European Maritime Safety Agency

SAFE BUNKERING OF BIOFUELS

HAZID AND RISK ASSESSMENT REPORT

Rev.2.0

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EMSA

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List of Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
ASTM	American Society for Testing and Materials
BOG	Boil-Off Gas
DME	Dimethyl Ether
ECHA	The European Chemicals Agency
ESD	Emergency Shut Down
FAME	Fatty Acid Methyl Ester
FT-diesel	Fischer-Tropsch diesel
HAZID	Hazard Identification
HVO	Hydrotreated Vegetable Oil
IBC Code	The International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk
IGC Code	The International Code of the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
IGF Code	The International Code of Safety for Ships using Gases or other Low-flashpoint Fuels
MEG4	Mooring equipment guidelines (4th edition)
NIOSH	National Institute for Occupational Safety and Health
OCIMF	The Oil Companies International Marine Forum
OSHA	Occupational Safety and Health Administration
PPE	Personal Protective Equipment
PtS	Port(shore)-to-ship
SSL	Ship-shore-link
StS	Ship-to-ship
ToR	Terms of Reference
TtS	Truck-to-ship

1. Summary

A three-day Hazard Identification (HAZID) workshop was conducted from March 11th to 13th, 2024, as part of the Safety study on safe bunkering with biofuels. The workshop focused on the following five biofuels:

- Bio-methanol,
- Dimethyl Ether (DME),
- Fischer-Tropsch (FT) diesel,
- Hydrotreated Vegetable Oil (HVO), and
- Fatty Acid Methyl Ester (FAME).

The liquids, HVO, FT-diesel, and FAME were grouped together for assessment based on their characteristics. The gases, bio-methanol and bio-DME were assessed separately due to significant differences in their properties. The workshop aimed to identify hazardous situations during bunkering and recommend additional evaluations or safeguards that could help reduce the risk involved with the operation. After the workshop, a qualitative risk ranking of each identified hazard was set based on a review of similar studies carried out in the past.

The HAZID workshop identified hazards primarily tied to the transfer phase of bunkering. Two key safeguards were found crucial to ensure safe bunkering operations: conducting a thorough compatibility assessment and following sound bunkering procedures. Bunkering bio-methanol and bio-DME is associated with a higher risk, in terms of the potential severity of an accidental event, than bunkering of drop-in biofuels (such as HVO, FT-diesel, and FAME).

Regulations for bunkering and handling of bio-methanol and bio-DME are more rigorous than for the other assessed biofuels, requiring adherence to the IGF Code, and interim guidelines in the case of bio-methanol. According to the IGF code, vessels fuelled by low flashpoint fuels are required to have a separate risk assessment considering potential onboard hazards, which should include bunkering scenarios as well.

Specifically, for DME, it is essential to consider thermal expansion when setting DME filling limits. DME supplied at low temperatures could lead to overflowing in the receiving ship as the liquid DME expands. Additionally, the capacity of a refrigerated receiving ship's reliquefication system could be exceeded if DME is supplied at ambient temperature. While no additional safety risks were identified for HVO, FT-diesel, and FAME, operational risks may exist due to their potentially shorter longevity compared to conventional fuels. Proper storage practices are crucial to avoid deterioration or contamination.

A total of 59 recommendations were made across the assessed fuels, whereof several may already be covered by current bunkering best practices, yet still recorded as they were addressed during the HAZID. For the complete set of recommendations, please see section 6.3 of the report.

Table 1 Risk index with risk ranking for bunkering of Bio-methanol. No risks were identified as high-risk, 9 were identified as medium risk, where the risk of "filling methanol in a conventional fuel tank" was considered the most severe (however, also considered highly improbable), and 9 were identified as low risks.

Risk Index for bunkering of Bio-methanol						
Frequency		**Severity (safety for people)**				
		1	2	3	4	5
5	Frequently	3.7, 5.2, 5.3				
4	Very likely					
3	Likely		1.2, 3.5, 4.1			
2	Unlikely	3.4	2.2, 3.6, 3.9	2.1, 5.1		
1	Extremely remote		3.1, 3.8	3.2, 3.3, 3.10,	3.11	

Table 2 Risk index with risk ranking for bunkering of Bio-DME. No risks were identified as high-risk, 19 were identified as medium risk, where the risk of "fire/explosion caused by passengers or vehicles interfering with bunkering operations" was considered the most severe and likely hazardous event. 5 were identified as low risks.

Risk Index for bunkering of Bio-DME						
Frequency		**Severity (safety for people)**				
		1	2	3	4	5
5	Frequently					
4	Very likely	1.1				
3	Likely		1.2, 3.5, 3.7,	4.1,	5.3	
2	Unlikely	1.5	1.4, 3.6	2.3, 2.4, 3.8, 5.1	1.3, 2.1, 2.2, 3.9, 5.2	
1	Extremely remote			3.3, 3.4	3.1, 3.2, 3.10	

Table 3 Risk index with risk ranking for bunkering of FT-diesel, HVO and FAME. No risks were identified as high-risk, 2 were identified as medium risk. These were the hazardous events of "incomplete compatibility assessment between bunker supply and ship" and "fire/explosion caused by passengers or vehicles interfering with bunkering operations". 21 were identified as low risks.

Risk Index for bunkering of FT-diesel, HVO and FAME						
Frequency		**Severity (safety for people)**				
		1	2	3	4	5
5	Frequently					
4	Very likely					
3	Likely	2.1, 3.4, 4.1	1.2, 5.3			
2	Unlikely	1.3, 1.4, 3.1, 3.2, 3.5, 3.6, 3.9, 4.2	3.7, 3.8, 5.1			
1	Extremely remote	1.5, 1.6, 1.7, 3.11	3.3, 5.2	3.10		

2. Introduction

2.1 Background

As part of Task 2, *Qualitative risk assessment of biofuels bunkering and operation,* in the Safety study on bunkering with biofuels, a three-day Hazard Identification (HAZID) workshop was carried out on March 11^{th} -13^{th}, 2024. The workshop covered the following five biofuels selected by EMSA: Bio-methanol, Dimethyl Ether (DME), Fischer-Tropsch (FT) diesel, Hydrotreated Vegetable Oil (HVO), and Fatty Acid Methyl Ester (FAME).

The overall goal of the workshop was to identify and screen potential hazardous situations in bunkering of the selected biofuels and their blends (when relevant), identify existing safeguards and recommendations for additional safeguards and risk mitigation measures. After the workshop, a qualitative risk ranking of each identified hazard was performed. The findings from this risk assessment will be used as a basis for developing a goal-based guidance document, Task 3 of the current safety study carried out by DNV for EMSA.

Findings in the preliminary hazard analysis carried out in Task 1 (and presented in D.1), were considered when preparing for the workshop. This included typical accident and loss of containment scenarios and the chemical properties of the preselected biofuels. Each day of the HAZID workshop focused on a specific fuel type, with certain biofuels grouped according to their properties.

2.2 Objective

The objective and scope of the workshop are aligned with the request by EMSA provided in the tender specification (EMSA, 2023).

- Perform a number of HAZID workshops to identify and screen potential hazardous situations in bunkering the selected biofuels and their blends.
- Use typical accident and loss of containment scenarios from bunkering conventional fuels in the same state, gaseous and/or liquid, as a reference. These might include failure of bunkering equipment and piping.
- Consider accident scenarios specific to the nature of biofuels.
- Identify environmental factors and characteristics of typical onboard and onshore bunkering systems that can trigger the hazards associated with the chemical properties.
- Consider different bunkering arrangements – transfer operation from the bunkering vessel, road tankers or shore facilities to a receiving ship.

2.3 Scope and limitations

The study is limited to the following:

- Extracted information for the study basis. As mentioned, findings from Task 1 formed the basis of the study. This included:
  - Properties of each biofuel (including physical properties and critical conditions)
  - Toxicity effects on humans
  - Regulatory framework for each biofuel
- Bunkering configurations. The following three configurations were considered:
  - Ship-to-ship (StS)
  - Port(shore)-to-ship (PtS)
  - Truck-to-ship (TtS)
- Preliminary qualitative risk assessment
  - The risk ranking was set based on and drawing on experience from past similar studies and subsequently reviewed by the HAZID team.

3. Work processes

The following activities were carried out as part of the study:

1. Preparation meeting with EMSA
2. Preparing Terms of Reference for the HAZID workshop
3. Setting up the HAZID team
4. Execute the HAZID workshop
5. Generate risk ranking based on previous studies following the HAZID workshop,
6. Summarise recommendations
7. Write report and send report and risk ranking for review to the HAZID participants
8. Finalise report following participants' comments.

3.1 Composition and expertise of the HAZID team

DNV organised a multidisciplinary HAZID team. The participants represent stakeholders and were invited based on their signed letter of intent submitted as a part of the tender proposal and on the invitations provided through DNV's network.

Table 4 Overview of participants in each HAZID workshop day.

	Participant name	Role	Organisation	Email	Monday, March 11th (Bio-methanol)	Tuesday, March 12th (DME)	Wednesday, March 13th (FT-diesel, HVO, FAME)
1	Thomas Bondenzen	Industry stakeholder	Bunker One	thbo@bunkerone.com	x	-	x
2	Steffen Volder Kortegård	Industry stakeholder	Bunker Holding / Bunker One	sko@bunker-holding.com	x	-	-
3	Sotris Memalis	Expert	CLEOS	smamalis@cleos.gr	-	-	x
4	George Skevis	Expert	CLEOS	gskevis@cleos.gr	x	-	-
5	Karolina Lundgren	Maritime Authority representative	Norwegian Maritime Authority	KLU@sdir.no	x	x	x
6	Bjørn Mikkel Rygh	Maritime Authority representative	Norwegian Maritime Authority	BMRY@sdir.no	x	x	x
7	Rafael Luis Alfaro Sánchez	Industry stakeholder	Port of Huelva	rlalfaro@transportes.gob.es	x	x	x
8	José Casado Martínez	Industry stakeholder	Port of Huelva	jcasadom@transportes.gob.es	x	x	x
9	Pablo Rodriguez-Rubio Mediavilla	Industry stakeholder	Port of Huelva	pablo.rodriguez@puertohuelva.com	x	x	-
10	Javier Martinez Gonzalez	Industry stakeholder	Port of Huelva	javier.martinez@puertohuelva.com	x	x	x
11	Juan Jesus Reyes	Industry stakeholder	Exolum	juanjesus.reyes@exolum.com	x	x	x
12	Gonzalo Pastor Delgado	Industry stakeholder	CEPSA	gonzalo.pastor@cepsa.com	-	-	x (present at Høvik)
13	Jorge Esteban Uria Garcia	Industry stakeholder	CEPSA	jorge.uria@cepsa.com	-	-	x
14	Oscar Danilo Rodriguez Luna	Industry stakeholder	CEPSA	oscardanilo.rodriguez@cepsa.com	x	x	-
15	Jose Carlos Piñero Gutierrez	Industry stakeholder	CEPSA	josecarlos.pinero@cepsa.com	x	x	x
16	Martin Verle	Industry stakeholder	BP	martin.verle@bp.com	-	-	x (present at Høvik)
17	Reimer Duge	Industry stakeholder	Hapag Lloyd	reimer.duge@hlag.com	-	-	x
18	Nikolai Dorner	Industry stakeholder	Hapag Lloyd	Nikolai.Doerner@hlag.com	-	-	x

	Participant name	Role	Organisation	Email	Monday, March 11th (Bio-methanol)	Tuesday, March 12th (DME)	Wednesday, March 13th (FT-diesel, HVO, FAME)
19	Thomas Groot	Industry stakeholder	GoodFuel / Fineco	thomas.groot@fincoenergies.com	x	x	x
20	Olav Tveit	Expert	DNV	Olav.Tveit@dnv.com	x	x	x
21	Sarath Raj	Task lead (Task 3)	DNV	Sarath.Raj@dnv.com	x	x	x
22	Zhang Yang	Scribe	DNV	Yang.Zhang@dnv.com	x	x	x
23	Håkon Ruud Jonsson	Scribe	DNV	Hakon.Jonsson.Ruud@dnv.com	x	x	x
24	Magnus Jordahl	Facilitator, Task lead (Task 2)	DNV	Magnus.Jordahl@dnv.com	x	x	x
25	Åsa S. Hoem	Project manager	DNV	Asa.Snilstveit.Hoem@dnv.com	x	x	x
26	Carl-Erik Høy Petersen	Observer	DNV	Carl.Erik.Hoy-Petersen@dnv.com	x	-	x
27	Lanfranco Benedetti	Observer	EMSA	Lanfranco.benedetti@emsa.europa.eu	x	x	x
28	Monica Ramalho	Observer	EMSA	Monica.ramalho@emsa.europa.eu	x	x	x
29	Nicolas Charalambous	Observer	EMSA	Nicolas.charalambous@emsa.europa.eu	x	x	x

4. Analysis basis

4.1 Biofuels (potential grouping of fuels with comparable characteristics)

In the report "Bunkering of Biofuels in Maritime: Characteristics, Regulatory Landscape, and Safety Assessment," a preliminary hazard identification was made for each of the five selected biofuels. Based on the work carried out in Task 1, it was proposed that HVO, FT-diesel, and FAME be bundled together for assessment based on their characteristics, whereas bio-methanol and DME were assessed separately as their characteristics differ significantly from those of the other three biofuels in question.

The primary differentiator between the fuels is the flashpoint, and in addition for DME, it is in gaseous form at ambient conditions. Secondly, bio-methanol is considered toxic, whereas the remaining biofuels are not. Remarks were made that DME and FAME are classified as toxic in the IGC and IBC Code, respectively, however, datasheets for FAME (ref. Task 1) did not disclose toxic properties, and for DME the toxicity of inhalation is considered minimal (oral and dermal toxicity are not considered to be a hazard, ref. Task 1). Thus, it was assumed that the IGC and IBC Code classification was based on a precautionary approach just in case any toxic properties were encountered at some point.

4.2 Bunkering configurations, systems and sub-systems

The analysis was set to assess different configurations for bunkering; from truck, bunker barge/vessel (Ship-to-ship transfer) or shore facility. Boundary limits were set from the presentation flange of the supplier, through the bunker hose, ship's bunker flange, piping and all the way to the tank, as illustrated in Figure 4-1 below. Although the focus was on bunkering in terms of transfer and interface between bunker supply and vessel, onboard piping and tanks were included to ensure that any potential negative effects on board were not neglected.

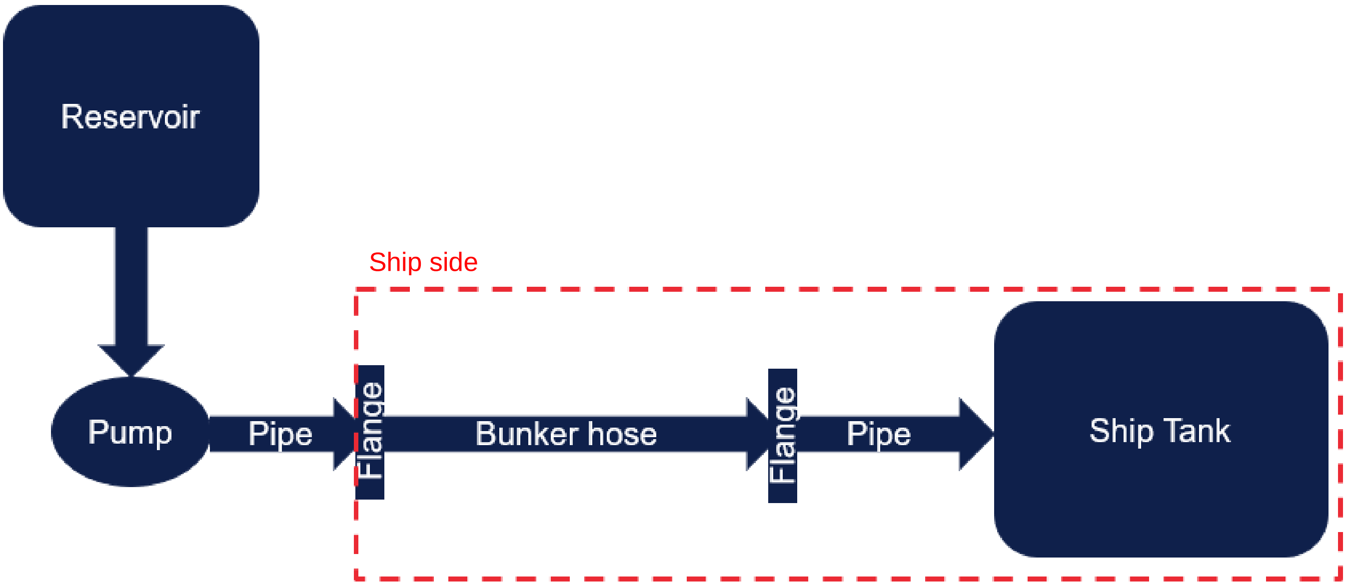

Figure 1 Physical boundary limit for assessment of bunker operation.

4.3 Analysis assumptions

The HAZID is based on the following assumptions:

- The receiving vessel is appropriately Class- and Statutory-approved to use the fuel intended for bunkering.
- If the fuel is supplied from a bunker vessel, it is assumed that the vessel in question also has the necessary applicable approvals to conduct a safe bunkering operation.
- Arrangements for bunker supply (all configurations) are approved by applicable authorities (port/national).
- Location in the port, for bunkering operation is approved by applicable authorities (port/national) if required.
- The bunker provider has obtained the necessary approvals from relevant national authorities to provide bunkering services.
- The bunker provider personnel are adequately trained and equipped with PPE that is fit for purpose.
- The receiving vessel has an approved bunkering procedure, accordingly trained crew involved in bunkering operations, and adequate PPE.
- FT-diesel can have a flashpoint just below 60°C, but it is assumed all FT diesel delivered as a marine will have a flashpoint above 60°C.
- It is assumed that the case of 100% biofuel is the worst-case scenario; hence, blends of biofuels represent an equal or lower risk than blended fuels.

The types of risks as described in this report and the qualitative ranking of frequency and consequence for safety are provided as expert judgments and approved by the HAZID workshop participants.

5. Methodology

5.1 Preparatory work

As mentioned in the introduction, findings from Task 1 laid the foundation for the HAZID, along with the Terms of Reference (ToR) of the workshop, explaining the scope and methodology for the participants. This included:

- Properties of the selected biofuel(s)
- Safety risk of the selected biofuel(s)
- The relevant regulatory framework (IGF Code, Interim guidelines, Class rules, etc.)
- Bunkering configurations
- Boundary limits of the bunkering operation
- Proposed HAZID nodes (See section 5.3.)
- List of guidewords
- Composition of HAZID team

The ToR was agreed upon in a preparation meeting with EMSA (February 23rd, 2024) and provided to the HAZID team prior to the workshop. The HAZID recording template and format were also agreed upon in the preparation meeting.

5.2 Hazard Identification Technique

Hazard identification (HAZID) is a structured brainstorming exercise that aims to identify all relevant hazards and hazardous scenarios, their causes and consequences, and mitigating measures. An outcome of the HAZID is an evaluation of potentially hazardous events during bunkering of the selected biofuels, which provides a basis for further evaluation and qualitative assessment of the risk involved. The HAZID procedure followed the workflow as outlined in Figure 1 Below. Note that the workflow presented in the figure includes “risk ranking” (dark blue box), which was carried out after the workshop.

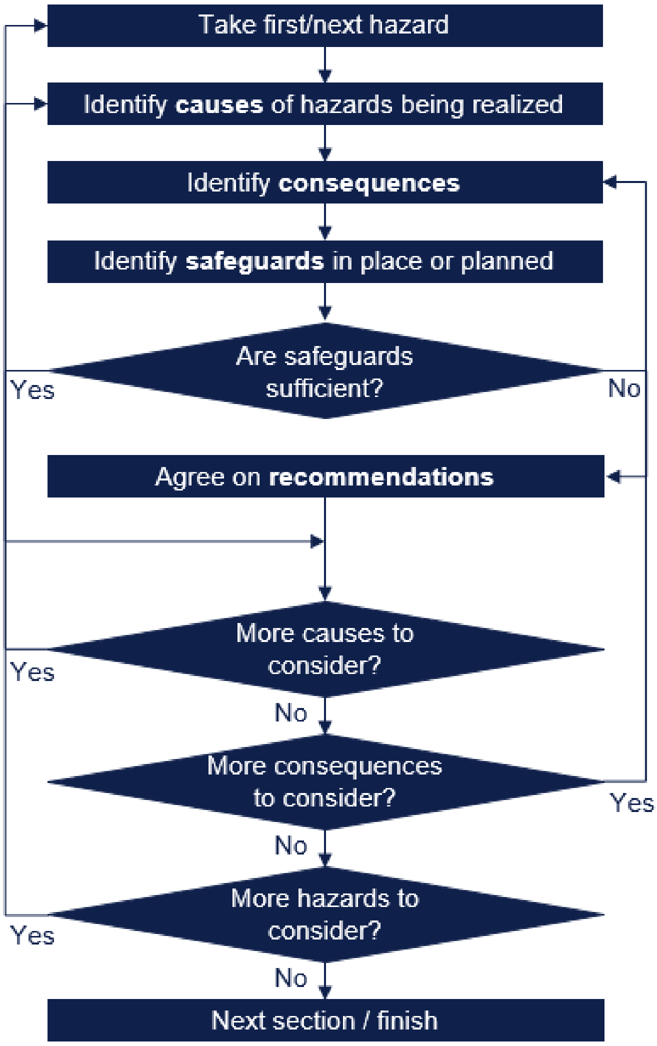

Figure 2 The chosen HAZID procedure.

Hazards identified in the workshop were documented in a log sheet according to the workflow, with every node having columns to record:

- Node
- Guideword
- Relevant bunkering configuration
- Hazardous event
- Potential causes
- Potential consequences
- Safety measures
- Proposed additional safety measures (actions/recommendations)
- Comments and notes

5.3 Customization of HAZID method (nodes, modes, systems, configurations, etc.)

The hazard identification is typically split up into nodes. These were selected according to the phases of a bunkering operation, comprising of:

- Node 1: Preparation for bunkering (before the ship's arrival, approach, and mooring)
- Node 2: Connection of bunkering equipment
- Node 3: Fuel transfer operation
- Node 4: Disconnection of bunkering equipment
- Node 5: Simultaneous operation
- Node 6: Additional causes

5.4 Risk ranking of identified hazards

Following the HAZID workshop, the hazards were qualitatively risk-ranked according to the findings. The risk assessment utilised the severity and frequency categories according to the risk matrix in Figure 2 below, based on DNV recommended practice for Technology Qualification, DNV-RP-A203. Risk ranking was set based on a review of similar studies carried out in the past and was subsequently accepted by the workshop participants.

Risk Index							
			Severity (safety for people)				
			1	2	3	4	5
			None	Minor	Significant	Severe	Catastrophic
			None / insignificant	Single or minor injuries	Multiple or severe injuries	Single fatality or multiple severe injuries	Multiple fatalities
Frequency							
5	Frequently	Occurs several times per year per facility or ship (10–1 < pf)					
4	Very likely	Occurs several times per year per operator (10–2 < pf < 10–1)				High	
3	Likely	Has been experienced by most operators (10–3 < pf < 10–2)			Medium		
2	Unlikely	An incident has occurred in industry or related industry (10–4 < pf < 10–3)		Low			
1	Extremely remote	Failure is not expected (pf < 10–4)					

Figure 3 Risk index used for risk ranking.

6. Results

6.1 Identified hazards and key findings

Hazards identified during the workshops were largely tied to the fuel transfer operation phase. Preparing well for the operation in terms of a compatibility assessment between the delivering and the receiving vessel and sound bunkering procedures were two of the predominant safeguards to ensure accidental event-free bunkering operation.

Bunkering of bio-methanol and DME were identified as an overall more hazardous bunkering process (see Figure 4 and Figure 5, despite the required additional safeguards, compared to bunkering of biofuels considered as drop-in fuels such as HVO, FT-diesel and FAME. The rules for handling bio-methanol and DME are somewhat more rigorous, as these fuels have to adhere to the IGF Code and interim guidelines (MSC/Circ. 1621) for methanol, just as for ships using LNG, subsequently requiring a separate ship-specific risk assessment for the fuel supply system, thus covering potential hazards that may occur onboard during the bunkering operation.

Although flammability is the primary hazardous property of methanol, it should always be kept in mind that it is also a toxic substance. While the toxicity of methanol is mainly hazardous by ingestion, skin exposure, and inhalation (long-term exposure limit 200 ppm (ECHA, OSHA, NIOSH, ACGIH), and 250 ppm up to 15 min (ECHA, NIOSH, ACGIH)) should also be prevented as far as possible by adequate PPE. Recommendations for methanol include technical measures to have control of process parameters, control of potential ignition sources, and improvement of bunkering procedures, whereof some are already outlined in the IGF code/interim guidelines.

Storage compatibility is an issue that was discussed for DME, as it is a gas at ambient pressure and temperature, usually stored in a liquid state by either refrigeration or pressurisation or, in a hybrid state, semi-refrigerated. Hazards are likely to arise if DME is bunkered in a state not supported by the fuel tank design, with a potential rupture of the tank as the worst-case consequence. Thus, the compatibility assessment is an important tool to uncover if there may be an issue of incompatibility with regard to the state of the DME being bunkered. Recommendations for DME involve technical and procedural measures related to thermal challenges, control of process parameters, development of bunkering procedures, and potential compatibility with LPG (considered the closest related fossil fuel).

No potential risks were identified that could be attributed to the bio-component of the biofuels used as blend-in and drop-in fuels (i.e., HVO, FT-diesel and FAME when compared with conventional fuels. As such, it is assumed that for these fuels bunkering operations could be carried out using established best practices and procedures for conventional fuels. Recommendations for these fuels were, in general, related to quality and the fact that there is limited operational experience, pointing to monitoring of potential issues on material compatibility.

Although no other relevant / no other main safety risks were identified for HVO, FT-diesel, and FAME, it should be noted that there may be added operational risks, as the longevity of these fuels may not be as good as for conventional fuels, and care should be taken to avoid deterioration or contamination of the bunkered fuels when storing them for longer periods of time.

6.2 Risk Evaluation

6.2.1 Bio-methanol

For the bio-methanol part of the HAZID as presented in Appendix A 21 hazards were identified, 0 of which were high risk, 9 of which were medium risk, and 9 of which were low risk. The risk of "filling methanol in a conventional fuel tank" was considered the most severe (however, also considered highly improbable). Three hazards (1.1, 1.3 and 3.12) were not risk-ranked due to either insufficient information or being determined not to be a safety risk.

See Figure 5 for a visual representation of the risk distribution of identified hazards for bio-methanol.

Risk Index for bunkering of bio-methanol							
			Severity (safety for people)				
			1	2	3	4	5
			None	Minor	Significant	Severe	Catastrophic
			None / insignificant	Single or minor injuries	Multiple or severe injuries	Single fatality or multiple severe injuries	Multiple fatalities
Frequency							
5	Frequently	Occurs several times per year per facility or ship (10^{-1} < pf)	3.7, 5.2 5.3				
4	Very likely	Occurs several times per year per operator (10–2 < pf < 10–1)					
3	Likely	Has been experienced by most operators (10–3 < pf < 10–2)		1.2, 3.5 4.1			
2	Unlikely	An incident has occurred in industry or related industry (10–4 < pf < 10–3)	3.4	2.2, 3.6 3.9	2.1, 5.1		
1	Extremely remote	Failure is not expected (pf < 10–4)		3.1, 3.8	3.2, 3.3 3.10,	3.11	

Figure 4 Risk distribution of hazards identified for bunkering of bio-methanol. Risk ID 1.1, 1.3 and 3.12 were not risk-ranked.

6.2.2 DME

For the DME part of the HAZID in Appendix B, 26 hazards were identified, 0 of which were identified as high risk, 19 as medium risk, and 5 as low risk. The risk of "fire/explosion caused by passengers or vehicles interfering with bunkering operations" was considered the most severe and likely hazardous event. Three hazards (1.1, 3.11 and 3.12) were not risk-ranked due to either insufficient information or being determined not to be a safety risk.

See Figure 6 below for a visual representation of the risk distribution of identified hazards for bunkering of DME.

Risk Index for bunkering of DME								
			Severity (safety for people)				
			1	2	3	4	5
			None	Minor	Significant	Severe	Catastrophic
			None / insignificant	Single or minor injuries	Multiple or severe injuries	Single fatality or multiple severe injuries	Multiple fatalities
Frequency							
5	Frequently	Occurs several times per year per facility or ship (10–1 < pf)					
4	Very likely	Occurs several times per year per operator (10–2 < pf < 10–1)					
3	Likely	Has been experienced by most operators (10–3 < pf < 10–2)		1.2, 3.5 3.7,	4.1,	5.3	
2	Unlikely	An incident has occurred in industry or related industry (10–4 < pf < 10–3)	1.5	1.4, 3.6	2.3, 2.4 3.8, 5.1	1.3, 2.1 2.2, 3.9 5.2	
1	Extremely remote	Failure is not expected (pf < 10–4)			3.3, 3.4	3.1, 3.2, 3.10	

Figure 5 Risk distribution for hazards identified for bunkering of DME. Risk ID 1.1, 3.11 and 3.12 were not risk-ranked.

6.2.3 FT-diesel, HVO and FAME

For the FT-diesel, HVO, and the FAME-part of the HAZID, 25 hazards were identified, out of which 0 were identified as high risk, 2 were identified as medium risk, and 21 hazards were identified as low risk. The two medium risks were the hazardous events of “incomplete compatibility assessment between bunker supply and ship” and “fire/explosion caused by passengers or vehicles interfering with bunkering operations”. Two hazards were not risk-ranked: Hazard ID 1.1 was determined not to be a safety risk, and hazard ID 3.12 lacked sufficient information.

See Figure 6 for a visual representation of the risk distribution of identified hazards for bunkering of FT-diesel, HVO, and FAME.

Risk Index for bunkering of FT-diesel, HVO, and FAME							
			Severity (safety for people)				
			1	2	3	4	5
			None	Minor	Significant	Severe	Catastrophic
			None / insignificant	Single or minor injuries	Multiple or severe injuries	Single fatality or multiple severe injuries	Multiple fatalities
Frequency							
5	Frequently	Occurs several times per year per facility or ship (10–1 < pf)					
4	Very likely	Occurs several times per year per operator (10–2 < pf < 10–1)					
3	Likely	Has been experienced by most operators (10–3 < pf < 10–2)	2.1, 3.4 4.1,	1.2, 5.3			
2	Unlikely	An incident has occurred in industry or related industry (10–4 < pf < 10–3)	1.3, 1.4 3.1, 3.2 3.5, 3.6 3.9, 4.2	3.7, 3.8 5.1,			
1	Extremely remote	Failure is not expected (pf < 10–4)	1.5, 1.6, 1.7, 3.11	3.3, 5.2	3.10		

Figure 6 Risk distribution for hazards identified for bunkering of FT-diesel, HVO and FAME. Risk ID 1.1 and 3.12 were not risk-ranked.

6.3 Recommendations for risk mitigation

Below are three tables summarising the recommendations for mitigation of the risks identified in the workshop for each biofuel. The table also includes references to those not risk-ranked, such as 1.3 in table 6.3.1, which are considered operational issues rather than a safety risk for bunkering the biofuel. And hazard ID 1.1 in 6.3.2 and 6.3.3 where more information is needed to determine the risk level. However, these recommendations were addressed in the risk assessment and are included in the tables to provide input to the guidance document in the next phase of the project.

6.3.1 Recommendations for bunkering of Bio-methanol

Rec. ID	Recommendation	Hazard ID	Comments and/ or reference to existing rules and regulation
1	Recommend sampling of fuel upon delivery to ensure that the bio-methanol is in accordance with agreed specification and does not pose additional and unexpected hazards.	1.3 (not considered a safety risk)	Engine manufacturer recommendations, MARPOL Annex VI, and ISO 6583 (Part 8) under development. MSC.1/Circ. 1621 (sect. 17)
2	Supplier to share fuel quality analysis prior to bunkering and its compatibility to be assessed by vessel crew or third party (considered best practise, not a requirement)	1.3 (not considered a safety risk)	MARPOL Annex VI (?) ASTM D7901- 20 and ISO 16861:2015, are relevant fuel quality standards, ISO 6583
3	Investigate measures to collect methanol spills to sea in case of a leakage during bunkering.	2.1	Methanol is water soluble. Hence, we do not expect that there are any effective measures enabling collection of spills to sea.
4	Investigate if electrical bonding (earthing) of bunkering hose to reduce potential electrostatic discharge could be introduced as a requirement to reduce the risk of ignition in case of a leakage.	2.1	OCIMF Guidelines for the handling, storage, use, maintenance and testing of STS hoses. Bonding wires is not recommended by SIGTTO and OCIMF. Instead, installation of insulating flanges is recommended at one end of the connection hoses for all transfer or vapor return connections. Note that Methanol is not a static accumulating medium, and it is assumed that bio-methanol is the same. Hence the issue of static electric discharge is less critical.
5	Ensure that sufficient nitrogen supply is available prior to bunkering to ensure adequate purging of system is available on demand.	2.2	IGF/Circ.1621
6	Consider to provide sampling arrangements enabling portable O2 measurements to confirm that piping and tanks are inerted prior to bunkering.	2.2	

Rec. ID	Recommendation	Hazard ID	Comments and/ or reference to existing rules and regulation
7	Investigate whether it is required for vessels to have a mooring plan which includes mooring during bunkering. (Specifically for STS bunkering).	3.2	Mooring equipment guideline for tankers in OCIMF. Port Authority Regulations on fuel supply. Note also that HELCOM Recommendation 28/3 Guidelines on bunkering operations and ship-to-ship cargo transfer of oils, subject to annex I of MARPOL 73/78, in the Baltic Sea area specifically requires a mooring plan.
8	Consider adding a high-pressure ESD shutdown to protect the loading hose in case of overpressure (ESD shutdown will give automatic shut-down of bunker flow via the mandatory ESD ship-shore link (SSL)).	3.5	
9	Investigate if the closing time requirements for remotely operated valves (IGF code) may cause "water hammering" effects. If this is the case the closing time should be delayed to prevent "water hammer" effects in the bunkering line.	3.6	There are no maximum closing times specified for automatic valves (incl. bunker valves) in MSC.1/Circ.1621. The IGF code specifies 30 seconds for automatic valves other than bunker valves. For bunker valves the closing time shall be 5 seconds unless pressure surge calculations determine that an extended closing time is needed.
10	Consider having a reduced target tank pressure of the bunker vessel to reduce the risk of unintentional venting of methanol vapour from bunker barge and subsequent risk of gas release in areas outside defined hazardous zones onboard the receiving vessel.	3.7, 3.8	
11	Consider prohibiting internal transfer of fuel in bunker barge during bunkering to prevent potential venting of methanol vapours and subsequent risk of gas release in areas outside defined hazardous zones onboard the receiving vessel.	3.8	
12	Consider ensuring methanol hose/manifold connections are physically incompatible with fuel oil hose/manifold connections. Ensure that colour coding of methanol hose/piping is used to distinguish it from lines for other fuels and prevent incorrect connection.	3.11	
13	Investigate whether the electrostatic properties of bio-methanol are the same as for pure methanol from hydrocarbons and whether bio-methanol blends are static accumulators. Depending on the result, consider applying normal industry precautions (grounding, bonding and avoidance of turbulent flow that may induce static electricity).	3.12 (not considered a safety risk)	Ref. Recommendation ID 4: Marine practice is that hoses are assumed to convey static accumulating media.
14	Bunkering procedures are to consider whether simultaneous operation during bunkering may be allowed; however, under no circumstance is the operation in question allowed to take place inside the established safety zone.	5.1, 5.2, 5.3	Port of Gothenburg: Methanol bunker operating regulations, ch. 3.2 on Simultaneous operations during bunkering

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Rec. ID	Recommendation	Hazard ID	Comments and/ or reference to existing rules and regulation
15	Limit passenger access to weather deck or balconies on the side where methanol bunkering is performed to prevent accidental introduction of potential ignition sources.	5.2, 5.3	Port of Gothenburg: Methanol bunker operating regulations, ch. 2.4
16	Consider physical/visual barriers of the bunkering safety zone to prevent passenger access into the safety zone while bunkering is carried out.	5.3	

6.3.2 Recommendations for bunkering of DME

Rec. ID	Recommendation	Hazard ID	Comments and/ or reference to existing rules and regulation
17	Investigate whether Ship-Shore ESD link should be a requirement.	1.1, 1.2	As DME is not LPG, it is unclear whether MSC.1/Circ.1666 applies. In any case, the circular includes mandatory requirements to such a link by reference to the IGF Code ch.8. I.e. in an Alternative Design process, we would assume that an ESD link would be considered mandatory.
18	Ensure that fuel tanks and pipes are cooled down prior to bunkering, if applicable, to prevent excessive damage to the tank due to thermal stress.	1.2	DNV- RU-SHIP. The IGF Code requires operational procedures covering cool-down.
19	Consider to provide arrangements enabling portable O2 measurements to confirm that piping and tanks are inerted prior to gassing-up.	1.3	
20	Consider means of verifying that a successful gassing-up procedure has been conducted.	1.4	
21	Recommended to sample fuel upon delivery to ensure compatibility with engine requirements and prevent potential damage to the engine(s). (Engine manufacturer recommendations). ASTM D7901- 20 and ISO 16861:2015, are relevant fuel quality standards.	1.5	ASTM D7901- 20 and ISO 16861 (2015) Note that sampling of gas fuel is significantly more complicated than oil fuel sampling.
22	Consider routines for suppliers to share fuel quality analysis prior to bunkering and compatibility to be assessed by vessel crew or third party (not a requirement)	1.5	
23	Investigate if electrical bonding (earthing) of bunkering hose to reduce potential electrostatic discharge could be introduced as a requirement to reduce the risk of ignition in case of a leakage.	2.1	IGF (18.4.5) specifies that hoses, transfer arms, piping and fittings provided by the delivering facility used for bunkering shall be electrically continuous, suitably insulated and shall provide a level of safety compliant with recognized standards e.g. API RP 2003, ISGOTT: International Safety Guide for Oil Tankers and Terminals. Bonding wires is not recommended by SIGTTO and OCIMF. Instead, installation of insulating flanges is recommended at one end of the connection hoses for all transfer or vapor return connections. Insulation flange specifications and arrangements are to be in accordance with recognized industry standards such as ISGOTT “International Safety Guide for Oil Tankers and Terminals” and

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Rec. ID	Recommendation	Hazard ID	Comments and/ or reference to existing rules and regulation
			SIGTTO "LNG Ship to Ship Transfer Guide for Petroleum, Chemicals and Liquefied Gases".
24	Ensure no materials incompatible with DME are used neither in the bunkering operation or further in the system. Specifically rubbers or elastomers (gaskets and seals).	2.1	ISO 2928:2021(en) Rubber hoses and hose assemblies for liquefied petroleum gas (LPG) in the liquid or gaseous phase and natural gas up to 2,5 MPa (25 bar) — Specification or Standard EN1762, BS4089, ISO 2928:2003, British Standard (BS) EN 13766:2010, BS EN 1762:2003
25	Consider the use of water curtains to protect ship hull against negative thermal effects in case of a liquid leak of DME.	2.2, 3.3	IGF Code (8.5.7) and MSC Circ. 1666
26	Drip trays recommended to be according to specifications in MSC Circ. 1666.	2.2	IGF Code (8.5.7) and MSC Circ. 1666
27	Consider dry break-away coupling in bunker hose connection to prevent excessive amounts leaked to water in case of an emergency disconnection if not already part of requirements in MSC 1666.	2.2	Such couplings are mandatory as per IGF (8.4.1). MSC.1/Circ.1666 incorporates same by reference.
28	Ensure that sufficient nitrogen supply is available prior to bunkering to ensure adequate purging of system is available on demand.	2.3	
29	Ensure arrangements to verify the inerting and purging of piping and hose are available on the vessel.	2.3	
30	Consider adding temperature shell sensors to tank and piping in order to identify insufficient cooling prior bunkering.	2.4	IGF Code (15.4.11) requires shell temperature measurements in top, middle and top of tanks. LNG piping is subject to mandatory pipe stress analysis to demonstrate that it can manage thermal stresses.
31	Investigate whether it is required for vessels to have a mooring plan which include mooring during bunkering (specifically for STS bunkering).	3.2	Port Authority Regulations
32	Consider carrying out a location-specific QRA for the bunkering operation, considering the properties of DME being heavier than air, to enable establishment of sufficient safety zone around the bunkering operation similar to what is done for LNG (Port/supplier responsibility).	3.2, 3.4, 5.2, 5.3	Port Authority Regulations
33	Consider adding tightness testing to bunkering procedures, if not already required, to reduce the likelihood of leakages.	3.3	ISO 2928:2021(en) Rubber hoses and hose assemblies for liquefied petroleum gas (LPG) in the liquid or gaseous phase and natural gas up to 2,5 MPa (25 bar) — Specification or Standard

Rec. ID	Recommendation	Hazard ID	Comments and/ or reference to existing rules and regulation
			EN1762, BS4089, ISO 2928:2003, British Standard (BS) EN 13766:2010, BS EN 1762:2003
34	Investigate certification requirements for bunkering hoses that could be used for bunkering of DME (look to IGC code for requirements, 5.11.7)	3.4	IGC code - 5.11.7
35	Consider adding liquid relief valve on the outboard of the bunkering isolation valve (both on supply and receiving side) to prevent excessive over-pressurisation of the hose in the event the hose is dropped in water.	3.5	
36	Consider adding ESD based on high pressure (close to the setting of the liquid relief valve) to prevent liquid relief and potential spray on deck through the vent mast.	3.5	
37	Investigate if the closing time requirements (IGF code) may cause water hammering effects. If this is the case, the closing time should be delayed preventing water hammer effects in the bunkering line.	3.6	The IGF code specifies 30 seconds for automatic valves other than bunker valves. For bunker valves the closing time shall be 5 seconds unless pressure surge calculations determine that an extended closing time is needed.
38	Consider a low target tank pressure of both supplying vessel and receiving ship before bunkering to ensure pressure control to prevent the risk of gas release in areas outside defined hazardous zones onboard the receiving vessel.	3.7, 3.8	
39	Consider adding gas detection in the gas mast outlet on the supply vessel to identify potential gas release from tanks.	3.7, 3.8	
40	Consider prohibiting internal transfer of fuel in bunker barge during bunkering to limit the risk of gas release in areas outside defined hazardous zones onboard the receiving vessel.	3.8	
41	If conflicting hazardous areas are identified during compatibility assessment, consider means to mitigate risk to prevent any ignition sources or similar being available in the hazardous area imposed by the bunker vessel.	3.8	
42	Investigate the interchangeability of engines in burning both LPG and DME, implications of this and discuss it in the post-processing.	3.11, 3.12	To be followed up by DNV in the next phase. Note: DME has a lower heating value but a higher density than LPG. Hence, there will be some different engine settings.

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Rec. ID	Recommendation	Hazard ID	Comments and/ or reference to existing rules and regulation
43	Consider a pressure sensor outboard of the bunkering valve to detect pressure increase due to residual fuel in the hose, and no pressure increase when the hose is empty.	4.1	
44	Bunkering procedures are to consider whether simultaneous operation during bunkering may be allowed, however under no circumstance is the operation in question allowed to take place inside the established safety zone.	5.1, 5.2, 5.3	
45	Limit passenger access to weather decks and balconies on the side where DME bunkering is performed to prevent accidental introduction of potential ignition sources.	5.2, 5.3	
46	Consider physical/visual barriers of the bunkering safety zone to prevent passenger access into the safety zone while bunkering is carried out.	5.3	

6.3.3 Recommendations for bunkering of FT-diesel, HVO and FAME

Rec. ID	Recommendation	Hazard ID	Comments and/or reference to existing rules and regulation
47	Consider adding procedures to check bunker area and consider adequate measures for protection of hot surfaces above 200°C to bunkering procedures, in order to avoid autoignition. Current requirement is surfaces above 220°C (relevant for FT and HVO)	1.1	
48	Fuel suppliers should share the fuel analysis report, both for the 100% biofuel and the blend, prior to bunkering to ensure fuel quality is within specification. This report should also be available upon fuel delivery.	1.4	
49	Consider increasing the inspection interval time until more operational experience is gained with regards to increased corrosivity.	1.6	
50	Investigate the corrosivity of different levels of fuel blends towards unprotected steel tanks specifically for heated fuels and long-term storage.	1.6	
51	Suppliers must verify compatibility with their own seals, gaskets, and, specifically, bunker hoses to lower the likelihood of leakages.	1.6	
52	When receiving biofuels verify that your gasket, seals and coatings are compatible with the specific fuel.	1.6	
53	Consider special care and precautions in case fuel is heated within 10°C below its flashpoint (valid also for flashpoints above 60°C).	2.1	IEC 60092-502
54	It is recommended that vessels implement independent overflow alarm in fuel tanks.	3.1	
55	Revise certification and inspection regime for bunker hoses used for biofuels to account for potential material incompatibility (EN1765 (2016) currently used for bunkering hoses)	3.4	EN 1765 (2016)
56	Consider a manual ESD link with a remote stop button between the receiving vessel and the fuel supplier in order to enable stop from the receiving vessel in case of any deviations from normal operation.	3.4, 3.6	
57	Consider the failure mode of any remotely operated valves in the bunker system to limit any potential water hammer effect.	3.5, 3.6	
58	Investigate whether electrostatic charging could be an issue concerning bunker barges and fuels in question and what implications that might have for fuels with flashpoints above 60°C.	3.12	
59	If simultaneous operations are to be conducted during bunkering, consider doing a specific risk assessment for the operation.	5.1	

Appendix A HAZID logsheet for bunkering of Bio-methanol

Table 5 HAZID log sheet for bunkering of Bio-methanol including risk ranking.

ID	Guideword	Relevant bunker config.	Hazardous event	Potential causes	Potential consequences	Safety measures	F1	Ss1	R1	Proposed additional safety measures (actions/recommendations)	Comments and notes
Node 1: Preparation for bunkering											
1.1	Human error	All configurations	Checklists not followed	- High workload - Insufficient time to prepare - Insufficient training - Safety culture	- Increased likelihood of accidental events - Compatibility not assessed - Safety checks are omitted	- Checklists have to be filled out and signed by both parties in order to commence bunkering. - Dedicated bunkering crew with relevant training - Necessary approvals are obtained both on delivery and receiving side prior to bunkering. (ref. assumptions) - Safety systems both on supplier and receiver side, - Ship-Shore ESD link - Communication between supplier and receiver during bunkering. - Automatic closing of ship bunker valve at H-H level	-	-	-		not specific for MeOH, but a general observation of bunkering for conventional fuels. Conservative for MeOH: **Not following the checklist does not necessarily cause an accident; however, a safety barrier is impaired**.
1.2	Human error	All configurations	Improper compatibility assessment between bunker supply and ship	- High workload - Insufficient time to prepare - Insufficient training - Safety culture	- Excessive bunkering rate (overfilling) - Overflow through tank vent - Tank rupture - Hose rupture - Exposure of personnel to methanol - Leakage of flammable liquid - Fire/explosion if ignited	- Checklist item - Tank level sensors and alarms - Ship-Shore ESD link - Vessels is required to have an approved bunkering procedure with system limitations. - Automatic closing of ship bunker valve at H-H level - Drip trays with level detection resulting in ESD	3	2	5		- Leak at flanges expected before hose rupture. - The IMO guidelines do not specify drip tray with level detection resulting in ESD as a requirement. DNV rules require leakage detection with alarm and safety actions (assumed ESD) where the bunkering station is closed or semi enclosed.
1.3	Composition change	All configurations	Fuel quality out of spec.	- Contamination onboard barge, truck or shore tanks. - Production issues - Contamination onboard receiving vessel - Connection to wrong fuel line	- Increased corrosivity of ship systems - Operational issues, no safety risk.	- BDN (Bunkering delivery note) is mandatory from supplier.	-	-		- Recommend sampling of fuel upon delivery to ensure that the bio-methanol is in accordance with agreed specification and does not pose additional and unexpected hazards. (Engine manufacturer recommendations) ISO 6583 under development. - Supplier to share fuel quality analysis prior to bunkering and compatibility to be assessed by vessel crew or third party (not a requirement)	- Water is seen as mostly likely contamination (somewhere along the value chain), which would cause increased corrosivity. Analysis could be a challenge depending on location as methanol samples cannot be sent by air. - Not risked ranked due to being considered an operational issue with no safety risk.
Node 2: Connection of bunkering equipment											

ID	Guideword	Relevant bunker config.	Hazardous event	Potential causes	Potential consequences	Safety measures	F1	Ss1	R1	Proposed additional safety measures (actions/recommendations)	Comments and notes
2.1	External leakage	All configurations	Leakage of methanol when commencing bunkering	- Assembly error - Hose damage / equipment failure	- Exposure of personnel - Potential fire if ignited - Release of methanol to water	- Bunkering procedures, incl. tightness testing - EX equipment and hazardous zone classification. - PPE - Safety measures covered in Ref. MSC circular 1621 - Safety zones and security zones around the area of bunkering operations. - Bunkering hose is subject to rigorous certifications. - Drip trays with level detection resulting in ESD	2	3	5	- Investigate measures to collect methanol spills to sea in case of leakage during bunkering. - Investigate if potential bonding of bunkering hose to reduce electrostatic static discharge upon connection of bunker hose could be introduced as a requirement.	- Methanol would presumably mix with water and couldn't be collected by oil boom and skimmers in the same way as oil products. According to API, pure methanol is not a static accumulator as it has a high electrical conductivity (greater than 50 picosiemens per meter). Blends of methanol could, however, be static accumulators, and it is therefore recommended to apply normal precautions (grounding, bonding, and avoidance of turbulence). There may also be uncertainty regarding bio-methanol.
2.2	Reaction	All configurations	- Air inside bunkering piping, hose and tank.	- Insufficient inerting prior to bunker commencement.	- Explosive atmosphere - Potential fire or explosion if ignited.	- Bunkering procedures / compatibility assessment / meeting. Agree on purging method.	2	2	4	- Ensure that sufficient nitrogen supply is available prior to bunkering to ensure purging of system. - Consider installing arrangements for O2 measurement within bunker supply piping and fuel tank to enable detection of potentially flammable/explosive atmosphere prior to commencing bunkering.	- Existing nitrogen systems tend to be too small - Main risk is tied to bunkering of methanol after the tank has been gas-freed (e.g. in connection with docking)
Node 3: Fuel transfer operation											
3.1	Overfilling	All configurations	Overfilling of fuel tank during bunkering	- Incorrect sounding of fuel tank - Failure to shut down supply on bunker supplier side - Too high bunkering rate - Incorrect operation of valves	- Increased tank pressure - Tank rupture - Exposure of personnel to methanol - Leakage of flammable liquid - Fire/explosion if ignited	- Bunkering rate and amount to be according to compatibility assessment. - Ref. safety measures in MSC circular 1621 - Automatic closing of ship bunker valve at H-H level in fuel tank	1	2	3		- Both high and high-high shall activate alarm and automatic ESD with closing of bunker valve. DNV rules only require ESD of bunker valve at high-high but closing of methanol tank valves at high level.
3.2	External leakage	All configurations	Drift off during bunkering	- Mooring failure - Large relative movements between bunker supply and vessel (incl. Weather)	- Rupture of bunker hose - Release of methanol onto quey-side or spill to sea.	- Flexible bunker hose - Dry-break coupling - Bunkering procedure/compatibility assessment/port requirements to set weather limitations. (incl. Weather window) - Safety zones and security zones around the area of bunkering operations. - Bunkering hose is subject to rigorous certifications - Compatibility assessment should cover mooring in terms of STS bunkering.	1	3	4	- Investigate whether it is required for vessels to have a mooring plan which include mooring during bunkering. (Specifically for STS bunkering). → HELCOM Recommendation 28/3	- Some bunker barges today use vacuum pad systems instead of mooring and fenders (are heavy compensated)

ID	Guideword	Relevant bunker config.	Hazardous event	Potential causes	Potential consequences	Safety measures	F1	Ss1	R1	Proposed additional safety measures (actions/recommendations)	Comments and notes
3.3	External leakage	All configurations	Leakage of fuel from bunkering manifold	- Equipment malfunction (Leakages in valves, piping, flanges)	- Exposure of personnel - Potential fire if ignited - Release of methanol on deck	- Ref. MSC circular 1621 - Vessel specific risk assessment during approval to consider risk of leakages internal of the vessel. - Bunkering procedures (incl. Tightness testing) - Periodic pressure testing of system	1	3	4		- Smaller leaks expected prior to a large failure
3.4	External leakage	All configurations	Leakage of fuel (to water)	- Equipment malfunction - Assembly error - Hose damage	- Exposure of personnel - Potential fire if ignited - Release of methanol to water	- Ref. MSC circular 1621 - Vessel specific risk assessment during approval to consider risk of leakages internal of the vessel. - Bunkering hose is subject to rigorous certifications - Compatibility assessment. - Bunkering procedures (incl. Tightness testing)	2	1	3		
3.5	Over/ under pressure	All configurations	Over-pressuring of bunkering line	- Incorrect operation of valves - ESD valve closing too fast	- Hose damage (leaks or rupture) - Connection damage	- Ref. MSC circular 1621 - Bunkering hose is subject to rigorous certifications - Compatibility assessment. - Bunkering procedures (incl. Tightness testing)	3	2	5	- Consider adding a high pressure ESD shutdown to protect loading hose in case of overpressure (ESD shutdown will give automatic shut-down of both bunker flow via the mandatory ESD ship-shore link (SSL)).	- The receiving vessel is assumed having to comply with significant more stringent regulations compared to the suppling vessel/barge which may lack automatic ESD/systems. - ISO 28460 2010 is referred to in MSC circular 1621. Potentially applicable.
3.6	Unintentional activation	All configurations	- Inadvertently closing of remotely operated valves (fail-close)	- Blackout - Loss of control air - Loss of hydraulic power supply	- Supply pumping against closed outlet - Potential water hammer and damage to hose - Leakage of fuel - Exposure to personnel - Potential fire /explosion if ignited	- Ship side pressure alarms in bunkering manifold. - The bunkering procedure to consider pressure drop across bunkering line. - Compatibility assessment.	2	2	4	- Investigate if the closing time requirements (IGF code) may cause water hammering effects. If this is the case the closing time should be delayed to prevent water hammer effects in the bunkering line. → There are no maximum closing times specified for automatic valves (incl. bunker valves) in MSC.1/Circ.1621. The IGF code specifies 30 seconds for automatic valves other than bunker valves. For bunker valves the closing time shall be 5 seconds unless pressure surge calculations determine that an extended closing time is needed.	- The valve response depends on type of actuator - LNG has time-closing requirement on ESD valves.
3.7	Reaction	All configurations	Methanol vapour out of receiving ship P/V valves during bunkering	- Displacement of volume in tanks during bunkering	- Release of methanol vapour on deck - Potential fire if ignited - Exposure to personnel	- Hazardous zones and EX equipment at outlets. - Possibility to use vapour return /vapour balancing. - Inerting gas blanket inside fuel tanks. (req. In MSC 1621).	5	1	6	- Consider having a reduced target tank pressure of the bunker vessel to reduce the risk of unintentional venting of methanol vapour from bunker barge and subsequent risk of gas release in areas outside defined hazardous zones onboard the receiving vessel. - Ensure that fire- and gas detection is sufficiently covered in fuel supply system risk assessment as required by MSC/Circ. 1621	- Occurs during normal operations whenever vapour return is not used. - The composition of the gas inside the tanks converges towards gas vapour closer to liquid surface, and may come out of the vent during bunkering.

ID	Guideword	Relevant bunker config.	Hazardous event	Potential causes	Potential consequences	Safety measures	F1	Ss1	R1	Proposed additional safety measures (actions/recommendations)	Comments and notes
3.8	Reaction	StS	Methanol vapour out of supply ship / bunker barge P/V valves during bunkering.	- Internal transfer in barge - Vapour return disturbances - Thermal expansion	- Hazardous zone from the supply vessel imposed onto the receiving ship to a location not fitted with EX equipment. - Potential fire / explosion if ignited - Exposure to personnel	- Compatibility assessment used to make sure there are no conflict hazardous zones between supplying and receiving vessels.	1	2	3	- Consider having a reduced target tank pressure of the bunker vessel to reduce the risk of unintentional venting of methanol vapour from bunker barge and subsequent risk of gas release in areas outside defined hazardous zones onboard the receiving vessel.	
3.9	Collision	StS	- Collision during approach of bunkering vessel to receiving vessel	- Loss of navigational control - Limited visibility (fog, night, etc) - Human error	- Damage of vessel(s) - Loss of containment	- Communication between vessels during approach (reduced effectiveness if receiving vessel is moored). - Fenders (if deployed) could limit potential damages. - Port accreditation for bunker vessel operation within port limits. - Bunkering vessels typically are fitted with bow thrusters for increased manoeuvrability. - IAPH requirements. - Receiving vessel's methanol tank must have double hull	2	2	4		
3.10	Fire / explosion in other areas	All configurations	Nearby fire in non-hazardous areas	- Fire on quayside - Fire on bunker vessel - Fire on receiving vessel (non-hazardous zones)	- Potential fire spread to bunkering operation, escalating the fire.	- Fire alarms on both vessels. - Bunkering procedures to include stop of operation in case of fire detection. - Fire suppression. - Fire extinguishing capabilities.	1	3	4		
3.11	Human error	TtS+PtS	Filling methanol in a conventional fuel tank: Connect methanol hose to the diesel tank	- human error	- Methanol in a tank not designed for methanol - Methanol in system not designed for methanol (double piping, etc) - Fire/explosion hazards	- Bunkering procedures - Compatibility assessment - Methanol bunkering manifold arrangement is visually different from diesel manifold.	1	4	5	Methanol is not compatible with certain rubber/plastic and aluminium: - Ensure methanol hose connection is not compatible with diesel manifolds and correct colour coding of methanol hose.	
3.12	Reaction		Electrostatic issue (see 3.12 of FAME, HVO and FT diesel HAZID log).	- biofuel may cause higher generation of static electricity.	- Potential generation of spark in the fuel system. - Potential fire/explosion.	- Conductive steel pipes. - Potential bonding between bunker provider and vessel (?)				- Investigate whether the electrostatic properties of bio-methanol are the same as for pure methanol from hydrocarbons and whether bio-methanol blends are static accumulators. Depending on the result, consider applying normal industry precautions (grounding, bonding and avoidance of turbulence).	According to API, pure methanol is not a static accumulator as it has a high electrical conductivity (greater than 50 picosiemens per meter). Blends of methanol could, however, be static accumulating and it is therefore recommended to apply normal precautions (grounding, bonding, and avoidance of turbulence). There may also be uncertainty regarding bio-methanol.
Node 4: Disconnection of bunkering equipment											

ID	Guideword	Relevant bunker config.	Hazardous event	Potential causes	Potential consequences	Safety measures	F1	Ss1	R1	Proposed additional safety measures (actions/recommendations)	Comments and notes
4.1	External leakage	All configurations	Residual fuel left in hose and/or pipes	- Insufficient purging	- Exposure of personnel - Leakage on deck - Potential fire if ignited	- Bunkering procedures and compatibility assessment to describe how to conduct purging of system prior to disconnection. - PPE for all personnel involved in bunkering operation.	3	2	5	Recommendation?	- The supply of inert gas, both in terms of volume and pressure, shall be discussed during the compatibility assessment to ensure the vessel(s) ability to purge system. - Quick closing disconnect couplings could reduce the need for purging (as the case with LNG vessels).
Node 5: Simultaneous operation											
5.1	Dropped object	All configurations	- Impact to bunkering equipment	- Dropped load during simultaneous operations (cargo supply / provisions)	- Spark generation - Equipment damages - Potential fire /explosion - Hose rupture / damage	- Rules and regulations should cover dropped loads during mandatory HAZID. - All simultaneous operations are to be subject to approval prior to commencement. - Ship side pressure alarms in bunkering manifold	2	3	5	- Bunkering procedures are to consider whether simultaneous operation during bunkering may be allowed; however, under no circumstance is the operation in question allowed to take place inside the established safety zone.	
5.2	Fire / explosion	StS	- Release of fuel during embarkation / disembarkation /vehicle movement	- Passengers or vehicle interfering with bunkering operations	- Passengers or vehicles introducing potential ignition sources in hazardous zones. - Potential ignition of vapours inside hazardous zone. Potential fire / explosion	- Established safety zones around bunkering equipment. - Bunkering is likely carried out on opposite side of passenger handling.	5	1	6	- Limit passenger access to weather deck or balconies on the side where methanol bunkering is performed to prevent accidental introduction of potential ignition sources. - Bunkering procedures are to consider whether simultaneous operation during bunkering may be allowed; however, under no circumstance is the operation in question allowed to take place inside the established safety zone.	- 25m radius safety zone around the bunkering point which may conflict with passenger areas.
5.3	Fire / explosion	TtS	- Embarkation / disembarkation /vehicle movement	- Passengers or vehicle interfering with bunkering operations	- Passengers or vehicles introducing potential ignition sources in hazardous zones. - Potential ignition of vapours inside hazardous zone. Potential fire / explosion	- Established safety zones around bunkering equipment.	5	1	6	- Limit passenger access to weather deck or balconies on the side where methanol bunkering is performed to prevent accidental introduction of potential ignition sources. - Bunkering procedures are to consider whether simultaneous operation during bunkering may be allowed; however, under no circumstance is the operation in question allowed to take place inside the established safety zone. - Consider physical/visual barriers of the bunkering safety zone to prevent passenger access into the safety zone while bunkering is carried out.	- Truck-to-ship is considered a more severe case than port-to-ship.

Appendix B HAZID logsheet for bunkering of DME

Table 6 HAZID log sheet for bunkering of DME including risk ranking.

ID	Guideword	Relevant bunker config.	Hazardous event	Potential causes	Potential consequences	Safety measures	F1	Ss1	R1	Proposed additional safety measures (actions/recommendations)	Comments and notes
Node 1: Preparation for bunkering											
1.1	Human error	All configurations	Checklists not actually followed	- High workload - Insufficient time to prepare - Insufficient training - Safety culture	- Increased likelihood for accidental events - Compatibility not assessed - Safety checks are omitted	- Checklists have to be filled out and signed by both parties in order to commence bunkering. - Dedicated bunkering crew with relevant training - Necessary approvals are obtained both on delivery and receiving side prior to bunkering. (ref. assumptions) - Safety systems both on supplier and receiver side, - Communication between supplier and receiver during bunkering. - Automatic closing of ship bunker valve at H-H level	-	-	-	-Investigate whether Ship-Shore ESD link should be a requirement.	MSC Circ. 1666 interim guidelines for the safety of ships using LPG as fuel may contain measures which are relevant for DMA
1.2	Human error	All configurations	Improper compatibility assessment between bunker supply and ship	- High workload - Insufficient time to prepare - Insufficient training - Safety culture	- Excessive bunkering rate (overfilling) - Overflow through tank vent - Tank rupture - Hose rupture - Discharge of gas through vent mast during bunkering	- Checklist item - Tank level sensors and alarms - Vessels is required to have an approved bunkering procedure with system limitations. - Automatic closing of ship bunker valve at H-H level - Drip trays with level detection resulting in ESD	3	2	5	- Ensure that fuel tanks and pipes are cooled down prior to bunkering, if applicable, to prevent excessive damage to the tank due to thermal stress. -Investigate whether Ship-Shore ESD link should be a requirement.	- The IMO guidelines do not specify drip tray with level detection resulting in ESD as a requirement. DNV rules require leakage detection with alarm and safety actions (assumed ESD) where the bunkering station is closed or semi enclosed.
1.3			Not inerted atmosphere in fuel tank	- High workload - Insufficient time to prepare - Insufficient training - Safety culture	- Flammable / explosive atmosphere in fuel tank - Potential explosion / fire if ignited.	- Vessel need to have and conduct proper inerting procedures.	2	4	6	- consider to provide arrangements enabling portable O2 measurements to confirm that piping and tanks are inerted prior to gassing-up.	- Detection might be a challenge due to different properties of flammable atmosphere depending on fuels.
1.4			Fuel tank not gassed up prior to bunkering	- High workload - Insufficient time to prepare - Insufficient training - Safety culture	- Failure of liquefication plant / refrigeration system. - Release of gas to atmosphere.	- Vessel need to have and conduct proper gassing up procedures (tanks need to be inerted prior to gassing up).	2	2	4	- Means of verifying that successful gassing up procedure has been conducted.	- Typically, the need for gassing up is very limited for fuel tanks (only if the tank has been gas freed (for some reason, repair, etc.)
1.5	Composition change	All configurations	Fuel quality out of spec.	- Contamination onboard barge, truck, or shore tanks. - Production issues - Contamination onboard receiving vessel - Connection to wrong fuel line	- Increased corrosivity of ship systems - Operational issues - Formation of ice (if water is present in refrigerated state) - Potential presence of nitrogen or other gases may affect the boiling point, vapor pressure, and the liquefaction of the fuel.	- BDN (Bunkering delivery note) is mandatory from supplier. - Safety relief valves to alleviate high pressure.	2	1	3	- Recommended sampling of fuel upon delivery to ensure compatibility. (Engine manufacturer recommendations) ASTM D7901- 20 and ISO 16861:2015, are relevant fuel quality standards. - Consider routines for suppliers to share fuel quality analysis prior to bunkering and compatibility to be assessed by vessel crew or third party (not a requirement)	- Water is seen as mostly likely contamination (somewhere along the value chain), would cause increased corrosivity. ASTM D7901- 20 Please be advised that sampling of gas fuel is significantly more complicated than oil fuel sampling
Node 2: Connection of bunkering equipment											

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ID	Guideword	Relevant bunker config.	Hazardous event	Potential causes	Potential consequences	Safety measures	F1	Ss1	R1	Proposed additional safety measures (actions/recommendations)	Comments and notes
2.1	External leakage	All configurations	Leakage of DME when commencing bunkering	- Assembly error - Hose damage / equipment failure	- Exposure of personnel to asphyxiating / toxic gases. - Potential fire if ignited. - Release of liquid DME.	- Bunkering procedures, incl. tightness testing - EX equipment and hazardous zone classification. - PPE - Safety measures covered in Ref. MSC circular 1666 - Safety zones and security zones around the area of bunkering operations. - Bunkering hose is subject to rigorous certifications.	2	4	6	- ~~Investigate measures to collect DME spills to sea in case of a leakage during bunkering.~~ DME is a gas at atmospheric pressure. I.e. it is difficult to see how to collect a DME spill to sea. - Investigate if potential bonding of bunkering hose to reduce electrostatic static discharge upon connection of bunker hose could be introduced as a requirement. - Ensure no materials incompatible with DME are used neither in the bunkering operation nor further in the system, specifically rubbers or elastomers (gaskets and seals).	- DME would presumably mix with water and wouldn't be collected by oil boom and skimmers in the same way as oil products.
2.2			Liquid release of DME when commencing bunkering	- Assembly error - Hose damage / equipment failure	-Excessive cool-down of ship structure. - Embrittlement of materials - Potential hull damage - Potential frost-burn injuries on personnel - Release of toxic and flammable gas - Potential fire if ignited	- Bunkering procedures, incl. tightness testing - PPE - Safety zones and security zones around the area of bunkering operations. - Bunkering hose is subject to rigorous certifications - Vessel emergency respond plan - Drip trays (assumed not to have the capacity of a major spill). - SSL link	2	4	6	- Consider use of water curtains to protect ship hull against negative thermal effects in case of a liquid leak of DME. - Drip trays are recommended to be according to specifications in MSC circ. 1666. - Consider dry break-away coupling in bunker hose connection to prevent excessive amounts leaked to water in case of an emergency disconnection if not already part of requirements in MSC 1666	- Not a hazard that is unique for node 2. - A spill of liquid DME would be a significantly larger volume (once in gas form) compared to methanol. (More severe). - *(IGF Code) - 8.5.7 A ship-shore link (SSL) or an equivalent means for automatic and manual ESD communication to the bunkering source shall be fitted.* MSC 1666 comes in addition to the IGF code
2.3	Reaction	All configurations	- Air inside bunkering piping, and hose.	- Insufficient inerting of hose and piping prior to bunker commencement.	- Internal icing in pipes and hose. - Explosive atmosphere in hose, piping and tank. - Potential fire or explosion if ignited.	- Bunkering procedures / compatibility assessment / meeting. Agree on purging method. -Oxygen measurements in piping	2	3	5	- Ensure that sufficient nitrogen supply is available prior to bunkering to ensure purging of system. - Ensure arrangements to verify the interting and purging of piping and hose are available on the vessel.	- Existing nitrogen systems tend to be too small
2.4			Insufficient cool-down of hose, bunkering line and tank prior to commencement of bunkering	- Procedures are neglected	- Excessive evaporation during bunkering - Over-pressurisation - Excessive thermal stress - Hose, pipe and potential tank damage - Release of DME - Potential fire or explosion if ignited	- Pressure relief valves - Liquid relief valves (bunker supply line) - Bunkering procedures - Dedicated bunkering crew with adequate training - Temperature sensors inside tank (measuring gas temperature) and piping	2	3	5	- Consider adding temperature shell sensors to tank and piping in order to identify insufficient cooling prior to commencement of bunkering.	
Node 3: Fuel transfer operation											

ID	Guideword	Relevant bunker config.	Hazardous event	Potential causes	Potential consequences	Safety measures	F1	Ss1	R1	Proposed additional safety measures (actions/recommendations)	Comments and notes
3.1	Overfilling	All configurations	Overfilling of fuel tank during bunkering	- Incorrect sounding of fuel tank - Failure to shut down supply on bunker supplier side - Too high bunkering rate - Incorrect operation of valves -	- Increased tank pressure - Liquid DME discharge through vent mast and subsequent spray on deck. - Tank rupture - Exposure of personnel to DME (frost burns, asphyxiating, toxic) - Leakage of flammable and toxic liquid/gas - Fire/explosion if ignited	- Bunkering rate and amount to be according to compatibility assessment. - Level sensors and alarms (high and high-high) - ESD of bunkering on high-high triggers. - Ref IGF and MSC 1666 contain relevant safety measures	1	4	5		- PPE not considered as a safety measure due to location of spill (vent mast), unless there is a requirement for personnel to wear PPE at all times. - Note that if DME is loaded at very low temperature and high design pressure, you will have restrictions on filling limit during bunkering to avoid the DME expanding and overflowing when the DME temperature increases on voyage. I.e. this is not a source of overflow during bunkering but later.
3.2	External leakage	All configurations	Drift off during bunkering	- Mooring failure - Large relative movements between bunker supply and vessel (incl. Weather)	- Rupture of bunker hose - Release of DME onto quayside or spill to sea.	- Flexible bunker hose - Dry-break coupling /VSD (vessel separation device) / ERC (emergency release coupling) - Bunkering procedure/compatibility assessment/port requirements to set weather limitations. (incl. Weather window) - Safety zones and security zones around the area of bunkering operations. - Bunkering hose is subject to rigorous certifications - Compatibility assessment should cover mooring in terms of STS bunkering.	1	4	5	- Investigate whether it is required for vessels to have a mooring plan which includes mooring during bunkering. (Specifically for STS bunkering). - Consider to carry out a location specific QRA for the bunkering operation to enable establishment of sufficient safety zone around the bunkering operation similar to what is done for LNG (Port/supplier responsibility)	- Some bunker barges today use vacuum pad systems instead of mooring and fenders (which are heave compensated) *The (HAZID) and the QRAs, which were carried out for both supply modalities: Truck-To-Ship (TTS) and Ship-To-Ship (STS), were perform with the aim of identifying the technical, legal and environmental aspects necessaries to perform the operation safely and efficiently. Then those aspects are included in the regulation of fuel supply in the Port Authority that embrace both types of operational scenarios.*
3.3	External leakage	All configurations	Leakage of fuel from bunkering manifold	- Equipment malfunction	- Exposure of personnel - Potential fire if ignited - Release of DME on deck - Potential embrittlement of deck structure due to low temperature	- Ref. IGF code and MSC circ. 1666 - Vessel specific risk assessment during approval to consider risk of leakages internally on the vessel.	1	3	4	- Consider adding tightness testing to bunkering procedures, if not already required, to reduce the likelihood of leakages. - Consider use of water curtains to protect ship hull against negative thermal effects in case of a liquid leak of DME.	ISO 2928:2021(en) Rubber hoses and hose assemblies for liquefied petroleum gas (LPG) in the liquid or gaseous phase and natural gas up to 2,5 MPa (25 bar) — Specification or Standard EN1762, BS4089, ISO 2928:2003, British Standard (BS) EN 13766:2010, BS EN 1762:2003
3.4	External leakage	All configurations	Leakage of fuel (to water)	- Equipment malfunction - Assembly error - Hose damage	- Exposure of personnel to DME - Potential fire if ignited - Release of DME to water causing flashing of DME.	- Vessel-specific risk assessment during approval to consider risk of leakages internal of the vessel. - Compatibility assessment - Bunkering procedures (incl. Tightness testing) - Dry-break coupling /VSD (vessel separation device) / ERC (emergency release coupling) - Safety zones and security zones around the area of bunkering operations.	1	3	4	- Investigate the certification requirements for bunkering hoses that could be use for bunkering of DME (look to IGC code for requirements, 5.11.7) - Consider to carry out a location specific QRA for the bunkering operation to enable establishment of sufficient safety zone around the bunkering operation similar to what is done for LNG (Port/supplier responsibility)	

ID	Guideword	Relevant bunker config.	Hazardous event	Potential causes	Potential consequences	Safety measures	F1	Ss1	R1	Proposed additional safety measures (actions/recommendations)	Comments and notes
3.5	Over/ under pressure	All configurations	Over pressuring of bunkering line	- Incorrect operation of valves - ESD valve closing too fast - Hose dropped into water (leading to heating of trapped DME in hose) - Trapped liquid between shutoff valves	- Hose damage (leaks or rupture) - Connection damage - Leaks from flanges / couplings	- Ref. MSC circular 1666 - Bunkering hose is subject to rigorous certifications - Compatibility assessment. - Bunkering procedures (incl. Tightness testing) - Requirement (IGC code, IGF code) to have liquid relief valve between points where liquid could potentially be trapped.	3	2	5	- Consider adding liquid relief valve on the outboard of the bunkering isolation valve (both on supply and receiving side) to prevent excessive over pressurization of the hose in the event the hose is dropped in water. - Consider adding a ESD based on high pressure (close to the setting of the liquid relief valve) to prevent liquid relief and potential spray on deck through the vent mast.	- *ISO 28460 2010 (Installation and equipment for liquefied natural gas Ship-to-shore interface and port operations) might be referred in MSC circular 1666. Potentially applicable.*
3.6	Unintentional activation	All configurations	- Inadvertently closing of remotely operated valves	- Blackout - Loss of control air	- Supply pumping against closed outlet - Potential water hammer and damage to hose - Leakage of fuel - Exposure to personnel - Potential fire /explosion if ignited - Trapped liquid	- Ship side pressure alarms in bunkering manifold. - The bunkering procedure should include monitoring of the pressure drop over the bunkering line. - Compatibility assessment.	2	2	4	- Investigate if the closing time requirements (IGF code) may cause water hammering effects. If this is the case the closing time should be delayed to prevent water hammer effects in the bunkering line.	- The valve response depends on type of actuator - LNG has time-closing requirement on ESD valves. Valves on gas carriers typically have pneumatic-actuated valves due to low temperature changing the viscosity of the hydraulic oil.
3.7	Reaction	All configurations	DME vapor out of receiving ship SRV (safety relief valves) valves during bunkering	- Human error - Failure of the reliquefication plant - Failure during vapor return (inadequate vapor return capacity)	- Release of DME vapor on deck - Potential fire if ignited - Exposure to personnel	- Hazardous zones and EX equipment at outlets. - Pressure sensors in tanks - Temperature sensors in tanks - Bunkering procedures (incl. Boiloff gas management and target tank pressure) - Use the spray line to reduce pressure in tanks during bunkering (depending on the temperature of the DME); you will, however, normally have the reliquefication system in operation. (Note for the sake of good order that where reliquefication is the method of BOG control, it must be redundant.)	3	2	5	- Consider target tank pressure before bunkering to ensure pressure control to prevent release of DME to atmosphere. - Consider adding gas detection on the supply vessel for identifying any potential gas release from tanks.	- Check whether the use of spray line to reduce the BOG also applies for DME. - Vapor return depends on similar tank systems / design pressures on both receiving and supply side

ID	Guideword	Relevant bunker config.	Hazardous event	Potential causes	Potential consequences	Safety measures	F1	Ss1	R1	Proposed additional safety measures (actions/recommendations)	Comments and notes
3.8	Reaction	StS	DME gas out of supply ship / bunker barge vent during bunkering.	- Human error - Failure of the reliquefication plant - Failure during vapor return (inadequate vapor return capacity) - Internal transfer in supply vessel.	- Hazardous zone from the supply vessel imposed onto the receiving ship to a location not fitted with EX equipment. - Potential fire / explosion if ignited - Exposure of (toxic) gas to personnel	- Compatibility assessment used to make sure there is no conflict hazardous zones between suppling and receiving vessel. - Bunker vessel / barge is unloading thus the likelihood of release through vent mast is lower compared to loading. - Safeguards from 3.7 also applicable to bunker vessel.	2	3	5	- Consider prohibiting internal transfer of fuel in bunker barge during bunkering to prevent to prevent the risk of gas release in areas outside defined hazardous zones onboard the receiving vesse - Consider have target tank pressure before bunkering to ensure pressure control and avoid imposing hazardous zones onto receiving vessel in areas not fitted with EX equipment. - Consider adding gas detection on the supply vessel for identifying any potential gas release from tanks. - ~~Consider adding inert gas supply to bunkering vessel to inert/purge vent mast in the event of a release~~. Difficult to see the purpose: Purging out any gas left in the mast riser will increase gas release to surroundings(which is what we are trying to mitigate). - If conflicting hazardous areas are identified during compatibility assessment consider means to mitigate risk to prevent any ignition sources or similar being available in the hazardous area imposed by the bunker vessel.	*The only vents permitted will be those resulting from purging with nitrogen the gas trapped in pipes and/or hoses/arms, provided that these cannot be managed by the DME supplier (supply ship/truck or terminal).*
3.9	Collision	StS	- Collision during approach of bunkering vessel to receiving vessel	- Loss of navigational control - Limited visibility (fog, night, etc.) - Human error	- Damage of vessel(s) - Loss of containment	- Communication between vessels during approach (reduced effectiveness if receiving vessel is moored). - Fenders (if deployed) could limit potential damages. - Port accreditation for bunker vessel operation within port limits - Bunkering vessels typically are fitted with bow thrusters for increased manoeuvrability. - IAPH requirements.	2	4	6		
3.10	Fire / explosion in other areas	All configurations	Nearby fire in non-hazardous areas	- Fire on quay side - Fire on bunker vessel - Fire on receiving vessel (non-hazardous zones)	- Potential fire spread to bunkering operation, escalating the fire.	- Fire alarms on both vessels - Bunkering procedures to include stop of operation in case of fire detection. - Fire suppression - Fire extinguishing capabilities	1	4	5		

ID	Guideword	Relevant bunker config.	Hazardous event	Potential causes	Potential consequences	Safety measures	F1	Ss1	R1	Proposed additional safety measures (actions/recommendations)	Comments and notes
3.11	Human error	All configurations	Filling DME into a tank containing LPG	- Procedures are neglected	-Flashing of LPG due to adding hotter DME. - Over pressurization of tank. - Potential rupture of tank - Release of fuel	- Safety relief valves - Pressure sensors inside tank - Bunkering procedures - Compatibility assessment				- Investigate the interchangeability for engines in burning both LPG and DME, implications to this and discuss in the post-processing.	- Risk ranking pending results from follow up of recommendation. - Filling LPG into a tank containing DME might be the more severe scenario. - If not interchangeable the bunkering procedures and compatibility assessment should consider this.
3.12	Human error	All configurations	Filling LPG into a tank containing DME	- Procedures are neglected	-Flashing of LPG due to entry into hotter tank. - Over pressurization of tank. - Potential rupture of tank - Release of fuel	- Safety relief valves - Pressure sensors inside tank - Bunkering procedures - Compatibility assessment				- Investigate the interchangeability for engines in burning both LPG and DME, implications to this and discuss in the post-processing.	- Risk ranking pending results from follow up of recommendation.
Node 4: Disconnection of bunkering equipment											
4.1	External leakage	All configurations	Residual fuel left in hose and/or pipes	- Insufficient purging - Insufficient draining	- Exposure of personnel - Leakage on deck - Potential fire/explosion if ignited	- Bunkering procedures and compatibility assessment to describe how to conduct purging and draining of system prior to disconnection. - PPE for all personnel involved in bunkering operation. - Pressure sensors inboard of the bunkering valve.	3	3	6	- Consider a pressure sensor outboard of the bunkering valve to more easily detect pressure increase due to residual fuel in the hose, and no pressure increase when the hose is empty.	- The supply of inert gas, both in terms of volume and pressure, shall be discussed during the compatibility assessment to ensure the vessel(s) ability to purge system. - Quick closing disconnect couplings could reduce purging time (as the case with LNG vessels).
4.2	Trapped liquid	All configurations	Ref. 3.5								
Node 5: Simultaneous operation											
5.1	Dropped object	All configurations	- Impact on bunkering equipment	- Dropped load during simultaneous operations (cargo supply / provisions)	- Spark generation - Equipment damages - Potential fire /explosion - Hose rupture / damage - Potential embrittlement of ship structure / frost burns on personnel - Release of asphyxiating/ toxic gas		2	3	5	- Bunkering procedures are to consider simultaneous operation and no activity is to take place in established safety zones.	Some operators may require all simultaneous operations to be subject to approval prior of commencement.

ID	Guideword	Relevant bunker config.	Hazardous event	Potential causes	Potential consequences	Safety measures	F1	Ss1	R1	Proposed additional safety measures (actions/recommendations)	Comments and notes
5.2	Fire / explosion	StS	- Release of gas during embarkation / disembarkation /vehicle movement	- Passengers or vehicle interfering with bunkering operations	- Passengers or vehicles introducing potential ignition sources in hazardous zones. - Potential ignition of vapours inside hazardous zone. Potential fire / explosion	- Established safety zones around bunkering equipment - Bunkering is likely carried out on opposite side of passenger handling.	2	4	6	- Limit passenger access to weather decks or balconies on the side where DME bunkering is performed. - Bunkering procedures are to consider simultaneous operation and no activity is to take place in established safety zones. - Consider to carry out a location specific QRA for the bunkering operation, considering the properties of DME being heavier than air, to enable establishment of sufficient safety zone around the bunkering operation similar to what is done for LNG (Port/supplier responsibility).	
5.3	Fire / explosion	TtS	- Embarkation / disembarkation /vehicle movement	- Passengers or vehicles interfering with bunkering operations	- Passengers or vehicles introducing potential ignition sources in hazardous zones. - Potential ignition of vapours inside hazardous zone. Potential fire / explosion	- Established safety zones around bunkering equipment	3	4	7	- Limit passenger access to weather deck or balconies on the side where DME bunkering is performed. - Bunkering procedures are to consider simultaneous operation and no activity is to take place in established safety zones. - Consider physical/visual barriers to limit passenger access into safety zone while bunkering. - Consider to carry out a location specific QRA for the bunkering operation, considering the properties of DME being heavier than air, to enable establishment of sufficient safety zone around the bunkering operation similar to what is done for LNG (Port/supplier responsibility).	- Truck-to-ship considered a more severe case than port-to-ship.

Appendix C HAZID logsheet for bunkering of FT-diesel, HVO and FAME

Table 7 HAZID log sheet for bunkering of FT-diesel, HVO and FAME including risk ranking.

ID	Guideword	Relevant fuel(s)	Relevant bunker config.	Hazardous event	Potential causes	Potential consequences	Safety measures	F1	S1	R1	Proposed additional safety measures (actions/recommendations)	Comments and notes
Node 1: Preparation for bunkering												
1.1	Human error		All configurations	Checklists not actually followed	- High workload - Insufficient time to prepare - Insufficient training - Lack of safety culture	- Increased likelihood for accidental events - Risk that safety checks are not carried out - Safety equipment and pollution prevention equipment are not available	- Checklists must be filled out and signed by both parties. - Compatibility assessment / pre-bunkering meeting/check-out - Bunker crew training	-	-	-	- Consider adding procedures to check bunker area and consider adequate measures for protection of hot surfaces above 200°C to bunkering procedures, in order to avoid autoignition. (Current requirement is surfaces above 220°C) (relevant for FT and HVO)	*About training:* *The crews of the receiving ship and the supplying ship must be trained and have competencies in accordance with the STCW convention.*
1.2	Human error		All configurations	Incomplete compatibility assessment between bunker supply and ship	- High workload - Insufficient time to prepare - Insufficient training - Lack of safety culture	- Increased likelihood of accidental events - Risk that safety checks are not carried out - Safety equipment and pollution prevention equipment are not available.	- Checklists must be filled out and signed by both parties. - Compatibility assessment / pre-bunkering meeting/check-out - Bunker crew training	3	2	5		
1.3	Human error		All configurations	Not inert atmosphere in fuel tank	- High workload - Insufficient time to prepare - Insufficient training - Lack of safety culture	N/A		2	1	3		-
1.4	Composition change	FAME	All configurations	Fuel quality out of spec.	-Oxygenized FAME, biofuel components not accounted for (currently mostly FAME) or microbial growth.	- Clogging of filters and systems - Sediment build-up in tanks - Increased corrosivity (with increased water content or acidic content)	- Testing of fuel upon delivery (common, not mandatory)	2	1	3	- Fuel supplier should share the analysis report of the fuel in advanced of bunkering to ensure fuel quality is in spec., this report should also be available upon delivery of fuel.	- Operating experience is that microbial growth is not an issue with FAME (B100) - Material incompatibility is not a challenge only for out of spec - Results from testing are received a few days after delivery. - Mainly a commercial / operational risk
1.5	Composition change	HVO FT	All configurations	Fuel quality out of spec.	- Flashpoint below 60°C	-Increased flammability risk in case of leakages	- Testing of fuel upon delivery (common, not mandatory) - Special DNV (and others) procedures available on how to deal with fuels with flashpoint under 60°C in case of accidental receiving such fuels. - Worst case, debunkering of the fuel	1	1	2		- IMO is investigating specific requirements for fuels between 52 - 60 °C (amendment to IGF code) - HVO and FT-diesel are not normally heated.

ID	Guideword	Relevant fuel(s)	Relevant bunker config.	Hazardous event	Potential causes	Potential consequences	Safety measures	F1	S1	R1	Proposed additional safety measures (actions/recommendations)	Comments and notes
1.6				Material incompatibility (gaskets, hose, equipment)?	- Receiving blends with increased solvency or corrosive properties	- Reduced lifespan of gaskets, hose material and seals. - Increased likelihood of leakages (increases with decreased viscosity) - Potential damage / incompatibility with zinc-based coating and subsequent corrosion and damage of tanks and pipes - Potential corrosion and damage of unprotected steel tanks and piping.		1	1	2	- When receiving biofuels, verify that your gasket, seals, and coatings are compatible with that specific fuel. - Suppliers need to verify compatibility with own seals, gaskets, and specifically bunker hoses to lower the likelihood of leakages. - Investigate the corrosivity of different level of fuel blends towards unprotected steels tanks specifically for heated fuels and long-term storage. - Consider increasing the inspection interval time until more operational experience is gained with regard to increased corrosivity.	- Under certain conditions, the failure of materials may occur rapidly - Current experience from CEPSA is that there is no (short-term) damage to shore tanks - The risk is considered an operational issue with no safety risk.
1.7				Fuel incompatibility with other fuels and blends	- Degradation of finished product (unstable fuel) - Wrong ratio blending of incompatible components (paraffinic vs. aromatic, specific for HVO)	- Clogging of filters, pipes and separators - Sediment / sludge build-up in tanks	- Compatibility check	1	1	2		- The risk is considered an operational issue, no safety risk.
Node 2: Connection of bunkering equipment												
2.1	External leakage		All configurations	Leakage of fuel when commencing bunkering	- Assembly error - Hose damage / equipment failure - Defective gasket or seals - Defective drain valves	- Fuel on deck or at sea	- Drip trays - SOPEP / SMPEP equipment - Fixed fire extinguishing - Bunker vessels would have spill coamings at aft and sides to prevent spills going to sea - Scupper plugs in use while bunkering - Bunkering procedures	3	1	4	- Consider special care and precautions in case fuel is heated within 10°C below its flashpoint (valid also for flashpoints above 60°C)	- Low viscosity already discussed in earlier hazard - Risk picture is deemed similar to conventional duels - IEC standard 60092-502; bunker vessels heating the cargo within 10°C of flashpoint are considered vessels carrying low flashpoint cargo
Node 3: Fuel transfer operation												
3.1	Overfilling		All configurations	Overfilling of fuel tank during bunkering	- Incorrect sounding of fuel tank - Failure to shut down supply on bunker supplier side - Too high bunkering rate - Incorrect operation of valves - Thermal expansion of fuel?	- Spill through tank vents - Damage to tank - Release of fuel internally on ship - Spill to sea	- Bunkering procedures (incl. Pre-meeting) - Suppliers will monitor and not deliver more than the agreed amount. - Remote level monitoring system (with high and independent high-high alarm for tankers) - Spill coamings around air pipes and sounding pipes. (USCG requirement)	2	1	3	- Recommended that vessels implement independent overflow alarm.	- Nothing biofuel specific. - No additional hazards imposed by biofuel usage.

ID	Guideword	Relevant fuel(s)	Relevant bunker config.	Hazardous event	Potential causes	Potential consequences	Safety measures	F1	S1	R1	Proposed additional safety measures (actions/recommendations)	Comments and notes
3.2				- Clogged bunkering line	- Solidification of previous bunker in fuel bunker system due to poor cold flow properties	- Overpressure in the bunker line - Bursting or leakages of hose or bunker line	- Low start-up pump rate to detect potential blockages. - Air blowing of bunkering lines after bunkering - Drip trays - SOPEP / SMPEP equipment - Bunker vessels would have spill coamings at aft and sides to prevent spills going to sea - Scupper plugs in use while bunkering - Bunkering procedures	2	1	3		- Primarily a hazard related to FAME - Heat tracing and insulation of the bunkering line could alleviate potential cold flow issues. - The risk is considered an operational issue, no safety risk.
3.3	External leakage	HVO + FT diesel + FAME	All configurations	Drift off during bunkering	- Mooring failure - Large relative movements between bunker supply and vessel (incl. Weather)	- Rupture of bunker hose - Release of fuel onto quayside or sea.	- Bunkering procedures and pre-meeting (incl. Agreement of weather window and assessment of mooring capabilities)	1	2	3		- No additional hazards imposed by biofuel usages. - OCIMF standard for oil tankers - Mooring equipment guidelines (MEG4).
3.4	External leakage		All configurations	Leakage of fuel from bunkering manifold	- Equipment malfunction - Material incompatibility - Low fuel viscosity (HVO and FT) - Damage to hose	- Release of fuel onto deck or sea.	- For FAME blends above 25% have certification requirements for bunkering hoses (IBC code) - Drip trays - Bunkering procedures - SOPEP and SMPEP equipment	3	1	4	- Revise certification and inspection regime for bunker hoses used for biofuels to account for potential material incompatibility (EN1765 (2016) currently used for bunkering hoses) - Consider remote stop button between receiving vessel and fuel supplier in order to enable stop from receiving vessel in case of any deviations from normal operation.	
3.5	Over/ under pressure		All configurations	Overpressuring of bunkering line	- Incorrect operation of valves - Valve failure (fails to close, close too fast)	- Ref. hazardous event *Clogged bunkering line* - Potential water hammer effect if a valve is closed too fast. - Damage to sliding joints (if applicable) - Hose damage / rupture	Bunkering procedures - Crew training - Pre-meeting / compatibility assessment / communication	2	1	3	- Consider failure mode of valves in bunker line to limit any potential water hammer effects.	
3.6	Unintentional activation		All configurations	- Inadvertently closing of remotely operated valves	- Blackout - Loss of control air - Loss of control for hydraulicly operated valves	- Ref. hazardous event *Clogged bunkering line* - Potential water hammer effect if a valve is close too fast. - Damage to sliding joints (if applicable) - Hose damage / rupture		2	1	3	- Consider failure mode of valves in bunker line to limit any potential water hammer effects. - Consider remote stop button between receiving vessel and fuel supplier in order to enable stop from receiving vessel in case of any deviations from normal operation.	- No additional hazards imposed by biofuels compared to conventional fuels.

ID	Guideword	Relevant fuel(s)	Relevant bunker config.	Hazardous event	Potential causes	Potential consequences	Safety measures	F1	S1	R1	Proposed additional safety measures (actions/recommendations)	Comments and notes
3.7	Reaction		All configurations	Fuel vapor out of receiving ship air pipes during bunkering (Ignition sources may be within the perimeter of the air vent pipes during bunkering)	- Displacement of air in fuel tanks during bunkering	- Fire / explosion if ignited - Personnel injury (fire, explosion or exposure to fumes / vapors)	- Flashpoint of fuel above 60°C - Common practice not to locate air vents close to ventilation air inlets and access doors.	2	2	4		- No additional hazards imposed by biofuels compared to conventional fuels.
3.8	Reaction		StS	Fuel vapor out of supply ship / bunker barge vent during bunkering.	- Human error - Internal transfer in supply vessel.	*- Same as for Methanol 3.8*		2	2	4		- Special considerations for chemical tankers with multi-fuel supply that carry methanol together with FAME. The hazardous zone on the suppling ship cannot interfere with non-EX equipment on the receiving vessel
3.9	Collision		StS	- Collision during approach of bunkering vessel to receiving vessel	- Loss of navigational control - Limited visibility (fog, night, etc.) - Human error - Weather conditions	- Less severe event compared to DME/ Methanol?		2	1	3		- No additional hazards imposed by biofuel usages - Greater possibility that the bunkering barge has double hull compared to methanol (size dependent)
3.10	Fire / explosion in other areas		All configurations	Nearby fire in non-hazardous areas	- Fire on quay side - Fire on bunker vessel - Fire on receiving vessel (non-hazardous zones)	- Escalation of fire	- Same as methanol 3.10 - Less likely compared to methanol	1	3	4		- No additional hazards imposed by biofuel usages
3.11	Composition change		All configurations	Filling biofuel into a tank containing conventional fuel	- Procedures are neglected	- Operational issues *- Ref. fuel incompatibility with other fuels and blends, 1.7*		1	1	2		
3.12				- Electrostatic charging of fuel							- Investigate whether electrostatic charging could be an issue concerning bunker barges and fuels in question and what implications that might have for fuels with flashpoints above 60°C.	
Node 4: Disconnection of bunkering equipment												
4.1	External leakage		All configurations	Residual fuel left in hose and/or pipes	- Insufficient air blowing/purging - Insufficient draining	- Spill of remaining contents to deck or sea	- Drip trays - Bunker procedures	3	1	4		- Upon disconnection both bunker pipe and hose is usually blind flanged prior to return of hose to bunker supply, preventing spill of any remaining contents to deck or sea.
4.2	Trapped liquid		All configurations	Trapped liquid inside bunkering hose or piping		- Solidification of liquid *- See clogged piping*		2	1	3		
Node 5: Simultaneous operation												
5.1	Dropped object		All configurations	- Impact to bunkering equipment	- Dropped load during simultaneous operations (cargo supply / provisions)	- Spark generation - Equipment damages - Potential fire / explosion - Hose rupture / damage	- Sim. Ops. Are subject to approval (addressed in pre-meeting) prior to commencement.	2	2	4	- If sim- ops. Are to be conducted during bunkering, consider doing a specific risk assessment for the operation.	- No additional hazards imposed by biofuel usages
5.2	Fire / explosion		StS	- Release of fuel during embarkation / disembarkation /vehicle movement	- Passengers or vehicle interfering with bunkering operations			1	2	3		- No additional hazards imposed by biofuel usages

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5.3	Fire / explosion		TtS	- Embarkation / disembarkation /vehicle movement	- Passengers or vehicle interfering with bunkering operations			3	2	5		- No additional hazards imposed by biofuel usages

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