASTWATER project partners Port of Antwerp-Bruges and the Swedish Maritime Administration provided feedback and information on experiences with the training conducted for the crews of the tugboat and the pilot boat, respectively. These two vessels were the focus as they are the two FASTWATER demonstration vessels that were to be taken into regular service during the course of the project.

Results and Conclusions

Existing regulatory guidance and training material for methanol-fuelled vessels is limited as of 2023 because the number of methanol vessels is still quite low (although quickly growing). The experience within the FASTWATER project was to develop "bespoke" training material for each specific vessel. General material on methanol properties, hazards, fire characteristics, and safe handling for the courses was sourced from industry practice, publications, and research reports. Vessel specific material was obtained from vessel design documentation

and equipment providers. Engine providers ABC and ScandiNAOS provided training and manuals for the engines installed on the tugboat and the pilot boat, respectively.

The first training session for the pilot boat was carried out in 2021 and refresher training was conducted in 2023. For the tugboat, training session were conducted in 2022 and 2023, with refresher training conducted prior to the launch in 2024. On board practical training was carried out in May 2024 and was expected to continue in June and July as vessel trials continue.

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List of abbreviations

ABC	Anglo Belgian Corporation
CESNI	European Committee for drawing up Standards in the field of Inland Navigation
ES-QIN	European Standard for Qualifications in Inland Navigation
ES-TRIN	European Standard laying down Technical Requirements for Inland Navigation vessels
HTW	Sub-Committee on Human Element, Training and Watchkeeping
IGF Code	International Code of Safety for Ship Using Gases or Other Low-flashpoint Fuels
IMO	International Maritime Organization
IR	Infrared
ISO	International Organization for Standardization
LNG	Liquefied Natural Gas
RPN	Regulations for Rhine Navigation Personnel
STCW Code	Seafarers' Training, Certification and Watchkeeping Code, as amended 2015

1 INTRODUCTION

The FASTWATER project aimed to demonstrate the feasibility of using renewable methanol as a marine fuel on three different vessel types and to create a detailed design and feasibility study for a fourth. In addition to developing the technology and on-board installations to burn methanol as a fuel for propulsion, the FASTWATER project also investigated bunkering processes for smaller vessels, fuel supply and quality, rule development, and training.

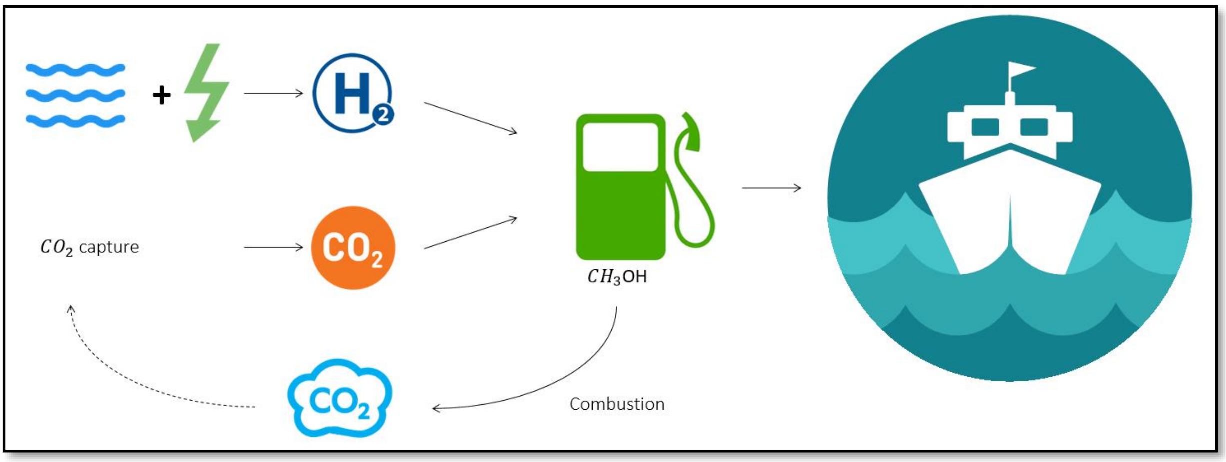

Figure 1: The FASTWATER project covers the full renewable marine methanol supply and use chain. Source: FASTWATER Consortium

The FASTWATER project thus investigated the supply and use of methanol as a marine fuel for smaller vessels, as shown in Figure 1. The consortium includes the entire value chain including methanol producer, shipyards, ship owner, engine manufacturer, equipment supplier, classification society, port authority, and research institutes. The overall project goal was to demonstrate a fast transitionary path to move waterborne transport away from fossil fuels and reduce pollutant and greenhouse gas emissions through the use of renewable methanol as fuel.

The FASTWATER project had the aim of demonstrating lessons learned during the design and operation of the case vessels. Operational experiences including bunkering, emissions, economic and environmental performance, and crew training were also demonstrated and assessed during the project. This report is focussed on training activities and experiences from the project.

1.1 Background

Safety management procedures and trained ship personnel are required for safe operation using alternative fuels such as methanol. A study by the Maritime Technologies Forum (MTF), a group of flag states and classification societies, identified gaps with selected international shipping conventions in these subject areas. With respect to training, insufficiencies with model courses, lack of incentives for training course developers, and inconsistent implementation of training were among the gaps identified for the future safe implementation of alternative fuels (Maritime Technologies Forum, 2023).

The Green Curriculum Position Paper (The Nautical Institute et al., 2022) and subsequent revised Nautical Institute paper (2023) states that standards and curricula for training needs to be developed to ensure that seafarers have the knowledge and skills to safely operate vessels on alternative fuels. They note that although there is currently training for LNG and LPG, alternative fuels such as methanol and ammonia have widely differing properties and health and safety issues. The Nautical Institute thus suggests that courses should be tailored to specific fuels.

Adequate training for crew and other personnel is considered necessary for the mitigation of the safety hazards and associated risks with the adoption of new fuels and technologies. Indeed, the hazard identification and safety assessment studies carried out as part of the FASTWATER demos identified training as a mitigation measure for some of the identified hazard scenarios. Additionally, training was required as part of the approval process for the tug and pilot boat demonstrators. This had to be specifically developed for the demonstrator vessels, as there is currently a lack of available training courses for methanol-fuelled vessels.

1.2 Purpose

The objective of the training task within FASTWATER work package 7 was to provide training recommendations for ship crew and shore side workers and to support the demonstration vessels in development of their specific training programs. Activities include:

- identifying training requirements and best practices from industry for methanol-fuelled vessels
- reviewing and reporting on regulatory development for training requirements for alternative fuels, including the IMO's requirements for low flashpoint fuels and Inland Waterway regulations for alternative fuels
- making recommendations on generic higher level training material regarding methanol safety and characteristics, based on industry standards and requirements for low flashpoint fuels, for background
- collecting feedback on experiences from the demo training which included ship and equipment specific training and materials from the vessel specific risk assessments and bunkering procedures
- summarizing guidelines and lessons learned from the training carried out within FASTWATER demos.

1.3 Scope and Approach

Identification of current practices of training on methanol-fuelled vessels was conducted through literature review and contact with operators of existing methanol-fuelled vessels. The regulatory requirements and upcoming developments regarding training of crews on vessels using low flashpoint fuels were assessed through review of regulations for other low-flashpoint fuels and contact with providers of training courses for the IGF Code.

Recommendations for model course materials covering methanol properties, safety, characteristics, hazards, and safe handling on board were developed based on industry literature regarding safe handling, chemical industry publications, research reports, and literature review.

Experiences and descriptions of training for crews and personnel working with the Port of Antwerp-Bruges methanol dual fuel tugboat and the Swedish Maritime Administration methanol-fuelled pilot boat were based on communications within the FASTWATER project consortium. These two vessels were the focus as they are the two FASTWATER demonstration vessels that were to be taken into regular service during the course of the project.

2 Regulatory Background for Training

Training of crew is considered to be key for ensuring safe operation of vessels and reducing accidents and incidents at sea. Training is crucial for ensuring that the introduction of new zero and low carbon fuels which will help shipping meet emissions reduction targets can be done with equivalent safety to conventional fuels and propulsion systems. Special training requirements were brought in both for inland waterways vessels and for sea-going vessels when LNG was introduced as a fuel. For sea-going vessels training is required for vessels using fuels covered by the IGF code. Specific training guidance has been developed for LNG but not yet for methanol. Similarly, for inland waterways there are specific qualifications and knowledge requirements for personnel responsible for LNG operations on vessels. For smaller methanol-fuelled vessels that are operating along the coast, some flag states may require the training specified as part of the STCW Code for IGF code vessels, but it may not be mandatory for ships with gross tonnage less than 300. Flag states may grant exemptions for some of the training requirements for seafarers on these smaller ships.

A summary of the regulations pertaining to training and qualifications of personnel on vessels using low flashpoint fuels is provided in the following sub-sections.

2.1 Inland Waterways Regulations

Vessels operating on the inland waterways of the European Union are governed by EU Directive 2016/1629, which sets out technical requirements for these vessels. The Directive states that the minimum technical requirements are as set out in the "European Standard Laying Down Technical Requirements for Inland Navigation Vessels" (ES-TRIN). ES-TRIN Edition 2019/1 did not generally permit the use of internal combustion engines burning fuel with a flashpoint of 55 degrees Celsius and lower. Supplementary provisions were in place for vessels using LNG, but for vessels using other low flashpoint fuels such as methanol a derogation is required. Work has been underway to include special provisions for methanol and hydrogen, but as of 2024 had not yet been completed. The work for the drafting of requirements for methanol has been given high priority. In the meantime, for use of methanol and other alternative fuels, a derogation is required, pursuant to Article 25(1)(b) of Directive (EU) 2016/1629. This Article allows the possibility of derogations to encourage innovation and new technologies, as long as an adequate and equivalent level of safety is ensured.

Applications for derogations from ES-TRIN standards are reviewed and assessed by the European Committee for drawing up Standards in Inland Navigation (CESNI). Derogations issued may specify conditions for the vessel operation, to permit deviation from Directive (EU) 2016/1629. The conditions are meant to ensure that an adequate level of safety is achieved – at least equivalent to existing operations. A methanol fuel cell vessel operating in Germany - the *MS Innogy* - was authorized to derogate from the technical requirements for inland waterway vessels in 2020. Conditions listed in the derogation included the requirement that all crew members be instructed in the dangers, use, servicing and inspection of the methanol fuel cell system. For the Port of Antwerp-Bruges tug boat 21 (Sleepboot 21), one of the FASTWATER demo vessels, a derogation was also required for the operation of the methanol dual-fuel engine, and training was also specified as a condition of granting the derogation.

Chapter 30 of ES-TRIN details all the assessments that need to be made and the documentation that must be kept on board. A safety rota, including safety instruction and a safety plan, must be approved and stamped by the authorities and kept on board. A detailed operating manual of the propulsion or auxiliary system must be kept on board. Essentially very detailed information must be developed and provided according to ES-TRIN for all vessels certified, and this documentation can form part of the training materials.

2.1.1 Qualifications and Training for EU Inland Waterway Vessel Personnel

Conditions and procedures for the certification of the qualifications of persons operating European Union inland waterways craft are set out in the EU Directive on recognition of professional qualifications in inland navigation (Directive (EU) 2017/2397). This directive applies to deck crew members, "liquefied natural gas experts", and passenger navigation experts. A "liquefied natural gas expert" means a person who is qualified to be a boat master sailing an LNG craft or qualified to be involved in the bunkering procedure of such a craft. The directive currently does not include procedures and conditions for qualifying persons to work on vessels with other types of alternative fuels. However, the CESNI work plan for 2022-2024 sets a high priority on the task for drafting competence standards for new and innovative technologies, including the use of relevant alternative fuels. Competence standards would be detailed in upcoming editions of the European Standard for Qualifications in Inland Navigation (ES-QIN).

Essential competences requirements for LNG Expert qualification could be considered as an example of those that would be required for other alternative fuel experts such as for methanol. In the EU Directive on the recognition of professional qualifications in inland navigation (Directive (EU) 2017/2397) the following is stated regarding the abilities of an LNG expert:

> "Every applicant shall be able to:
>
> - ensure compliance with legislation and standards applicable to craft that use LNG as fuel, as well as with other relevant health and safety regulations;
> - be aware of specific points of attention related to LNG, recognise the risks and manage them:
> - operate the systems specific to LNG in a safe way;
> - ensure regular checking of the LNG system;
> - know how to perform LNG bunkering operations in a safe and controlled manner;
> - prepare the LNG system for craft maintenance;
> - handle emergency situations related to LNG." (Directive (EU) 2017/2397)

The essential competence for an LNG expert must comply with ES-QIN, specifically CESNI Resolution 2018-II-8. ES-QIN specifies theoretical knowledge that must be demonstrated, described in Part I "Standards for Competences", as well as practical training and knowledge that is tested in a practical exam (described in Part II of ES-QIN).

2.2 IMO: IGF Code Training

2.2.1 Regulatory Background for Training

The Seafarers' Training, Certification and Watchkeeping (STCW) Code, (Section A-V/3-1) sets out mandatory minimum requirements for the training and qualification of masters, officers, ratings and other personnel on ships subject to the IGF Code. Part A of the STCW code is made mandatory by Regulation V/3 of the STCW Convention which entered into force in 1984 (IMO, n.d.). Parties to the Convention are required to provide detailed information to the IMO regarding the measures that are taken to comply with the Convention, education and training courses, and certification procedures (IMO, n.d.).

The STCW code specifies minimum level of competence for both "Basic Training for Ships Subject to the IGF Code" and "Advanced Training for Ships Subject to the IGF Code". For basic training, Flag state Administration may grant exemptions for some of the training requirements for seafarers on ships less than 500 gross tonnage (except for passenger ships).

For basic training, knowledge required includes the following:

- basic design and operational characteristics of ships subject to the IGF Code, including their fuel systems and fuel storage systems
- physical properties of fuel on board ships subject to the IGF Code, and understanding of fuel characteristics as shown on a safety data sheet
- safety requirements and safety management on board ships subject to the IGF Code
- hazards associated with the operations on ships subject to the IGF Code
- hazard controls
- application of occupation health and safety precautions and measures
- firefighting operations on ships subject to the IGF Code, including special hazards and firefighting agents and methods
- emergency procedures
- measures and precautions to prevent pollution of the environment from the release of the fuels found on ships subject to the IGF Code.

For advanced training, knowledge of the following is required:

- design and operational characteristics of ships subject to the IGF Code, including the ability to safely perform and monitor all operations related to the fuels used
- physical and chemical properties of fuels aboard ships subject to the IGF Code
- operating principles of marine power plants using fuels subject to the IGF Code, including control systems, and safety devices
- planning and monitoring of safe bunkering, stowage and securing of the fuel
- effects of pollution on humans and the environment
- precautionary measures to be taken in the event of spills/leakage/venting
- relevant provisions of legislative requirements including MARPOL, the IGF Code, and port requirements
- hazards and hazard control measures
- proper use of safety equipment and protective devices, and knowledge of safe working practices and procedures
- fire prevention, control and firefighting methods and systems for fuels addressed by the IGF Code.

2.2.2 Model IGF Code Training Course

The IMO's Sub-Committee on Human Element, Training and Watchkeeping (HTW) validates model training courses that have been developed as guidance for organisations carrying out maritime training. The model courses aim to cover all the important aspects required by the regulations and serve as a foundation for course development but are not able to capture ship specific details.

IGF Code model training course were validated by the IMO's HTW sub-committee in 2019, as follows:

- basic training for masters, officers, ratings and other personnel on ships subject to the IGF Code
- advanced training for masters, officers, ratings and other personnel on ships subject to the IGF Code.

Although the minimum standards of competence set out in the STCW Code for IGF code training are not specific to a particular fuel, the model courses have many specific references to LNG. For example the teaching aids in the "course framework" section specify textbooks and reference materials for LNG. For other parts of the course storage tanks for gaseous fuels including type A, B, and C tanks, the need to describe the design and function of cryogenic valves, cryogenic hazards associated with LNG; and LNG industry specific bunker checklists are referred to, etc. Similar references and in-depth material specific to methanol or other fuels is not currently provided in the IGF Code model courses. Currently the IGF Code model training courses are given the priority 4, meaning "existing course does not require change" by the IMO's HTW sub-committee (HTW 9/3, 2022), but perhaps this may be reconsidered as more ships subject to the IGF Code and using fuels other than LNG are ordered. The International Chamber of Shipping (ICS) raised the need for development of interim guidance on training for seafarers on ships using alternative fuels at the 10th session of the HTW held in February 2024 (see HTW 10/6/4, submitted by ICS, 2023). They note that interim guidance for training for LNG ships was issued already approved in 2014 prior to the IGF Code for LNG being adopted in 2015. They advocate that similarly training guidance for methanol and other alternative fuels should be progressing now.

The responsible agency in each Flag state must approve the training program and facility.

3 Previous Training Experiences from Methanol-fuelled Vessels

Until the middle of 2023, there were 26 dual fuel methanol vessels in service, plus *Pilot 120 SE*, the methanol-fuelled pilot boat that was converted as part of the FASTWATER project. The remainder of these vessels, with the exception of the RoPax vessel *Stena Germanica,* were chemical tankers. The chemical tankers carry methanol as cargo, and the crew must be trained according to the IMO's STCW mandatory minimum requirements for the training and qualifications of masters, officers and ratings on oil and chemical tankers (IBC Code vessel). Thus the crew were already familiar with the hazards of methanol and requirements for safe handling as cargo. This was similar to the early use of LNG as fuel, where the first adopters were LNG carriers using boil-off cargo as fuel. The crews were already familiar with handling LNG as cargo.

The *Stena Germanica*, a RoPax ferry, developed its own methanol training program, specific to the system installed on the vessel. In July 2023 the first methanol-fuelled container ship, the *Laura Maersk*, entered into service. Prior to the FASTWATER project, there was only one example of a training program for a smaller (non-SOLAS) methanol fuelled vessel. This was the *MS Innogy* mentioned previously, an inland waterways vessel powered by methanol fuel cells. A crew training program was required for a derogation from CESNI to be issued for the use of a methanol fuel cell propulsion system.

Training carried for methanol-fuelled vessels up until 2023 is described below.

3.1 Stena Germanica

The *Stena Germanica,* one of the largest roro passenger ferries in the world, was converted to dual fuel methanol operation in 2015. Stena Line organized safety training for the crew regarding methanol handling, bunkering, and storage (Stojcevski et al, 2016). Wärtsilä, who developed the adaption kit for conversion of the *Stena Germanica*'s four Wärtsilä Sulzer ZA40S engines to dual-fuel methanol operation, provided training at their facilities regarding the engine, with a focus on the engine automation system functionalities. The crew and chief engineer experienced operation of the converted engine to be very similar to operation on diesel (Stojcevski et al., 2016).

3.2 MAN PrimeServ

MAN Energy Solutions developed the first two-stroke dual-fuel methanol engine, the MAN B&W ME_LGIM, to be used in commercial shipping, with the first going into service in 2016. From 2016 to 2023, all vessels using the engine were chemical tankers carrying methanol as cargo. Thus crew on board already had training in handling, loading, and unloading of methanol as cargo. To cover the additional knowledge required with using methanol as fuel in their dual-fuel engines, MAN PrimeServ Academy developed and offered training for engineers working on vessels with these engines. Course content includes detailed information about the engine, concept, and controls, as well as methanol detection, safety systems and trouble-shooting.

3.3 Maersk

The *Laura Maersk*, the world's first methanol-fuelled container vessel, entered into service in September 2023. As the IMO's IGF Code Model Training Course was developed with a focus on methane gas-fuelled vessels, primarily LNG, a training program tailored for the needs of crews on these vessels was developed by Aboa Mares in Finland specifically for Maersk. The program fulfils the IMO's IGF Code training requirements (Mfame editor, 2023).

3.4 MS Innogy

The *MS Innogy*, a 29 metre long passenger vessel operating Baldeneysee, Germany, was modified for methanol fuel cell operation in 2017. Training was carried out as a requirement for the approval of the vessel. Training material included a theoretical and practical component and covered topics including familiarization of methanol and its properties, interpreting the safety data sheet, safety, risk assessment and risk management, fire protection, use of personal protective equipment (PPE), technical aspects of the systems on board, system maintenance, bunkering, preparation of the vessel for maintenance, and emergency scenarios.

4 Training Approach for FASTWATER Project

As the FASTWATER demonstrators were both retrofits of existing vessels, training focussed on the properties and hazards of methanol, the new systems and equipment installed for methanol-fuelled operation of the vessel, methanol safety systems, and response to incidents. Training for the FASTWATER project demonstrators included the following main components:

- Theoretical training in a classroom setting including:
  - General information on methanol for marine fuel use including properties, hazards and risks; information on regulations relevant to methanol use as a marine fuel; environmental risks if accidently released; fire characteristics and fire safety considerations; safe handling and use of personnel protective equipment.
  - Vessel specific topics including:
    - basic design and operational characteristics of the methanol storage, supply, and safety systems onboard the vessel
    - methanol engine description, operation, controls, automation system, and safeguards
    - bunkering procedures
    - main hazards and risks on the vessel as determined during the HAZID and HAZOP study and implemented safety measures
    - vessel hazardous area plan.
- Practical demonstrations and training carried out at the quayside and vessel included
  - bunkering: “dry run” training and review of procedures
  - engine demonstration and instruction
  - instruction and onboard training for methanol supply and storage systems, safety systems retrofit or installed for methanol, and personnel protective equipment.

Further details of the general methanol safety information for classroom instruction assembled within FASTWATER are provided in the following subsections. The information was assembled for an “audience” of the smaller vessel operators in focus for the FASTWATER project.

More detailed information on the vessel specific information and training carried out for the FASTWATER pilot boat and tugboat demonstrators is presented in Chapter 5.

4.1 Definition and Characteristics of Methanol

Methanol, also referred to as methyl alcohol, is an organic compound and the simplest of the alcohols. It has the chemical formula CH_3OH (also written as CH_4O). It is sometimes written as MeOH. It is a colourless, flammable liquid at ambient temperatures. It has a characteristic pungent odour (PubChem, 2021).

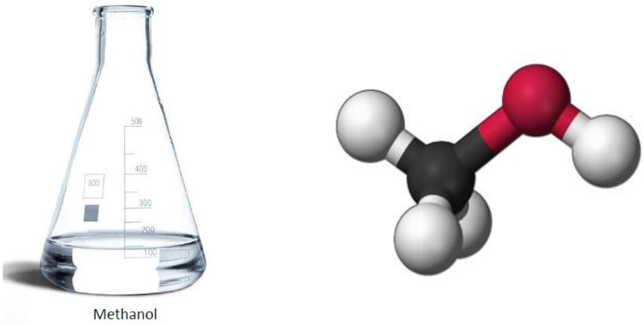

Figure 2 Methanol (CH_3OH)

Some properties and characteristics of methanol relevant to its use as a marine fuel are shown in Table 1.

Table 1 Selected Properties and characteristics of methanol.

Boiling Point at 1 bar (°C)[1]	64.7
Freezing Point (°C)[1]	-97.6
Density at 20°C [1]	0.791 – 0.793
Molecular Weight (g/mol)[1]	32.04
Lower Heating Value (MJ/kg)	20
Dynamic Viscosity at 25°C (cSt)	0.6
Vapour Density at 20°C (air = 1)[2]	1.1
Relative density of the vapour/air-mixture at 20°C (air = 1)[2]	1.01
Vapour Pressure, kPa at 20 °C[1]	12.8
Flash Point (CC) (°C)[1]	11
Auto Ignition Temperature (°C)[1]	464
Minimum Ignition Energy (mJ)	0.14
Conductivity (Typical value for alcohols) (PicoSiemens/m)[3]	100 000
Explosive Limits (by % Vol of Mixture)[1]	5.5 – 36.5

1. Methanex Safety Data Sheet according to Regulation (EC) No. 1907/2006 (REACH) as amended, SDS-ID Methanol EU

2. From www.inchem.org (Internationally Peer Reviewed Chemical Safety Information)

3. CCNR/OCIMF. 2010. International Safety Guide for Inland Navigation Tank-barges and terminals. Edition 1- 2010. Available https://www.isgintt.org/

Methanol's classification for transport according to the UN Model Regulations is Class 3, Flammable Liquid. It has the subsidiary class 6.1, toxic substances.

The grade of methanol commonly sold conforms to the International Methanol Consumers and Producers Association (IMPCA) reference specifications (Available: https://www.impca.eu/IMPCA/Technical/IMPCA-Documents). According to this specification the methanol is 99.85% pure on a weight basis (IMPCA, 202a). This is in widespread international use for methanol transactions (IMPCA, 2021b). Some methanol supplied from smaller producers may have characteristics that deviate somewhat from the IMPCA standard, or that are slightly off-spec. Thus the technical data sheet for the specific product to be used on board should be consulted.

4.2 Regulations

4.2.1 Regulations for Methanol-fuelled Vessels

Interim guidelines for vessels using methanol fuel were developed by the IMO and adopted by the Maritime Safety Committee in November 2020. They were published in the following circular:

• IMO, MSC.1/Circ. 1621, INTERIM GUIDELINES FOR THE SAFETY OF SHIPS USING METHYL/ETHYL ALCOHOL AS FUEL

The interim guidelines are to be used together with the International Code of Safety for Ship Using Gases or Other Low-flashpoint Fuels (IGF Code), which was adopted in 2015 for LNG. The interim guidelines are not mandatory for non-IMO vessels such as those operating on inland waterways or smaller vessels operating in national waters only, but they can be viewed for guidance where applicable.

For European inland waterway vessels, Edition 2023/1 of the European Standard laying down Technical Requirements for Inland Navigation vessels (ES-TRIN) sets out special provisions applicable to craft equipped with propulsion or auxiliary systems operating on fuels with a flashpoint equal to or lower than 55° C. These special provisions are described in Chapter 30, which covers all low flashpoint fuels. Supplementary provisions for specific fuels that are in addition to those in Chapter 30 are included in Annex 8. The chapters in Annex 8 on methanol fuel storage and on "propulsion or auxiliary systems with internal combustion engines using methanol as fuel" have been left void with the intent to include in the next edition in 2025. Until such requirements are included in ES-TRIN, the process described in the LEAFLET ON DELIBERATION ON DEROGATIONS AND EQUIVALENCES OF TECHNICAL REQUIREMENTS OF THE ES-TRIN FOR SPECIFIC CRAFT (March 2019) can be followed to obtain approval.

More detailed information on regulations relevant to vessels using methanol as fuel can be found in FASTWATER Deliverable 7.8 (Hacker and Schröder, 2021) and FASTWATER Deliverable 7.9 (Hacker, 2024).

Many classification societies have developed specific rules for low flashpoint liquid fuels or specifically methanol. Examples include:

• Lloyd's Register "Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels, July 2023, Appendix LR1 – Requirements for Ships Using Methyl Alcohol (Methanol) or Ethyl Alcohol

• DNV GL classification rules for low flashpoint liquid fuelled engines, which covers methanol

• Bureau Veritas Rule NR670 Methyl/ethyl alcohol Fuelled Ships.

4.2.2 Relevant Health and Safety Regulations

Indicative Occupational Exposure Limit Values (IOELVs) are set in European Commission Directives and member states must establish national Occupational Exposure Limit (OEL) values. In most countries the OELs are legally binding. The European Commission Directive IOELVs for methanol for an 8 hour time weighted average reference period are:

- 200 ppm (parts per million by volume in air)
- 260 mg/m3 (milligrams per cubic metre of air at 20 °C and 101.3 kPa)

(Commission Directive 2006/15/EC)

Acute exposure guidelines for the general public for emergency situations ranging from 10 minutes to one hour are described in Section 4.9 on toxicity.

4.3 Environmental Characteristics – Behaviour if Released to Water or Land

For marine spill events, methanol is classified as a "dissolver that evaporates" according to the Standard European Behaviour Classification (HNS-MS, 2021). It is fully miscible with water, meaning it will dissolve completely if spilled in water, with some fraction evaporating depending on the temperature. According to the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection hazard procedure system (GESAMP, 2019), methanol is fully biodegradable with no potential to bioaccumulate (See https://www.hns-ms.eu/result/72). Kass et al. (2021) state that given both the high diffusivity of methanol in air and high level of water partitioning methanol is unlikely to accumulate on the water surface in the event of a spill. Many microorganisms can break down methanol but a high concentration near a release point may cause localized inhibition of activity (Kass et al., 2021).

Methanol spilled to ground is expected to biodegrade over time, with an estimated half-life in soil and ground water of one to seven days (Pirnie, 1999). Methanol spilled on impermeable surfaces volatilizes to air over time, as it has a low vapour pressure (Shepherd, 2005). In air it will degrade via reaction with airborne hydroxyl radicals and has a half-life of approximately 18 days but may also be removed via rainfall (Shepherd, 2005).

4.4 Hazards and Risks

The main hazards associated with methanol are flammability and toxicity to humans. The hazard statements according to the European chemical agency database are:

- Highly flammable liquid and vapour
- Toxic if swallowed
- Toxic in contact with skin
- Toxic if inhaled
- Causes damage to organs.

Hazard symbols for methanol according to the harmonised classification and labelling (CLP00) approved by the European Union are shown in Figure 3.

Figure 3. Hazard symbols for methanol as shown on the European Chemicals Agency website substance card for methanol (ECHA, 2021).

4.5 Methanol Fire Characteristics

The flash point of a liquid can be defined as the lowest temperature in which the liquid gives off sufficient vapour to ignite in air (with an external ignition source). Because the flash point of methanol is only 12 °C the risk of ignitable vapours should always be considered in case of a methanol leak at room temperature, as compared to diesel with a flash point of 52 °C.

Additionally, methanol has a broad span between the explosive limits. Explosive limits can be defined as the concentration range of a gas (or vapour) in air which will burn or explode in the presence of an ignition source. At concentrations below the lower explosion limit (LEL) there is not enough combustible fuel vapour to ignite or explode. At concentrations above the upper explosive limit (UEL) the fuel vapour has displaced too much oxygen in the air for ignition or an explosion to occur. The explosive limits for methanol vapour in air is between 6-36 vol%, compared to 1-6 vol% for diesel making methanol more likely to create an explosive atmosphere in case of a leakage (Methanol Institute, 2020).

Luckily there are not only increased risks to methanol as shipping fuel compared to traditional fuels. In several aspects the consequences of methanol fires are considered less severe than diesel oil or gasoline. The heat of combustion, i.e. the total amount of energy released as heat during combustion, is significantly lower for methanol than conventional fuels. In fact, the heat of combustion for methanol is half that of diesel and gasoline. Additionally, the heat release rate of a methanol fire is about 1/3 of diesel and the radiative heat flux (the amount of heat transported as radiation) is 1/5 of diesel (Evegren, 2017). The low heat release rate and radiative heat flux implies that a methanol pool fire is less likely to spread to surrounding materials, and a firefighter would be able approach a methanol fire from a relatively short distance without suffering from burns.

In two studies conducted by SP (now part of RISE) (Holmstedt et al., 1980; Evegren, 2017) radiative heat flux was measured from free burning methanol of pool sizes of 5 m^2 and 50 m^2. In the following table, the measured heat fluxes from the previous studies have been summarized and transformed into time until second degree burns according to ISO: 13571:2012 "Guidelines for estimation of time to compromised tenability in fire". Safe long term radiative heat flux exposure of 2.5 kW/m^2 was chosen according to MSC.1 Circ. 1552. It should be noted that the time until second degree burn is calculated for bare skin and that protective clothing such as suits for firefighting will increase the time to second degree burn.

Table 2. Time until second degree burn from pool fires for different fuels and distances. Radiative heat flux was collected from Holmstedt et al, 1980 (50 m^2 pools) and Evegren 2017 (5 m^2 pools). Time until second degree burn from incident radiation was calculated according to ISO: 13571:2012.

Safety distance	**Radiative heat flux**	**Time until second degree burn**
	Methanol (5m^2)	
2.0 m	5.0 kW/m^2	34 s
3.0 m	3.5 kW/m^2	59 s
3.5 m	2.5 kW/m^2	N/A (safe)
	Diesel (5 m^2)	
2.0 m	38 kW/m^2	1.4 s
	Methanol (50 m^2)	
2.0 m	10 kW/m^2	11 s
4.0 m	6.0 kW/m^2	25 s

7.0 m	2.5 kW/m^2	N/A (safe)
M15 - Gasoline 85%, methanol 15% (50 m^2)		
2.0 m	22 kW/m^2	3.3 s
4.0 m	14 kW/m^2	7.1 s
7.0 m	7.5 kW/m^2	18 s
10 m	5 kW/m^2	33 s

Table 2 shows that the radiation from methanol fires is less severe to bare skin according to ISO: 13571:2012 and firefighters would be able to approach significantly closer without suffering from second degree burns compared to diesel and gasoline fires. For fires in fixed volume spaces such as machinery spaces, the contribution of the convective heat (heat spread through the air) should also be considered, as compared to outdoor fires during bunkering where convective heat has a small impact on the total heat transfer.

Based on tests performed in proFLASH (Evegren, 2017), methanol high pressure sprays are less likely to ignite with sustained flame without an external heating source as compared to diesel (In proFLASH the use of a 460°C steel plate kept a sustained methanol spray fire).

Methanol burns with a clean combustion (no soot), the flames are weakly blue and almost invisible to the naked eye in daylight. Due to its lack of soot and near to invisible flames, methanol fires can be hard to identify without the help of technical instruments such as infrared (IR) thermal imaging cameras.

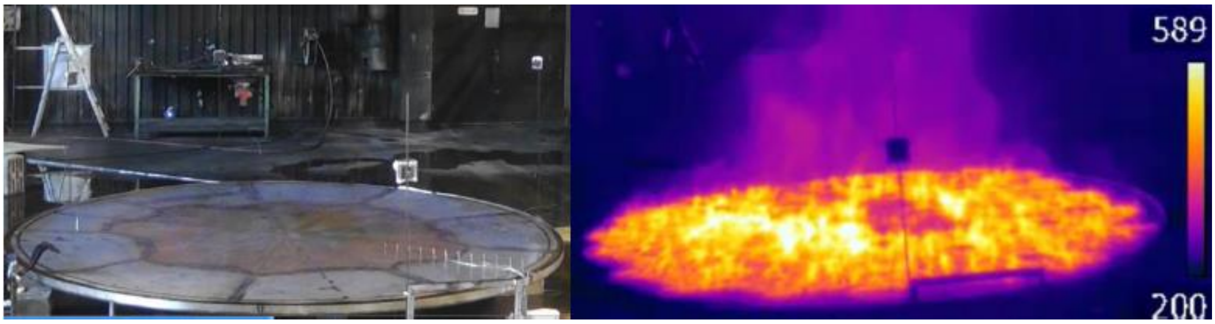

Figure 4. On the left side is a photo of burning methanol taken using a normal camera, representing how it appears to the naked eye, and on the right side is an image of the same fire taken using an IR camera. Image taken from proFLASH (Evegren 2017).

Methanol is fully water soluble, but up to 9 times more water than the methanol spill may be required to extinguish a methanol fire. Additionally, it was shown in ProFLASH that the visibility of methanol flames decreases with higher water content. This creates a risk of running invisible fires during extinguishment with water (Evegren, 2017).

4.6 Extinguishment of Methanol Fires

Extinguishing methanol with water has limited effects and the dominating extinguishing mechanism is dilution. As previously mentioned, it can take up to 9 times more water than the volume of the methanol spill to achieve total extinguishment. Additionally, methanol becomes less visible with higher water content which together with the large amount of water needed induces the risk of running and invisible fires during firefighting (Evegren, 2017). Different fixed water-based systems can have different effects on a methanol fire and should be selected with consideration of the purpose of the system. Water spray systems provide larger droplets and higher flow, meaning more volume of water and faster dilution. As for water mist systems, the droplets are smaller and they are more efficient at suppressing the fire, protecting surroundings until extinguishment or allowing fire fighters a closer approach (Methanol Institute 2020). To increase the efficiency of water-based extinguishment, foam additives can be applied to manual firefighting tools as well as in fixed water-based systems. As for manual firefighting, alcohol resistant foam extinguishers can be used, as well as alcohol resistant foam additive with aspirated foam nozzles connected to fire hoses. In the study proFLASH (Evegren, 2017) extinguishment with alcohol resistant foam additives for fixed water spray, and water mist systems were tested for methanol pool fires up to 7 m^2. The results showed that the additives shortened the time to total extinguishment and suppressed the methanol pool fires significantly. With foam additives, dilution is no longer the single dominating extinguishing mechanism. The thin foam layer blocks both the vaporized gases (separating the flame and the gases), and the heat radiation from the flame towards the fuel surface (reducing vaporization rate). However, obstructing objects can prevent the foam from reaching the fuel surface which hinder the foam from fully coating the pool. Manual firefighting is therefore recommended to extinguish small remaining flames to avoid reoccurring fire escalation.

As stated in the previous chapter, a methanol high pressure spray is less likely to ignite with self-sustained flame as compared to diesel. However, a sustained flame was established in proFLASH by adding an external heating source, as could be found in for example a machinery space. Nevertheless, the conventional fixed water-based fire extinguishment systems with foam additives used in the proFLASH experiments extinguished the methanol spray fire in 2-3 minutes. This indicates that methanol spray fires can be controlled effectively if they were to occur (Evegren, 2017).

The effects of alcohol resistant foams towards methanol pool fires have also been validated in large scale experiments conducted by Tianjin Fire Research Institute in China (Zhang, 2014). Five tests were performed with 60 m^2 methanol pool fires with varying foam types and discharge rates. Four were successfully extinguished within 20 minutes. To verify that the pool fires were extinguished by mechanisms induced by the foam and not by dilution with water, re-ignition tests were performed with the waste liquid after total extinguishment. All the extinguished fires were possible to re-ignite, proving the main extinguishment mechanism was not by dilution (Zhang, 2014).

The foams used in the experiments were alcohol-resistant aqueous film forming foam (AFFF/AR) and alcohol-resistant fluoro-protein foam (FP/AR). Both AFFF/AR and FP/AR contain per- and polyfluorinated compounds (PFAS) that face considerable health and environmental scrutiny due to their suspect or proven persistency, bioaccumulation, and toxicity. Additionally, a wide range of PFAS used in the previously mentioned foam types are subject to regulation (EU) 2019/1021, meaning that the compounds will be banned in firefighting foams from July 2025. However, there are alcohol-resistant fluorine-free foams (FFF-AR) on the market that seem to be able to replace AFFF-AR towards polar fuels such as alcohols (Kaller et al, 2023).

For confined spaces, dry powder or carbon dioxide fire-extinguishing systems are most likely to provide quick extinguishment (Methanol institute, 2020). However, due to its asphyxiant and toxic effects, there could be a considerable time delay from the start of the fire until the activation of the system to ensure that there are no crew members inside the space. This delay can result in considerable fire damage and jeopardize the performance of the system as compared to water-based systems which generally allow quick activation.

Manual firefighting of methanol pool fires can, as previously discussed, be very different to conventional fuels and requires different methods and equipment. If only water is used as suppressant there must be sufficient space to increase the volume of the methanol-water solution to prevent running fires and further fire spread. If drainage or freeboard is not possible, one should ensure the burning solution cannot enter drains and manholes or spread the fires to sensitive parts of the facility (Methanol institute, 2020). As mentioned earlier, alcohol resistant foam can significantly lower the time to extinguishment and thus the amount of water needed. Since methanol mixed with water decreases the visibility of the flames in daylight, infrared (IR) thermal imaging cameras should be used to verify total extinguishment.

4.7 Equipment for Methanol Firefighting

When responding to an incident involving methanol spills, the following personal protection equipment should be used as minimum (Methanol Institute, 2020).

- methanol compatible fire-resistant uniform with helmet, gloves, and anti-static boots
- full face, positive-pressure SCBA; and
- communication equipment (EX-classed).

As for firefighting, besides the fixed extinguishment system, the following equipment should be readily available as minimum:

- fire extinguishers with alcohol resistant foam or with dry chemical powder suited for methanol (see: Figure 5).
- fire hoses to provide large volumes of water. In case of a spill during bunkering, these can also be used to flush methanol overboard or block heat radiation if the hose can be adjusted to fine droplets.
- portable IR heat detector. Preferably one with thermal imaging.

Figure 5 Dry powder based fire extinguisher suitable for methanol.

4.8 Use of Personal Protective Equipment

Personal Protective Equipment (PPE) should be "Fit for purpose", depending on the task and expected level of exposure.

The following PPE should be used for a low risk situation, such as when bunkering or other situations where risk of exposure to methanol is expected to be low:

- Eye protection such as safety glasses with side shields or safety goggles
- Gloves in a material resistant to alcohols (e.g. Silvershield or Disposable Nitrile)
- Fire retardant, anti-static clothing
- Full boot cover / anti static footwear
- EX classed portable gas detector (see Figure 6).

Figure 6. Ex classed portable gas detector used on the Swedish Maritime Administration's Pilot Boat 120 SE

For situations where higher levels of exposure may occur, such as a larger spill clean up where sustained exposure to higher methanol concentrations in air are possible, a "supplied air breathing apparatus" with positive pressure (SCBA) must be used.

Any crew member or emergency response personnel responsible for firefighting should wear appropriate PPE as described in section 4.1.7.

4.9 Methanol Toxicity

Methanol is toxic if swallowed, in contact with skin or if inhaled (Methanol Institute, 2020). Signs of systemic toxic effects may be delayed between 8 and 36 hours after initial exposure and methanol is irritating to the eyes, the skin and the respiratory tract (Methanol Institute, 2020). With cases of methanol poisoning by ingestion, initial symptoms similar to ethanol intoxication may occur after two hours, while there is a latent period of 4 to 12 hours prior to onset of metabolic acidosis and associated symptoms (Pursell, 2018). Ocular effects may begin 8 to 36 hours after exposure (Purssell, 2018). Methanol can cause permanent damage to the optic nerve and peripheral nervous system (risk for blindness). Other signs and symptoms include headache, dizziness, vomiting, severe abdominal pain, back pain, difficulty breathing, cold extremities, lethargy, and lack of coordination. In contact with the eyes, methanol can also cause a burning sensation accompanied by tearing, swelling and redness (Methanol Institute, 2020).

Acute Exposure Guideline Levels (AEGLs) are threshold limits used as guidance for responding to accidental releases of chemicals into the air (EPA, 2024). They are based on exposure by the public to an airborne chemical for periods ranging from 10 minutes to 8 hours. Three levels are designated depending on the severity of the toxic effects that may be experienced. The United States Environmental Protection Agency (2024) describes the levels as follows:

- Level 1: Notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure
- Level 2: Irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.
- Level 3: Life-threatening health effects or death. (EPA, 2024)

Interim AEGLs for methanol have been recommended by the U.S. National Advisory Committee for Acute Exposure Guideline Levels for Hazardous Substances (NAS/COT Subcommittee for AEGLs, 2005) and are summarised in Table 3.

Table 3 Interim AEGL Levels for Methanol recommended by the U.S. National Advisory Committee for Acute Exposure Guideline Levels for Hazardous Substances ((NAS/COT Subcommittee for AEGLs, 2005)

Exposure Time	10 min	30 min	60 min	4 hours	8 hours
AEGL 1	670	670	530	340	270
AEGL 2	11,000	4,000	2,100	730	520
AEGL 3	**	14,000*	7,200*	2,400	1,600

* = > 10% LEL; ** = > 50% LEL

4.10 First Aid Response to Methanol Exposure

Quick action should be taken in response to methanol exposure through any of the possible routes including inhalation, skin contact, eye contact, or ingestion. The safety data sheet issued for the specific methanol product used should be consulted for recommended first aid measures before product use. First aid measures identified in the Methanol Institute's Safe Handling Manual (Methanol Institute, 2020) are summarized as follows:

- Inhalation of methanol vapours: if it is safe to do so, remove the individual to fresh air and keep them warm and at rest. With breathing difficulties oxygen should be administered by trained personnel and medical assistance should be sought.
- Skin contact: flush the area with copious amounts of water for 15 minutes. Contaminated clothing and shoes should be removed while showering and the exposed areas should be washed thoroughly with soap and water. Medical attention should be sought if irritation or symptoms develop.
- Eye contact: The eyes should be flushed with water for 20 minutes, while holding the eyelids apart and ensuring that all areas of the eyes and eyelids that were exposed are thoroughly flushed.
- Ingestion: Ingestion of methanol may be life threatening. Do not induce vomiting and get medical attention immediately. The individual should remain under medical care and observation for several days. There are several well established treatments for methanol poisoning. These include administration of alkali, ethanol, and hemodialysis. Additionally, Fomepizole is an antidote that is administered intravenously (by injection) to treat methanol poisoning.

The IMO's Medical First Aid Guide for Accidents Involving Dangerous Goods (MFAG) (IMO, 2022) specifies that for cases with exposure to methanol via skin contact "the casualty should remove contaminated clothing and wash with soap and water". Methanol is noted to be particularly dangerous when swallowed. The administration of ethyl alcohol is specified as a treatment to reduce the risk of toxicity until the casualty can be evacuated to a shore hospital.

4.11 Reference Material to Support Methanol Training

Reference material consulted within the FASTWATER project and considered useful for developing general training material as described in the previous sections, is as follows:

General Publications:

- Methanol Safe Handling Manual: Produced by the Methanol Institute. This is periodically updated and the latest version is available here: https://www.methanol.org/safe-handling/

Methanol Properties:

- SDS Sheets: Methanex Provides SSDS sheets in different languages and for different regions here: https://www.methanex.com/about-methanol/methanol-safety-data-sheets
- Internationally Peer Reviewed Chemical Safety Information: www.inchem.org
- PubChem. Available: https://pubchem.ncbi.nlm.nih.gov/compound/Methanol#section=Computed-Properties

Bunkering:

- CEN (European Committee for Standardisation) "CWA 17540:2020 Ships and marine technology – Specification for bunkering of methanol fuelled vessels". This document is now under development by the International Organization for Standardization (ISO) as ISO/CD 22120. Ships and marine technology. Specification for bunkering of methanol fuelled vessels.
- Introduction to Methanol Bunkering – Technical Reference (LR/MI)

Safety – Response Management

- IMO's Medical First Aid Guide for Use in Accidents Involving Dangerous Goods (IMO-251E) as supplement to the International Maritime Dangerous Goods Code (IMDG code).
- proFLASH: Methanol Fire Detection and Extinguishment (Evegren, 2017 (Research Institutes of Sweden)

Videos:

- Methanol Institute Video: "How to Safely Handle Methanol" – 2019. Available: https://www.youtube.com/watch?v=nS3hf6zDafQ
- ProFlash project video showing methanol pool fires and effects of extinguishment techniques: https://www.youtube.com/watch?v=18eGaGHx_RU

5 FASTWATER Demo Vessel Training

Training was carried out for the crew of the pilot boat operating in Oxelösund, Sweden, and for the tugboat owned and operated by the Port of Antwerp-Bruges in Belgium. Training was developed specifically for each vessel and is described in the following sub-sections.

5.1 Port of Antwerp-Bruges Harbour Tug Demo

Harbour tug 21 (Sleepboot 21) was converted for dual-fuel methanol operation within the FASTWATER project. The vessel was built in 2002 and is classed as an inland navigation vessel (Pu et al., 2023). It has length overall of 29.5 meters and is powered by two 1945 kilowatt engines. It has a bollard pull of 55 tons and was operated 3500 hours per year prior to conversion (Pu et al., 2023). Conversion of the tugboat for methanol dual fuel operation was carried out in the framework of the FASTWATER project, with work commencing in 2022. Sea trials took place in May 2024.

Figure 7 Port of Antwerp-Bruges Harbour Tug 21 during retrofit in 2023

Approval for the harbour tug operation was sought from and granted by CESNI, the European Committee for drawing up Standards in the field of Inland Navigation, in May 2021. This was necessary because there were no regulations at that time concerning the use of methanol fuel for inland navigation within the ES-TRIN framework. CESNI required a training plan for the harbour tug crew, and this was developed based on CESNI standards for other alternative fuel vessel training programs for inland waterways vessels and consulting other industry standards.

Two levels of training were provided by the Port of Antwerp-Bruges to the tugboat crew, as follows:

- Basic Level Crew – for the tugboat crew to give the basics of the operation

- Expert level training - for the maintenance engineers who are on call to cover any issues on board with the engines.

Additionally high level information sessions were provided for other relevant Port of Antwer-Bruge employees.

The training carried out for the crew included a theoretical session, carried out in a classroom setting at the port, and an on-board session. The classroom session was developed to accommodate up to 12 persons. The groups taken on board for the practical training were smaller due to the limited space. The classroom used for the training was located very close to where the tugboat was docked. The harbour tug is operated with three crew on board: a master, a machine engineer, and a boatman. Normal operations require four crews in rotation to operate the vessel 24/7, but two additional crews are trained to ensure there is back-up in case of illness, holidays, etc. So the target was to have 18 crew members receive training. All crew members received the same type of training. Employees responsible for technical support of the vessel received additional training, including in confined space entry.

The following information and training sessions were organized for Port of Antwerp-Bruges relevant harbour tug crew and employees:

- Information sessions for nautical and technical employees, carried out in 2021
- Crew training carried at the Port of Antwerp Development Centre in January 2023
- Education and training session conducted by Anglo Belgian Corporation (ABC), for the dual fuel methanol engine installed as part of the tug boat conversion (session carried out in December 2022).
- Bunker procedure run through and dry bunkering tests (September 2023 and during the spring of 2024).
- Refresher training of the crew carried out in the spring of 2024. This was considered necessary due to the time lag between the initial crew training and the time when the retrofitted vessel became operational.

After commissioning and acceptance the following practical training is to be carried out on board the vessel (in May/June 2024):

- Enclosed space entry training for the pump room
- Practical training on the operation of the engines, by ABC
- Detailed technical training on ship systems (methanol supply, storage and safety systems, including the onboard gas detection system).

Main topics covered in the theoretical and practical portions of the training sessions is described in the following subsections.

5.1.1 Classroom (theoretical) Training Topics

Classroom training topics for the tugboat included:

General methanol training topics:

- properties, hazards, and handling, including information on toxicity, occupational exposure limits for methanol (8 hour time weighted exposure limits and 15 minute short term exposure limits).
- methanol as marine fuel: Rules and regulations applicable to methanol-fuelled vessels

- methanol bunkering: Procedures, risks, and guidelines (general)

Vessel specific training topics:

- description of the vessel conversion and hazard identification study
- technical aspects of the methanol fuel system including the methanol bunker station, the fuel preparation room (pump room); the methanol tanks; and the drain tanks; nitrogen inerting system, ventilation system, and double-walled piping system
- vessel hazardous zones
- system safeguards including tank protection and vent mast; bunkering emergency shut down system; fire and gas detection system
- maintenance and inspection of the methanol fuel system
- emptying/degassing the methanol system
- vessel specific bunkering

5.1.2 Practical Training Topics

Practical training topics to be carried out include:

- operation of the onboard methanol system and sub-systems
- safety equipment and procedures
- operational manuals and relevant documents
- technical knowledge of the system components
- control, monitoring and safety systems operational knowledge
- bunkering procedure
- maintenance including dry dock operations (Advanced training)
- emergency procedures

5.1.3 Engine Training

Training material for the ABC medium speed dual fuel methanol DZD engine was developed and presented by Anglo Belgian Corporation (ABC). A manual was also provided by ABC. Training was carried out over two days. The first day was classroom training and the second was onboard. The focus of the training was on the parts of the engine systems that were new for the methanol dual fuel retrofit, as compared to the previous diesel-fuelled engine operation. Topics covered by the training included:

- methanol system on ABC engine
- Marine Diesel Oil (MDO) system
- cooling system
- lubrication system
- electrical

- dual fuel principle, illustrated with flowcharts, including procedures from switching from MDO to methanol and vice versa
- engine emergency shutdown, and methanol system shutdown
- specific changes for methanol dual fuel
- factory acceptance testing description.

5.2 Pilot Boat

Pilot 120 SE (see Figure 8) is owned and operated by the Swedish Maritime Administration (SME). It is a single engine, fixed propeller vessel with length of 14.4 metres and width of 4.6 metres. The original engine installed on the vessel was a Caterpillar engine running on diesel fuel, with a rated power output of 515 kW at 22000 RPM. The design for conversion of the pilot boat for methanol-fuelled operation was developed at the start of the FASTWATER project, beginning in June 2021. The vessel was converted at the Tenö shipyard in Sweden during the fall of 2021 and the vessel was launched in December 2021. It has been in operation from the Oxelösund pilot boat station in Sweden since its launch.

Figure 8 Swedish Maritime Administration's Pilot 120 SE

The 16 litre, 8-cylinder engine installed on *Pilot 120 SE* was developed for methanol operation by project partner ScandiNAOS. The base of the engine is the Scania DI16 and it was converted to operate with a common rail alcohol type fuel system and to operate on methanol with 3% ignition improver (Beraid 3555M) and a 0.1% mass fraction lubrication additive (Pu et al., 2022).

A fuel dispensing station with an integral above ground storage tank (see Figure 9) was procured for the Swedish Maritime Administration's Oxelösund pilot boat station for bunkering *Pilot 120 SE* with methanol. The inner methanol storage tank has a capacity of 7.19 m^3 and the additive storage tank capacity is 2.5 m^3. There is a secondary containment system around the methanol tank that is capable of holding 110% of the inner tank volume. The station was constructed and installed by Malte Fuel & Wash and operates in a similar manner to stations that dispense gasoline and diesel fuel to cars.

Figure 9 Methanol MD97 Fuel Dispensing Station at the Oxelösund Pilot Boat Station

Training to familiarize the crew at the Oxelösund pilot station with the converted vessel, the methanol fuel dispensing station, and the bunkering process was done on two occasions, as follows:

- 2021-12-09: Arranged shortly after the pilot boat entered service
- 2023-01-12: Follow-up training

Training on the first occasion in 2021 took place over a one-day period and included both classroom and practical training. Follow-up training was conducted one year later, for the benefit of crew members new to the Oxelösund station and familiarization of existing crew. Not all crew members had the same level of experience operating the vessel as there is always more than one vessel at the station and some had limited experience with the methanol-fuelled boat. Thus follow-up training was considered valuable for re-familiarization with the vessel and procedures. The first training session was conducted by the ScandiNAOS, SSPA, and the Swedish Maritime Administration. Follow-up training was conducted by ScandiNAOS.

5.2.1 Classroom Training

Classroom training was conducted in a meeting room at the pilot boat station. The following topics were covered:

General Topics:

- methanol properties and characteristics – differences from conventional fuels
- methanol hazards, fire characteristics, use of PPE, toxicity, first aid procedures if exposed via skin, inhalation, or ingestion
- properties and characteristics of the additives for the M97 fuel blend: (Beraid 3555M) and lubricant (Ethomeen).
- Swedish regulations for storage and handling of methanol on land, Swedish occupational health exposure limits

- regulations referred to for use of methanol as fuel onboard (Swedish Transport Agency TSFS 2017:89 regulation for IMO's IGF Code for SOLAS-vessels)

Vessel specific topics:

- presentation of emissions reductions expected with the methanol dual-fuel engine
- risk assessment and class approval of vessel
- Enmar MD97 engine characteristics and performance
- differences between the Scania DI16 engine and the Enmar MD97 engine (which is built on the Scania engine base)
- pilot boat retrofit design, showing differences from the original *Pilot 120* vessel. The following systems were described:
    - methanol fuel storage system:
        - "tank within a tank" concept to provide an extra layer of protection in case of spill
        - tank level indicators; high and high-high level alarms
        - fuel filters
        - fuel delivery and return lines
    - extraction ventilation system
    - updated fire suppression system
    - gas detectors
    - engine hood with extraction ventilation
    - engine fuel delivery system with double-walled piping
    - onboard monitoring and control system.

Bunkering dispensing station topics:

- summary of key findings from the risk analysis submitted for the permit process to store and handle methanol at the Oxelösund pilot boat station
- overview of the methanol dispensing station:
    - main components and safety features
    - hazardous area plan
- procedures for handling small and large spills
- procedures for handling small fire.s

Bunkering procedure:

- Presentation of Pilot Boat 120 bunkering procedures and checklist.

5.2.2 Practical Training Components

Practical training was conducted on the quayside and on board the vessel after the classroom training sessions.

Practical training components included:

- methanol dry bunkering practice
- familiarization with quayside safety equipment (dry powder fire extinguishers, absorbent for small spills, eyewash bottle, water hoses, etc.) (See Figure 10)
- onboard engine demonstration and instruction
- instruction and onboard training for methanol supply and storage systems and safety systems.

Figure 10 Practical training session at the Oxelösund Pilot Boat Station, December 2021

Additionally personnel from Malte Fuel & Wash, the designer and provider of the methanol dispensing station, provided training on operation of the methanol bunkering station on a separate occasion. They also provided a manual on operation of the system.

6 Practical Training for Release and Exposure Scenarios

Methanol training for incident response should be carried out for crew members who are expected to provide first response to accidental releases. Suggestions for practical training exercises is provided in the following subsections. For both the FASTWATER pilot boat and tugboat demo vessels, practical exercises and familiarization with personal protective equipment and detectors were carried out. Practical training of extinguishing of methanol fires was not carried out as the crew instruction was to seek assistance from emergency response and land-based responders for larger spills and where ignition was a concern. Practical training programs for spill response and firefighting, could, however, be considered for future training programs on vessels where appropriate.

Due to the toxicity of methanol, training with the actual fluid can be hazardous and should be practiced with an abundance of caution. Unless it is necessary to use the actual fluid, methanol training should be performed with dummy fluid such as water or ethanol. Training with actual methanol should only be performed at specialized training sites with specialized training personnel. Simulation training can be used to practice response to larger scale incidents that may otherwise be too dangerous in practice. Practical training of methanol can include the following types of exercises:

1. Practical equipment practice
2. Practical handling of methanol spill without ignition.
3. Practical firefighting of methanol pool fires
4. First aid

6.1.1 Practical Equipment Training

Equipment practice should involve all the equipment expected to be used on the specific vessel, as described in 4.7 and 4.8. The training should involve practicing donning PPE and becoming aware of the limitations of the gear, handling of detection devices and managing settings, and activation and managing of fire extinguishers and hoses.

6.1.2 Practical Handling of Methanol Spill without Ignition

This type of training involves a “methanol” spill with no ignition, creating a scenario where the crew must handle a potential explosive atmosphere with spark-free equipment, anti-static clothing and footwear, as well as personal protective equipment to protect them from toxicity hazards. The exercise should involve practice of the different strategies that might be useful in real-life incidents such as collecting spill, flushing overboard, directing spill to bilges/draining pits, and diluting the spill with water. The scenario could also involve limiting and stopping the leak but that might be very ship specific. There is no need for actual methanol in this exercise and water could act as a substitute.

6.1.3 Practical Firefighting of Methanol Pool Fires

Firefighting practice of small methanol fires could involve extinguishment of methanol pools with fire extinguishers (both foam and dry powder), diluting with water from hoses to get an understanding of how much water is needed for total extinguishment and verification of total extinguishment with IR thermal detectors.

If possible, a controlled demonstration of running methanol fires could be performed to show the risks of water application in open spaces without considering where the increased burning mixture will end up.

Due to the toxicity of methanol, the risk of explosion in closed or insufficiently ventilated spaces, and the risk of running fires from overfilling a tray, practical firefighting training should be performed outdoors. A risk analysis should always be performed before practicing with real methanol. The risk analysis should include parameters that affect the vaporization rate of the methanol such as the area of the pool, temperature and vapour pressure. Additionally, wind conditions can affect the concentration of methanol surrounding the pool.

6.1.4 Practical First Aid Response to Methanol Exposure Training

Practical training of first aid treatment to methanol exposure should involve simulating response to the following incidents:

- Inhalation of methanol vapours
- Skin contact
- Eye contact
- Ingestion

Treatment of each scenario is described in section 4.10 “First Aid Response to Methanol Exposure”.

7 SUMMARY AND CONCLUSIONS

Training of crew and personnel is key for ensuring acceptance and proper use of new fuels such as methanol. It is also an important mitigation measure for risk reduction, as each fuel has a different hazard profile which needs to be understood. Guidance for training for the use of alternative fuels other than LNG is not currently provided in the regulations, although for EU inland waterways regulations the priority for developing this has been identified. At the International Maritime Organization level, model course development for other fuels has not yet been started but the need has been identified.

Within the FASTWATER project, training material was developed and provided for the methanol-fuelled pilot boat and the methanol dual fuel tugboat. As both of these vessels were previously run on conventional marine fuel and retrofit to operate on methanol fuel, training focussed on the differences in properties and hazards of methanol fuel as compared to conventional fuel.

General material on methanol properties, hazards, fire characteristics, and safe handling for the courses was developed based on industry practice, publications, and research reports. There is much information available on methanol as it is widely used in the chemical industry and is routinely transported by ships.

Vessel specific information for training for the FASTWATER demonstrators was sourced from the vessel retrofit design drawings, reports, and hazard identification studies. Basic design and operational characteristics of the methanol storage, supply and safety systems was taught in a classroom setting. Engine providers ABC and ScandiNAOS provided training and manuals for the engines installed on the vessels. For the both the pilot boat and the tugboat, practical demonstrations and instruction were conducted on board the vessels. Methanol bunkering procedures were described and reviewed in a classroom setting before dry-run practice of methanol bunkering was carried out on the quayside.

The experience within the FASTWATER project was that it was necessary to develop “bespoke” training material for each specific vessel. There is currently a lack of marine training facilities to provide general methanol training and practical response training such as extinguishment of small fires, but it is expected that this will develop as the use of methanol-fuelled vessels increases.

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