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Ultra-low emission vessel field experience

Exhaust Gas Aftertreatment Solutions & CCS

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ABSTRACT

Engine emissions in protected areas or for special applications are progressively subject to ambitious emission reduction requirements. The driving force behind such requirements are not only regulatory bodies, but increasingly commercial, stemming from green operators or investors. Publicly exposed applications like passenger ships or the growing offshore wind turbine industry are two good examples. The emission targets are derived from the most stringent non-road mobile machinery emission rules like EU Stage V. Unlike in IMO regulation, not only nitrogen oxides (NOx) but also carbon monoxide (CO), hydrocarbons (HC), particulate matter on mass (PM) and number (PN) base are limited due to their health and environmental impact.

Previously, the world’s first successful EU Stage V certification results of a combined medium-speed engine and aftertreatment system package were presented – now field experience with such systems shall be presented. The employed concept uses a total system optimization approach for minimizing fuel consumption and maximizing service intervals for the aftertreatment system.

Field experience was gathered from vessels with installed power ranging from 1 MW to 25 MW operating on commercial marine distillate fuels. Onboard emission tests were run to confirm emissions were reduced as intended and service experience was collected.

The aftertreatment systems consist of a diesel particulate filter (DPF) with active regeneration and a selective catalytic reduction (SCR) system, the engine was fuel optimized with increased NOx raw emissions compensated by the SCR system to EU Stage V and ultra-low emission vessel (ULEV) levels and below. The onboard measurements include gaseous emissions like NOx, CO, HC, but also particulate emissions like PN and black carbon as anticipated by the IMO. Results indicate diesel engines can outperform state-of-the-art gas engines in terms of pollutant emissions – with a possibility to switch to available low greenhouse gas footprint biofuels already today, thereby not only reducing pollutants but also overall climate impact.

1 INTRODUCTION

Legislation for engine emissions has been evolving at a rapid pace. The European Union implemented strict rules to which newly built engines need to comply. Besides very clearly dividing the different categories for engines and their applications, several pollutants are to be controlled. Diesel engines for powering inland vessels have strict emission levels, regulated under the EU Stage V legislation. Both the gaseous components nitrogen oxides (NOx), hydrocarbons (HC), carbon monoxide (CO) as well as the particle emissions defined as particle mass (PM) and particle number (PN) are limited.[1] In the US, the Environmental Protection Agency (EPA) has defined similar regulation.[2] An aftertreatment system is commonly used to control the emissions of a combustion engine for such emission ambitions. A typical setup for complying with the low emission levels is a diesel particulate filter (DPF) in combination with a selective catalytic reduction (SCR) system. Particle mass (PM) is considered as the total mass of particles per unit of air or per energy unit (e.g. kWh). It's not a single chemical compound but rather a complex mixture of solids and aerosols comprised of small liquid droplets and solid cores with liquid coatings under specific temperature conditions. Large sized particles have the biggest impact on the value for PM. Particle number represents the total number of particles per volume unit of air, here nanosized particles typically have the biggest impact. To ensure a proper SCR design, NH_3 slip is also regulated, not only for new systems but moreover at end of life when NH_3 slip is typically higher. This guarantees a fully functional SCR during the complete lifespan of the engine.

In Figure 1, different emission regulations are compared, including IMO Tier III and EU's Euro VI heavy duty on-road emission regulation for reference. The values are shown separately in Table 1 for clarity. For EPA, the limits are shown for 'category 2' engines (engines with a displacement between 7 and 30 liters). For EU Stage V, the inland waterway category for engine power above 300 kW is shown.

Besides specific limits for pollutants, the emission control strategy is a very important part of the certification. In the EPA certification process, a fundamental part of the submission is the so called AECD (Auxiliary Emission Control Device) reporting. According to EPA rules, the definition of AECD is: any element of design that senses temperature, speed, engine rpm, transmission gear, manifold vacuum, or any other parameter for the purpose of activating, modulating, delaying, or deactivating the operation of any part of the emission control system.

For the EU, even additional measures are required besides the 'regular' emission control system. According to EU rules, the emission control strategy is an element or a set of design elements incorporated into the overall design of an engine, or into non-road mobile machinery in which an engine is installed and used for controlling emissions. In addition to this a counter measure for defeat, strategy needs to be implemented. Defeat strategy stands for an emission control strategy that reduces the effectiveness of the emission control system under ambient or engine operating conditions encountered either during normal machine operation or outside the EU type approval test procedure.

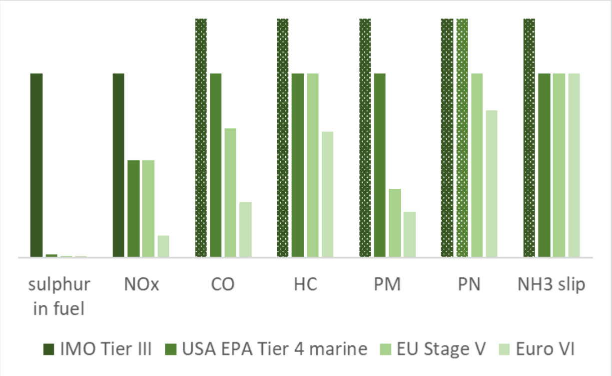

Figure 1: Emission regulation in comparison, the patterned area denotes that no limits are specified for the pollutant in the respective regulation.

Table 1: Emission limits as shown in Figure 1

	IMO Tier III	USA EPA Tier 4 marine	EU Stage V	Euro VI
Sulphur in fuel	1000 ppm	15 ppm	10 ppm	10 ppm
NOx	2-3.4 g/kWh	1.8 g/kWh	1.8 g/kWh	0.4 g/kWh
CO	not limited	5.0 g/kWh	3.5 g/kWh	1.5 g/kWh
HC	not limited	0.19 g/kWh	0.19 g/kWh	0.13 g/kWh
PM	not limited	0.04 g/kWh	0.15 g/kWh	0.10 g/kWh
PN	not limited	not limited	1×10^{12} #/kWh	8×10^{11} #/kWh
NH_3 slip	not limited	10 ppm	10 ppm	10 ppm

This paper is not intended to inform on the specific rules set forth in EU and EPA requirements, but it's clear to see is that for similar kinds of engines used in similar applications (marine vessels), the requirements for the emissions are on the same level. Moreover, the additional requirements ensure a good house father principle for both the engine manufacturer and the end user, making sure that the engine will comply with the emission levels it was certified for. Engine manufacturers are stimulated to step up and make a continuously performing engine and EAT system, complying with the emission standards.

While the abovementioned EU Stage V and EPA Tier 4 marine is covering inland shipping and - in case of EPA - also coastal shipping, international shipping is covered by the International Maritime Organization (IMO). Looking at IMO air pollutant regulation for seagoing vessels, only NOx emissions are regulated. The emission of sulfur oxides (SOx) is controlled by the sulfur cap in the fuel or by exhaust scrubbing technology. For the latter there is no international restriction on using open loop technology, thereby effectively shifting air pollutants to the sea.

In consequence, there have been activities to transfer either abovementioned more stringent regulations to specific areas governed by other authorities than the IMO exclusively, or to incentivize more ambitious emission profiles. Examples include Norwegian NO_X regulation, the Swedish harbor and fairway dues reduction program, but also the California Air Resource Board (CARB) harbor craft regulation or NO_X tax program in the Netherlands.

There also is a growing number of applications that want to go beyond required emission regulations on a voluntary basis. In those cases, owners want to align with more strict regulations like for example EU Stage V or even the heavy-duty on-road EURO VI emission levels. For marine markets, Bureau Veritas (BV) created a ULEV (Ultra Low Emission Vessel) notation that - amongst other measures - requires EU Stage V emissions levels for the installed engines.[3]

Even with the very strict requirements on engine emissions, some customers pioneer the way forward and request even lower NOx emissions. Euro VI NO_X emissions are requested to be achieved with medium speed engine setups.

While there is a wide consensus in the marine and large engine industry that a shift away from fossil fuels is desired, it should be clearly stated that when using low greenhouse gas footprints fuels, there will still be unavoidable exhaust emissions from their combustion. Hence, the abovementioned pollutant reduction regulation will remain relevant. Pollutants are likely to even grow in relevance, as many other combustion processes in our society will be replaced with less pollutant-forming technologies, while the hard to abate large engines are to persist. Thus, the presented exhaust gas aftertreatment technology presented for niche applications in this contribution could serve as a reference and a first impression of what to expect in the coming years.

1 OVERVIEW FIELD APPLICATIONS

1.1 Voltaire

In 2022 jack-up installation vessel Voltaire joined Jan De Nul's offshore fleet. At the time of delivery Voltaire was the world's largest jack-up installation vessel with a hoisting capacity up to 3200 ton. The vessel is equipped with four 12DZC engines with each a nominal power of 2.650 kW at 1000 rpm and four 16DZC engines with each a nominal power of 3.535 kW at 1000 rpm. All eight engines are equipped with both an SCR and DPF system.

The extensive exhaust after-treatment system allows Voltaire to comply with IMO Tier III and EU Stage V certification as well as with Bureau Veritas' Ultra Low Emission Vessel (ULEV) certification. With this voluntary notation Jan De Nul wishes to distinguish Voltaire and other vessels by demonstrating their commitment to environmental protection and performance. The ULEV emission limits are equal to the EU Stage V limits.

Figure 2: JDN jack-up installation vessel

1.2 Hydrotug

An extraordinary application where an EU Stage V emission system was installed on voluntary basis, is the Hydrotug. This tugboat operated by the Port of Antwerp-Bruges is powered by two ABC 12DZD dual fuel hydrogen engines, with a power of each 2.000 kW. This tugboat operates in the same port where inland waterway vessels have to comply with

EU Stage V, and close to the Antwerp city center where a LEZ (Low Emission Zone) applies for road traffic. Therefore, it makes perfect sense to equip the tug with an EU Stage V compliant emission system including SCR and DPF, although not required by the IMO, which would only mandate an SCR system to comply with IMO Tier III.

This, combined with the dual fuel hydrogen engines, the Hydrotug is a beacon for CO_2 neutral and clean shipping.

This comes not for free, however. Tugboats are very compact power houses and DPF systems take space. Additionally, hydrogen engines operate with a high air excess ratio, meaning they have a large exhaust gas flow compared to their power. Therefore, mainly the DPF has to be sized relatively big compared to diesel engines. For comparison, the aftertreatment size for these 2 MW hydrogen engines could fit a 3 MW diesel engine. In Figure 4 a size comparison of the aftertreatment compared to the engines and the tugboat is provided.

Next to the compact dimensions of a tug, also the load profile is rather atypical for marine applications. Tugboats use their full power only a very limited amount of time and have a lot of low load operation.

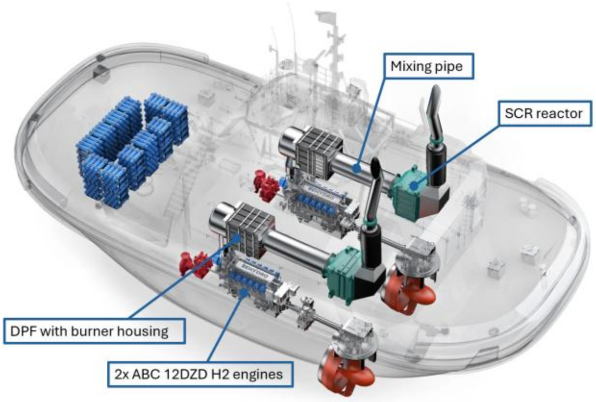

Figure 4: Hydrotug aftertreatment layout

This is now taken care of by the EATs, regardless whether the engines are in diesel or dual fuel mode. This specific load profile, in combination with hydrogen combustion, has some specific challenges for the aftertreatment. It is essential to maintain a sufficiently high temperature for SCR operation during low load, ensure adequate temperature in the particle filter for regeneration, and manage hydrogen combustion safely.

Figure 3: Hydrotug in front of the Port of Antwerp-Bruges port house. Note the soot-free exhaust pipes

1.3 Other applications

Next to the two applications above, other applications with ABC engines combined with Hug Engineering DPF+SCR systems include EU Stage V inland waterway vessels, EPA Tier IV dredging vessel, diesel and dual fuel powerplant engines, research vessels, etc. Currently only DZC engines (up to 4 MW) are in operation in the field with DPF systems, but also ships with D36 engines (up to 10.5 MW) with DPF technology are under construction.

2 IMPACT ON DESIGN AND OPERATION

2.1 Control software and anti-tampering

For EU regulations different anti-tampering functions are required. The rules are very clear in defining the boundary conditions for the functioning. An FMEA was performed to determine how well the system can handle manipulation. One could for example remove filter cassettes out of the DPF and create a passage for unfiltered exhaust gasses. The result of this would be that the system would not meet the requirements for PM and PN levels. For this reason, the DPF is equipped with a differential pressure sensor which does a comparative measurement of the differential pressure over DPF and SCR. In case the value falls below a minimum threshold an alarm will be generated indicating the system is being manipulated.

2.2 Backpressure

Since back pressure has a significant impact on the size and therefore also cost of a system, the target for the engine design is to allow higher back pressures. Before the introduction of aftertreatment systems, normal design backpressures were in the range of 25-30 mbar.

To minimize the volume of a DPF+SCR aftertreatment, a new limit of 100 mbar total backpressure has been set. This typically leaves 75 mbar for the EAT system alone. Soot and ash loading on the particle filter will increase backpressure, this is accounted for in the layout of the system and thus taken into account for the 75 mbar backpressure requirement.

This higher back pressure has an impact on the engine performance. By design, the DZ engine has a high air excess ratio. In addition, the turbocharger has a relatively low pressure ratio and has therefore a wide operating area where it has good efficiency. Additional back pressure will reduce the air flow and the turbocharger operating point, but because of the large margin there is still enough air to achieve complete combustion and the different operating point for the turbocharger is still efficient. Thanks to these effects, the negative impact on fuel consumption remains below 1%. The biggest impact is found on the exhaust temperatures and flow because of the exhaust flow reduction and therefore the exhaust temperature increases. An increase of 75°C per 100 mbar extra backpressure is normal.

This means typically more than 50°C increase in temperature compared to non DPF engines can be seen. This needs to be accounted for since temperatures are an important factor both for designing the DPF regeneration system and the SCR.

For Dual Fuel engines, and certainly hydrogen engines, the air excess ratio is much more important than for diesel engines. Specifically for hydrogen engines, high air excess ratios are used to avoid pre-ignition [4]. For this reason, the backpressure limit for the Hydrogtug engines is reduced to 75 mbar compared to the 100 mbar for a diesel engine. This means the system is bigger, but engine performance and hydrogen ratio are maximized. This can be tuned for each specific project depending on the customer's preferences.

2.3 Fuel optimization

As the existing NO_X regulation is also a constraint for engine design, in case an exhaust gas aftertreatment system is specifically designed for lowest emission profiles, prior tuning constraints can be lifted again. In consequence, fuel efficiency can be improved, compensating past concessions in engine tuning to be emission compliant. In Figure 5 the standard IMO Tier II emission tuning fuel consumption is compared with the preceding IMO Tier I, in-between engine measures were taken to comply with the lower NO_X limit of IMO Tier II. However, the EU Stage V emission tuning, with the engine being free in terms of raw NO_X emissions, is providing the best fuel efficiency, while reaching also lowest pollution levels, far beyond IMO Tier II. For further information we refer to previous CIMAC congress and MTZ contributions on the combined design of engine and aftertreatment systems [5] and [6].

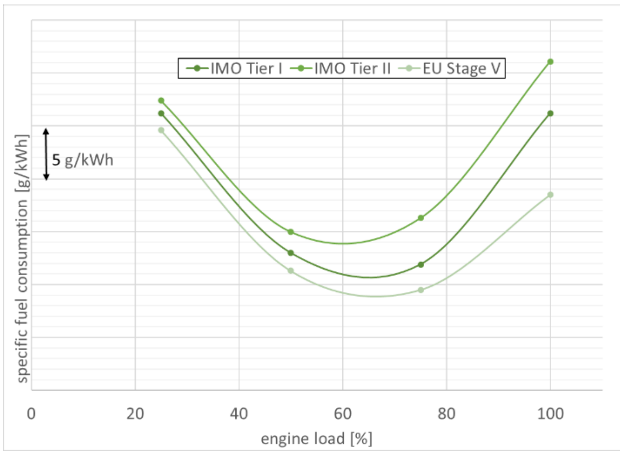

Figure 5: Fuel efficiency at ISO 8178 E3 test cycle points for different engine emission tunings.

2.4 Low ash oil

DPF systems regularly regenerate (burn) the soot cake which is collected in the filter. Regeneration does not remove the ash that accumulates in the DPF. Over time, this ash builds up in the filter channels, causing blockages and increasing backpressure. When this back pressure is too high, the filters need to be cleaned, which is a time-consuming job.

To increase this maintenance interval, the accumulation of ash should be limited. This ash has several sources: mainly fuel and lube oil consumed by the engine, and to lesser extend wear of metallic parts in the engine. Figure 6 shows the total collected mass compared to the amount of ash that remains after regeneration. If an application would use normal engine oil with a sulphated ash content of 1.6% and a lube oil consumption of 0.2 g/kWh in combination with using marine distillate fuel, about 40% of the ash originates from the fuel, and 60% ash finds it origin in oil consumption ending up in the exhaust.

This means it's important to limit the oil consumption. With reported values of 0.1-0.2 g/kWh in field operation, the oil consumption of the DZC engines is relatively low and even very low compared to medium speed standards. The graph below shows oil consumption values from two engines equipped with a ULEV system. Note that the fluctuating values can be due to slightly different sump levels at the moment of registration, however for a field recording over 5.000 operating hours, this is relatively stable.

To further limit the ash accumulation in the DPF, specific 'low SAPS' (low sulphated ash, phosphorus and sulphur) oils can be used. These oils are known from on road applications -where DPF's are standard- and have additive packages that contain less non burnable components; ash.

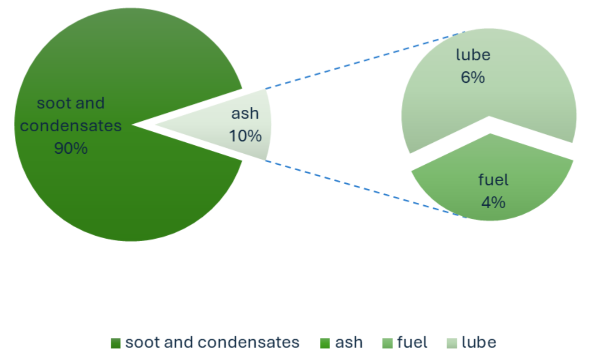

Figure 6: Composition of particle mass collected on the DPF, the ash remaining after regeneration is dominated by lubrication oil when using standard lubrication oil. (Assumptions: 1.6% sulphated ash lubrication oil, marine distillate fuel, 195 g/kWh BSFC and 0.2 g/kWh BSOC)

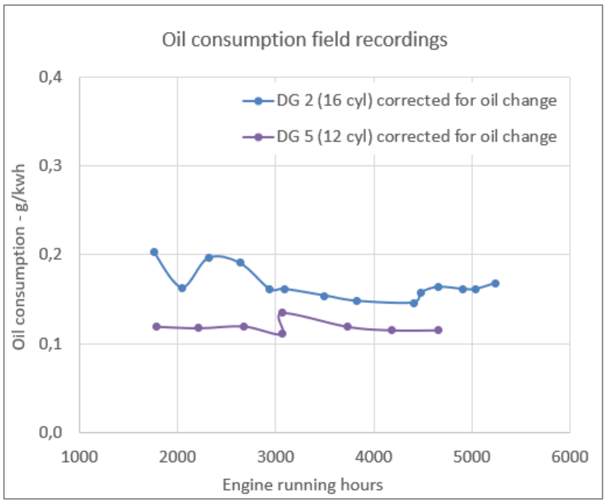

Figure 7: Oil consumption till 5.000 operating hours

Table 2 shows the ash content of a standard lubricant (Total Caprano Special Plus; 1.44) used for MGO operation without DPF, and two low SAPS oils used in combination with DPF.

Table 2: ash content and base number for different oils

Brand/Type	Ash content (%wt)	Base Number (mgKOH/g)
Total Caprano SP	1.44	11
Total TDK	0.99	10
Chevron HDAX 9700	0.7	5.8

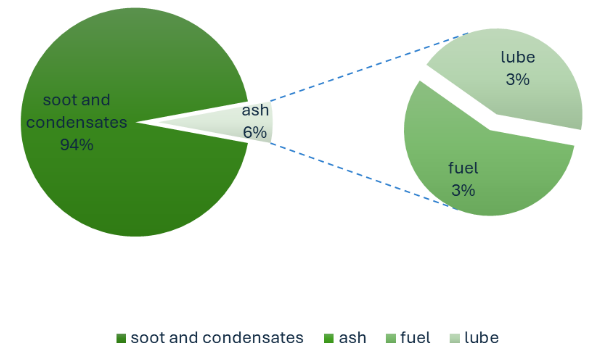

Figure 8: Composition of PM collected on the DPF, the ash remaining after regeneration is derived by approximately similar shares of fuel and lubrication oil when using a low SAPS oil (Assumptions: 0.7% sulphated ash lubrication oil, marine distillate fuel, 195 g/kWh BSFC and 0.25 g/kWh BSOC)

The use of these low SAPS oils is a quick win to limit the ash loading of the DPFs further. As can be seen in Figure 8, the total ash content is reduced from 10% to 6%. However, every rose has its thorn; the lower the ash content, the lower the ability to neutralize acids, mainly coming from the sulphur in the fuel. This ability to neutralize, is expressed in the Base Number mentioned above. Also other functions of the lubricant could be compromised, therefore in-house tests and field test are done with these low SAPS oils.

At Voltaire, engine components were inspected at approximately 3.000 and 5.000 running hours. The pictures below show piston and ring package are in good condition. Measurement of carbon deposit thickness of anti polishing ring, top land, ring gap and ring groove and ring and liner wear confirmed the good visual appearance.

Figure 9: inspection after operation on low SAPS oil.

Obviously also oil quality was monitored over this period. One of the important parameters, specifically for the low ash oil, is to monitor the remaining TBN. Below the evolution of the TBN over operation hours of two engines is shown. It's important to note engine 2 had a partial oil change at 3.000 h, engine 5 had no oil change until 5.000 h. Both engines use the same fuel with a sulphur percentage close to 0.1% and oil consumption is low and similar for both engines. The difference might be a result of a difference in load profile. This shows the importance of oil analysis.

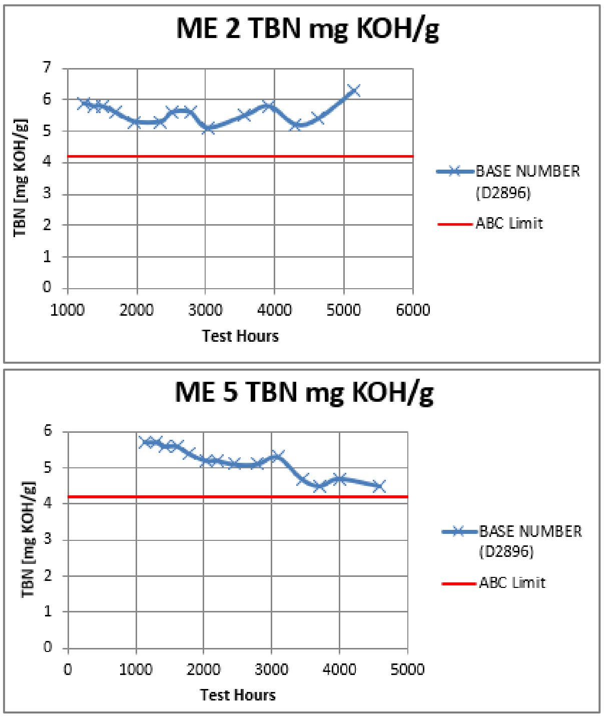

Figure 10: TBN of engine oil over test time

2.5 Regeneration

In the figure below one can clearly observe the differential pressure over the DPF and SCR changes in function of the engine load (due to the increase or decrease in exhaust mass flow).

In Figure *11* the differential pressure remains stable when the engine is running over a timespan of approximately 48h at a relative high load (and temperature). The system reaches an equilibrium where soot accumulates and burns off while guaranteeing a very high filtration efficiency. Two mechanisms can trigger an automatic regeneration; one being time-based and the second condition based on the differential pressure. A typical time-based regeneration takes place every 20 running hours. In cases where the conditions are favorable and the time between regeneration can be increased to 40 running hours. To have or create these favorable conditions, it is amongst others, important that exhaust temperature is sufficiently high. Reducing the number of regeneration cycles is favorable because fuel for the exhaust burners can be saved, and the system has less thermal cycles. It is therefore important to take the operational profile of the engines into account in the design and the operation of the vessel. Mainly measures to limit very long periods with low load operation can reduce operation cost, however is no requirement to remain emission compliant. In this case the condition based mechanism kicks into action and triggers a regeneration more frequent than the time based regeneration.

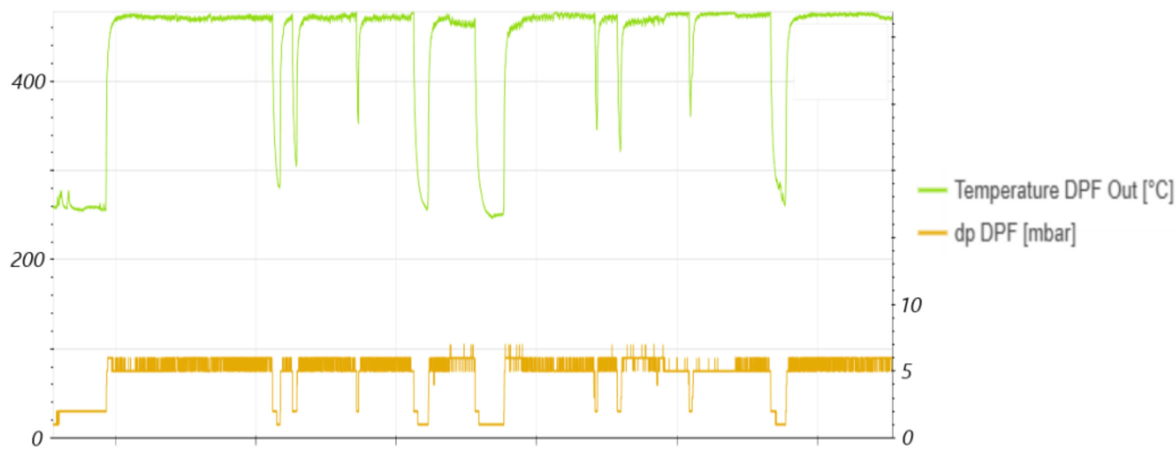

Figure 11: Normal operation without regeneration cycle over 48 hours.

3 EMISSION PERFORMANCE

3.1 Long duration test

A part of both the EU and EPA certification application is deterioration of the engine emissions throughout its useful life. This is taken into account via deterioration factors for each regulated pollutant. Meaning that besides making sure that an engine meets the emission requirements one also needs to take into account deterioration factors for every pollutant. EU legislation allows for assigned values to be used. The EPA requires engines to accumulate a minimum number of running hours, which can be less than their useful lifetime. However, the duration test must accurately represent engine operation. Real load profiles of different applications serve to determine a representative test plan for the engine to run. A full-scale setup is installed in a test cell and can be seen in Figure *12*. an 8DZC engine providing 2.000 kW at 1000 rpm is generating electrical power equipped with an EAT system consisting of a DPF and SCR ran for 2.501 hrs.

During this duration test three emission measurements were conducted. One at the beginning, one halfway through and one at the end of the test. Based on these three measurements a linear extrapolation can be done to determine deterioration factors. During every emission measurement the three common test cycles D2, E2 and E3 according to ISO 8178 are measured.

In this paper the D2 cycle is used as reference cycle to plot the results of each pollutant. The measurements of the two other cycles showed the exact same trend. HC emissions of a regular diesel engine are relatively low. A combination of a diesel engine and an advanced aftertreatment system results in a very low HC emission as can be seen in Figure *13*. The measured value is far below the allowable limit and indicates a decreasing value over time. The same can be seen for the CO emission. The measured values are below the threshold values and display a decreasing value over time. The NOx value is relatively stable as the control system actively monitors and regulates the dosing amount resulting in a stable NOx output. The filtration efficiency of the DPF increases over time as ash and soot accumulate in the filter. This will of course reach some kind of equilibrium after proper degreening of the system is done. Hereafter the system will perform in a stable manner. Figure *13* shows this higher PM emission of a “green” system and lower PM emission from a degreened system.

Also NH_3 and dinitrogen oxide (N_2O) were measured. The measured values in Table 3 show very low values for both NH_3 and N_2O after 2.501 running hours. The target for EPA and EU legislation is to not exceed 10 ppm ammonia slip at end of life. N_2O is not regulated but is requested to be recorded. Some regulations such as CARB have an even lower threshold for NH_3 of 5 ppm which is also met with the current setup.

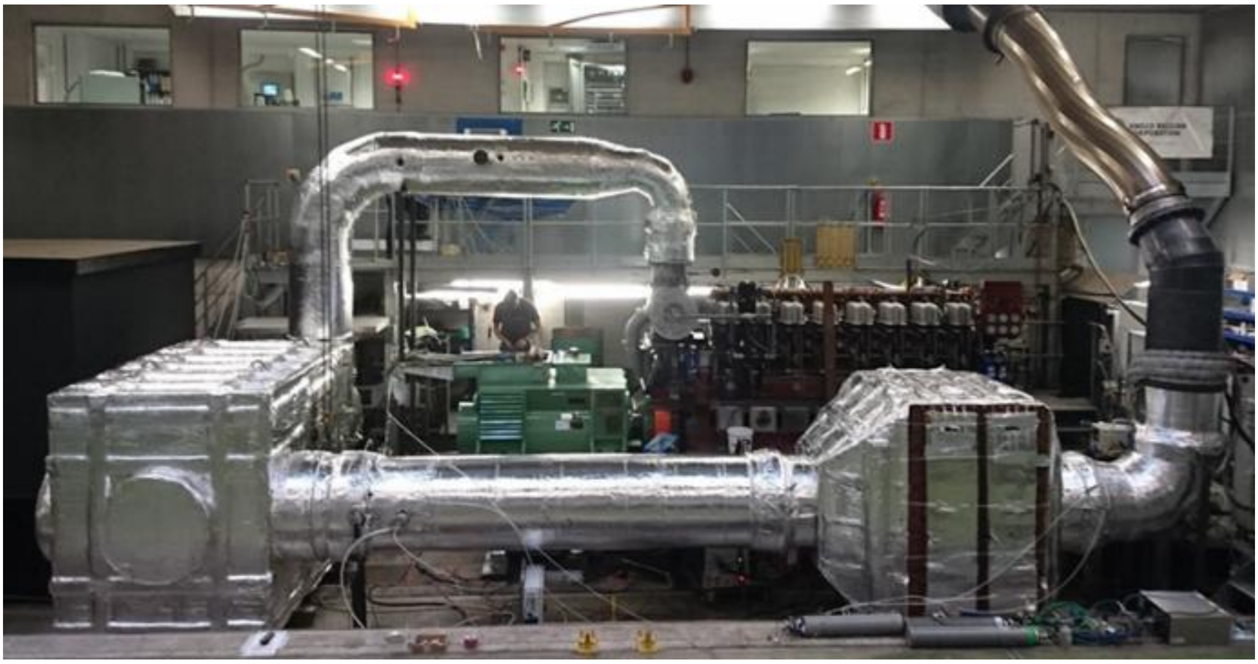

Figure 12: Test setup with an 8DZC engine, DPF, SCR and backpressure flap

Figure 13: HC, NO_X, CO and PM emissions measured during start, mid and end of test.

Table 3: N_2O and NH_3 emissions for E2/E3/D2 cycle

	E2	D2	E3
N_2O [ppm]	0.5	0.5	0.5
NH_3 [ppm]	1.6	2.8	0.96

3.2 Voltaire on board measurements

At Voltaire, next to the the low SAPS oil inspection, also the DPF performance was evaluated. Just like the engines, also the particle filters were exposed to around 5.000 hours of operation. Due to the low lube oil consumption and low sulphated ash content, the backpressure over the DPF remained clearly within requirements even after 6.000 hours of operation without need for ash maintenance.

As the vessel is equipped with an engine load management system, particle number measurements at 90% engine load could be performed onboard, results for engines number 5 (after 5.000 hours of operation) and for number 8 (after 6.000 hours of operation) are presented in Figure 14.

Also black carbon emissions were measured in the field, at engine number 3 and 6 during 90% engine load. Black Carbon emissions below 0.0005 g/kWh were recorded, in line with previous measurements downstream of particle filters.[7]

Figure 14: particle number emissions measured in the field at 90% engine load on engine numbers 5 and 8 after 5.000 and 6.000 hours of operation respectively.

4 OUTLOOK

In order to enable the widespread adoption of the presented low emission solutions, efforts intensified to reduce the footprint of the exhaust gas aftertreatment system. The collaboration between engine design and aftertreatment system layout is essential in order to optimize the total system – not only in terms of footprint, but also with regard to operational costs as mentioned above. Thanks to field experience with diverse applications, several ideas for next generation DPF aftertreatment are identified and are in development. This will result in more compact, cost-effective and even more performant systems.

Compared to other emission reduction technologies, DPF+SCR systems already outperform solutions using EGR (exhaust gas recirculation) and are at least equivalent to dual fuel gas engines [6]. Knowing DPF's are always 'on'; also at low load, also during transient behavior, also in diesel-mode, they are a robust solution guarantying compliance beyond current legislation.

5 CONCLUSIONS

Exhaust aftertreatment systems with particle filters reduce emissions effectively, both during lab tests and in in real life applications in the field (where conditions are not always ideal). The same aftertreatment setup is suitable for a broad variation of applications. Not only can different emission requirements be met; ranging from EPA Tier 4, EU Stage V or voluntary notations like ULEV. Diverse engines ranging from regular diesel engines to hydrogen dual fuel engines are emitting record low emission levels thanks to the same aftertreatment system as well. This is being demonstrated by several customers. Thanks to proper layout, optimal engine configuration, low oil consumption and low SAPS oil, intelligent power management, service intervals can be extended so that operational impact is minimized.

The systems operate with minimal impact on the operations, and on top they remain beyond emission compliant over time. Emissions after 6.000 hours of operation are still with significant margin below the current most strict EU Stage V limits. This demonstrates the future-proofness of the layout. With this concept, emission levels are in line with the on-road EURO IV emission limits can be reached.

Although all these emission requirements can be met with the same system, there are many other requirements in terms of control software and emission compliance demonstration. This makes it more complicated than necessary; a worldwide homogeneous approach would reduce the cost and effort of certification. That will on its term improve market take-up and thus improve air quality and societal acceptance of large engine applications.

ABC has successfully deployed engines equipped with Hug Engineering DPF systems with a combined mechanical power of 34.279 kW. Assuming these engines operate for 6.000 hours per year at an average of 75% of their nominal load, the DPF systems collectively prevent the emission of nearly four tons of particulate matter (PM) annually. This demonstrates the significant environmental benefit of integrating DPF technology, thus reducing air pollution from diesel engine operations.

In the coming year alone, several ABC engines with more than 60 MW in total will be installed and equipped with Hug Engineering particle filters. This increasing number of - mostly voluntarily - installed particle filters underlines the ambition of our customers to invest in clean and sustainable solutions. This combined with ABC's carbon neutral biofuel, methanol and hydrogen engines, makes the large engine business not hard to abate. We make it easy as ABC.

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