Marine Fuel Stability and Compatibility – Issues, Tests and Management

Armelle Breneol, Marine Logistics Advisor, EAME for ExxonMobil

Introduction

The marine fuel market is undergoing complex and far-reaching change, largely as a result of a growing body of environmental legislation. Issues surrounding fuel stability and compatibility have never been more relevant, especially in light of the new 0.10 per cent sulphur cap for fuels used in Emission Control Areas (ECAs), which has triggered the development of a range of ECA-compliant products of differing formulations.

There are two basic types of marine fuels – distillate and residual. Distillate fuel, also known as Marine Gas Oil (MGO), is composed of petroleum fractions that are separated from crude oil in a refinery with a "distillation" process. Residual fuel, or Heavy Fuel Oil (HFO), is comprised of process residues – the fractions that did not boil – and has an asphaltene content of between 3 and 10 per cent.

The need to switch to and from one of these fuel variants when entering or leaving an ECA poses a range of issues for vessel operators – many of which are still not fully understood by the wider industry. In order to best deal with these difficulties it is essential that vessel operators recognise the characteristics of the various ECA-category fuel grades and how to manage the fuel switch-over.

Importantly, when a ship switches fuel it needs to be done safely and effectively so as to avoid any technical issues and to also ensure that the emission limits are not breached.

The International Convention for the Prevention of Pollution from Ships (MARPOL) requires vessels using separate fuel oils to develop and utilize written procedures showing how the fuel oil change-over is to be carried out, allowing sufficient time for the fuel oil service system to be fully flushed of all fuel oils exceeding the applicable sulphur content prior to entry into an ECA.

Fuel stability: **The potential for a fuel to change condition in storage in certain circumstances, depending on its resistance to breakdown**

Bulk fuel stored for long periods can become unstable – the asphaltene content can precipitate out of solution causing the formation of sludge. This has the potential to block filters and pipes, leaving tanks with an unpumpable residue.

The ‘break up’ is dependent on the nature of the liquid hydrocarbons in which the asphaltenes are suspended. If the medium is aromatic (hydrocarbons in ring formation) then they will remain in suspension but if it is paraffinic (linear hydrocarbon formation) the asphaltenes may have a propensity to coalesce into sludge. Once a fuel has chemically broken down there is no way to satisfactorily reverse the process. Precipitated asphaltene cannot be redissolved.

Fuel compatibility: **The tendency of fuels to produce deposits when mixed. The issue may immediately occur when fuels comingle.**

The industry best practice is to avoid mixing fuels from different sources and with different formulations as arbitrary comingling can lead to incompatibility problems and a loss of stability in the resultant blend. For example, when a heavy fuel oil (HFO) with a high

asphaltene content is mixed with a low-gravity distillate with a predominance of paraffinic aliphatic hydrocarbons the solvency reserve can be depleted and asphaltenes can flocculate and precipitate as sludge.

Although incompatibility is not a common phenomenon its likelihood increases in tandem with fuel switching, such as when entering and leaving an ECA. Compatibility problems must be treated as a critical concern as it can result in power failure, fuel systems can become paralysed and the job of cleaning up the results is both difficult and time consuming.

There are a number of precautionary measures that can be taken:

- Avoid mixing bunker fuels from different sources wherever possible
- Store fuels separately until compatibility testing has been carried out
- Do not mix straight-run fuel oil [the product of atmospheric or vacuum distillation] with a cracked [additionally processed] one – if not possible keep the ratio to a minimum.
- Steer clear of mixing fuels with greatly dissimilar densities
- Where possible choose fuels with similar viscosities *and* densities
- Do not mix a fuel oil with a marine diesel oil or marine gas oil

In practise it is often not possible to ensure against a degree of comingling and although the rule of thumb is not to comingle or load on top in excess of 20 per cent mix ratio, the only way to ensure there are no issues is to test a sample mix.

It is important to remember that a stable fuel oil can become unstable when mixed with another stable grade although generally fuels of the same viscosity grade with similar densities will be compatible. Also, although ISO 8217 (Specifications for Marine Fuels) is the most frequently used standard for fuel bunkers it was developed prior to the introduction of ECA category fuels, which often fall between its grade specifications.

Testing regimes

1. Fuel stability testing
There are three sediment tests covered within ISO 8217. They all use the hot filtration test method [described in ISO 10307 Petroleum Products] and all aim to define the total amount of sediments contained in a fuel sample.

Total Sediment Existent (TSE): ISO 10307-1
A fuel sample is heated to 100ºC and passed through a filter paper. The amount of dry sludge retained on the filter paper correlates with the amount of sludge that is likely to be separated by an on-board centrifuge.

Total Sediment Potential (TSP): ISO 10307-2 (Thermal Aging)
A heated sample of the fuel is placed in a flask, which is then placed in an ageing bath at 100ºC ± 0.5ºC for 24 hours ± 15 minutes. After 24 hours the flask is removed from the bath and shaken vigorously prior to passing through a filter paper. The result of the test is reported to the nearest 0.01% m/m and is expressed as Total Sediment Potential (TSP).

Total Sediment Accelerated (TSA): ISO 10307-2 (Chemical Aging)
A sample of the fuel is heated to achieve a viscosity of approximately 50mm^2/s. After 10 minutes, a measured amount (10% of sample size) of hexadecane is added and the sample is placed in an ageing bath at 100ºC ± 0.5ºC for 60 minutes ± 2 minutes. The sample is shaken vigorously prior to passing through a filter paper. The result of

the test is reported to the nearest 0.01% m/m and is expressed as Total Sediment Accelerated (TSA).

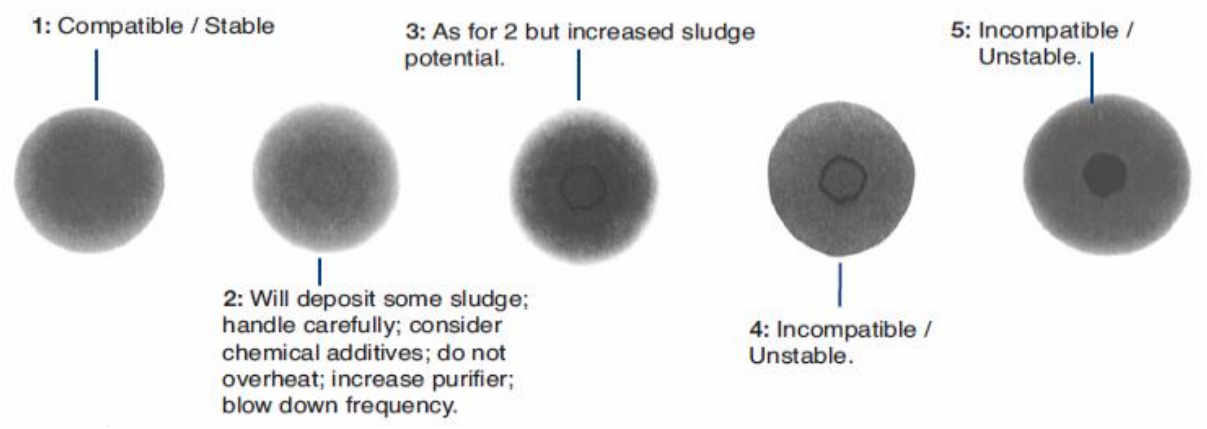
The agreed limit for both TSP and TSA is 0.10% m/m – a fuel that falls below this limit should be viewed as thermally stable and able to homogenously maintain asphaltenic phase suspension.

As far as ISO 8217 is concerned, the ISO 10307-1 method is used to determine the level of sediment in distillate fuels whereas the ISO 10307-2 method is used to ascertain the level of sediment in residual products (ISO 8217 2010/2012 allow for the TSA method to be used for sediment determination but TSP is still classed as the official reference method).

2. Fuel compatibility testing
On board a vessel, a good way to measure the compatibility of marine fuels, including residual and distillate fuels, is the ASTM D4740 spot test. The ideal percentage mix is 50/50 as this is the worst case scenario.

Note: One of the test fuels must be a residual fuel otherwise there will be negligible asphaltenes to precipitate. Spot tests do not work for comingled distillates due to their low asphaltene content; additionally compatibility tests can actually produce false positives for distillate blends due to pigment separation. For the same reason spot tests are not applicable for distillate tests with HDME 50.

Spot tests
For the ASTM D4740 spot test a blend composed of representative[1] volumes of the sample fuel and the blend stock is heated and homogenised. A drop of the blend is put on a test paper and heated to 100°C. After 1 hour, the test paper is removed from the oven and the resultant spot is examined for evidence of precipitation and rated for compatibility against D4740 reference spots.



Storage, handling and use

In order to properly manage on-board fuel it is necessary to store it at the right temperature. If comingling is to take place it is essential to know what it will be mixed with and how best to manage this blending process. It is also important to ensure that the fuel is at the optimum viscosity at the point of engine injection.

Conclusion

[1] If loading 90mt of HFO on top of 10 mt of HFO already in tank, the spot test should use a 90/10 ratio.

The need to change fuels when entering and leaving an ECA increases the risk of incompatibility, triggering asphaltenes to precipitate as heavy sludge. This can result in fuel system issues, which in extreme cases can cause engine shutdown due to fuel starvation.

Best practise is to not mix fuels in the storage and settling tanks; and when switching fuels vessel operators should ensure that the service tank is at its lowest safe operating level before introducing a new fuel to the system.

However, the only way to fully ensure against compatibility issues is to carry out compatibility tests – either on board during bunkering and via an independent laboratory.