innospec

TECHNICAL BULLETIN

Customer Technical Service

VLSFO REPORT- Q1 2020

It has been an unpredictable start to the year. We have seen marine fuel prices in flux, concerns over VLSFO availability and VLSFO pricing even exceeded that of MGO. Demand for MGO has exceeded some estimates and the reason could be that VLSFO and MGO prices are closer than expected, while VLSFO supply has not always matched demand in all ports and a spike in incidents on vessels using VLSFO has caused many to switch to MGO to mitigate that risk.

Many expected there would be issues with VLSFO as the switch happened quickly and put pressure on refiners/blenders to produce an affordable, low sulphur marine fuel from often incompatible components.

Because of this, each VLSFO bunkering can be different depending on geographical location, plant capability and component availability. In simple terms, low sulphur fuel can be made by diluting high sulphur residual streams with lower sulphur light fractions, but the problem is that these streams are structurally dissimilar and separate given enough time, temperature or comingling. In more complex blends, marine fuel may have been through multiple refinery processes that strip a great deal of the natural stability and quality away from the oil, resulting in the operability and performance issues we are seeing today.

VLSFO FAULT DISTRIBUTION

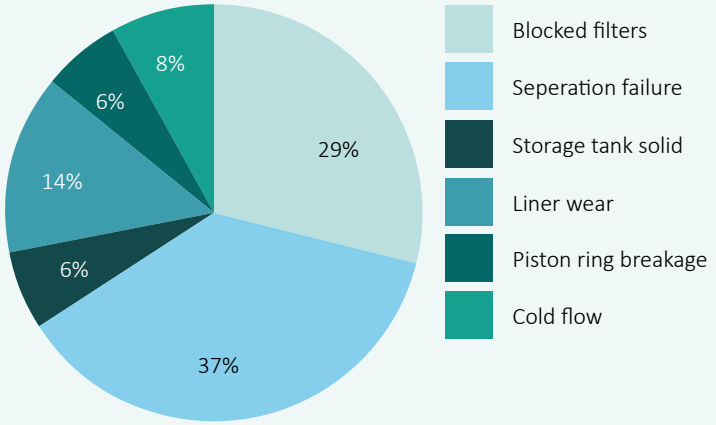


Figure 1. The frequency of incidents experienced by vessels using VLSFO in Q1 2020: 72% of cases are related to unstable fuel; 20% to poor combustion; & 8% due to cold flow

In this paper we will discuss the issues reported by vessels from around the globe in Q1 of 2020. We will explore why they are happening and what the marine community can do to prevent them going into Q2 and beyond. Innospec joins the chorus of marine fuel test laboratories and ship operators who are reporting increased performance issues when using VLSFO, including the worrying trend in liner wear and piston ring breakages. Figure 1 shows the distribution of incidents reported to Innospec in Q1 2020.

The global picture

Total Sediment results

Regular bunker alerts from ports such as Rotterdam and Singapore through Q1 show that there are still some teething issues with VLSFO. Many expected to see this as suppliers used unfamiliar blends to achieve lower sulphur levels while continuing to include residual streams. Total Sediment by hot filtration is the ISO8217 method for stability in marine residual fuels, it essentially involves stressing a fuel (either chemically (TSA) or by heating (TSP)) before filtering it through a fine filter, and measuring the residue remaining to give an indication of a fuel's ability to remain stable.

More concerning is the number of cases where operability issues were experienced when Total Sediment testing indicated no risk to the vessel at all.

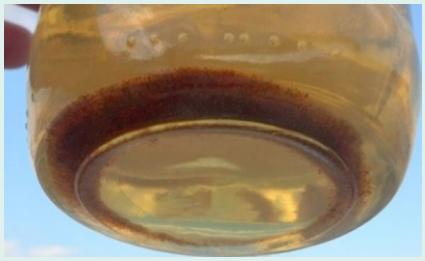
If Total Sediment is good, why is my fuel still unstable?

As mentioned before, the shipping community is reporting multiple cases of significant sludge drop out on-board where Total Sediment results are good. In the worse cases, entire storage tanks have been rendered unusable while in most cases blocked fuel lines and Purification issues have increased the risk to crew and ship.

Distillate ageing is an important part of the puzzle. The percentage of distillate blend components in VLSFO has increased significantly over HSFO, these distillates often come from complex secondary refinery streams where much of the natural stability has been removed or weakened.

Distillate ageing is a chemical process that produces sludge in the presence of elevated temperature, oxygen or by a catalyst present in the fuel (from inorganic material such as metal). These processes can be prevented but not reversed with the use of additive.

Innospec is the only chemical additive company with a proven history of preventing these issues.



Sediments: Hard oxidation product, sand-like insoluble, accelerated by increased temperatures, storage time and comingling.

Gums: Sticky oxidation product (Adherent insoluble). Become impregnated with inorganics (metals, cat fines etc.) and act like a grinding paste on surfaces.

Polymers: A highly reactive chemical process which rapidly forms large structures that are difficult if not impossible to reverse once formed.

Wax formation in VLSFO

Long chain paraffins present in many fractions of VLSFO are responsible for wax formation in fuels. These waxy elements must be heated to prevent them transforming into large waxy crystals that drop out of solution, blocking tanks, filters and purifiers at low temperatures. Fuel test laboratories have recognised this issue and developed Wax Appearance Temperature (WAT) test method (amongst others) to establish at what temperature VLSFO starts to produce wax crystals, in essence a cloud point.

The advice for preventing wax drop out is to maintain temperatures 15°C above Pour Point (PP) during handling and separation. Most vessels have heating capabilities on-board, however still experience wax blockages at purifiers as the wax is removed during separation.

In conclusion, we are seeing; fouling in purifiers due to distillate aging when recommended separation temperatures are used; wax drop out when temperatures are too low, asphaltene drop out due to instability in fuel and distillate sludge from oxidisation.

Figure 2. Wax formation in fuel tanks

Liner wear and piston ring damage

There has been a worrying number of incidents related to VLSFO in Q1 2020. The shipping community has raised questions about Cylinder Lube Oil (CLO) suitability and VLSFO combustion quality not covered by ISO8217.

The switch to lower sulphur has added uncertainty around matching the CLO's base number (BN) and feed rate to fuel characteristics. Twenty (20) percent of incidents reported to Innospec have related to piston ring breakages, liner wear, failed scrape down analysis and even scavenge fires. So what is going on?

Understanding liner wear

Liner wear can occur for a multitude of reasons such as overor under lubrication, over or under cooling and poor combustion. We will explore these topics in brief below and show that vessels are taking the necessary advice around correct lubrication and cooling, but still experience liner wear.

The chemistry of lacquering

The four factors of lacquering are: engine design; engine load pattern; fuel oils; and lubricating oils.

We know it occurs due to over lubrication, but there are two schools of thought regarding its origin. First, the CLO itself oxidises and becomes baked onto surfaces and second, fuels which have oxidised or polymerised before or during combustion, impinge upon the liner where they combine with calcium and zinc salts found in the CLO to form deposits in the liner honing grooves.

In both examples above, the process involves oxidisation and the formation of deposits that cure on the liner surface due to the addition of temperature and pressure. Controlling CLO flow and volume is an important factor in ensuring that any excess material for reactions is not available.

We are using the correct BN, why am I still experiencing issues?

Base Number (BN) is defined as the oil's ability to neutralise acids that are produced as a consequence of sulphur in the fuel. The higher the BN, the more acid it will be able to neutralise, therefore we use higher BN for higher sulphur fuels.

BN is only one part of the complex set of characteristics within CLO and when talking about cylinder wear, detergency is just as important. The detergency of CLO determines its ability to remove unburnt products of combustion from the piston crown, top land, rings and grooves. Failure to do so can cause a loss of lubrication effect resulting in metal on metal contact.

Traditional fuels (HSFO) for marine applications come from residual streams which, depending upon origin, had high sulphur content and poor ignition quality (not as a consequence of the sulphur) compared to distillates. Poor ignition meant more deposits and a need for higher detergency required to combat them. Hence, high BN CLO tended to have greater detergency. This is widely understood and which is why those experiencing liner wear are making the switch to high BN CLO for the added detergency, but unfortunately this is against engine manufacturers guidelines (Figure 3).

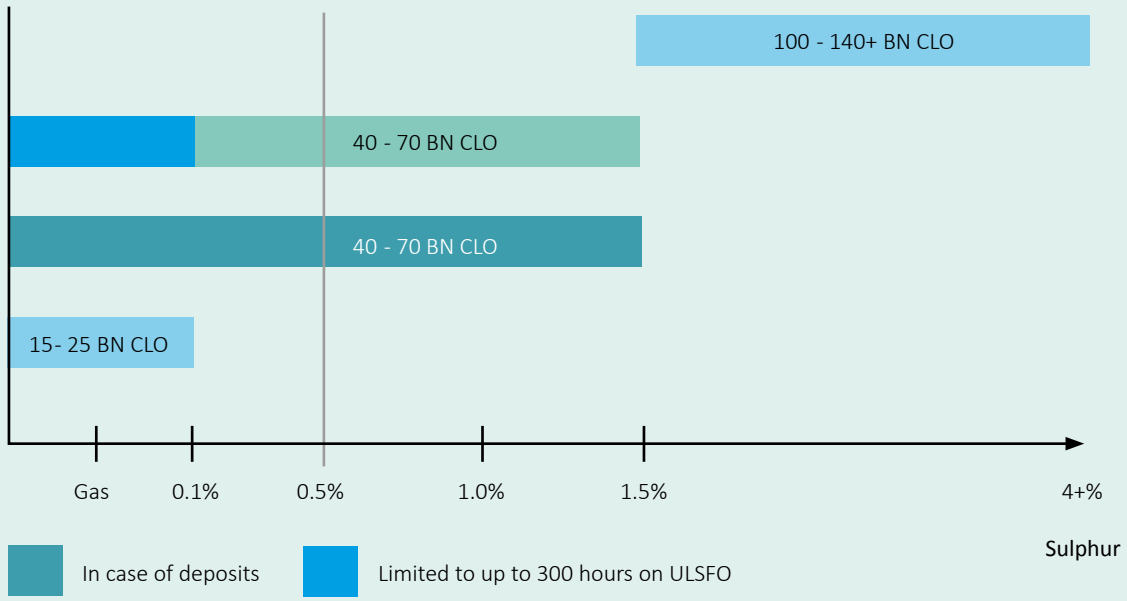


Figure 3 MAN Service letter SL2019-671/JAP - For all MAN B&W engines

What else causes liner wear?

Sub-optimal engine running conditions, such as excessive idling or slow steaming, increase the risk of poor combustion and inefficient lubrication. These conditions can lead to increased deposit formation and lacquering.

Is fuel a factor?

The short answer is yes, but to what extent? Increased deposits in the combustion chamber and post combustion spaces (turbo charger, SCR, EGR and economisers) indicate poor combustion; while injector blockages and separation failures indicate aged distillate material (distillate sludge) is a factor not only before, but after the purifier.

Unstable distillates oxidise (most commonly under elevated temperatures and pressures) forming “sand-like” sediments which block injector nozzles, while gums become impregnated with inorganics (cat fines, metals, sediments) creating a grinding paste on fine tolerance contact surfaces (fuel pumps, injectors etc).

Innospec has spent decades developing stable diesel and bio-diesel blends for the automotive industry ensuring consistent fuel performance in a low sulphur world. Our additives are uniquely proven in industry to prevent the distillate sludges that reduce engine fuel performance while boosting injection efficiency and reducing deposit formation.

But is VLSFO a residual fuel?

Yes and no. VLSFO is sold under a residual grade (RM) according to ISO8217, and it is widely believed that for the most part will replace HSFO over the coming years. This puts pressure on blenders to dispose of residual streams once reserved for HSFO, these residual streams (containing large heavy hydrocarbons such as asphaltenes etc.) carry much of the sulphur and are either diluted with lighter incompatible fractions or refined further to remove the sulphur (removing much of the natural stability in the process).

In a poor quality VLSFO, asphaltenes join into much larger molecules and once injected require more time and oxygen than is available within one combustion cycle to burn. These unburnt residuals deposit on liners and pistons in the combustion chamber; or burn later and contribute to poor ignition and after burn.

By chemically rebalancing the fuel and restoring the stability, these asphaltenes can be broken up, dispersed and kept in suspension. Innospec’s additives target problem elements in the fuel to allow for minimal dosing and maximum effect, thus ensuring residual components are kept small enough to burn quickly, preventing combustion performance issues at the source.

Liner polishing

The reduction/removal of honing marks due to material loss through either friction, corrosion or abrasion is caused by inorganic material (such as cat fines). Cylinder lube oil has the important task of providing sufficient lubrication for contact surfaces as well as providing the detergency to remove combustion by-products (such as unburnt fuel) from the liner and piston rings. Failure to do so, leads to a sudden risk of engine damage.

Case study

In this case from Q1 2020, the vessel switched to VLSFO and was using a BN 40 CLO designed for use with VLSFO. The vessel experienced damage across multiple main engine cylinder liners within days of changing over. Engineers conducted scrape down analysis and visual inspections after high exhaust temperature alarms sounded. Figures 4 and 5 show material loss in the combustion chamber, the liner honing marks removed and scavenge ports burred.

Figure 4. Scavenge ports after switch to VLSFO

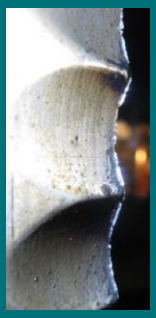


Figure 5. Burr on liner surface

Figure 6. Deposits behind piston rings

Figure 6 shows combustion deposits and a fouled/ dry top land across all pistons from poor ignition and/or detergency in the CLO. Once deposits build up behind piston rings, they are pushed outwards until they impinge on to the cylinder liner surface, breaking through the protective CLO layer and achieving metal on metal contact. leading to wear.

The inability of piston rings to form an effective seal causes blow-by, reducing compression and ignition efficiency, increasing deposit formation in the scavenge space and potentially leading to scavenge fires, as it did in this case.

Figure 7. new Cylinder liner

Figure 8. Same liner after days of VLSFO use

Experts from the engine manufacturer were on-board to oversee component changes (Figure 7), and to ensure lube oil suitability and feed rate were correct. Unfortunately, within days of overhauling, the vessel experienced a scavenge fire and further inspections revealed liner topography had once again been compromised (Figure 8).

Can I improve fuel performance?

Yes, and with VLSFO it is more important than ever to ensure a complete and efficient combustion. We understand that unstable or oxidsed fuels cause sludge, however it is also known that they have a negative effect on combustion. An unstable fuel separates into its constituent parts causing dangerously early and late ignition, forming deposits on injectors or liners, damaging injectors and stressing cylinder lubrication with excessive combustion deposits.

By chemically balancing the fuel, you can restore fuel quality and ensure a better and more complete combustion. Our detergency and dispersancy packages are extensively proven to stop fuel breaking down, clean-up injectors and prevent blockages in filters, injector nozzles and fuel pumps. This ensures excellent engine performance and spray pattern to ensure maximum fuel efficiency.

The importance of a consistent spray pattern cannot be overstated. Figure 9 shows an injector using aged distillate fuel, which shows noticeably poor spray pattern meaning the fuel droplets are too large and close together to find

Figure 9. spray pattern after 100 hours using stressed fuel

Figure 10. spray pattern after additive application to same fuel

sufficient oxygen to burn during an ignition cycle. In the engine, this means less fuel will be burnt, more deposits in the combustion chamber and increased fuel consumption, as more fuel is required to achieve the same power output.

Figure 10 shows the same injector and fuel over the same time interval, only now the fuel includes Innospec's patented technology. **Octamar™ HF 10 PLUS** is the only additive that includes this technology because we understand how important spray pattern is for engine performance, fuel economy and emissions.

Our additive trials on locomotive Cummins engines have proven a 3% improvement in fuel economy along with emissions reduction through engine performance improvements alone. Ask your Innospec representative for further information.

How can I improve on-board handling?

A large variance in viscosities purchased under the same ISO grade of fuel has increased demands on ships crew and handling equipment. Low viscosity fuels are more likely to contain paraffinic, cracked or processed components within the VLSFO blend. This is evident by the number of pipe and purifier blockages that are being reported.

Pressure on crew has increased when handling low viscosity fuels, balancing purification efficiency while maintaining handling temperatures as low as practicable to avoid ageing the fuel and damaging equipment. Once stabilised with **Octamar™ HF 10 PLUS**, VLSFO separation temperatures can be maintained, ensuring maximum purification efficiency.

Advice from manufacturers

Purifier manufacturers have re-stated separation temperature guidelines (Table 1) by attempting to prevent "cooking" of the distillate fraction when handling VLSFO. We know that if temperatures are too low, the effective removal of cat fines and other damaging impurities is not possible (Table 2).

Viscosity @ 50˚C	Storage Temp	Separation Temp
Up to 20 cST	30˚C	40˚C
20 to 30 cST	30˚C	50˚C*
30 to 40 cST	15˚C above PP	60˚C*
40 to 50 cST	15˚C above PP	70˚C*
50 to 70 cST	15˚C above PP	80˚C*
80 to 180 cST	15˚C above PP	98˚C

Table 1. ALFA LAVAL service letter 32343

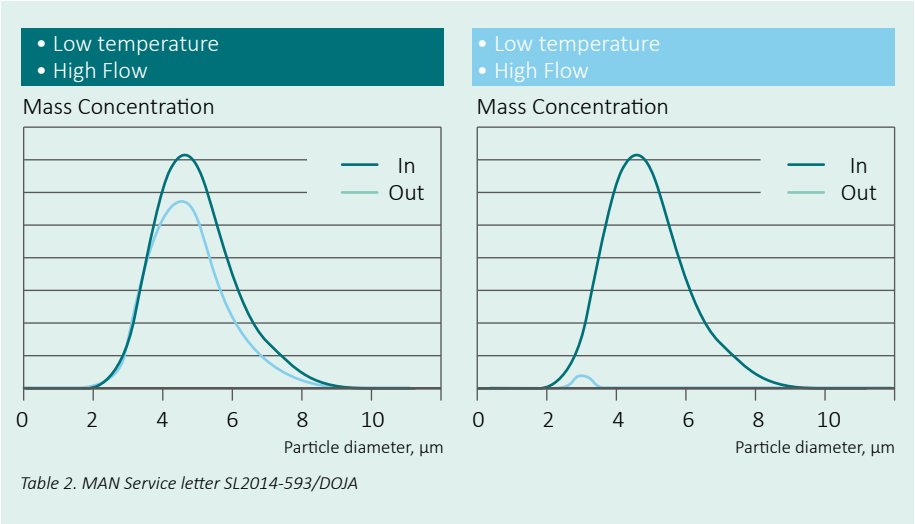


Table 2. MAN Service letter SL2014-593/DOJA

Despite following guidance, vessels are still experiencing serious handling issues on-board. One factor may be that many of the fuels have already begun to oxidise before they arrive in the ships bunker tanks. However, they are aging rapidly when exposed to temperatures and pressures during handling and separation.

How do I maintain purifier efficiency?

Storage is the first and arguably most important step in fuel handling. We know temperatures, stability, time and comingling all have a part to play in fuel stability. Six percent of cases reaching Innospec have resulted in un-pumpable solids in the Storage and Settling tanks. Most of the problems are not caused by the vessel, but from a fuel that may have been loaded and has already started to oxidise and a result of a change in circumstance causing an incident.

Figure 11. Purifier every 3 hours after loading VLSFO

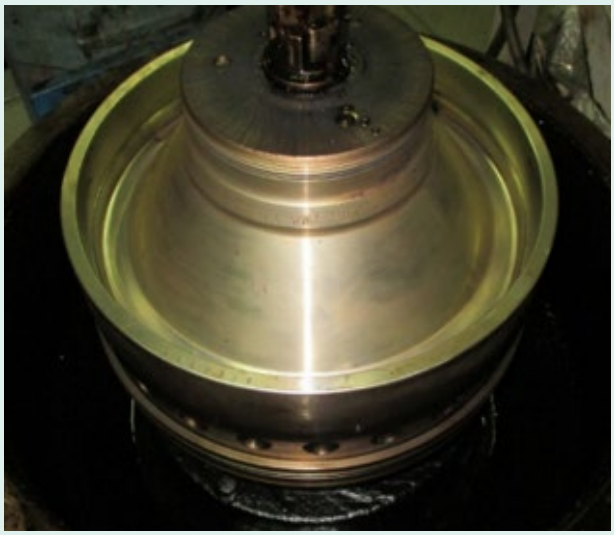


Figure 12. Same purifier, same fuel, 24 hours after additive application

Octamar™ HF-10 PLUS is a multifunctioning additive that captures oxidised material and prevents it from aging further and forming sludge. Octamar™ HF-10 plus has already helped countless vessels keep fuel stable to separation temperatures can be maintained for optimum separation.

(Figure 11) is a recent case of a VLSFO that was off spec for TSP and the vessel immediately experienced issues. The crew were stretched to their limits; cleaning continuously to keep the vessel running until Innospec recommended pre-treating with Octamar™ HF-10 PLUS. Within hours of following Innospec's guidance normal purifier operations had returned (Figure 12). Now through continuous use of additives, this vessel and the fleet can enjoy better performing fuels and less operability issues.

Summary

The VLSFO problems seen in Q1 can be seperated into three key areas:

72% FUEL INSTABILITY:	• Separator failure (37%): sludge dropping out, fuel ageing, purification plants inoperable, compliance issues related to hours of work and rest, and increased fuel handling costs related to more fuel lost as sludge and purifier servicing. • Filter blockage (29%): risk of fuel starvation caused by blocked filters and fuel lines. • Storage tank solids (6%): solid deposits in fuel tanks rendering them unusable.
20% POOR COMBUSTION	• Piston ring breakage (6%): increased deposits behind piston rings, on crowns and toplands due to poor ignition. • Liner wear (14%): scrape down analysis failures, high exhaust temperatures; and even scavenge fires. The introduction of VLSFO may have had a part to play.
8% WAXING	• Cold Flow (8%): A lack of heating in storage tanks and separation to prevent ageing the fuels has led to the heavier waxes depositing at the bottom of tanks and crashing out in purifiers.

VLSFO REPORT- Q1 2020

Maximise Fleet Performance

Octamar™ HF-10 PLUS has already delivered unparalled fuel performance improvements for fleets globally. Vessels have seen fuel handling on-board dramatically improved, seperation efficiency returned and the compound benefits on fuel savings through less fuel crashing out as sludge and better combustion efficiency.

Innospec are fuel specialists like no other, work with us to improve your fleet performance and ensure the safety of your crew, ship and the environment.

Octamar™ HF-10 PLUS

Use Octamar™ HF-10 PLUS to maximise fleet performance, stabilise VLSFO blends and reduce sludge formation.

- Improved engine performance through better efficiency.
- Better purifier performance.
- Tackle VLSFO compatibility and stability.
- Significant reduction in sludge, crew maintenance hours and component costs.
- Longer periods between unplanned maintenance intervals.
- Higher treat rates will clean-up fuel pumps and injectors in service.

Octamar™ Ultra HF

Octamar™ Ultra HF provides a complete solution for VLSFO and keeps your engine running by improving fuel blend stability and combustion while reducing soot formation.

- Optimum engine performance through improved combustion quality and efficiency in one additive.
- Clean up/keep clean for post combustion systems.
- Increased fuel stability and compatibility of marine fuel blends.

Innospec

Innospec is at the forefront of developing fuel additive technology for a changing world. Our focus is on supporting the fuel industry as it adapts to major environmental challenges, new legislation and the more demanding performance targets set by OEMs. While we operate at the novel and cutting edge of technology, our goal as market leader is always to create reliable and highly functional products. We build global supply chain solutions by understanding the important differences within regional and national markets. Our worldwide network spans 23 countries.
We can work with you to create the next generation of fuels, today.

Please contact your local sales representative for more information.

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