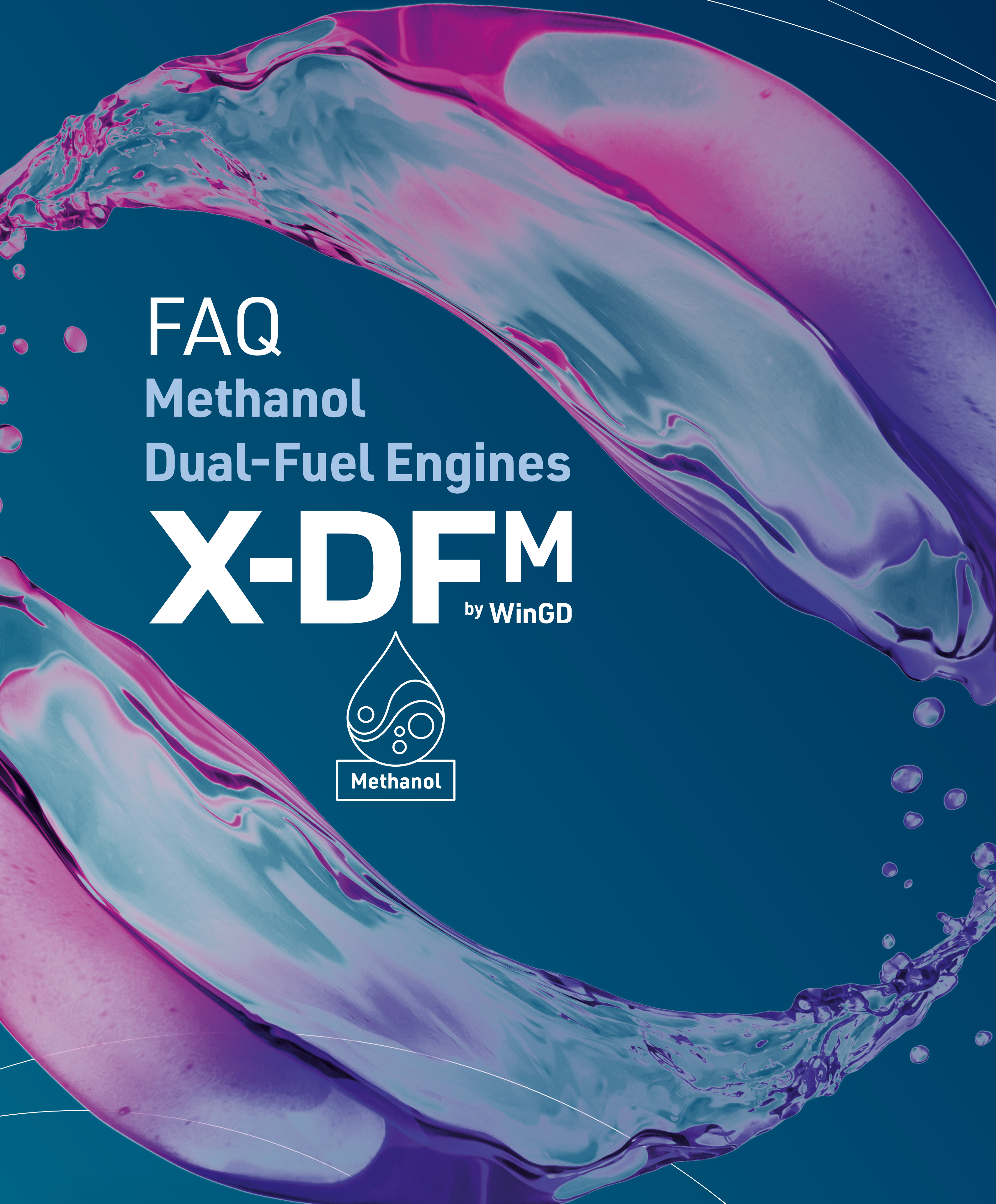
FAQ
Methanol Dual-Fuel Engines

X-DF-M
by WinGD

Methanol



WIN GD

FAQ Contents

1 Why are methanol marine engines in the spotlight?

Methanol is gaining attention as a marine fuel because of its potential to decarbonise ship operations.

Methanol combustion produces lower emissions of sulphur oxides (SO_X), nitrogen oxides (NO_X), and particulate matter compared to conventional marine fuel oils. As the shipping industry faces increasing pressure to reduce its environmental impact, methanol presents a cleaner and more sustainable alternative. Although current methanol production mainly relies on fossil energy sources, near-zero emission production methods are emerging. Combined with a low-emissions supply chain, renewable methanol can significantly reduce lifecycle emissions from shipping.

Compared to alternatives such as LNG or ammonia, methanol is relatively easy to store and handle as it is not in a cryogenic state. This also results in attractive newbuilding costs for methanol fuelled vessels.

While safety is a crucial concern for any fuel, methanol has a lower flammability range compared to conventional fuels, making it a safer option in certain respects. Rigorous standards and protocols are in place to ensure the safe handling, storage, and transportation of methanol.

Being a synthetic fuel, methanol presents a very narrow variation of its chemical composition and quality, meaning vessel operators will not need to consider multiple fuel grades at different locations and complex fuel treatment can be avoided.

2 What are the challenges associated with using methanol as a fuel?

While methanol offers several advantages as a marine fuel, there are challenges and considerations associated with its use. Some of the key challenges include:

Infrastructure Development: Establishing a comprehensive infrastructure for green methanol production, storage and distribution will be required to further develop its market as an alternative fuel. Adapting existing ports and bunkering facilities to accommodate methanol will require substantial investments.

Fuel Availability: The availability of methanol as a marine fuel could be limited in certain regions. Ensuring a reliable and consistent supply chain is crucial for the widespread adoption of methanol-powered vessels.

Energy Density: Methanol has a lower energy density compared to traditional marine fuels like fuel oils. This can impact the range and storage capacity of vessels, requiring larger fuel tanks or more frequent bunker calls.

Cost Competitiveness: While the cost of methanol is influenced by several factors, including production methods and regional dynamics, the anticipated high cost of near-zero or zero-emissions methanol will be an important consideration for shipowners and operators. Initial investments in methanol engines and infrastructure could also contribute to higher upfront costs.

Carbon Footprint of Production: The overall carbon footprint depends on the source of the carbon and energy used in its production. If produced from fossil fuels, the environmental footprint may be worse than of conventional fossil fuels. Therefore, ensuring a sustainable sourcing and production process is essential.

3 How is methanol produced?

Methanol can be produced from various feedstocks through different processes. The primary methods of methanol production include:

Natural Gas Reforming or Steam Methane Reforming (SMR): The most common method for industrial methanol production involves the use of natural gas (methane) as a feedstock. In this process, methane reacts with steam at high temperatures (typically 700-1,100°C) and under pressure, producing syngas (a mixture of hydrogen and carbon monoxide). The syngas is then catalytically converted into methanol.

Coal-based Methanol: Methanol can be produced from coal through a gasification process. Coal is converted into syngas, which is then processed to obtain methanol. However, this method is less common due to environmental concerns associated with coal-based processes.

Biomass Gasification: Methanol can also be produced from biomass through a gasification process. Biomass, such as wood, agricultural residues, or municipal solid waste, is heated in the presence of oxygen

3 How is methanol produced? continued...

and/or steam to produce a synthesis gas. The synthesis gas is then converted to methanol through similar catalytic processes used in natural gas reforming.

Carbon Capture and Utilisation (CCU): Carbon dioxide (CO_2) captured from industrial processes or directly from the atmosphere can be utilised in methanol production. Hydrogen is typically obtained from water electrolysis or other clean sources, and the combination of hydrogen and carbon dioxide results in the production of methanol.

4 How can zero or near-zero emissions methanol be produced?

Making zero-or near-zero emissions methanol involves mitigating or offsetting the carbon emissions associated with its feedstocks and production. Several approaches can be employed:

Use of Renewable Feedstocks: Utilising renewable feedstocks such as biomass or waste materials to produce methanol can significantly reduce the carbon footprint of the process. Biomass gasification or waste-to-energy technologies can generate syngas for methanol synthesis without adding carbon to the atmosphere.

Carbon Capture and Storage (CCS): Implementing carbon capture and storage technologies can capture CO_2 emissions generated during methanol production. Captured carbon dioxide can be permanently stored underground or returned for new renewable methanol production.

Direct Air Capture (DAC): Direct air capture involves capturing carbon dioxide directly from the atmosphere. Integrating DAC technologies into methanol production processes can offset emissions by removing an equivalent amount of CO_2 from the air, making the overall process carbon neutral.

Renewable Hydrogen Production: Hydrogen, a key component in methanol production, can be produced using renewable energy sources such as wind, solar or hydropower through a process known as electrolysis. Electrolysis splits water into hydrogen and oxygen without emitting carbon dioxide. Using renewable hydrogen in methanol synthesis contributes to the carbon neutrality of the overall process.

Circular Economy Approach: Implementing a circular economy approach involves recycling carbon-containing waste streams, such as industrial emissions or carbon-rich byproducts, as feedstocks for methanol production. This closed-loop system can contribute to carbon neutrality by repurposing carbon that would otherwise be emitted.

It is important to note that achieving carbon neutrality in methanol production often requires a combination of these approaches. The selection of methods depends on factors such as feedstock availability, technological feasibility, and the specific goals of the methanol production facility. As technology advances and sustainability practices become more widespread, the goal of producing carbon-neutral methanol is becoming increasingly achievable.

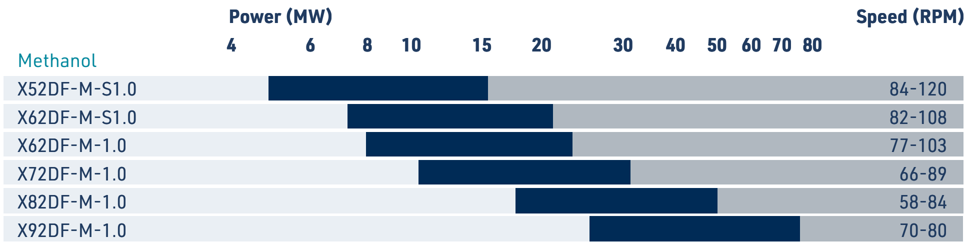
5 Are there any regulations or standards for methanol fuel and engines?

Using methanol as a marine fuel is covered by the 'IMO Interim guidelines for the safety of ships using methyl/ethyl alcohol as fuel' which are part of IMO's IGF Code. As the interim guidelines are still provisional, methanol-fuelled ships must follow the alternative design requirements under SOLAS and the related risk-based design and certification criteria provided in the interim guidelines as well as those described by the classification societies.

With the IMO interim guidelines as the basis, classification societies have also released their rules for classifying methanol-fuelled vessels.

6 Which methanol engine types do WinGD currently offer?

WinGD DUAL-FUEL ENGINES



7 When will the first WinGD methanol-fuelled engines be delivered?

The first engine deliveries to shipyards are scheduled for early 2025 for the X92DF-M-1.0 and for Q3 2025 for the X82DF-M-1.0. This will be followed by the first X62DF-M-1.0 deliveries in Q2 2026. Additionally, the first projects for upgrading existing X52-S2.0 diesel engines to methanol dual-fuel have been contracted and will be executed by Q4 2026.

8 When will an upgrade package be available for existing WinGD X/X-DF engines?

WinGD plans to introduce upgrade solutions enabling all diesel-fuelled X-Engines and LNG-fuelled X-DF engines to be converted to X-DF-M engines. This is possible due to the common robust engine platform shared by all WinGD engines, designed to accommodate the pressures and temperatures needed for use with alternative fuels.

The roll-out of upgrade packages for specific engine bore sizes will follow the introduction of newbuild X-DF-M engine configurations in the relevant bore-size, and depending on market demand. Upgrade packages are available approximately six months after the first newbuild design has been completed, at the earliest.

9 When did WinGD begin investigating methanol-fuelled engines?

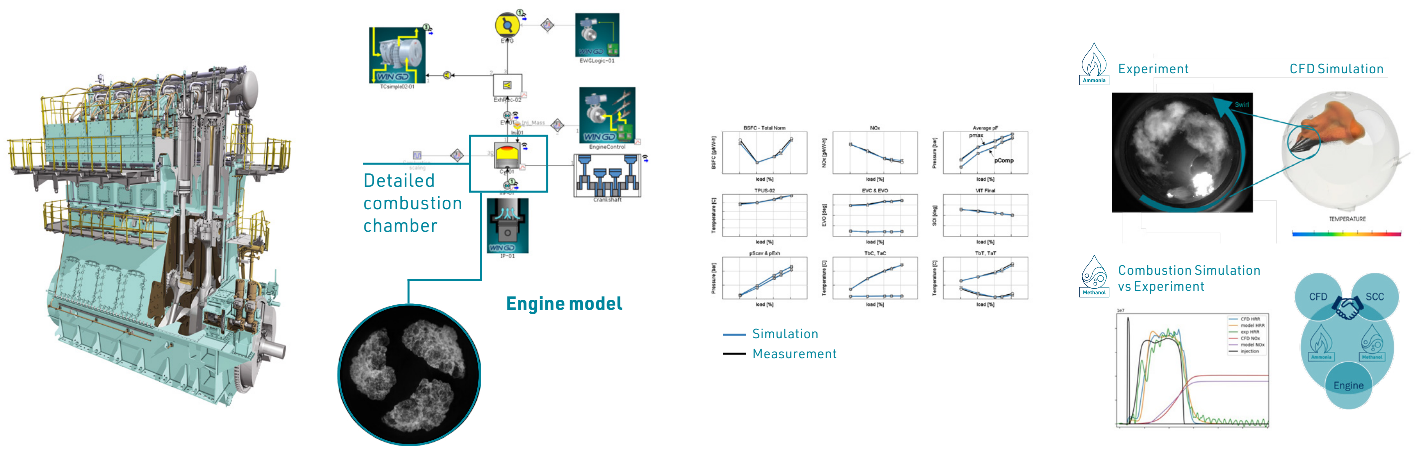
WinGD has been investigating methanol as a fuel for several years. From 2015 it was part of the European Union funded HERCULES-2 project, which aimed to develop engines that could switch between fuels whilst operating in the most cost-effective way and complying with regulations in all regions.

As part of this project, WinGD started to investigate methanol and ethanol combustion in its own Spray Combustion Chamber (SCC), in order to understand the spray morphology and combustion performance of a multi-fuel injection concept.

In 2018 a prototype injection system was designed based on the findings from the SCC and fitted on WinGD's RTX-6 test engine to burn ethanol and diesel fuel as two representatives of a broad fuel spectrum. Both ethanol and methanol are alcoholic fuels with similar combustion behaviour.

10 How did WinGD validate the X-DF-M concept?

Data Validation Process
Spray Combustion Chamber and Simulations



Real Engine

Various engine measurment series are used for calibration and validation

Spray Combustion Chamber

Used for an accurate CFD modelling of the combustion process

0D/1D GT-Power Model

Calibrated to engine measurement data

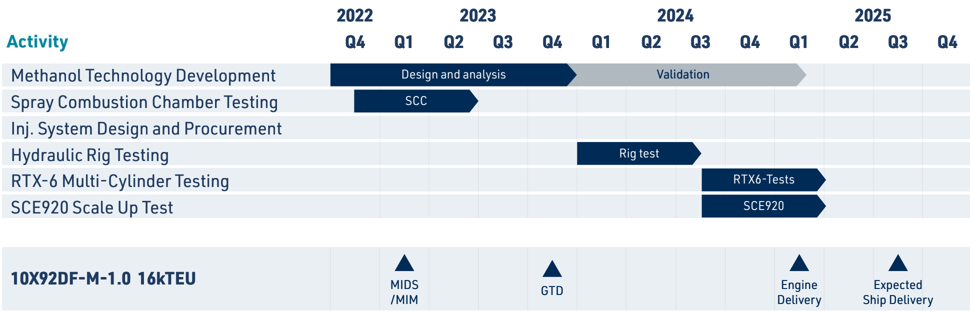
Methanol engines are sharing diesel base engine hardware but with specific combustion characteristics

Spray Combustion Chamber used with methanol allows for **new validated combustion models in a validated engine model**

B Engine availability

10 **How did WinGD validate the X-DF-M concept?** continued...

Technology Development and Project Timelines



C Engine concept

11 What is the X-DF-M engine design concept?

WinGD's X-DF-M engines are developed for dual-fuel operation using either methanol or conventional fuel oil. By deploying Diesel-cycle combustion with high-pressure fuel injection, the same concept as WinGD's diesel-fuelled X-Engines, the X-DF-M concept ensures highest engine efficiency in both modes, allowing operators to run engines cost-effectively on both conventional fuels and methanol.

X-DF-M engines are based on proven diesel engine design, with a limited scope of modifications required to adapt WinGD's diesel engine technology for use with methanol fuel. These include:

- Methanol fuel injection
- Additional actuation oil rail for methanol injection system
- Additional actuation oil supply unit
- Modified cylinder cover
- Adapted platforms and piping
- Minor modifications to bedplate and cylinder jacket

12 What is the combustion process for X-DF-M engines?

The stages of the combustion process are described below.

Compression stroke: Similar to a conventional diesel engine, the piston compresses the air inside the combustion chamber during the compression stroke, raising its temperature and pressure. This high-pressure and high-temperature environment is crucial for igniting the pilot fuel and subsequently the methanol fuel.

Fuel injection: In a methanol-based diesel engine, methanol is injected into the engine's combustion chamber as the primary fuel. The injection system ensures proper atomisation, interaction with the diesel pilot flame and mixing of methanol with air for efficient combustion.

Ignition and combustion: At the top of the compression stroke, just before reaching the maximum compression point, a small amount of pilot fuel is injected into the combustion chamber. The pilot fuel spray ignites due to the high temperature and pressure, initiating the combustion process.

Methanol combustion: Once the pilot fuel ignites, the heat generated ignites the methanol fuel injected into the combustion chamber, interacting with the pilot flame. The methanol-air mixture combusts, generating work on the piston.

Scavenging: After the piston has moved downwards during the power stroke, the combustion gases expand through the opening exhaust valve and are subsequently scavenged by new charge air from the intake ports to the exhaust valve. The cycle repeats.

13 How is methanol fuel supplied to the engine?

A methanol fuel supply system is used to supply methanol from the tank to the engine.

WinGD provides interface specifications and recommendations for the layout of the system based on best engineering practice. The Fuel Supply System (FSS) components themselves are designed and delivered by third party makers.

13 How is methanol fuel supplied to the engine? continued...

Methanol Storage: Methanol is stored in dedicated tanks or containers on the vessel. These tanks are designed to handle the pressure and temperature requirements of methanol storage and comply with safety regulations. They may include safety features such as pressure relief valves, temperature monitoring and nitrogen blanketing.

Fuel Supply System (FSS): Methanol is transferred from the storage tank to the engine by the FSS as required. The fuel is delivered to the engine within a specific range of temperature, pressure (13 bar(g)) and purity. This transfer is accomplished using low-pressure pumps, heat exchanger and filters. The fuel supply system must be designed to handle the specific characteristics of methanol, including its corrosive nature.

Fuel conditioning: Methanol fuel may undergo conditioning processes before it reaches the engine. This can involve filtration to remove impurities or contaminants that could potentially impact engine performance or damage components. Additionally, temperature control is installed to ensure the methanol remains within the desired operating range.

14 Which companies supply the fuel system components?

The supplier of the fuel supply system can be a preferred supplier of the shipyard or owner. However, they must meet WinGD's requirements. The supplier of the FVU additionally must be approved through WinGD's approved supplier process. The FSS and FVU can be supplied by different suppliers.

In general, the design of the methanol fuel system must be compliant with the international codes and classification society rules.

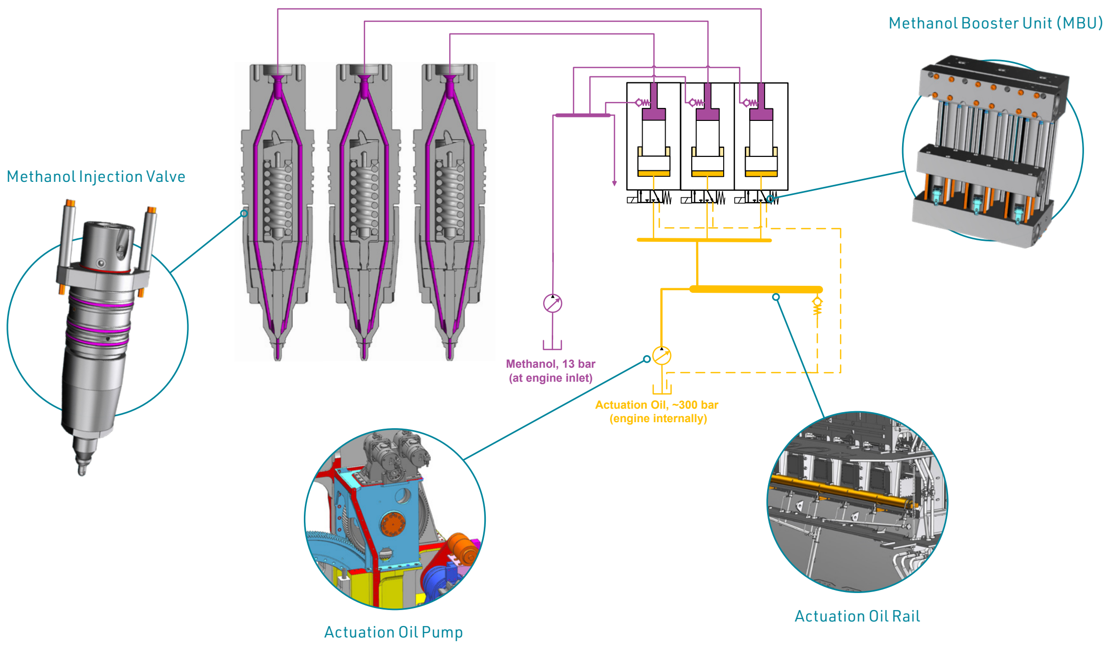
15 What precautions are taken related to corrosiveness of methanol?

Stainless steels, which provide sufficient corrosion resistance, are applied to components in direct contact with methanol fuel. Many of the standard sealing materials already used in WinGD engines (such as NBR, CR, FKM) exhibit good to excellent resistance to methanol corrosion.

16 What are the specific requirements for methanol fuel supply at the engine inlet?

Property	Value
Lower Heating Value (LHV)	**≥ 19.9 MJ/Nm³**
Purity	**≥ 95 (% w/w)**
Ethanol	**≤ 5 (% mass)**
Water	**≤ 5 (% w/w)**
Acetone	**≤ 30 (mg/kg)**
Chloride	**≤ 0.5 (mg/kg)**
Sulphur	**≤ 0.5 (mg/kg)**
Apperance	**Homogeneous, clear and free of suspended solids**
Methanol temperature range	**25-50°C (35-50°C if no dry air is supplied for annular space ventilation)**
Methanol feed pressure	**13 bar(g)**
Permissible methanol pressure fluctuation	**± 2 bar (across all frequencies)**

17 What does the X-DF-M methanol fuel injection concept look like?



18 Do engine design parameters need to be changed to optimise methanol combustion?

Methanol engine design parameters such as bore, stroke and mean piston speed are the same as for diesel engines in the WinGD portfolio. Tuning parameters such as injection timing, pressure, etc., are adjusted individually for methanol operation to achieve best possible efficiency and lowest emissions.

19 Which engine parts need to be converted to upgrade an existing WinGD engine for methanol?

Since X-DF-M engines are based on the conventional diesel engine design, all WinGD portfolio engines can be upgraded to use methanol as fuel. Necessary modifications will be related to the installation of the additional methanol injection system, acutation oil system and potentially an extension of the main lubricating oil supply capacity. Cylinder covers will have to be replaced to fit the additional injectors.

It is suggested to conduct case-specific studies for retrofit projects.

20 How is safety ensured on the X-DF-M engine and across the fuel supply system?

Safety measures are implemented throughout the methanol supply system, including leak detection, emergency shutdown, double wall barriers, ventilation, and fire suppression to ensure the safety of the crew, vessel and environment.

Crew members must be trained on safe handling procedures, the use of personal protective equipment and emergency response protocols.

Monitoring and control systems are employed to ensure the proper functioning of the methanol fuel supply system.

See the X-DF-M Safety Concept for a more detailed description.

21 Can the existing WiCE control system also control the methanol engine?

The latest state-of the-art control system WiCE is installed on all new WinGD engine types including methanol engines. WiCE covers the additional requirements for the methanol system.

22 How are injectors sealed?

Multiple barriers are applied. A low-pressure fuel barrier is applied on the first level and sealing oil on the second level. Any small quantity of sealing oil in contact with methanol is burned during combustion and there is no recirculation of sealing oil to the service tank.

23 Is blending methanol with water foreseen e.g. to reduce NO_X emissions?

Blending is not considered for X-DF-M because:

- It does not provide Tier III NO_X compliance in diesel mode
- It requires significant additional water consumption
- It increases the maximum injection quantity needed, meaning the methanol injection system is not optimally sized for methanol Tier II mode

24 How does pilot fuel injection work and which fuels can be used?

In methanol mode the main fuel is liquid methanol. The methanol fuel is injected into the engine at high pressure. The normal diesel injectors provide pilot fuel to ignite the methanol fuel. The pilot flame penetrates the methanol plume to ignite it from the inside.

The amount of injected pilot fuel is approximately 5% of the total energy consumption of the engine at 100% Contracted Maximum Continuous Rating (CMCR) engine power. Project-specific values are available in the GTD.

The pilot fuel can be Marine Diesel Oil (MDO), Marine Gas Oil (MGO) or Heavy Fuel Oil (HFO) with a maximum sulphur content of 0.5% m/m.

C Engine concept

25 Is the fuel injection duration higher for methanol?

The injection system is adapted to the higher flow rate which comes from the smaller Lower Heating Value of methanol. That means the injection duration is not longer than in diesel mode. The injection system design for optimal injection duration results in the best possible engine performance and emissions.

D Engine performance

26 What is the engine efficiency of the X-DF-M engine?

X-DF-M engines will achieve the same efficiency as X-Engines in diesel mode and better efficiency when running on methanol.

Higher efficiency is expected in methanol mode as combustion tests have confirmed a lower tendency to form NO_X when burning methanol compared to conventional diesel fuels. While diesel engine performance is typically limited by compliance with NO_X emission limits, the lower NO_X level on methanol allows better utilisation of the cylinder pressure design limits of the engine, delivering higher efficiencies when running on methanol.

Accordingly, energy consumption in methanol mode is approximately 2% lower than in diesel mode. The fuel consumption at each engine load point can be found in WinGD's General Technical Data (GTD).

27 Will there be major differences in the engine load acceptance and dynamic behaviour on X-DF-M engines compared to conventional diesel engines?

No. Similar load acceptance behaviour as on conventional diesel engines is expected since the engine employs the same Diesel-cycle combustion principle and controls.

28 Which emissions are created from methanol combustion and how are they treated with X-DF-M?

Methanol combustion produces several types of emissions, although it generally emits lower levels of pollutants compared to traditional fossil fuels like diesel. The emissions from methanol combustion include:

Carbon Dioxide (CO_2) : Like other hydrocarbon fuels, methanol combustion releases carbon dioxide, a greenhouse gas that contributes to climate change. However, when methanol is produced from renewable sources or with carbon capture technologies, the overall lifecycle emissions of CO_2 can be reduced.

Nitrogen Oxides (NO_X): NO_X emissions are formed during the combustion process when nitrogen in the air reacts with oxygen at high temperatures. Methanol combustion typically results in lower NO_X emissions compared to diesel combustion. This brings the opportunity to increase the engine efficiency by utilising the engine design limits.

Carbon Monoxide (CO): Incomplete combustion of methanol can lead to the formation of carbon monoxide, a poisonous gas. WinGD engine designs and efficient combustion processes aim to minimise CO emissions.

Particulate Matter (PM): Methanol combustion can produce particulate matter, consisting of tiny particles suspended in the air. While methanol generally produces fewer particulate emissions compared to diesel, the formation of PM can still occur, especially from pilot fuel and lubrication oil.

Formaldehyde (HCHO): Methanol combustion can produce formaldehyde that contributes to air pollution. Although formaldehyde emissions from methanol combustion are very low, they are still a consideration for air quality. At present there are no maritime regulations governing formaldehyde emissions.

Sulphur Dioxide (SO_2): Methanol itself contains no sulphur, so combustion of methanol does not produce sulphur dioxide emissions besides the small quantity of sulphur in the pilot fuel. This is advantageous compared to traditional marine fuels like heavy fuel oil, which can have high sulphur content and emit SO_2 when burned.

D Engine performance

28 Which emissions are created from methanol combustion and how are they treated with X-DF-M? continued...

Overall, while methanol combustion produces emissions like any other fuel, its use can offer environmental benefits, particularly when considering reductions in CO_2, SO_X, and particulate matter emissions compared to conventional marine fuels.

To ensure IMO NO_X Tier III compliance, a selective catalytic reduction (SCR) is installed. The SCR unit can be applied as a high-pressure SCR or a low-pressure SCR type which are fully established solutions on diesel engines.

E Engine operation

29 When does the methanol system need to be purged?

Purging and flushing of the methanol fuel system is performed prior to maintenance work or in the event of failure of methanol injection system components, such as a leakage. In these cases, the methanol fuel system must be depressurised and the remaining methanol must be removed by water and collected in the purging tank.

PDF More details can be found in the X-DF-M concept guidance: https://www.wingd.com/en/engines/engine-types/x-df-dual-fuel-methanol/methanol-documentation/

E Engine operation

30 Why is purging done with water?

Compared to conventional nitrogen purging, using water delivers several advantages, including:

- Liquid-to-liquid purging is generally more efficient than gas-to-liquid
- Purging with water allows greater flexibility in vessel layout, e.g. allowing a purge tank installation at higher level than the main engine
- Purging large vertical pipes is much easier with water than with a gas
- No additional pipe/valves are required on the main engine for the sole function of purging the engine. Water can replace methanol following the same route.
- Gas purging can lead to some areas of piping containing methanol being missed if a preferential path develops in the gas flow. This is less likely when using water.
- Using water for pressure tests to check for leaks or cracks is faster and more accurate than using nitrogen
- Methanol requires stainless steel, which is compatible with water

31 After purging, what happens to the water-methanol mixture in the purge tank?

During purging of the methanol injection system, the remaining methanol dissolves in the purge water and is collected in the purge tank.

The water-methanol mixture in the purge tank is mixed into the main methanol supply when the main engine runs in methanol mode. Small quantities are introduced to the engine until the purge tank is empty or has reached the minimum level, after which the engine runs with pure methanol.

32 What cylinder lube oils and feed rate should be used for an engine running with methanol?

WinGD currently foresees that operators will need to use low-BN lube oils, similar to those used in LNG dual-fuel engines and with similar feed rates. These lubricants are well-proven and widely available

PDF

Please refer to WinGD's list of validated engine oils: https://www.wingd.com/en/documents/w-2s/tribology/fuel-lubricants-water/validated-engine-oils-for-wingd-engines-v13.pdf/

33 Why is Selective Catalytic Reduction (SCR) favoured over Exhaust Gas Recirculation (EGR) as an NO_X Tier III emission solution?

NO_X compliance of X-DF-M engines is ensured via low-pressure (LP) or high-pressure (HP) SCR systems, the well-proven standard system on WinGD diesel engines. This setup guarantees compliance in both fuel modes and results in lower additional OPEX compared to an EGR system, which bears an efficiency penalty when running in Tier III mode. This efficiency drawback with an EGR system becomes increasingly costly when considering the high cost of green methanol.

Additionally, CAPEX for an SCR solution is typically lower than for an EGR system.

34 What is the reaction of the engine to a failure of the methanol system / operation?

In the event of an issue while running on methanol, the engine will automatically switch to diesel mode. The process and automation are similar to those used in dual-fuel LNG engines.

35 Can the engine start and stop with methanol, and what is the power range available for operation on methanol?

The engine is started in diesel mode. Fuel changeover from diesel to methanol takes place when the engine is running between 10-80% engine power. The operation range for methanol is 10-100% of engine power.

36 Is a fuel sharing mode offered for X-DF-M engines?

Fuel-sharing operation, combustion with a mixture of methanol and diesel, is possible. This feature is planned to be introduced at a later stage.

37 How does WinGD support training for the operation and maintenance of methanol-fuelled engines?

WinGD follows the same training methodology for X-DF-M engines as for its X-DF LNG engines, with courses covering operation and maintenance of the engine. These include information about control system logic, mechanical components and a strong focus on safety aspects related to the specific fuels as well as other relevant topics.

WinGD is already assisting operators and maritime academies in preparing training courses for the use of methanol as a marine fuel.

Notes

Notes

Committed to the decarbonisation of marine transportation through sustainable energy systems.

WinGD designs marine power ecosystems utilising the most advanced technology in emissions reduction, fuel efficiency, digitalisation, service and support. With their two-stroke, low-speed engines at the heart of the power equation, WinGD sets the industry standard for reliability, safety, efficiency and environmental design.

Headquartered in Winterthur, Switzerland, since its inception as the Sulzer Diesel Engine business in 1893, it is powering the transformation to a sustainable future.

WinGD is a CSSC Group company.

WinGD® is a registered trademark.
© Copyright, 2024 WinGD.

www.wingd.com