www.bunkerspot.com Volume 17 Number 5 October/November 2020

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Deep dive

A new technical paper from Innospec offers a close analysis of the operational impacts of blending distillate streams into very low sulphur fuel oils

In accordance with MARPOL Annex VI, the International Maritime Organization (IMO) has implemented a new global maximum allowable sulphur limit of 0.50% in marine fuel used for ships operating in international waters. This is down from the previous maximum allowable sulphur limit of 3.50%. As a result, refiners and blenders are now producing a new fuel for the industry known as very low sulphur fuel oil (VLSFO). Although ships with functioning scrubbers are allowed to consume and store high sulphur fuel oil (HSFO), also commonly referred to as heavy fuel oil (HFO), access to, and supply of, HFO is becoming more limited. At the time of writing, some ports are now banning open loop scrubbers, bringing into question the long-term economic viability of that mechanical approach.

There has been little to no guidance for refiners or blenders on how to produce VLSFO. Thus, producers and suppliers of VLSFO are using a variety of strategies to stay in compliance with IMO 2020 while still attempting to meet the guidance given in ISO 8217. Globally, the industry is using a wide variety of blend components and refinery streams to make a compliant VLSFO. Depending on refinery complexity or a terminal's access to blend streams, the composition of a bunker fuel may be primarily distillate based or residual based.

Processing these fuels onboard a ship will be difficult for ship operators as the energy content, density, and viscosity of the fuel can vary greatly depending on the streams selected to produce the fuel. In addition to these fuel property concerns, the inherent stability, stability while bunkered, compatibility with other bunkers, cold flow characteristics, and overall operational efficacy of the fuel can be ongoing concerns that need to be managed.

Otherwise, there is potential for the formation of sludge in tankage and inside fuel transfer lines, filter and purifier plugging, and fouling of injectors, preheaters, and burner tips when using incompatible or unstable fuels. Therefore, understanding the underlying stability and compatibility of VLSFO and marine gasoil (MGO)/marine diesel oil (MDO) fuels can help with identifying potential fouling risks and developing and implementing a successful mitigation strategy.

VLSFO is a new fuel for the industry and producers are using a variety of strategies to make the fuel. Figure 1 gives a simplified overview of refinery pathways to make blend components for the marine industry. Different refineries may have all or just a few of the units shown in the figure. Historically, European refiners focused on bunker fuel production. Refinery production was focused on the use of visbreakers to produce a lower viscosity HFO. North American refiners have historically focused on gasoline production, which requires the use of fluid catalytic cracking (FCC) and coker units. Some by-product streams from these process units have been used in the bunker market, but they have accounted for only a small percentage of the bunker fuel supplied on a global basis.

With the new low sulphur compliance requirements, refineries that have higher processing complexity have the advantage of being able to more readily produce low sulphur blend streams that are suitable for the marine industry The big winners of IMO 2020 are projected to be complex refineries in Asia, followed by refineries in the US.

FCC slurry oil, straight run distillate, and straight run vacuum gas oil (VGO) are great blend components for marine fuels as they are typically lower in sulphur, and they can be combined with higher sulphur streams to meet the 0.50% sulphur requirement. If a refiner has made the capital investment and built a hydrocracker unit, then VLSFO and ULSFO streams can be readily produced.

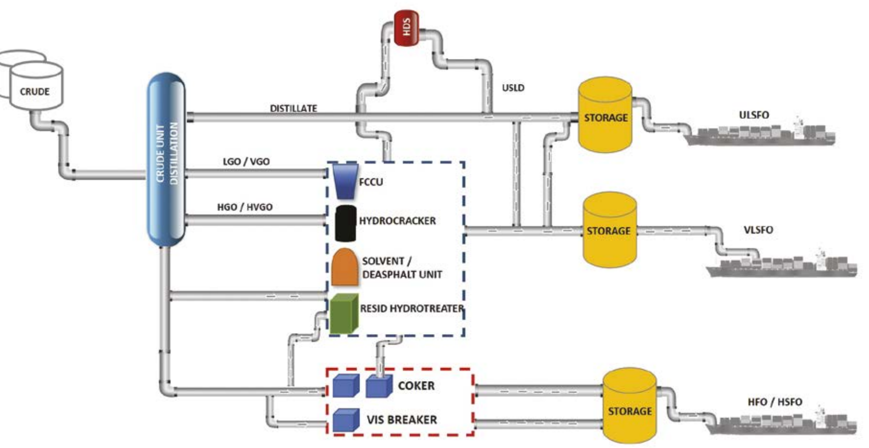


Image © Innospec

Figure 1: Refinery Pathways to Compliant Fuel

> 'Distillates and catalytically cracked slurry oils contain naturally occurring components and trace levels of contaminants that can impact their inherent stability and the stability of any subsequent blend in which they are used'

Capital projects for resid hydrotreaters have increased throughout the world. This processing unit provides a source of lower sulphur resid that has a high energy content similar to that of HFO. These streams can provide refiners greater value, while giving blenders and suppliers greater operational flexibility.

However, distillates and catalytically cracked slurry oils contain naturally occurring components and trace levels of contaminants that can impact their inherent stability and the stability of any subsequent blend in which they are used. The interaction of the contaminants in the blend streams can cause various instability mechanisms to occur, including the formation of degradation products such as polymeric gums, inorganic sediment, and sludge.

For example, it is entirely possible to have two distillate-based streams or a distillate-based and residual-based stream that are inherently stable on their own, but, when they are blended together, the result is an unstable fuel.

As indicated in Illustration 2, there are many naturally occurring species in distillate streams that can lead to the formation of polymer material or 'gums' that can result in

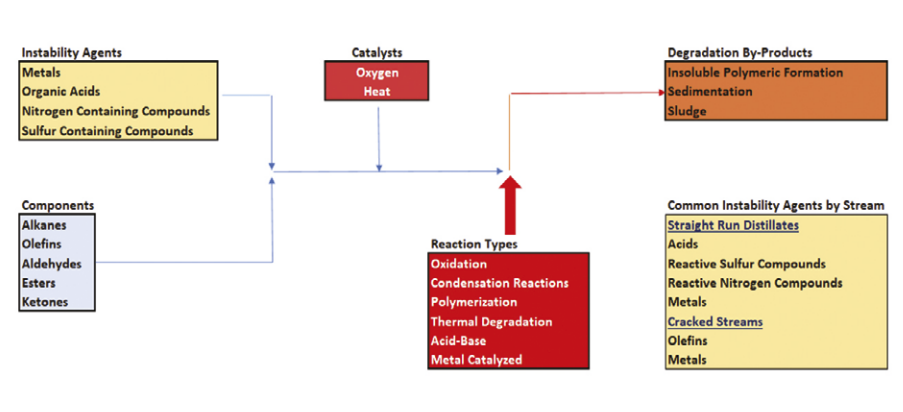


Image © Innospec

Illustration 2: Potential Instability Agents and Degradation Mechanisms

fouling or reduced performance when handling and using bunkers that contain distillate-based streams. Common instability agents include olefins, organic acids, metals, nitrogen, and reactive sulphur compounds. Their rate of reaction and the subsequent impact on stability are catalysed by temperature (thermal instability) and the presence of oxygen (oxidative instability). This instability can be further exacerbated over time as a fuel oil 'ages' during storage and/or bunkering.

There is a significant focus within the industry on VLSFO stability as it relates to blend stream compatibility and whether asphaltenes stay in colloidal suspension or precipitate out. However, the potential for instability issues with distillate streams (e.g., MDO and MGO) and distillate-based VLSFO blends can be just as severe and these issues can have the same negative effects on the quality of the fuel.

A refinery's crude oil feedstock, as well as the refining processes employed to produce fuel blends, influence the stability of distillate and VGO streams. Heavy, highly asphaltenic crude oils produce fuels with different stability problems than those produced from paraffinic crude oils. Acidity, nitrogen content, sulphur, metals, and olefin content will vary from crude oil to crude oil and will fluctuate depending on the operations used to produce the fuel.

Adding to the complexity, blenders and suppliers often use residual streams that can contain inorganic particulates, catalytic fines, reactive heterocyclic naphthalenes, asphaltenes, and metals in order to increase the density and energy content of the fuel. Each of these factors coupled with all of the process variability that can occur, not only between refineries but also within a single refinery, can create an environment that results in fuel stability issues.

For over 40 years, Innospec has been providing refiners, suppliers, ship owners, and fuel consumers with specialised products to improve fuel quality, handling, and operability. To meet the changing nature of bunker fuel, Innospec has a full line of Trident Bunker Fuel Additives specially designed to mitigate the stability issues associated with VLSFO and ULSFO. These products have a proven record of success in improving the quality of ULSFO, VLSFO and HFO fuels for the marine market.

A key to success is matching the mitigation strategy with the fuel quality issue/concern in order to properly address the underlying fouling mechanism and inhibit degradation reactions from occurring. Some common stability issues associated with distillate-based fuels and potential solutions to mitigate these issues include:

- Olefins will readily react with oxygen, metals, mercaptans, and other sulphur compounds to form polymeric residue. Aromatic and naphthenic molecules, including asphaltenes, are easily oxidised and can serve as free radical precursors. Acids are known to promote many polymerisation reactions and can form salts with amines and basic nitrogen compounds which can result in the formation of high molecular weight polymers that readily drop out of solution and foul equipment. Antioxidant and antipolymerant type additives can effectively inhibit many of these gum and sludge formation reactions in VLSFO and ULSFO.
- Metals such as vanadium and nickel are often found in asphaltenic resids and they can readily catalyse free radical polymerisation reactions. Even iron can be a weak catalyst for polymerisation reactions. The use of metal deactivators or metal chelators, particularly in combination with an antipolymerant, can completely prevent such reactions from occurring.
- Particulates, whether organic or inorganic, can agglomerate to the point where the fuel oil can no longer sustain the particles and they settle out of solution leading to fouling and sludge formation. Dispersants are effective in keeping particulates small in size, which improves flow assurance, reduces filter plugging, mitigates fouling and, thereby, helps to reduce maintenance costs.

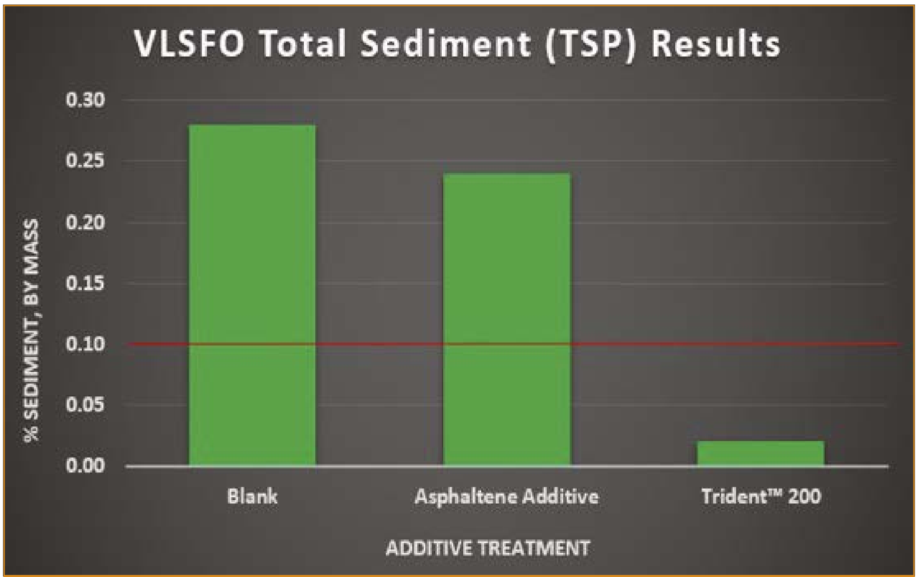
Some refiners could avoid inherent instability issues by severely hydrotreating their fuel streams (e.g., <15 ppm sulphur Ultra-Low Sulphur Diesel); however, there is an appreciable economic and opportunity cost in doing so. Hydrotreater capacity is limited and unit throughput could be better utilised on higher value distillate and the upgrading and sale of intermediate streams into more profitable market applications.

In addition, for blenders, bunkering companies, and end-use ship owners, there really is not a practical mechanical option to enhance this type of stability. Therefore, it is often substantially more cost-effective to address thermal and oxidative-type instability in a fuel stream with an appropriate chemical treatment program.

FUEL OIL STABILITY PERFORMANCE

Chemical programs can keep fuel stable, and on specification, when storing or transferring between vessels. A chemical approach can effectively inhibit gums, sediment and sludge formation during bunkering, thereby reducing handling issues and maintaining good operability performance in on-board ship fuel systems. In addition, chemical treatment can potentially reduce the total sediment (TSA or TSP) of distillate-based blends and blend components, improving their quality and making them more commercially viable.

To demonstrate this point, below are two examples of VLSFO blends that were comprised of both distillate and residual components (Graphs 1 & 2). The baseline stability of each blend was evaluated based upon potential total sediment (TSP) determined via hot filtration in accordance with ISO 10307.



Graph 1: VLSFO Total Sediment by Hot Filtration Results (ISO 10307)
Blend of Hydrotreated Diesel and FCC Slurry

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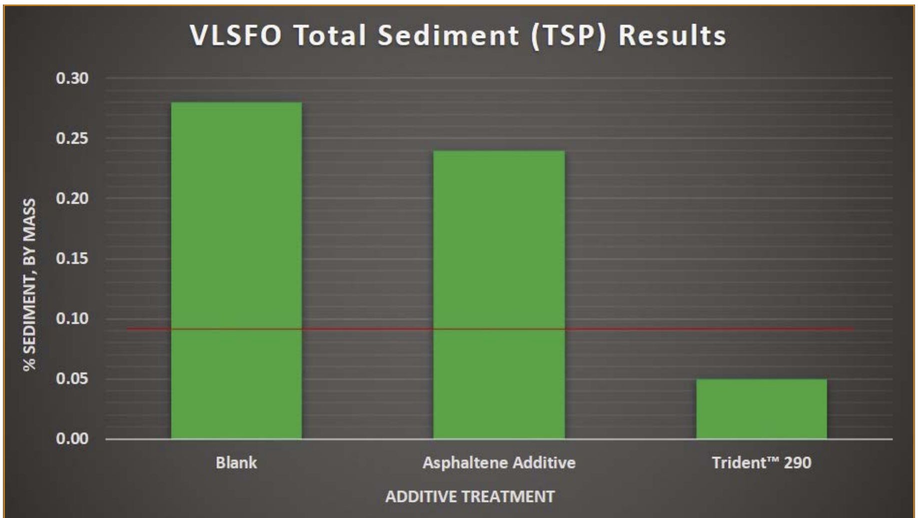

Graph 2: VLSFO Total Sediment by Hot Filtration Results (ISO 10307)
Blend of Hydrotreated Diesel, FCC Slurry and Visbreaker Bottoms

Graphs © Innospec

In both cases, the baseline TSP of the fuel oils was significantly higher than the ISO 8217 maximum guidance of 0.10% (by mass). Test results indicated that traditional asphaltene stability additives were not effective in reducing the TSP to an acceptable level. After treatment with several different Trident Fuel Stability Additives, the total sediment of both oils dramatically improved and their TSP values were reduced to less than 0.10%.

For decades, it has been well established that distillate and intermediate-based fuel streams can be inherently unstable due to their composition. This instability can potentially lead to a variety of field and operational issues within the marine market unless the underlying factors are addressed. The stability of these fuels can be improved by removing instability agents through refinery hydrotreatment or by implementing a chemical treatment program targeted at mitigating instability precursors and inhibiting degradation mechanisms.

With the implementation of IMO 2020, and the subsequent introduction of VLSFO, refineries are providing less refined, more distillate-based fuels to the marine industry. Therefore, as a best practice, it is recommended that distillate-containing VLSFO, MGO and MDO fuels be proactively treated to enhance their thermal and oxidative stability, especially if these fuels may be stored and/or bunkered for long periods of time.

Innospec provides products and services to improve the handling and performance of finished fuels and hydrocarbon streams. As illustrated in Graphs 1 & 2, the Trident bunker fuel line has been specifically formulated to meet the changing character of bunker fuels.

For more information on VLSFO challenges, fuel oil stability and the Innospec Trident bunker fuel product portfolio, contact:

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