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CIMAC Guideline

Cold flow properties of marine fuel oils

By CIMAC WG7 Fuels

The first edition of this CIMAC Guideline was approved by the members of the CIMAC WG7 Fuels in January 2015.

Content

1 Scope

The low-temperature flow properties of a waxy fuel oil are temperature dependent and can have an adverse effect on operability. For example whilst one fuel at very low temperatures may remain fluid another of a similar grade may either stop flowing or result in the deposition of wax crystals at the filters causing fuel starvation and possible engine shut down.

This paper is aimed at providing ships crews with a better understanding of a fuel's "Cold Flow" characteristics which are often overlooked when storing and handling distillates.

2 Introduction

So why is this more a concern now than before? With the exception of ships equipped with approved alternative means of reducing sulphur emissions, such as an exhaust gas cleaning system, the International Maritime Organization's (IMO) MARPOL Annex VI has set limits on the sulphur content in the fuels being used whilst operating in a sulphur Emissions Control Area (ECA-SOx). As of 1 Jan 2015, the most significant change requires that the maximum sulphur content for fuels being used in an ECA be reduced from 1.00 mass % to 0.10 mass %.

Although new fuel products, both residual based and distillate based are being introduced to the market, it is expected that the majority of fuels supplied with max 0.10% sulphur will be distillates. (**Note:** It is out of the scope of this paper to deal in details with the new fuels but when using these products careful attention should be given to the low-temperature flow properties as described in this CIMAC guideline.)

Traditionally considered a trouble-free fuel, distillates also have properties that could be challenging for operators; cold flow is one of these properties often overlooked by ships.

ISO 8217 limits the cold flow properties of a fuel through setting a limit on the pour point (PP). However, given that wax crystals form at temperatures above the PP, fuels that meet the specification in terms of PP can still be challenging to operations in colder operating regions, as the wax particles can rapidly block filters, potentially plugging them completely.

Since residual fuels are usually heated and marine gas oils are not, this brief CIMAC guideline will therefore focus on the cold flow properties of distillates.

Figure 1: Filter blocked due to wax deposit

3 Paraffin wax

In chemical terms, paraffin's are also known as alkanes which are long chained hydrocarbons typically consisting of 20-40 carbon atoms. In layman terms, the general appearance of paraffin wax can be compared to candles.

Paraffin's are present in varying amounts (depending on the crude composition and refinery process) in petroleum products. They have good combustion properties and burn well in the engine but if/when fuel temperature drops, the paraffin's may crystallise and/or deposit in the storage tanks leading to blockages at the filters and reduced fuel flow to the machinery plants (see also 4).

The problems of experiencing such difficulties can be prevented through understanding the flow properties of the specific fuel in use (see also 7).

4 Cold flow properties

The cold flow properties of a fuel can be evaluated through one of, or a combination of, the three most commonly used test methods, these being: cloud point, cold filter plugging point and pour point.

- Cloud Point (CP)
  The cloud point is defined as the temperature at which wax crystals start to visibly form in the fuel and a transparent fuel becomes cloudy, thereof the name (ISO 3015).

- Cold Filter Plugging Point (CFPP)
  The Cold Filter Plugging Point is the lowest temperature where the fuel of a set volume, drawn, by vacuum, through a standardised filter (45 micron) within a specified time (60 sec) still continues to flow (ASTM D6371).

- Pour Point (PP)
  The reported pour point is the lowest temperature at which the fuel will continue to flow when it is cooled (ISO 3016).

Typically, the difference between each of the above temperatures will be about 2-5 degrees for untreated fuels, although higher differences are recorded, (see 8 about Cold Flow Improvers - additives) with the CP having the highest temperature and the PP the lowest.

5 Pour Point

Pour point is an important cold flow characteristic that determines the temperature below which the fuel will become immovable (perceived as turning solid) rendering the fuel unusable.

Ships have reported solidified fuels in tanks when reaching colder regions. The energy required in order to transfer the solid wax back to a liquid is significant and exceeds what normal onboard heating capacity and arrangements can manage. Such solidified fuel is known to have had to be shovelled out of the tanks manually aided by pressured steam lances to spread the heat through the fuel.

Although the differences in fuel composition are becoming less pronounced across the regions due to increased blending and trading of petroleum products, there are still regional

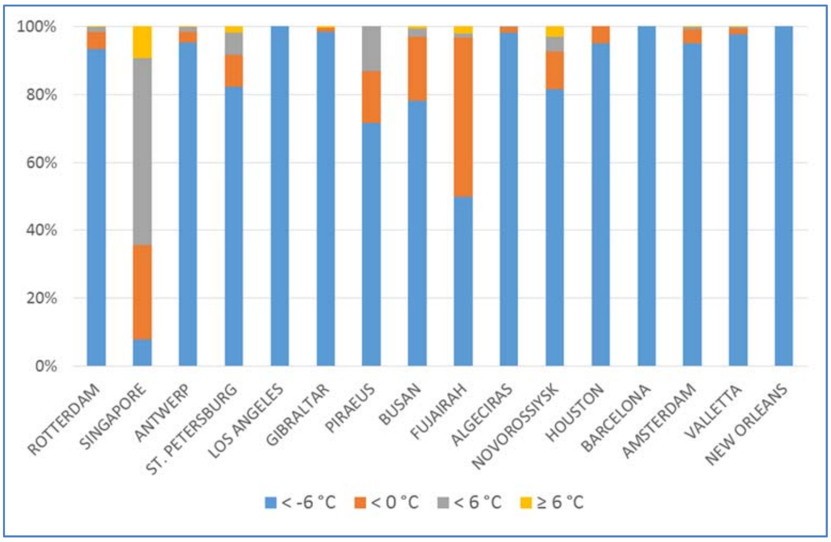

Figure 2: Distribution of pour point in DMA grade distillates in some main ports, Aug 2013 - Aug 2014 (Courtesy of VPS)

differences to fuel composition. As such, some regions tend to have higher PP than other regions. One reason for this is that the crude from which the fuel origin is more paraffinic resulting in end products with higher concentration of paraffin's. Unless depressed by cold flow improvers, the PP from that particular region will stand out as high on average (Figure 2). Records indicate pour points for distillates reaching as high as 12 deg C.

Note: The PP, the only parameter specified in the ISO 8217 specification, does not provide any indication of the temperature at which point filtration issues may occur.

6 Cloud Point (CP) and Cold Filter Plugging Point (CFPP)

The CP identifies the temperature at which crystals will start forming in the fuel, whereas CFPP provides a relative indication of where filterability problems may start to occur, leading to possible restrictions of fuel flow to the engine. Statistically it is not possible to determine the CP and CFPP from just knowing the PP figure as the correlation is very broad, notably illustrated in Figure 3.

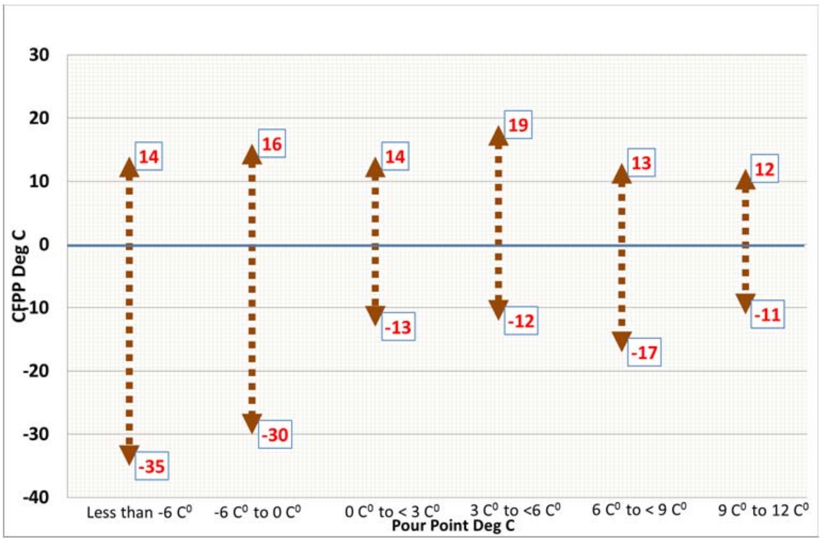

Figure 3: Max / Min CFPP range for DMA grade distillates against Pour Point - Global coverage 2013/14 (Courtesy of LR FOBAS)

When it comes to the CFPP, recently there have been a number of cases where the differences between the CFPP and PP have been as much as over 24 deg C; The PP was meeting specification being well below zero degrees Celsius. Ships were experiencing heavy wax deposits in the separators, restricted filters along with heavy wax deposits in the storage tanks.

7 Managing cold flow properties on board

The ECA sulphur requirements have a global impact when it comes to the purchasing of fuel, in that ships intending to enter ECA-SOx will have to bunker compliant fuel before heading towards Europe or North America. Whereas a PP of say 12 °C will not cause any problems in warm tropical climates, such as Singapore, lack of attention to the fuel's cold flow properties could have serious consequences once the ship arrives in Northern Europe or North America, especially during the colder months of the year.

Bear in mind that the fuel temperature should be kept approximately 10 deg C above the pour point in order to avoid any risk of solidification however this may not reduce the risk of filter blocking in case of high CFPP and CP.

7.1 Pre- Bunkering precautions

- It is important to check for any limitations the ship may have in the area of cold flow management on board, noting the ship's normal and likely future trading patterns, where upon the influence of the sea and ambient temperatures may be gauged against the worst case PP and CFPP properties.
- Suppliers should be advised of any anticipated limitation on cold flow prior to delivery as they may be able to supply fuel with better cold flow properties. If not, the vessel operator may be able to procure and apply additives to bring the distillate supplied within the ships operational requirements (See 8 on applying additives)**.**
- Understand the ship's heating possibilities for distillates on board. This is usually very limited, as it is not standard practice to have heating arrangements in distillate storage, settling or service tanks. Transfer arrangements may be adapted to pass through a residual fuel oil heat exchanger should the need arise. However noting that many ships are converting ships residual fuel tanks to carry ECA-SOx compliant fuel to increase capacity, in doing so they are retaining the heating arrangements.
- A fairly easy precaution to combat filter plugging is to heat the filters. This will assist in melting wax molecules either before they get caught by the filter or before they can accumulate to completely block the filter.

7.2 Post bunkering precautions

Knowing the fuel properties as soon as possible after bunkering will assist in taking the necessary precautions where and when necessary. If the ship is heading towards colder climates and the cold flow properties are inferior, the fuel may be:

- either used before entering cold regions, or
- used with suitable heating arrangement, as earlier advised

Special Notice: If the approach of applying heat is being followed it should be ensured that the fuel is not overheated resulting in the viscosity dropping below the minimum recommendation of 2 cSt at any point in the fuel system, including the engine inlet. In order to reduce this risk, heating should be limited to max 40 deg C.

Figure 4: Wax deposition in the diesel purifier where the distillate fuel temperature is below the CFPP of the fuel

A simple on board test can be carried out to determine the point at which the fuel starts to deposit waxes (see figure 4):

- Take a sample about 50-100ml of the fuel in a clear glass jar
- Clearly mark the glass jar: “Not for consumption”
- Place the fuel filled glass jar in a fridge at 3-6 deg C for 2-3 hours
- Confirm that the temperature of the fuel is at fridge temperature
- Note if the fuel has become cloudy or even deposited wax on the glass sides
- If so, the CP (and possibly the CFPP) exceeds the fridge temperature

8 Cold flow improvers - additives

Improving and managing the cold flow properties of a fuel by use of additives is a complex task requiring several considerations:

- Additives can be applied to depress the CFPP and PP; however, additives cannot influence the CP
- The CFPP reducing additives work by changing the shape of the wax crystals to facilitate the passage through the filters
- No additive will fit all fuels, however, there are additives available that will treat a broad range of fuels
- Some additives only impact PP whereas others will have an influence on both CFPP and PP (as illustrated in figure 5)
- Additives may be able to improve the cold flow properties; however response will vary based on the composition of the fuel.
- It is important to note that for the additives to be effective, they have to be applied before crystallisation has occurred in the fuel

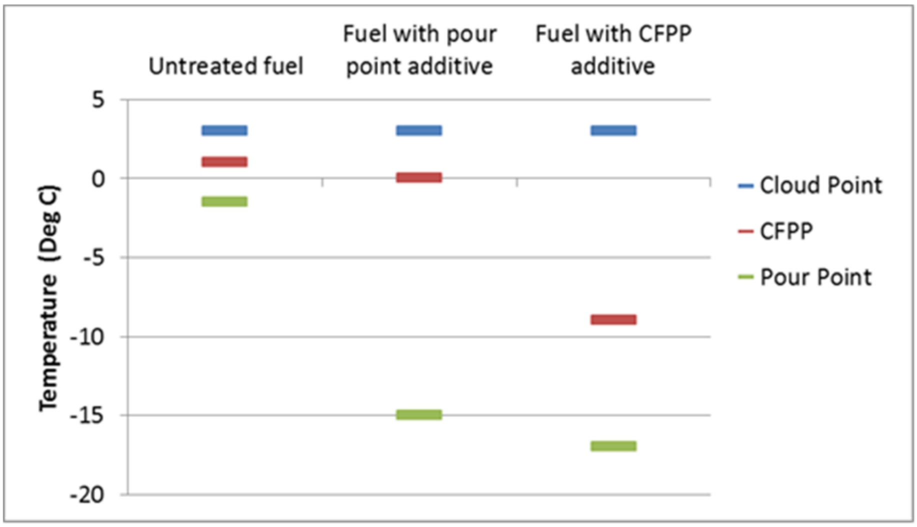

Figure 5: The impact of different additives on reducing the CFPP and PP (courtesy of Infineum)

9 Concluding remarks

Due to MARPOL Annex VI's sulphur limits, ship operators are faced with new challenges. Since distillate fuels does not require heating (in fact, typically, heating is not recommended due to the low viscosity of these products), the fuel's cold flow properties become a potential handling/storage challenge, especially when operating in colder regions.

It is however possible to successfully manage cold flow properties through good fuel management, from procurement to technical operation by considering the following:

- Where the ship will be operating
- Where the risk is higher of getting fuels with poor cold flow properties
- Can the required cold flow properties be specified in the fuel contract
- What is the actual low-temperature flow properties of the bunkered fuel
- Which actions have to be taken in order to safely consume the bunkered fuel (e.g. tank and filter heating)

Imprint

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