marine products

HDAX 9700: enabling the future of fuel flexibility

As the focus on dual-fuel engine technology continues to grow, Chevron Marine Products (CMP) brought a team of experts together to create an oil that could be used with both gaseous fuels, such as liquefied natural gas, and low sulphur liquid fuels, such as distillate and biofuels, without the need to match one oil to one fuel.

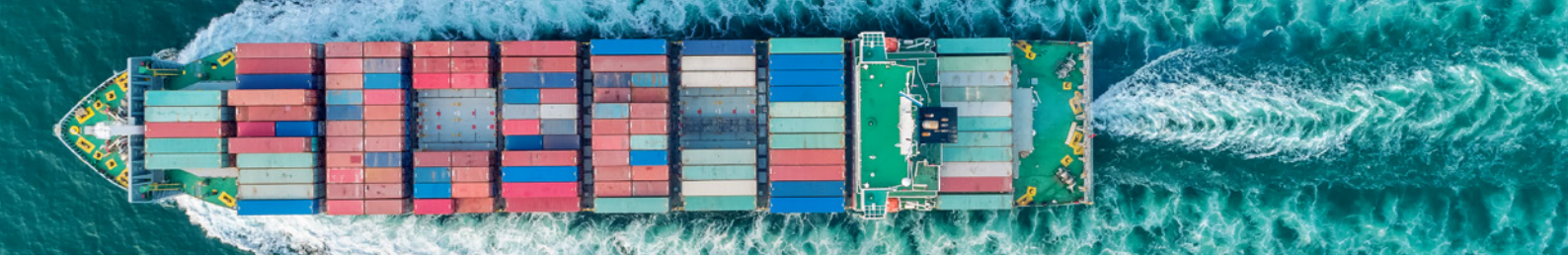
The result is a lubricating oil for engine operators in their energy transition journey helping contribute towards a lower carbon future and the lowering of vessel emissions.

Significantly, the new oil, HDAX 9700®, has also recently secured approval after extensive field testing from leading manufacturer MAN Energy Solutions for use with its four-stroke engines running on either Liquefied Natural Gas or distillate fuels with a sulphur content of up to 1,000 parts per million (0.10%).

Furthermore, HDAX 9700 has also proved its suitability for use with dual-fuel engines, having successfully completed testing on a Wärtsilä dual-fuel engine.

New lubricant oil brings host of benefits for four-stroke engines

Chevron Marine Products' HDAX 9700 is a versatile engine oil recommended for dual-fuel, medium-speed, four-stroke cycle, trunk piston engines that alternate between burning natural gas, with diesel pilot fuel ignition, and up to 100% low sulphur fuels (<1000 ppm sulphur).



HDAX 9700, which has proven field service experience, is recommended for engines in vessels operating in several marine applications, such as coastal and inland marine, but is also suitable for commercial sectors such as railroad and power generation. These high output engines may be turbocharged and equipped with exhaust catalyst systems.

Speaking about the development of the project, Luc Verbeeke, senior staff engineer, Chevron Marine Products, said: "At Chevron we recognised that dual-fuel engine technology was gaining traction as emissions regulations and alternative fuels discussions were developing. We worked to develop an optimised engine oil that could be used with multiple fuels without the need to specifically match one oil to one fuel, be it diesel, natural gas, LNG, compressed ntural gas (CNG) or biofuel."

Typical characteristics

MPID	219911
Density at 15°C, kg/l	0.87
Kinematic viscosity at 40°C, mm^2/s	117.0
Kinematic viscosity at 100°C, mm^2/s	13.4
Viscosity index	110
Pour point, °C	–36
Flash point COC, °C	268
Total base number, mg KOH/g	5.8
Sulfated ash, %wt	0.7

Typical characteristics of Chevron Marine Lubricants' HDAX 9700 oil.

Chevron's dual-fuel project

HDAX 9700 is the culmination of Chevron's long-standing experience and knowledge of lubricant development and understanding of customer needs in changing fuel landscapes. The project was spurred by global emissions reduction regulations that have driven the growing use of diesel particulate filters (DPF) and natural gas in applications which could benefit from HDAX 9700. HDAX 9700 was created to provide a solution for engines that run on multiple liquid and gaseous fuels and applications that require a low sulphated ash lubricant.

It had been expected that end users in a number of sectors would increasingly switch from traditional liquid fuels such as heavy fuel oil (HFO), marine diesel oil (MDO), and high- and low-sulphur diesel fuel to natural gas — both LNG and CNG — and combinations of both. In response to this fuel switching, and its consequent demand from customers for fuel source flexibility, engine manufacturers invested in new technology options such as dual-fuel engines that could operate on either gaseous or liquid fuels, but the need for lubrication solutions for the new operating conditions needed to be addressed.

This inspired a research project that involved a literature review of dual-fuel-related knowledge, followed by formulating guidance, engaging with key OEMs, benchmarking with lab and engine tests, and, finally, screening potential oils. HDAX 9700 was the result.

The project was led by Luc Verbeeke on the marine and powergen side and Melanie Tobias, currently product development engineer for powergen on the marine and powergen team focused on stationary gas engine oils, railroad, inland marine and dual-fuel engines.

HDAX 9700 development focused on the dual-fuel engine technology that was anticipated to come into the marketplace across a number of sectors, including marine (cargo ships, tankers, workboats, ferries, coastal and cruise vessels), along with power generation, inland marine (using rail and non-rail derived engines), oil and gas (drill rigs, fracking) and mining. It is suitable for DPFs due to its low sulphated level.

Advantages for ship operators

- **Fuel flexibility** brings advantages for ship operators in multiple sectors, particularly in marine where cargo such as LNG can be used to power engines.

- **Versatility** is a key feature of the oil's capabilities. It is suitable for use with a wide range of fuels which allows vessel operators to switch from gas to diesel without the requirement to change oil.

- **Hybrid technology** controls ash accumulation in combustion chambers. This helps minimize the risk of pre-ignition and the rough engine operation that may be associated with engine misfire and detonation. It is suitable for DPFs due to its low sulphated level.

- **Excellent oxidation and nitration resistance,** with a strong alkaline reserve that has the ability to help protect against the effects of acidic attack and oxidation, significantly prolonging the service life of the oil.

- **Very low combustion chamber and piston deposits** help to protect the liners from scoring and extend top-end maintenance cycles.

Case study: HDAX 9700 operating with pure biofuel

Following collaborative discussions, a two-year study enabled Chevron to assess how HDAX 9700 reacted with distillate fuels and B100 biofuels 100% biofuel, or FAME) in a medium speed engine, with a particular focus on after-treatment systems such as selective catalytic reduction (SCR) systems and DPFs.

Because HDAX 9700 has a low sulphated ash (SASH) level of 0.7% — lower than is typically found in a marine oil — the trials were expected to demonstrate good outcomes for those systems. The oil is designed for use with distillate fuels of up to 1,000 ppm sulphur and gaseous fuels. For this case study, a B100 biofuel was used for 6,500 hours continuous operation.

The field trial was performed on a diesel electric vessel, powered by three MAN 8L27/38 engines with a Maximum Continuous Rating (MCR) of 2,640 kw at 750 rpm. Engine one was selected as the test case, however all three engines were operated under similar conditions with the same lubricant type and fuel used.

The engines were equipped with exhaust gas aftertreatment systems; passive SCR first followed by an active DPF. The engines ran under the same conditions, although only one was monitored.

At the start of the test programme, the test engine had already generated about 5,500 running hours since new. After changing to the low sulphated ash test oil, the test engine was monitored as a baseline on distillate fuel (DMA and EN590) for approximately one year (6,500 hours operation), followed by another similar period of approximately one year on 100% biofuel. The engine was changed back to EN590 distillate fuel operation several weeks before the piston on B100 operation could be pulled for inspection.

The impact of new generation low ash lubricant

The investigation was focused on looking at the impact of a new generation low ash (0.7% SASH) lubricant for dual-fuel and exhaust gas aftertreatment operation, that is formulated to cope with gaseous and liquid fuels containing up to 1000ppm sulphur, while keeping the oil's SASH level within the low sulphated ash, phosphorus and sulphur (SAPS) requirements from the exhaust aftertreatment manufacturer.

The biodiesel test showed no negative effects on engine performance or after-treatment systems.

New pistons, piston rings, anti-polishing rings (APRs) and liners were then installed and the engine was monitored for 6,500 hours — about a year — while burning distillate fuel that met DMA and EN590 specifications.

Oil samples were taken at frequent intervals during the trial but the oil was not changed at any time during the trial's combined 12,553 running hours, although it was topped up as necessary.

During that period, HDAX 9700 showed little change. Its density at the end was only slightly different from its value at the start and its base number fell slightly although it remained well within the engine OEM's allowable limits and there was no obvious impact due to the distillate fuel's higher sulphur content, compared to the biofuel.

In order to meet emission regulations many engines require aftertreatment devices such as SCR and DPFs. Exhaust aftertreatment manufacturers require oils with lower levels of sulphated ash, phosphorus and sulphur. Failure to use the right oil can cause plugging or poisoning degradation. The industry, not unexpectedly, was concerned that there was not going to be enough ash containing components to provide sufficient alkalinity to protect against acidic corrosion. After CMP successfully validated the low sulphated ash engine oil with distillate fuel they approved its use for distillate fuels up to 0.10% sulphur and LNG.

The biodiesel test proved no negative effects on engine performance or after-treatment systems. Except for viscosity loss during biofuel operation, all other used oil analyses remained well within engine manufacturer's and within allowable limits at all times.

The recording and monitoring of the impact on used oil and oil consumption and oil analysis

Impact on used oil consumption
The oil consumption was accurately recorded during the entire monitoring programme. Significant differences in oil consumption were noticed among the three engines installed, nevertheless all were within the engine manufacturer's specification. No significant difference could be observed related to the use of different fuel types (Figure 9).

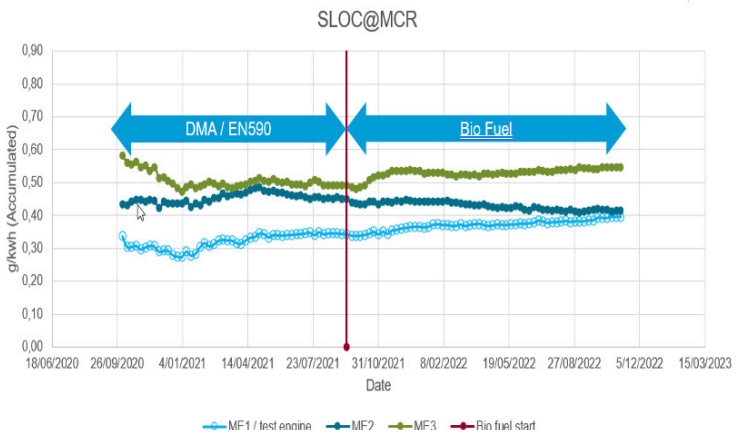
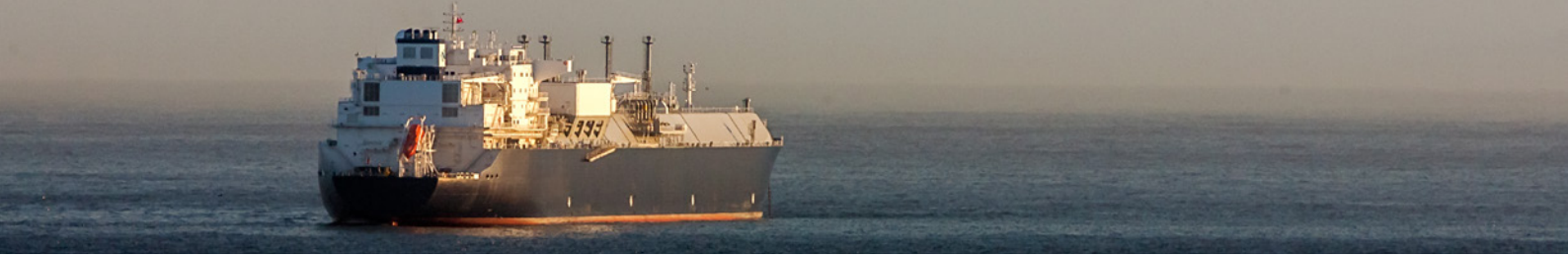


Figure 9: Oil consumption

		Start Test	End Test Distillate Fuel	End Test Bio Fuel
Date Sampled (MM/DD/YYYY)		01/10/2020	16/09/2021	07/11/2022
Engine designation		ME1	ME1	ME1
Engine hours		5500	11997	18105
Oil hours		0	6445	12553
Test	Method			
KIN. VISCOSITY @ 40C (ASTM D445); Cst	VISC_AUTO_142	120,9	121,5	116
KIN. VISCOSITY @ 100C (ASTM D445); Cst	VISC_AUTO_144	13,5	13,85	13,39
VISCOSITY INDEX (D2270)		108	112	112
Flash Point, "COC" °C (ASTM D92),	FLASH_110	268	260	256
BASE NUMBER (D2896)	TBN_185	6,2	5,1	5,5
DENSITY 15 °C, KG/L (ASTM D4052)	DENSITY_DE15	0,8775	0,8792	0,8778
OXIDATION abs/cm (IR)	FTIR_FTIRT	0,1	4,9	5,5
NITRATION abs/cm (IR)	FTIR_FTIRT	0,0	0,5	0,5

Impact on used oil analysis
The used oil condition was monitored at frequent intervals throughout the test programme. The table below compares some key parameters at the start of the test compared to at the end of the distillate fuel test, and furthermore at the end of the biofuel testing programme. The oil bath was not changed throughout the programme.



Except for some [more] viscosity loss during the biofuel operation, all parameters remained within a similar range. All wear elements (not shown) remained unchanged and BN or alkaline reserve remained well within the allowable limits from the engine manufacturer, with no apparent impact due to the higher sulphur content of the distillate fuel, compared to the biofuel. The different fuel types have a similar impact on oxidation and nitration of the used oil.

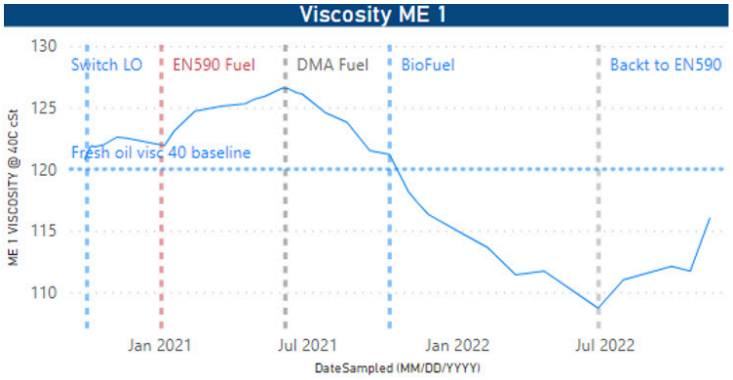


Figure 10: Impact on lubricant viscosity using different fuel types

The only significant difference observed is the impact of the different fuel types used on the viscosity of the lubricant (Figure 10). Figure 10 shows that the biofuel causes the lubricant to lose viscosity, some differences in viscosity behavior can be observed using the two types of distillate fuels EN590 versus DMA type marine diesel. The viscosity of the lubricant remains stable when operating on the more traditional DMA marine fuel, while operation on EN590, shows a thickening of the lubricant.

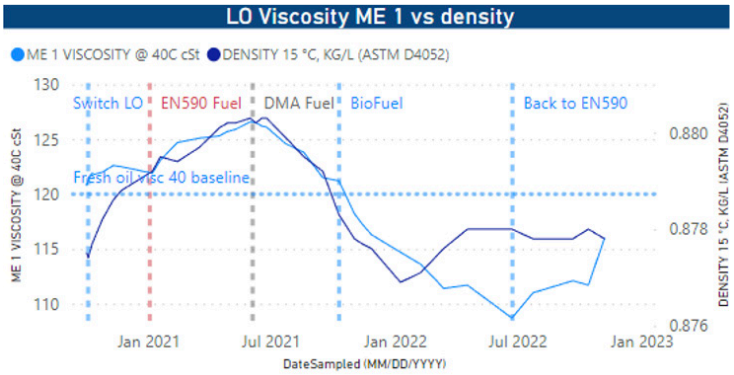


Figure 11: Relation between lubricant viscosity and used lubricant density.

In Figure 11 we see the relationship between the lubricant density impact of the used lubricant, following a similar trend as the lubricant viscosity.

This phenomenon does not seem to be related to pure fuel ingress in the lubricant, as demonstrated in Figure 12, as the density of fuels used do not follow this trend. The lower density of the EN590 fuels show more thickening compared to the higher density DMA type fuels used.

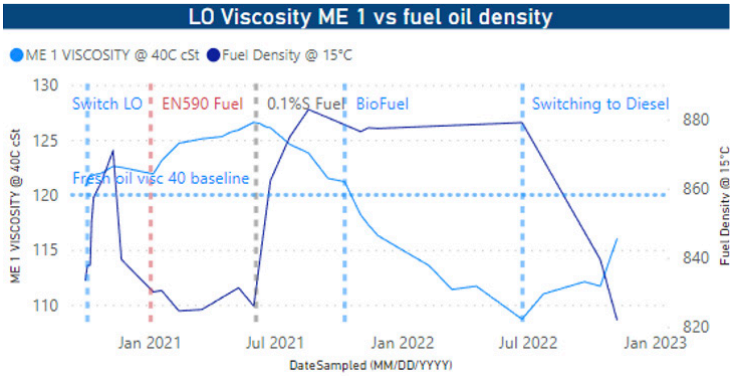


Figure 12: Relation on lubricant viscosity and fuel density.

Looking at the distillation curves (Figure 13) of the various fuels, the distillate fuels have a wider range, due to the blend with various feedstocks. The B100 has a very narrow bandwidth as this is only composed from esters. Evaporation of some lighter fractions while encountering some fuel leakage in the engine crankcase oil could contribute to this phenomenon.

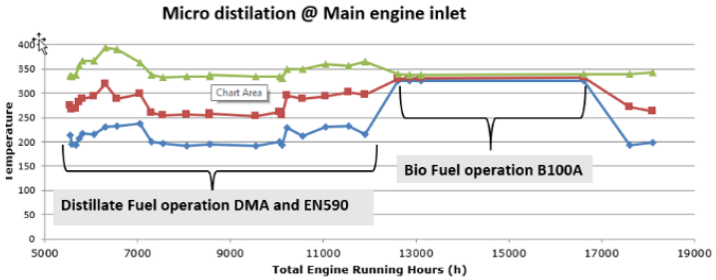


Figure 13: Distillation profile of fuels used.

		Start Test	End Test Distillate Fuel	End Test Bio Fuel
Date Sampled (MM/DD/YYYY)		01/10/2020	16/09/2021	07/11/2022
Engine designation		ME1	ME1	ME1
Engine hours		5500	11997	18105
Oil hours		0	6445	12553
Test	**Method**			
KIN. VISCOSITY @ 40C (ASTM D445): Cst	*VISC_AUTO_142*	120,9	121,5	116
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VISCOSITY INDEX (D2270)		108	112	112
Flash Point, "COC" °C (ASTM D92),	*FLASH_110*	268	260	256
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DENSITY 15 °C, KG/L (ASTM D4052)	*DENSITY_DE15*	0,8775	0,8792	0,8778
OXIDATION abs/cm (IR)	*FTIR_FTIRT*	0,1	4,9	5,5
NITRATION abs/cm (IR)	*FTIR_FTIRT*	0,0	0,5	0,5

Further work is required to quantify fuel dilution from various fuel sources and impact on engine lubrication oil is required.

Viscosity was the only parameter that showed a significant difference as a result of the different fuel types used, as shown in Figure 15.

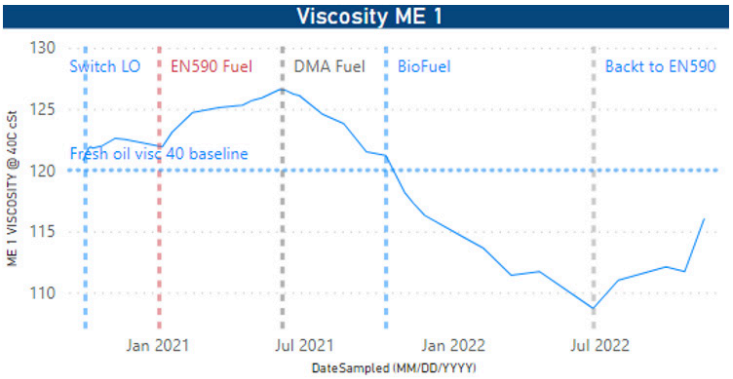


Figure 15: Viscosity differences.

Case study: How HDAX 9700 secured MAN approval

Chevron low sulphated ash trunk piston engine oil, HDAX 9700, is a versatile oil that has been approved by MAN Energy Solutions for use with its four-stroke engines running on either LNG or distillate fuels with a sulphur content of up to 1,000 ppm (0.10%).

The letter issued by MAN ES grants its approval based on the successful completion of its “Testing Procedure for Engine Lubricating Oil Approval”, declaring it to be suitable “for dual-fuel engines in distillate fuel operation, gas operation and engines with alternating natural gas and distillate fuel operation.”

First of a kind approval offering simplicity for operators

Other lubricants go through validation testing on engines running on either gas or distillate fuels and are granted limited approval for the other fuel so this approval was the first of its kind and offers simplicity for operators

switching between the two fuels. They can use just one lubricant, rather than having to change lubricants after a fixed period operating on one fuel or the other.

Chevron, in cooperation with MAN Energy Solution, conducted tests on Luxembourg dredging and offshore operator Jan De Nul Group's trailing suction hopper dredger and ultra-low emission vessel *Sanderus*, which uses low-sulphur diesel fuel and is fitted with an exhaust filter that enables it to be termed an ultra-low emission vessel.

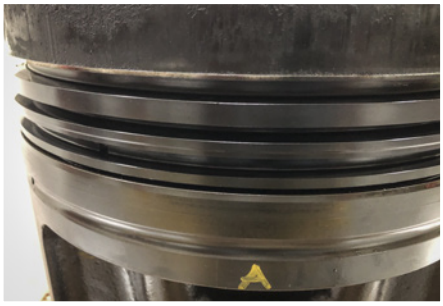
It was an ideal testbed, since the company required an engine oil with a very low sulphated ash formulation due to the use of a variety of low sulphur fuels (below 0.10% sulphur) with SCR and DPF, as part of its strategy to comply with European Stage V limits on nitrous oxides (NOx) and particulate matter (PM) emissions from ships. That test covered 6,500 running hours, after which approval for its use with distillate fuels was granted and because low sulphated ash oils are commonly used with gas engines — which are also sensitive to sulphated ash deposits — MAN ES was able to grant approval for the lubricant to be used not only with LNG but also with distillate fuel.

This resulted in a valuable step forward for ship operators using either LNG or distillate fuels. It gives them the ability to use single engine oil for four-stroke engine operations, which simplifies their operations. In Jan de Nul's case, it has subsequently used the lubricant on further dredgers, along with jack-up vessels used in windfarm construction.

However, HDAX 9700 has also proved that its use is not suitable solely for engines running on either LNG or distillate fuels with a sulphur content of up to 1,000 ppm (0.10%). It has wider availability.

HDAX 9700 has also successfully completed 20,000+ test hours on a Wärtsilä 34 dual-fuel engine.

This test is significant as it also proves the versatility of the lubricating oil for operators of dual-fuel engines in the marine sector as well as engines using both gaseous fuels, such as Liquefied Natural Gas, and low sulphur liquid fuels, such as distillate and biofuels.



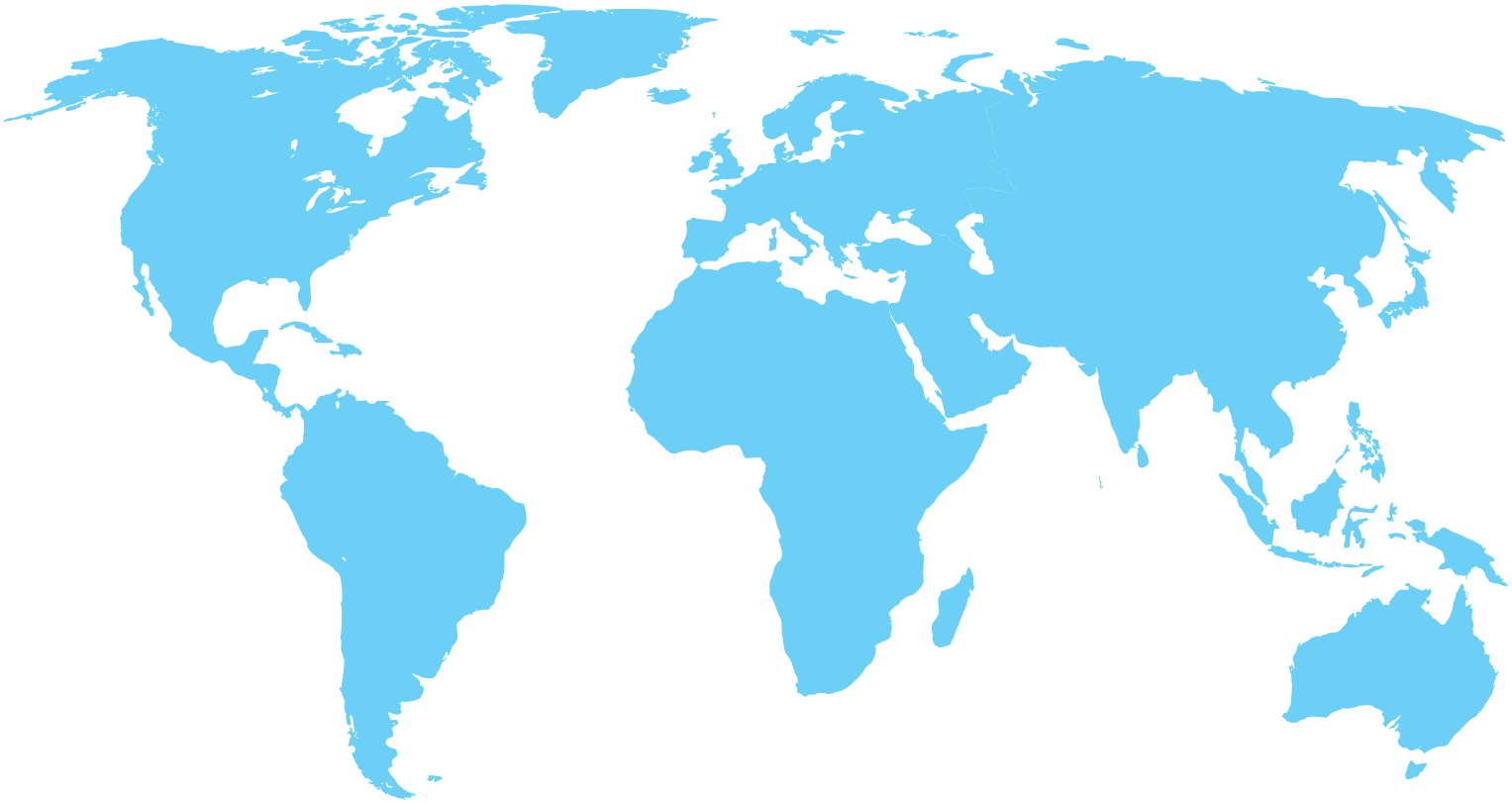
Wärtsilä 34 dual-fuel engine test cylinder

Summary of findings

Versatility is a key feature of this oil, it enables vessel operators to switch from gas to low sulphur diesel and biofuels, without the need to change lubricant. With HDAX 9700, ship operators can benefit from fuel flexibility in their four-stroke, medium speed engines.

Chevron HDAX 9700 has become the first lubricant to gain time-unrestricted approval for use with MAN Energy Solutions' four-stroke engines running on either LNG or distillate fuels (with a sulphur content of up to 0.10%). Furthermore, HDAX 9700 has also proved its suitability for use with dual-fuel engines having successfully completed testing on a Wärtsilä dual-fuel engine. The oil is proven beneficial in use when using exhaust gas aftertreatment systems such as DPFs requiring a low sulphated lubricant.

The hybrid technology controls ash accumulation in combustion chambers to minimise the risk of pre-ignition and the rough engine operation that can be linked to engine misfire and detonation. The oil has good oxidation and nitration resistance, with a strong alkaline reserve that has the ability to protect against the effects of acidic attack and oxidation, significantly prolonging the service life of the oil. Very low combustion chamber and piston deposits help protect the liners from scoring and extend top-end maintenance cycles. HDAX 9700 is the choice for operators looking for engine efficiency, and fuel flexibility.



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