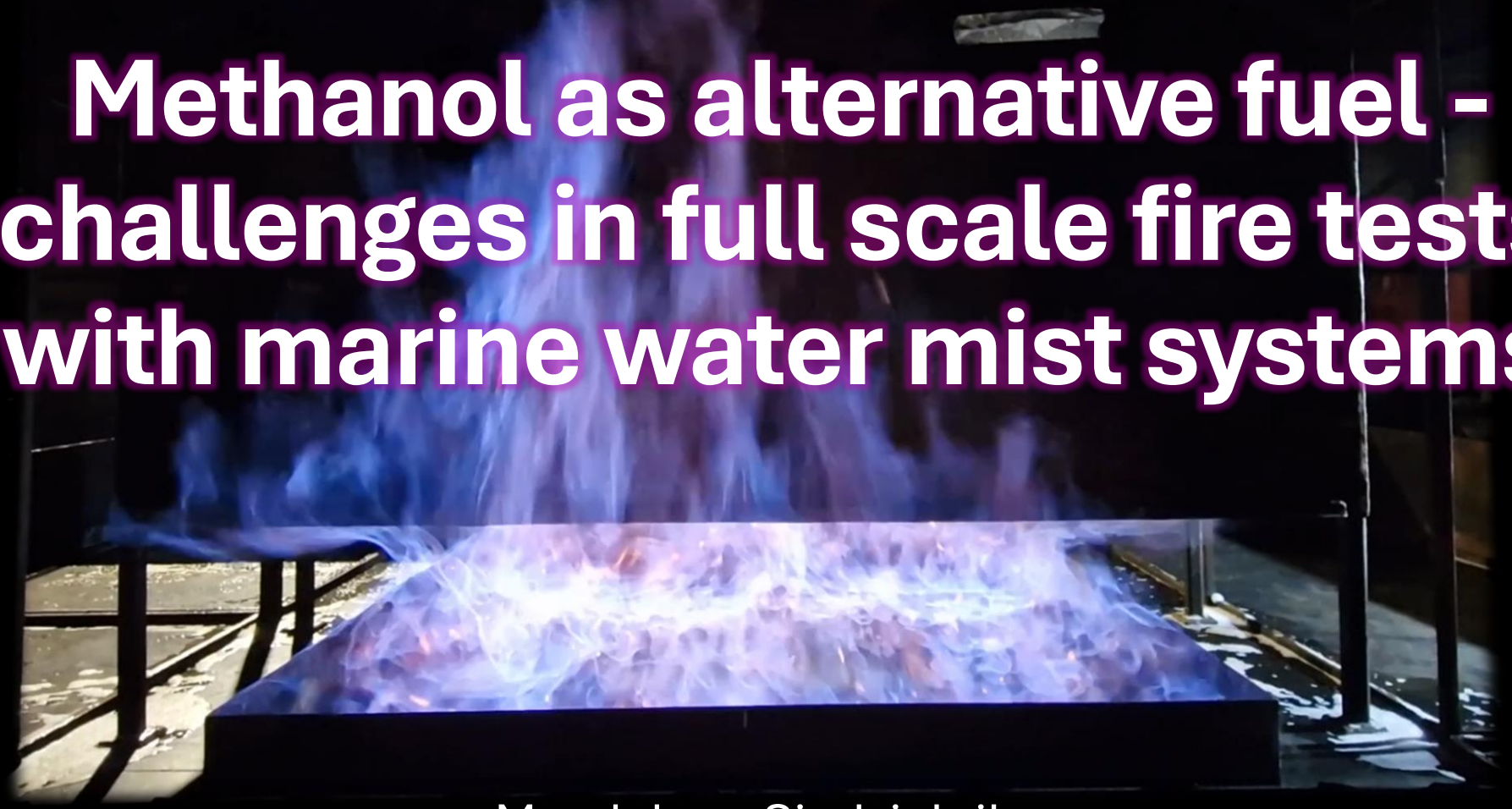
Baltic
Fire Laboratory

Methanol as alternative fuel - challenges in full scale fire tests with marine water mist systems



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Introduction

IMO GHG STRATEGY 2023

1. The carbon intensity of ships will decline through further improvements in the energy efficiency of new ships.

2. The carbon intensity of international shipping is expected to decline.

3. The uptake of zero or near-zero GHG emission technologies, fuels, and energy sources is expected to increase.

Reduce CO_2 emissions per transport work by at least 40% by 2030 – compared to 2008

4. GHG emissions from international shipping are expected to reach net zero.

Introduction

- Methanol (methyl alcohol, CH_3OH) – organic chemical compound, colorless, volatile and flammable liquid.

Table 1. The properties of methanol, gasoline and diesel [Zhen et al., 2018]

Fuel Property	Methanol	Gasoline	Diesel
Formula	CH_3OH	C_{5-12}	C_{10-26}
Molecular weight (g/mol)	32	95–120	180–200
Oxygen content	50%	0	0
Stoichiometric air/fuel ratio	6.45	14.6	14.5
Low calorific value (MJ/kg)	19.66	44.5	42.5
High calorific value (MJ/kg)	22.3	46.6	45.8
Freezing point (°C)	−98	−57	−1∼-4
Boiling point (°C)	64.8	30–220	175–360
Flash point (°C)	11	−45	55
Auto-ignition temperature (°C)	465	228–470	220–260
Research octane number	108.7	80–98	
Motor octane number	88.6	81–84	
Cetane number	3	0–10	40–55
Flammability limits (vol)	6.7–36	1.47–7.6	1.85–8.2
Specific heat (20°C) (kJ/kg K)	2.55	2.3	1.9
Latent heat (kJ/kg)	1109	310	270
Viscosity (20°C) (cP)	0.6	0.29	3.9

Instantaneous digital images 132 ms apart in the pulsing 1 m diameter methanol pool fire [Sung et al., 2021]

- X.Zhen, Chapter 11-Methanol As An Internal Combustion on Engine Fuel, Methanol, Elsevier, 2018
- K.Sung et al., The characteristic of a 1m methanol pool fire, Fire Safety Journal, Elsevier, 2021
- O.T.Kaario et al., A comparative study on methanol and n-dodecane spray flames using Large-Eddy Simulation, Combustion and Flame, Elsevier, 2024

Areas of interest

A

IMO MSC.1/Circ. 1621 bilge protection IMO MSC/Circ. 1165 as per Table 2

May 2023

B

IMO MSC.1/Circ. 1387 Local application

December 2023

C

IMO MSC/Circ.1165 total flooding as per Table 1

November 2024

Project A - IMO MSC.1/Circ. 1621

Scope

The purpose of IMO MSC.1/Circ. 1621 is to provide an international standard for ships using methyl/ethyl alcohol as fuel.

Tests are intended to evaluate the extinguishing capabilities of water-based total flooding fire-extinguishing systems for the protection of engine rooms bilge spaces of category A and cargo pump rooms as per **Table 2** in IMO MSC/Circ. 1165.

Project A - IMO MSC.1/Circ. 1621

Test area

- Area at least 100m^2;
- Height at least 5m.

Test procedure

- 2 minutes of pre-burn (Table 2, test no. 3);
- The fire should be extinguished within 15 min of system activation.

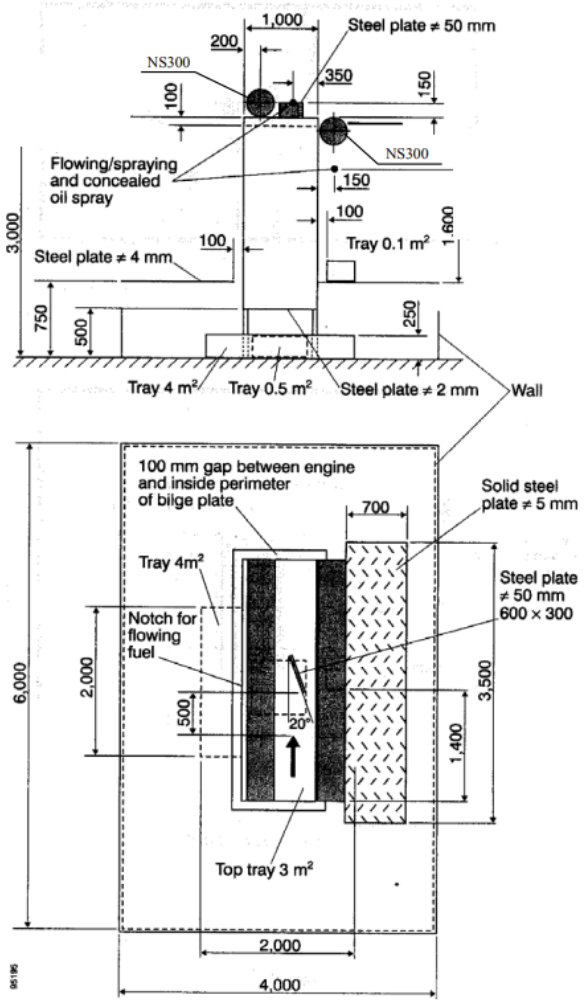


Table 2. Test programme for bilge nozzles [IMO MSC/Circ.1165]

Test No.	Fire Scenario	Test Fuel
1	0.5 m^2 central under mock-up	Heptane
2	0.5 m^2 central under mock-up	SAE 10W30 mineral based lubrication oil
3	4 m^2 tray under mock-up	Commercial fuel oil or light diesel oil

00:00:00

METHANOL

- Fuel: methanol
- Pre-burn time 2 minutes
- Fire extinguished: 2:26

DIESEL

- Fuel: diesel
- Pre-burn time 2 minutes
- Fire extinguished: 0:59

METHANOL

- Fuel: methanol
- Pre-burn time 2 minutes
- Fire extinguished: 2:26

DIESEL

- Fuel: diesel
- Pre-burn time 2 minutes
- Fire extinguished: 0:59

Project B - IMO MSC.1/Circ. 1387

Scope

,,Tests are intended to evaluate the fire-extinguishing capabilities of individual nozzles and grids of nozzles used as local application fire – fighting systems on light diesel oil duel spray fires.''

Diesel → Methanol

Design and installation criteria:

- Maximum spacing between nozzles;
- Minimum and maximum distance between the nozzles and the protected area;
- The need for nozzles to be positioned outside of the protected area;
- Minimum operating pressure.

Marine engine – real object to protect

[https://www.dnv.com/expert-story/maritime-impact/Methanol-as-fuel-heads-for-the-mainstream-in-shipping/]

Project B - test description

Test area

- Area at least 100m^2;
- Height at least 5 m.

Fire scenario

- The fire scenarios should consist of nominal 1 and 6 MW spray fires;
- Fuel spray installed horizontally and directed toward the centre of the nozzle grid;
- The fuel spray nozzle must be located 1 m above the floor and at least 4 m away from the walls.

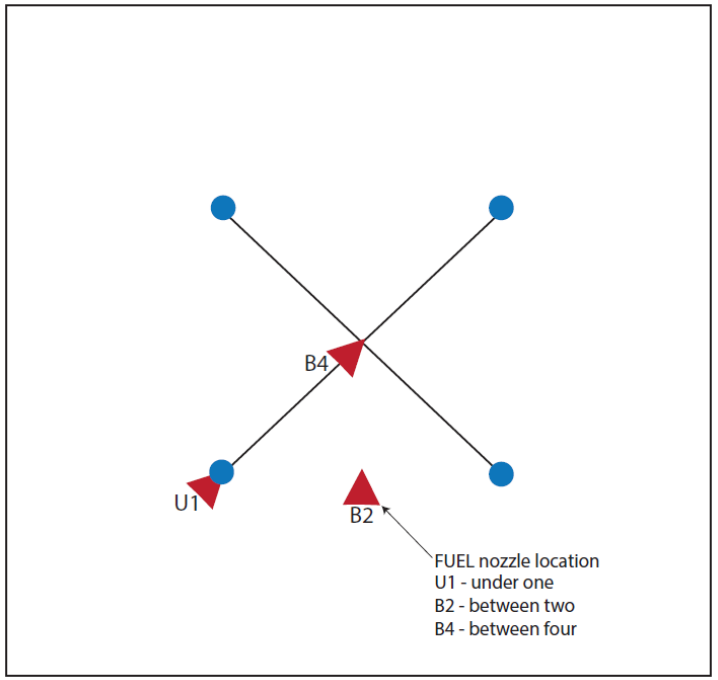
Installation

- 2x2 or 3x3-nozzle grid;
- Nozzles installed at least 1m below the ceiling.

Table 3. Spray fire parameters

Spray nozzle	Wide spray angle (120° to 125°) full cone type	Wide spray angle (80°) full cone type
Nominal oil pressure	8 bar	8.5 bar
Oil flow	0.16 ± 0.01 kg/s	0.03 ± 0.005 kg/s
Oil temperature	20 ± 5°C	20 ± 5°C
Nominal heat release rate	6 MW	1 MW

Project B - test programme - fire scenarios



Scheme 1. Fuel spray nozzle positioning. Fuel nozzles marked with red triangles, water mist nozzles marked with blue dots.

Table 4. Fire scenarios

Design Fire	Fuel Nozzle Position	Fuel Spray Nozzle Positioning	Minimum Separation Distance	Maximum Separation Distance
1MW	B4	Between Four Nozzles	YES	YES
	U1	Under One Nozzle at the Edge of Grid (Corner)	YES	YES
	B2	Between Two Nozzles at the Edge of Grid	YES	YES
6MW	B4	Between Four Nozzles	YES	YES
	U1	Under One Nozzle at the Edge of Grid (Corner)	YES	YES
	B2	Between Two Nozzles at the Edge of Grid	YES	YES

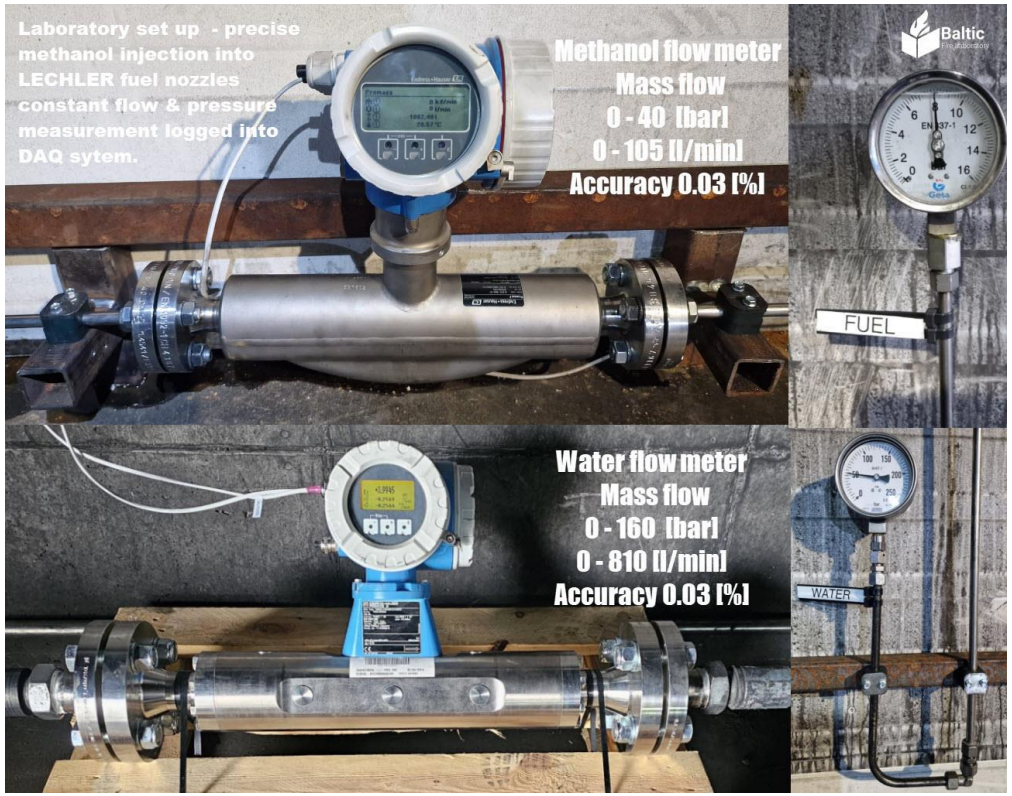
Project B - test procedure and measurements

Test procedure

- Pre-burn time from 10s to 15s;
- The fire should be extinguished within 5 min of water application;
- Fuel shut off 15s after extinguishment;
- Water mist system shut down minimum 1 min after extinguishment.

Measurements

- Fuel oil spray system pressure and flow rate;
- Oxygen concentration at the fire location 20% (by volume) for 5 min after ignition;
- Water spray system pressure and flow rate.



The fire should be extinguished within 5 min of water application!

Project B - IMO MSC.1/Circ. 1387

,,Methanol spray flame is the most unstable which is 13.33% and 151.58% less than that of the spray flame of isooctane and n-heptane respectively. ’’ [Ming et al., 2023]

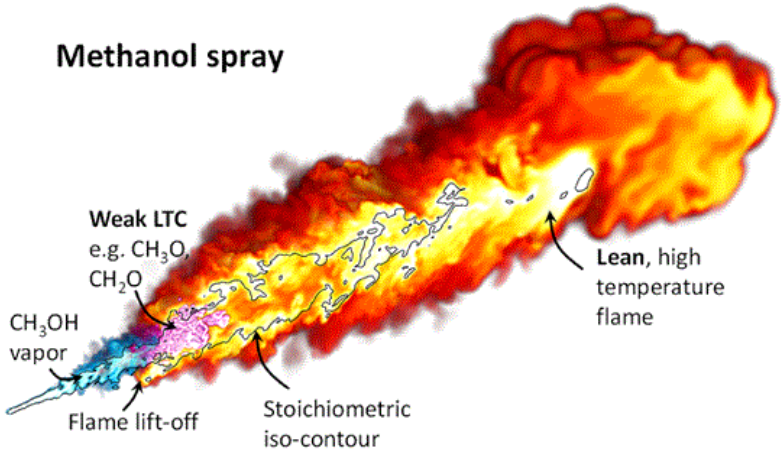


Figure 1. A visual illustation of the computational setup for methanol spray combustion process [Kaario et al. 2024]

1 MW methanol spray fire

6 MW methanol spray fire

- Z.Ming et al., Study of methanol spray flame structure and combustion stability mechanisms by optical phenomenology and chemical kinetics, Fuel Processing Technology, Elsevier, 2023
- O.T.Kaario et al., A comparative study on methanol and n-dodecane spray flames using Large-Eddy Simulation, Combustion and Flame, Elsevier, 2024

Project B - Test scenario U1 – under one

METHANOL

DIESEL

Project C - IMO MSC/Circ. 1165

Table 1

Test No.	Fire Scenario	Test Fuel
1	Low pressure horizontal spray on top of simulated engine between agent nozzles.	Commercial fuel oil or light diesel oil
2	Low pressure spray in top of simulated engine centred with nozzle angled upward at a 45° angle to strike a 12-15 mm diameter rod 1 m away.	Commercial fuel oil or light diesel oil
3	High pressure horizontal spray on top of the simulated engine.	Commercial fuel oil or light diesel oil
4	Low pressure concealed horizontal spray fire on the side of simulated engine with oil spray nozzle positioned 0.1 m in from the end of the engine and 0.1 m^2 tray positioned on tope of the bilge plate 1.4 m in from the engine end at the edge of the bilge plate closest to the engine.	Commercial fuel oil or light diesel oil
5	Concealed 0.7 m × 3.0 m fire tray on top of bilge plate centred under exhaust plate.	Heptane
6	Flowing fire 0.25 kg/s from top of mock-up (see figure 3).	Heptane
7	Class A fires wood crib (see Note) in 2 m^2 pool fire with 30 s preburn. The test tray should be positioned 0.75 m above the floor as shown in figure 1.	Heptane
8	A steel plate (30 cm × 60 cm × 5 cm) offset 20° to the spray is heated to 350°C by the top low pressure spray nozzle positioned horizontally 0.5 m from the front edge of the plate. When the plate reaches 350°C, the system is activated. Following system shutoff, no reignition of spray is permitted.	Heptane

Conclusions

- In the first seconds of water mist discharge was observed increase of flame turbulance. The methanol spray fires are difficult to sustain, because the fire spreading upward and forward.
- Tests have shown that well-designed water mist systems can effectively extinguish fires and prevent re-ignition.
- Water mist system nozzles that have passed diesel tests are not universal and do not always perform well in methanol tests.
- For methanol pool fires, a water mist system alone may not be sufficient. It is crucial to use alcohol resistant foam.
- Tested spacing in the range from 3 to 4 m.

Conclusions

- https://www.forbes.com/sites/lewisnunn/2023/11/07/celebrity-cruises-reveals-celebrity-xcel/
- https://www.vesselfinder.com/pl/vessels/details/9851189

Thank you for your attention.

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