Application Note

VISC-4, P-500, Sulfur Analyzer

Increase Product Revenue in Marine Fuel Oil Blending

AN001 2019-11-21 A

APPLICATION NOTE

With the availability of alkaline cylinder lubricants to neutralize the acids generated by the combustion of sulfur containing heavy fuel oils (HFO), motor ships overtook steamships in the 1960s and the marine diesel engine is nowadays the predominant engine type in the world ship fleet.

Marine fuel oils can be distinguished between two main types. Distillate fuel oils such as marine gas oil are produced from petroleum fractions in conventional distillation operations. Residual fuel oils (e.g. HFO) are a refinery by-product obtained from the undistilled residue during crude oil processing in atmospheric distillation towers. Depending on the crude oil source the containing three different types of hydrocarbons, paraffinic, naphthenic and asphaltenic (aromatic) may vary widely in their relative percentage, which makes it an almost impossible task to standardize e.g. the HFO composition.

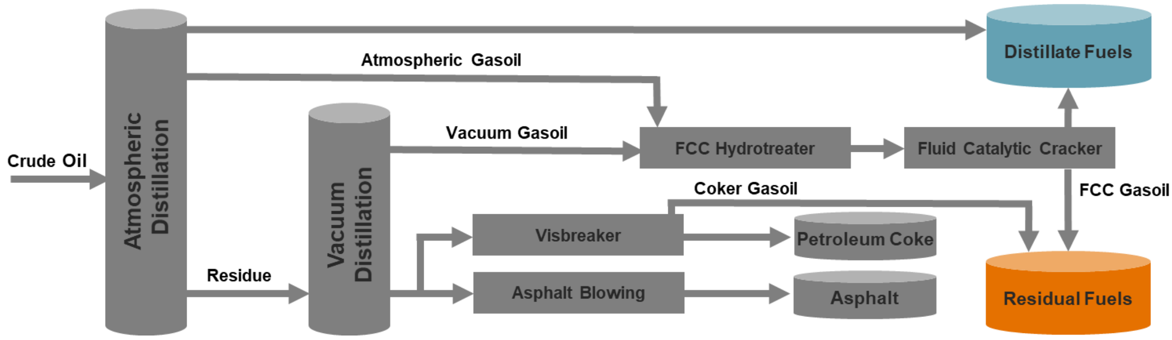

Figure 1: Atmospheric residue process path as feedstock for heavy fuel oils

In the MARPOL Marine Convention of 1973, HFO for example was defined either by a density of greater than 900 kg/m³ at 15°C or a kinematic viscosity of more than 180 cSt at 50°C.

Traditionally the classification and naming is according to their viscosity, for example RME 180 and RMG 380 have viscosities of 180 cSt and 380 cSt, respectively. Since 1987 an international ISO standard ISO 8217 exists to define the requirements for petroleum fuels for use in marine diesel engines. Characteristics to test are for example kinematic viscosity, density, calculated carbon aromaticity index (CCAI), flash point, pour point and sulfur concentration.

To meet the important ISO 8217 requirements, especially the kinematic viscosity, of the different marine fuel oil classes, residual fuels has to be blended with significant costlier distillate fuel oils, such as marine gas oils (MGO) or marine diesel oils (MDO).

Table 1: Classification overview of marine fuel oils (excerpt) regarding kinematic viscosity and density

Residual Fuel	Kin. Viscosity [cSt] at 50°C	Density [g/cm³ at 15°C]	Distillate Fuel	Kin. Viscosity [cSt] at 40°C	Density [g/cm³ at 15°C]
RMA 30	< 30	< 0.960	**DMA**	2.0 – 6.0	< 0.890
RMD 80	< 80	< 0.980	**DMB**	2.0 – 11	< 0.900
RME 180	< 180	< 0.991	**DMC**	< 14	< 0.920
RMG 380	< 380	< 0.991	**DMX**	1.4 – 5.5	–
RMH 700	< 700	< 1.010	**DMZ**	3.0 – 6.0	< 0.890

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The important viscosity parameter

The viscosity of a marine fuel oil at the moment it leaves the injectors must be within the specified limits to obtain an optimal combustion. Viscosity outside the limits leads to poor combustion, soot formation and decreased engine efficiency.

With markets becoming more price-competitive, companies are looking for ways to improve their marine fuel oil blending to be closer to the requirement limits. One way to achieve this is by using a more accurate online viscosity measurement that reduce fuel giveaway of higher economic value.

There are different technical solutions of online/inline viscometers available on the market that seem to fit this requirement. However, it can be shown that capillary viscometer combined with high temperature stability, allow the most precise control of marine fuel oil blending, which can then lead to increased revenue. In addition, the data can be directly compared with laboratory results without any need for conversion.

As an example, an error of 1% on product viscosity can easily result in increasing production cost of €0.01/$0.01 a gallon. For marine fuel oil manufacturer and blender, this can amount to hundreds of thousands US Dollars in lost revenue per year.

High performance kinematic viscosity measurement

The VISC-4 is based on the capillary viscometer principle that measures continuously and directly kinematic viscosity. As the sample passes through a capillary at a specific flow rate and temperature, the pressure drop across the capillary is measured to calculate the kinematic viscosity. Since the kinematic viscosity of liquids decreases with increasing temperature for most products, the temperature accuracy and stability is of utmost importance for a good and reliable measurement. This is particularly true for marine fuel oils as their viscosity rate of change per temperature unit is significantly greater than for other petroleum products.

Thanks to Bartec's unique thermal insulation of the capillary with a Dewar vessel, the VISC-4 shows an unrivaled temperature stability of ±0.02 Kelvin without the need for high-maintenance oil bath. The use of four temperature sensors inside the measuring chamber assures highest confidence in the isothermal condition and therefore in the collected data quality.

The VISC-4, with its adaptive thermal control shows industry-leading temperature accuracy and stability that easily meets the requirements of ASTM D445. Also the repeatability (r) of the kinematic viscosity according to ASTM D445 is clearly exceeded by several factors.

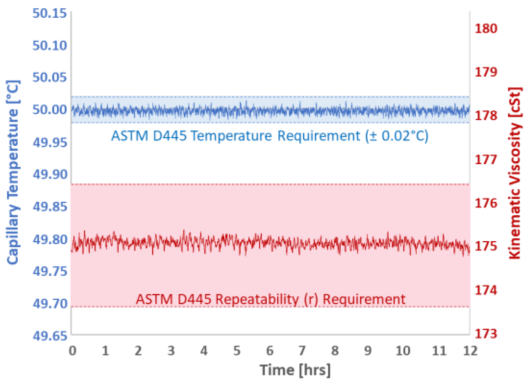

Fig. 2: 12hr kinematic viscosity and capillary temperature readings with the VISC-4 at 50°C of a marine fuel oil sample (RME 180). The repeatability (r) according to ASTM D445 and the temperature range of ±0.02 K are highlighted.

In addition the VISC-4 is suitable to handle the whole range of residual fuel oils thanks to its outstanding kinematic viscosity range of up to 1000 cSt at measurement temperatures of up to 100 °C.

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The safety parameter flash point

Flash point is the temperature at which the vapors of a liquid ignite, when a test flame or spark is applied. This parameter is used to categorize the apparent fire risk associated with marine fuel oils used for marine diesel engines. However, it infers no engine related performance characteristics, such as engine efficiency or optimal combustion.

The flash point temperature limit set in the ISO 8217 and the SOLAS Regulation II-2/4 is a minimum of 60°C measured with the Pensky-Martens Closed Cup method described in the ISO 2719 and ASTM D93.

However, with the Annex VI to the MARPOL Convention the 0.5% sulfur limit that took effect since 2020, it becomes a challenging task for marine fuel oil blenders to meet the minimum flash point requirement.

High performance flash point measurement

The P-500 is a state-of-the-art analyzer that uses the Pensky-Martens Closed Cup method. Here, the liquid sample is filled in a brass test cup closed with a transparent lid and stirred to develop an equilibrium between the liquid and the gas phase. While heating up the liquid an ignition source is directed into the cup at regular intervals with simultaneous interruption of stirring. The temperature when the vapor phase ignites by optical detection of the flash inside the cup is the liquid's flash point.

The measuring performance is independent from sulfur content and the analyzer is suitable to handle a wide range of residual fuel oils with viscosities of up to 180 cSt.

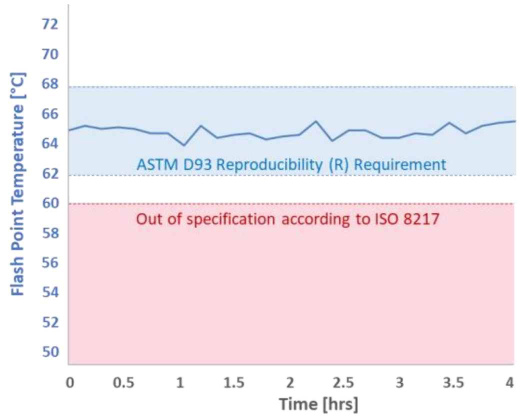

Fig. 3: 4hr flash point reading with the P-500 at 50°C of a marine fuel oil sample (RMD 80). The reproducibility (R) according to ASTM D93 and the ISO 8217 requirements are highlighted

The important sulfur concentration measurement

Sulfur tends to concentrate in heavier fractions during crude oil processing hence it is overrepresented in marine fuel oils compared to other fuel types and create harmful impacts on the environment. Consequently in the Annex VI to the MARPOL Convention a schedule for the reduction of the sulfur limit in marine fuel oils were set. In 2015, it was reduced to 0.1% in Emission Control Areas (ECA) and in the year 2020 the sulfur limit used on board ships was set to 0.5%.

The sulfur concentration in fuels can be determined either by high-temperature combustion elemental analysis or by X-ray fluorescence spectroscopy (XRF), which is the only sulfur measurement method given in the ISO 8217. In XRF the sample is excited by high-energy X-ray and the emitted fluorescent X-ray is used to determine the abundances of sulfur.

Table 2: Main classes with regard to the maximum allowed sulfur content

Marine fuel class	***Sulfur content***
High sulfur fuel oil (HSFO)	> 0.5%
Very low sulfur fuel oil (VLSFO)	< 0.5%
Ultra low sulfur fuel oil (ULSFO)	< 0.1%

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