Methanol fuel in commercial operation on land and sea

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Methanol has been considered a possible alternative fuel in gas turbines and reciprocating engines for decades due to its clean burning characteristics. Recent global constraints on emissions have prompted a renewed interest in the fuel, particularly as an applicable solution in isolated areas on land and in near-land areas at sea. GTW looks at a current existing methanol conversion project for a land-based gas turbine and a marine conversion of reciprocating engines, both now in commercial operation.

The city of Eilat, Israel, located near the Red Sea, has experienced rapid growth driven in part by increased tourism. Consequently, a higher demand for power outstripped the capability of the transmission line from the interior of the country. The Eilat generating plant (shown in Figure 1) has a 50 MW Pratt & Whitney FT4C Twin Pac (gas turbines driving both ends of the generator) installed in the 1970s using diesel fuel. Concern over air quality in the area limited the gas turbine operation to short periods, not exceeding 300 hours per year.

Dor Chemicals, the sole importer of methanol to Israel, partnered with the Israel Electric Company in 2012 and by the end of 2013 converted the gas turbines to use methanol fuel. By doing so, it allowed a substantial reduction in emissions, enabling the gas turbine to operate without restrictions.

Table 1. Operational performance on methanol

Year	2014	2015
Availability, %	80.5	90.3
Starts	104	69

The unit entered operation in 2014 and its performance data is shown in Table 1.

Methanol has about half the volumetric heat capacity of diesel fuel, making it necessary to remove bottlenecks to enable doubling the fuel flow into the combustors. The Dor/IEC collaborating team had replaced the original shaft-driven high-pressure pump and modulating valve with an off-board pump with a variable speed electric drive motor. The pressure and dump (P&D) valve was doubled in capacity by using a coarser screen.

The Excello fuel nozzles were replaced with Delevan high flow nozzles that were designed for twice the flow for water injection, for wet NOx control. The fuel control sequencer was left as is

Figure 1. The Eilat generating plant. The gas turbines were converted to use methanol at the end of 2013.

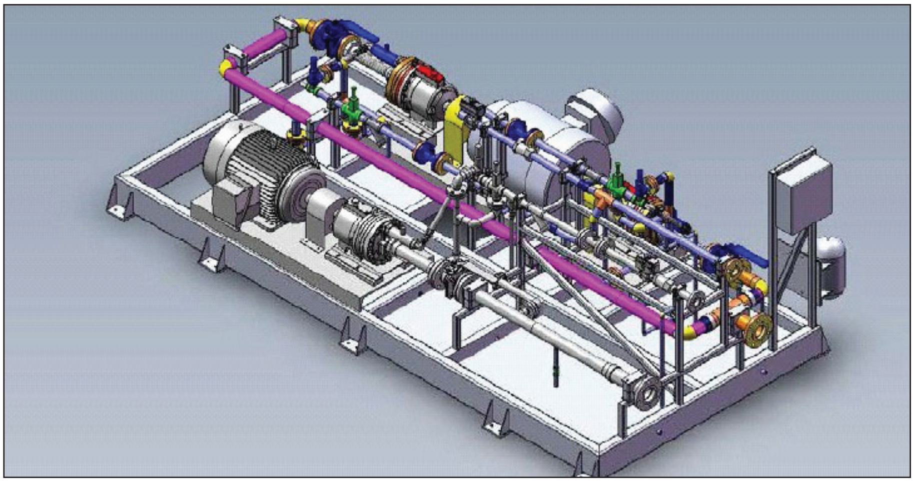

Figure 2. The fuel skid was modified to have one branch for each fuel.

for diesel fuel and the controller was designed to work along with it for methanol. In this manner the gas turbine can operate on either fuel. The fuel skid was modified to have one branch for each fuel (Figure 2).

The gas turbine fires up with diesel fuel and switches over to methanol at a minimum pre-selected load, which then increases until operating at the required load. Prior to shut down, the unit is switched back to diesel fuel at about the same load, after which it is turned off.

The methanol supply system consists of a 2000 m^3 storage tank with a floating roof to inhibit evaporation of methanol, which is quite volatile. The flame detection of the fire extinguishing system incorporates infrared flame detectors, as the methanol flame is invisible. The fire extinguishing system uses alcohol-resistant foams that remain active in the presence of methanol. The turbine in Eilat consumes 30 metric tons per hour of methanol.

Results

Heat rate is essentially the same with methanol as with fuel oil, as indicated in Figure 3. The subsequent charts show the emissions performance on methanol vs. diesel fuel. Figures 4 and 5 show NOx in absolute and relative terms with 80 - 85% reduction for the two gas turbines.

As seen in Figure 6, the CO is higher for methanol, particularly at low load. One reason was high exhaust temperature spread, indicating cool spots in the combustor. This was improved by replacing the P&D valve. Newer gas turbines contain variable inlet guide vanes allowing the IGVs to be adjusted at low loads with less excess air, thus less CO. Optimizing the atomizer for methanol fuel would further reduce CO, as can be seen from data with the original atomizer.

As indicated in Figure 7, particulates are greatly reduced (by 90%) with methanol vs. fuel oil, and sulfur emissions are eliminated altogether with methanol, as shown in Figure 8.

Operational performance has been good with methanol fuel, particularly for such an old gas turbine (see Table 1).

Land-based GTs on methanol

Another application of a gas turbine running on methanol is a MAN Diesel and Turbo 7 MW unit that was run in Trinidad.

From discussions with industry experts there seems to be agreement that methanol is a feasible fuel for gas turbines, the issue being whether the market is large enough to justify widespread

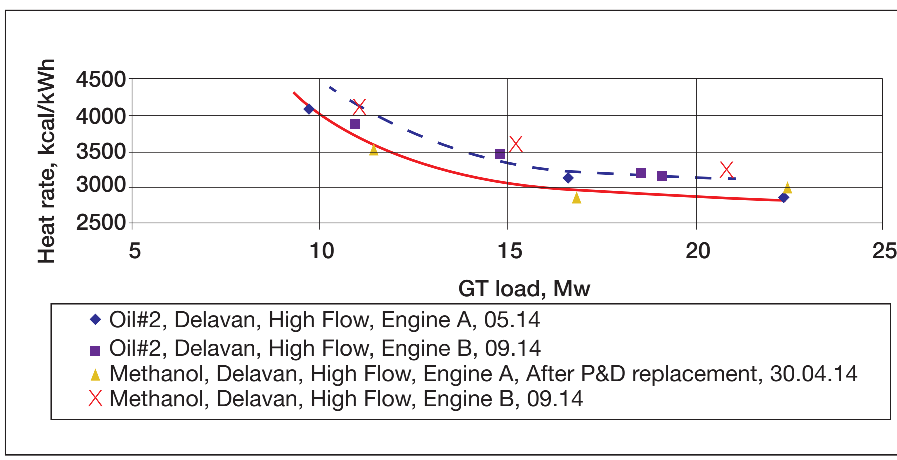

Figure 3. Heat rate as a function of GT load P&W GT, Eilat. Heat rate is essentially the same with methanol as with fuel oil.

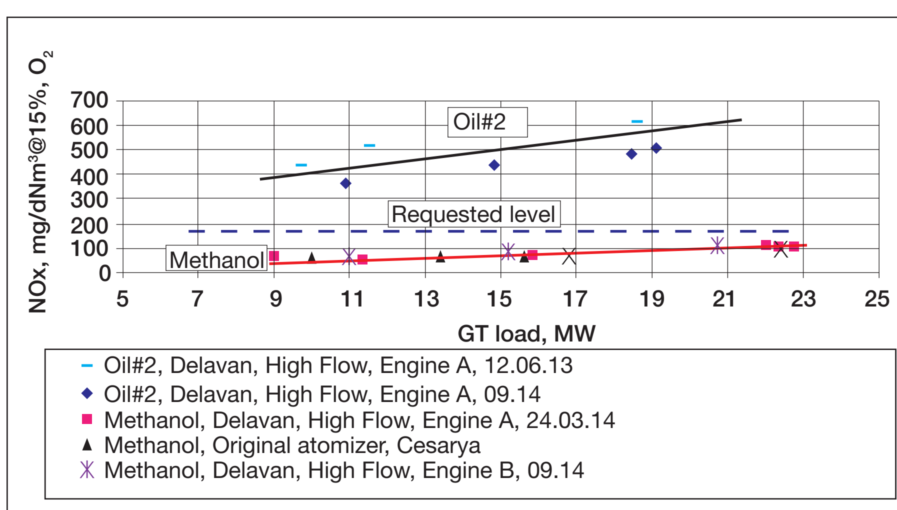

Figure 4. NOx emissions as a function of GT load P&W GT, Eilat.

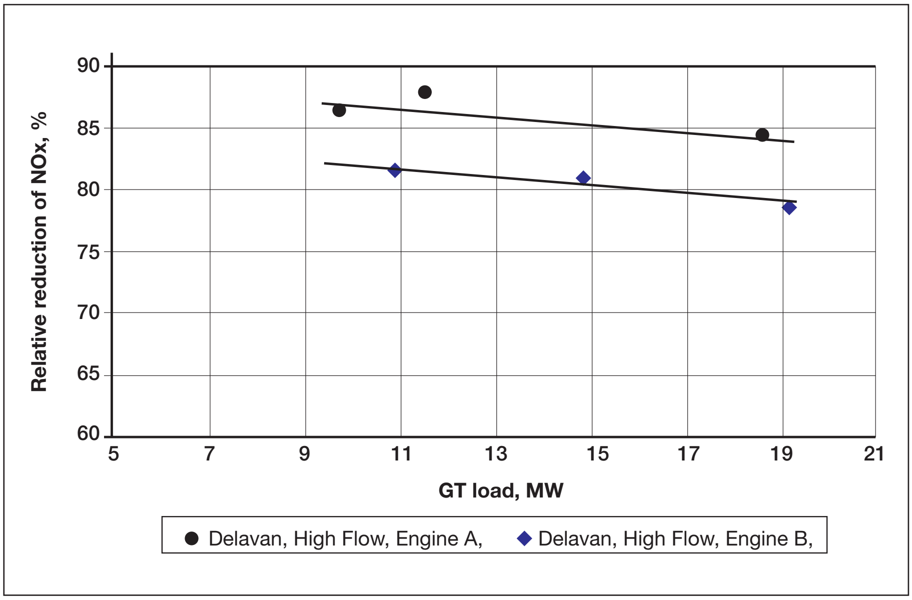

Figure 5: NOx emissions relative reduction as a function of GT load, P&W GT, Eilat.

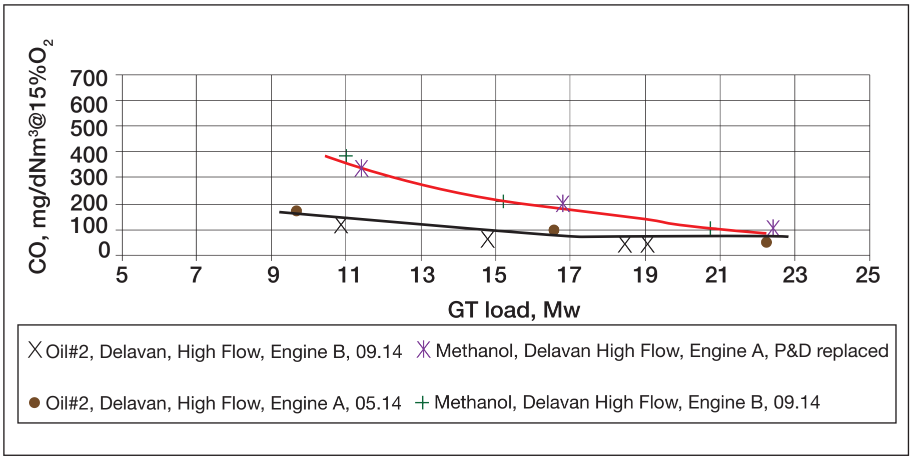

Figure 6: CO emissions as a function of GT load – P&W GT, Eilat.

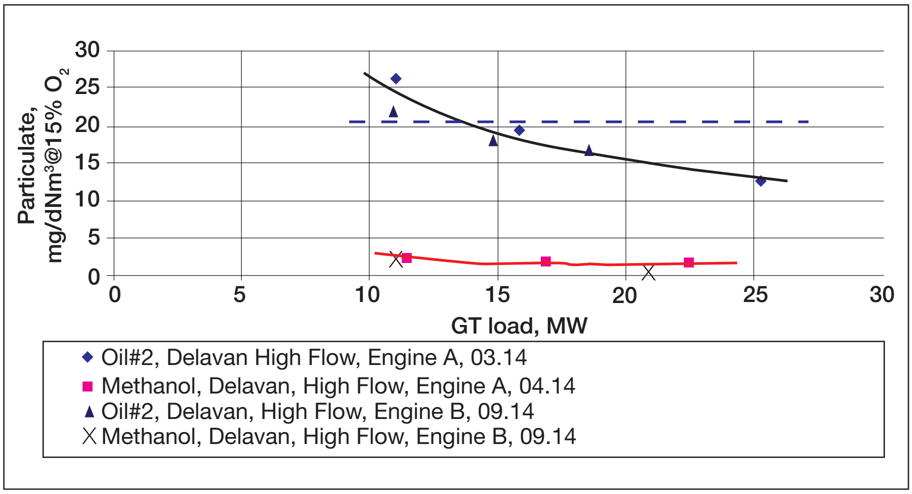

Figure 7: Particulate emissions as a function of GT load.

conversion of gas turbine models, both frame types and aeroderivatives. For an OEM to offer commercial guarantees on one of its gas turbine models using methanol, additional engineering and testing needs to be done to validate the operability and emissions performance. If a potential project isn't large enough to bear the development cost, the OEM needs to evaluate whether the overall market for that methanol-capable unit is large enough to justify it.

The market may be attractive in areas where there is no natural gas pipeline, emissions requirements are stringent enough that they would be difficult to meet with oil fuel, or the plant size is too small to justify the capital expenditure of LNG regasification infrastructure. Methanol may be an option to consider for island nations in the Caribbean, Hawaiian Islands, Philippines, and Indonesia.

On the supply side, methanol is one of the most widely distributed chemical commodities, and is increasingly used as a fuel for road and marine transport. According to the Methanol Institute, of the 70 million metric tons of methanol consumed in 2015, more than 40% of demand was for fast-growing energy applications. Wärtsilä has 60 GW of installed reciprocating engines power plant capacity in 176 countries around the world. Here we describe one of the reciprocating engines that is used in a marine application on board a ferry ship but equally capable of power plant application.

Ferry converted to methanol

When the new IMO sulfur regulations were decided in 2008, reducing the sulfur content in fuel to 0.1 %, Stena Line faced three alternatives for fulfilling the new requirements: changing to low sulfur diesel (MGO), installing scrubbers, or converting their ships to LNG. Their investigations showed that a shift to MGO entailed a 40% to 50% increase in fuel cost. Scrubbers were rather expensive and there were few marine installations to prove their functionality. Finally, except for the large tank ships transporting LNG worldwide, LNG only existed as fuel on some small passenger ships in Norway.

The problem was to find solutions for their existing fleet of 25 large RoPax (roll-on/roll-off passenger) ships operating within the SECA (Sulfur Emission Control Area) in Europe's Baltic and North Seas and retrofitting those ships would certainly be a challenge.

Methanol is an attractive fuel due to its availability and competitive price. The handling and installation of a liquid like methanol has clear advantages over gas or cryogenic fuels regarding fuel storage and bunkering. With help from engine manufacturer Wärtsilä and methanol producer/distributor Methanex, as well as support from the European Commission, Stena converted a large RoPax ship, Stena Germanica, to run on methanol. Marine methanol fuel produces no sulfur emissions and very low levels of nitrogen oxide emissions. It is therefore compliant with current emissions reduction measures such as emission control areas (ECAs) as well as California's Ocean-going Vessels Fuel Regulation.

The Stena Germanica ferry runs between Gothenberg, Sweden and Kiel, Germany. No changes were needed inside the engine, just the addition of methanol pumps, fuel rail and specially designed injectors.

The engine fuel system conversion is shown in Figure 11. Features of the conversion are as follows:

- ■ Adaptation of proven engine technology, minor modification to the engine
- ■ No reduction in efficiency or output running on methanol, load response unchanged, fuel redundancy
- ■ Existing fuel / ballast tanks can be converted to methanol tanks
- ■ Short off-hire time, can be done engine by engine
- ■ Lower thermic load on the engine
- ■ Much lower NOx, SOx, GHG and PM (particulates), safer for future ECA regulations
- ■ Available methanol infrastructure (bunkerable fuel to be developed).

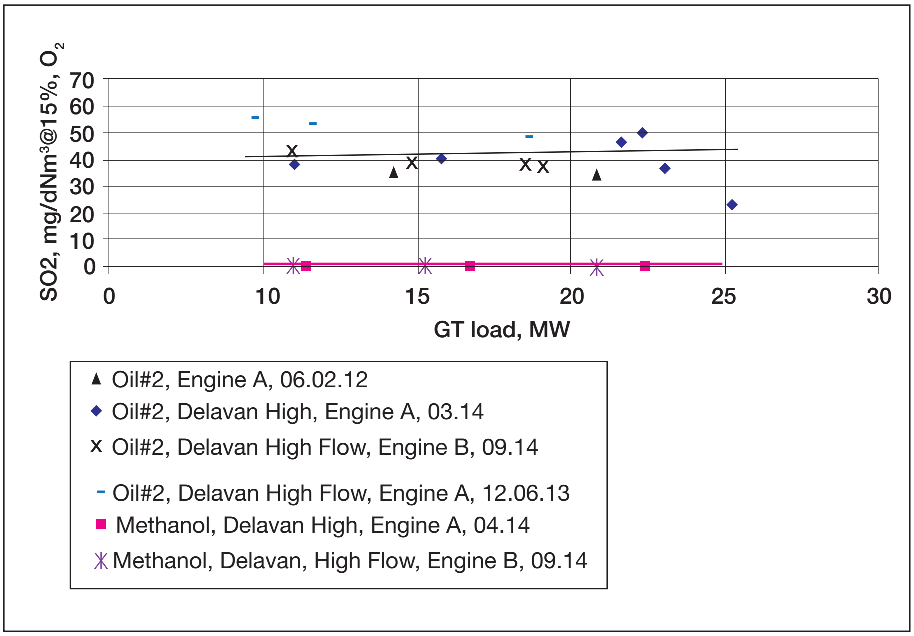

Figure 8. SO_2 emissions as a function of GT load, P&W GT, Eilat.

Emissions and fuel consumption

The following emissions results are from the laboratory engine converted to methanol, same type as on Stena Germanica.

At the maximum pressure tested, NOx was reduced by 59%, filter smoke was reduced by 90%.

Brake specific fuel consumption (BSFC), i.e. the ratio of the engine fuel consumption to engine power output, reduced by 2%.

The results are shown in Figures 12, 13 and 14, where ZA40S VS reference 2014 = Emissions on light fuel oil (marine diesel) and ZA40S VS load swing TAT and TAT01 = Type Approval tests, two test runs.

The objective for the Stena Germanica was not NOx optimization. The formation of NOx is coupled with combustion temperature. Tests were done in 2012 at VTT University with water blended methanol (10/90 H_2O/MeOH) lowering the NOx levels down to ~ 2 g/kWh. The limits for IMO NOx Tier III are between 2.6 and 2.2 g/kWh for the 500-900 rpm range of the Wärtsilä

Figure 9: RoPax ferry Stena Germanica (24 MW).

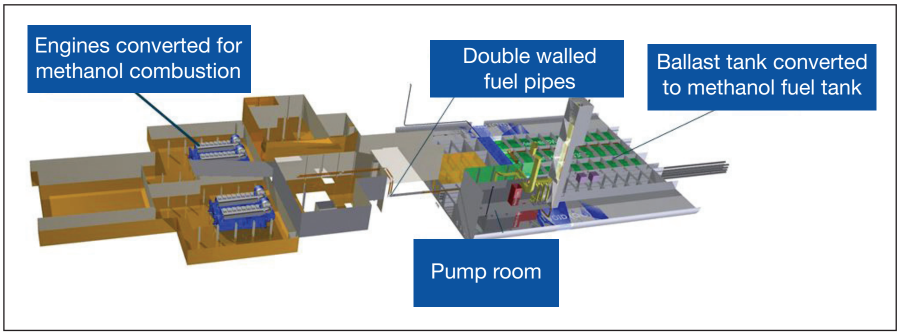

Figure 10: Conversion scope. No changes were needed inside the engine, just the addition of methanol pumps, fuel rail and specially designed injectors.

medium speed diesels. Also, the results from Stena Germanica are not targeted for low NOx optimization as that was not a criterion for the project, and Wärtsilä should be able to comply with TIER III levels with methanol and some engine optimization.

Operating features

The converted engines start on diesel and can switch to methanol at 20% load and above. They can run to 100% load on either fuel with seamless switchovers. When operating on methanol there is a pilot fuel of diesel of 5 - 8% diesel at full load, which is the minimum quantity that can be injected by conventional diesel jerk pump, which is used for normal diesel operation. The ship is refueled with methanol in Gothenburg every 4th - 6th day. The technology can be further adapted to use a lower amount of pilot fuel and could operate on wider ranges in methanol mode.

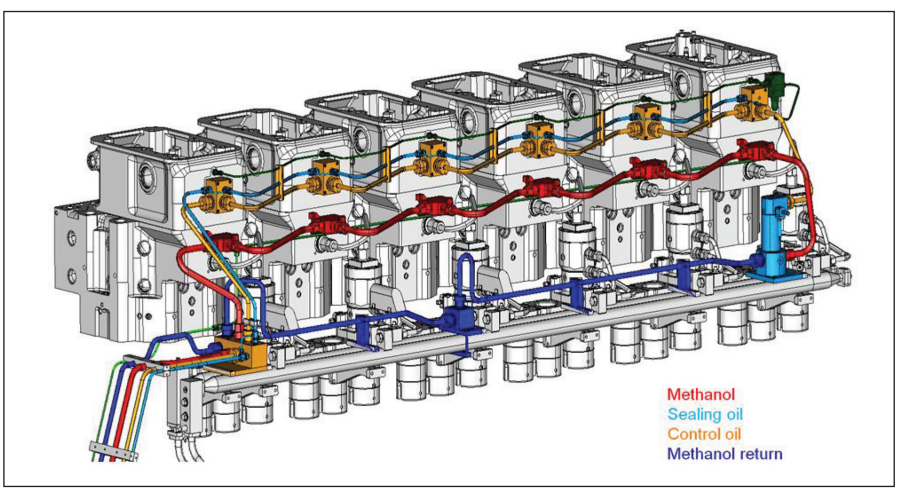

Figure 11. On-engine piping. The engine fuel system conversion

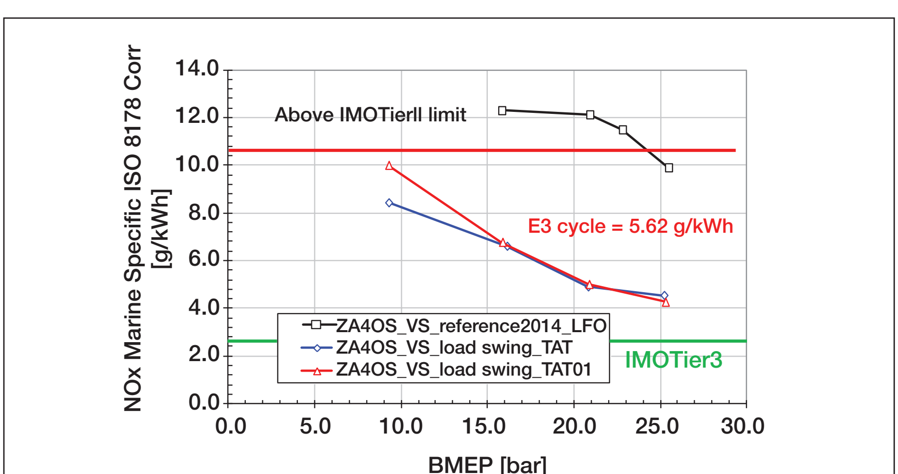

Figure 12: NOx emissions

The first engine was commissioned in the spring of 2015, and two of the other three engines were converted in early 2016, with the final engine expected to be commissioned in October 2016. So far there have been no major operational problems with the ship in service, and as of June 2016, Stena reports that engine 1 had 1500 hours of operation on methanol, with 400 hours for engine 2, and 200 hours for engine 3.

Economics

The Methanol Institute commissioned a report on methanol as a marine fuel; the following are some findings from the study on economic considerations.

Infrastructure costs are relatively modest compared to potential alternative solutions. Because methanol remains in a liquid state, infrastructure investment costs are low relative to competing alternatives such as liquefied natural gas (LNG). Installation costs of a small methanol bunkering unit have been estimated at around €400,000. A bunker vessel can be converted for approximately €1.5 million. In contrast, an LNG terminal costs approximately €50 million and an LNG bunker barge €30 million. Additionally, methanol allows for small incremental investments in infrastructure capacity as the number of users grows. An LNG terminal costs approximately €50 million and an LNG bunker barge €30 million. Methanol also allows for small incremental investments in infrastructure capacity as the number of users grows. Notably, both methane and methanol can be made from many renewable feedstocks that are available in large quantities, e.g. vegetable oils, biomass, organic waste. Methanol's advantage in infrastructure cost vs. methane also applies to renewable fuels.

Methanol prices show regional variation. Over the past five years, methanol has usually been less expensive, on an energy equivalent basis, than competing fuels such as marine gas oil (MGO). In the lower oil price environment, MGO prices have declined more than methanol and the economic advantage of methanol has eroded. However, methanol remains competitive in key shipping regions, including China. Expansion in methanol manufacturing capacity in key markets such as the US should put downward pressure on costs, making methanol even more cost-competitive. Since methanol engines are dual fuel, a temporary change to marine diesel is always possible at points in time when methanol is more expensive.

Conversion costs are expected to drop dramatically as experience mounts. The main reference point on vessel retrofit costs comes from the conversion of the 24 MW RoPax ferry Stena Germanica. Conversion specific costs amounted to €8 million and the total project cost was €22 million, which includes a methanol storage tank onshore and the adaptation of a bunker barge. Being the first of its kind, the retrofit of the Stena Germanica and associated infrastructure entailed much design work on new technical solutions, safety assessments, and adaptation of rules and regulations. It has been estimated that the cost of a second retrofit project would be much lower, at about 30% to 40% of the Stena Germanica conversion.

Current engines have performed well and upcoming technologies will further improve on this performance. So far, methanol ships have been powered by diesel concept engines, which have been modified to run on both methanol and marine diesel. In both field and laboratory tests, converted methanol engines have performed at equivalent or higher levels than diesel engines. Methanol-optimized marine engines are under development and once in service are expected to perform better than retrofits.

New-build ships optimized for methanol fuel can simplify the installation. Figure 15 shows the concept, which reduces piping and cost. This is shown for a methanol tanker; the concept could also be used in other marine applications.

Summary

Existing ships with diesel engines can be converted to enable methanol operation with the addition of a methanol fuel system and new fuel injectors. Emissions of NOx and smoke are substantial (56% and 79%, respectively at max pressure), and SFC is reduced by 2%. Conversion costs will drop dramatically as experience mounts. Infrastructure cost is relatively modest compared to alternatives such as LNG in meeting stringent emissions regulations. And new-build ships can reduce costs further by simplifying the installation. ■

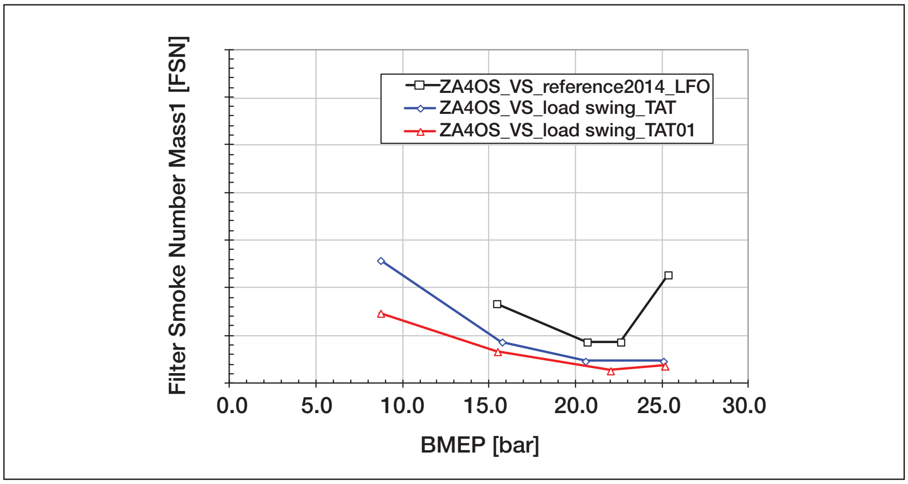

Figure 13: Smoke emissions.

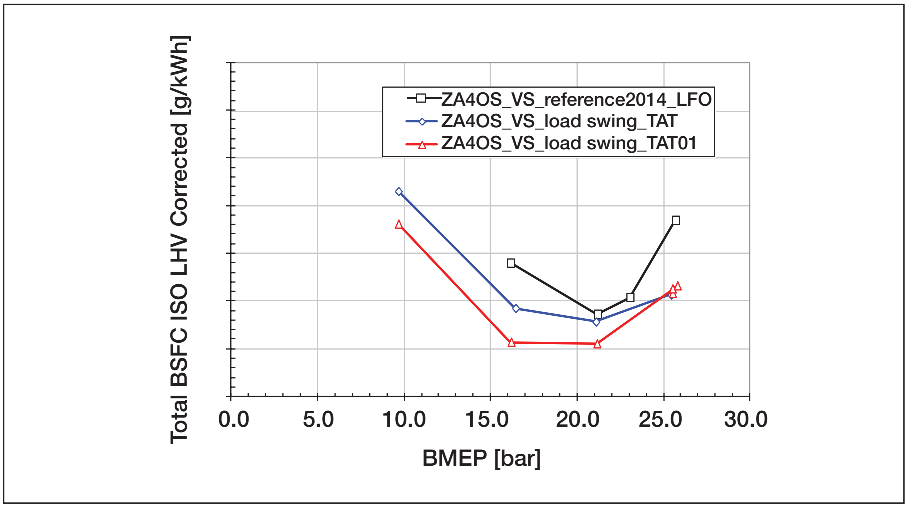

Figure 14: Specific fuel consumption.

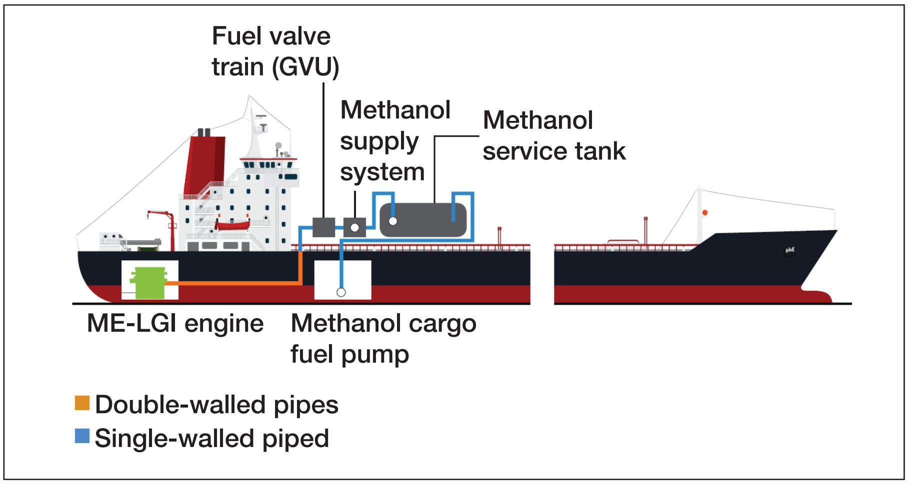

Figure 15: Installations on board a new-build methanol tanker.