innospec

TECHNICAL BULLETIN

Customer Technical Service

VLSFO– A POINT ON POUR POINT

Innospec is the market leader in marine fuel chemistry. This technical bulletin will present VLSFO cold flow trends, terminology, data and case studies to arm yourself and your team with the knowledge to handle and use high pour point residual fuels in a safe and efficient way.

This Technical bulletin will cover the following

- Why do some VLSFOs have high Pour Points (PP) and cause Cold flow issue?
- What are the consequences?
- What terminology is useful when dealing with PP?
- Cold flow trends, predicting issues
- Why there is no reliable chemical solution?
- Case studies from the field

Overview

Since the introduction of VLSFO there have been consistent reports from the industry of high Pour Point (PP) residual fuels when compared to HSFO.

Last year the MEPC (Marine Environmental Protection Committee) looked at the quality of over 100,000 marine residual fuels. It revealed that more than 1-in-5 VLSFOs has Pour Points above 21°C,

PP >21°C	VLSFO	HSFO
% of sample	21	2

This requires a change in the way to handle and treat marine residual fuels. Previously HSFO could be left in the tank for months, unheated with the main risk being sludge depositing in tanks over time.

The consequences of handling a high pour point fuel incorrectly are severe, ranging from fuel stratification, machinery damage, or entire storage tanks rendered unusable. By understanding the limitations and changing our onboard practices, we can better face these new challenges.

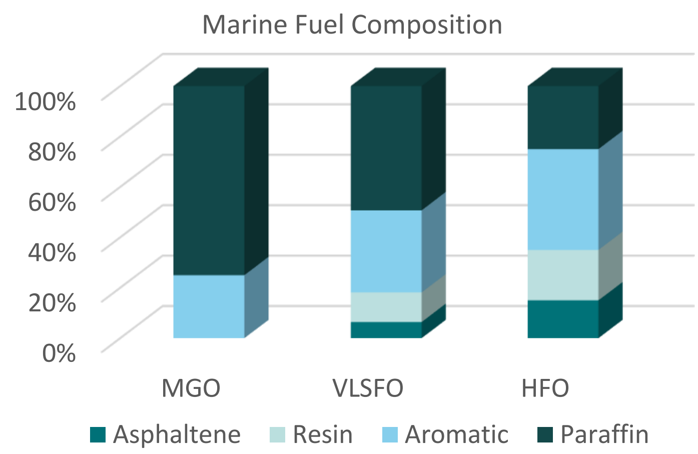
High pour point solids in fuel lines, blocking fuel systems and causing fuel starvation

What causes cold flow issues?

Solid wax in fuel lines, at the bottom of tanks or purifiers and filters are caused when paraffinic components within fuel crystalise into solids at a given temperature.

Distillate fuels such as MGO, are high in paraffinic material which increases the probability of cold flow issues. HSFOs are very low in paraffinic material and do not suffer cold flow issues in most circumstances, therefore no method has ever been formally introduced to predict cold flow issues in residual fuels.

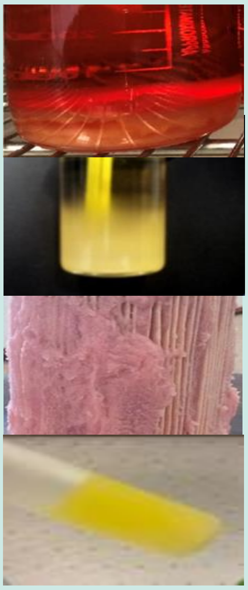
VLSFO sits at a juncture between the two, it is purchased under the residual ISO 8217 standard but more closely resembled a distillate MGO fuel in terms of its paraffin content.



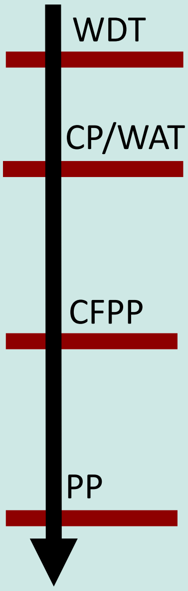
Cold Flow – Term toolkit

Cold flow issues in clear fuels (MGO, diesel) rely predominantly on optical testing methods such as cloud point, to detect 'cloudy' formations of waxy elements as they cool. Marine residuals are not clear, which is why no official method yet exists to predict and identify the wax formations responsible cold flow issues. Fuel testing services have been working to correct this and offer a solution, particularly in light of reports from the field of 'waxy' VLSFOs blocking filters, purifiers and tanks in when fuels are not heated.

Below is a list of terms commonly used when talking about fuel cold flow issues. You will note how as the temperature decreases, fuel operability is increasingly restricted.



Temperature °C



WDT (Wax Disappearance Temperature)
Temperature at which the last wax solids are melted into liquid

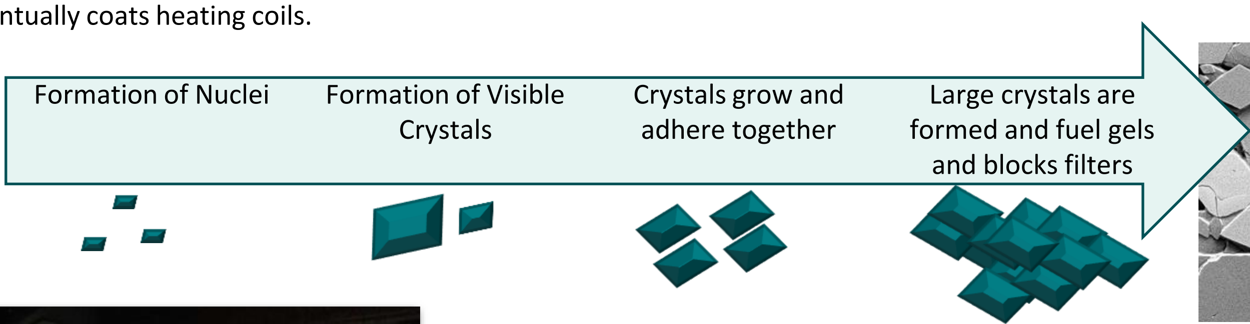
CP (Cloud Point) / WAT (Wax Appearance Temperature)
Temperature at which the first wax solids precipitates from a fuel, producing a visible cloudiness in clear distillate fuels. To avoid waxing issues, temperatures should be maintained above WAT.

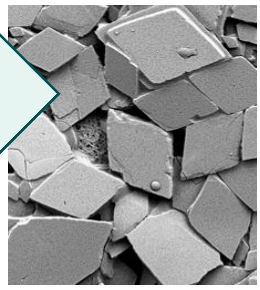
CFPP (Cold Filter Plugging Point)
As temperatures decrease further, fuels fail to flow freely through filters. This is a practical method to determine when fuels will impact operations. Currently unavailable for Residuals.

Pour Point
Temperature at which fuel cease to flow, a hard point in fuel operability. Results in fuel stratification and unpumpable solids

Waxy fuel

Wax in fuel begins with the formation of nuclei as the temperature drops and approaches the cloud point (Distillate) or WAT (Residual) of a fuel. As the temperature continues to drop, crystals form and increase in number and size until they become visible to the human eye as a cloudiness in a clear fuel, hence the term cloud point. With time these crystal adhere to one another and settle to the bottom of tanks, creating a solid paraffinic wax that eventually blocks filters, fuel suction lines and eventually coats heating coils.



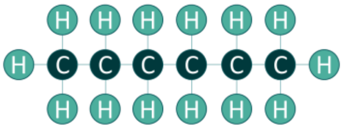


Paraffinic waxes are extremely poor conductors of heat, this means that if they occur in sufficient numbers to cover heating coils there will often be insufficient heat capacity to penetrate the wax and return the fuel to liquid. This can result in solids blocking suction lines, leaving no option but to manually empty the liquid phase of the fuel tank with the intention of digging out the solid wax at the bottom to clear the system.

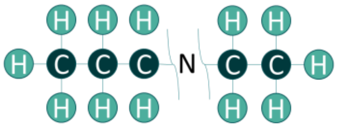
Prevention through treatment with cold flow improvers or maintaining a minimum heat is by far the most effective way of handling waxy fuels.

N-Paraffin – the linked between Waxy fuels and Pour Point

Both the **number** and **type** of paraffin determines the likelihood of cold flow issues in fuel.



A C6-Paraffin, straight chain hydrocarbon with 6 carbon molecules



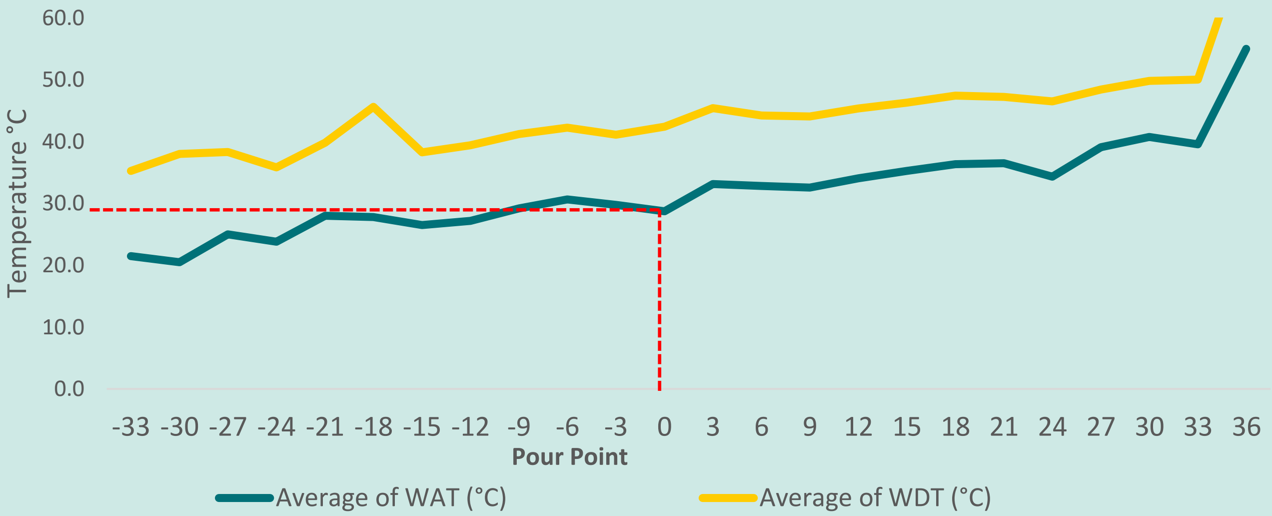
A N-Paraffin, straight chain hydrocarbon with N Carbon molecules

The term **n-paraffin** refers to long chain paraffins that rapidly precipitate when cooled. Just 2% n-paraffins in fuel is required to block filters at low temperatures, typically MGO can have up to 30% n-paraffins.

When the temperature of fuel drops, n-paraffins begin to solidify, this is because the bonds between the atoms stop vibrating as the lack of heat in the system means they have no energy. As the n-paraffins continue to precipitate, they bind to one another forming larger wax crystals that potentially blocks filters.

When temperatures increase, paraffin waxes melt and the fuel becomes homogenous again. This occurs as more heat in the system allows the bonds between the atoms to vibrate, returning the waxes from a solid state to liquid state. However the heating capacity of most vessels is insufficient to return wax back to liquid once they have formed, and do manual cleaning and digging out the wax may be required.

Link between wax and pour point



A sample of over 20,000 VLSFOs shows the correlation between pour Point and WAT/WDT temperatures with great clarity. Even low pour point (<0°C) VLSFO poses a cold flow risk, with waxes appearing at 20°C in most cases.

We have seen that as Pour points approaching 0°C, the average Wax Appearance temperature (WAT) is 28°C. This means that wax formations can be detected at temperatures of 28°C or less. The Wax Disappearance Temperature (WDT) is higher in every instance, this is due to latent heat needed to change state. Above this temperature the waxes are no longer detectable.

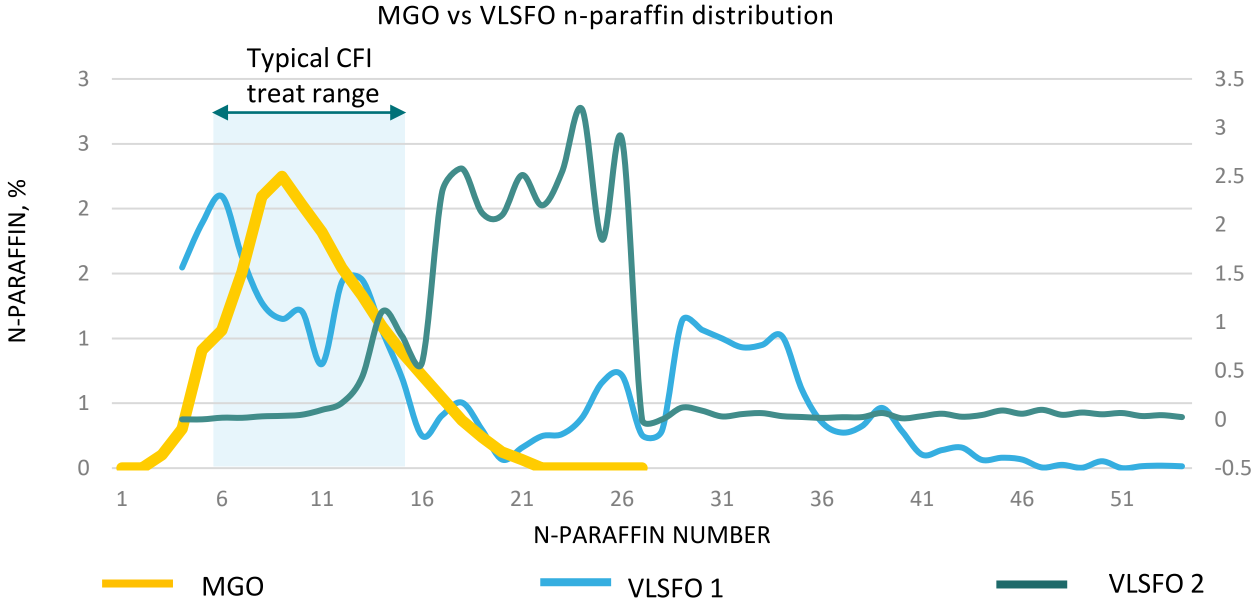
CFPP (Cold Filter Plugging Point) for VLSFO is currently unavailable, it is still too early, and the filter sizes on vessel vary so widely that it may have limited use.

It is better to understand that prolonged storage below the WAT would most likely results in wax formation at the bottom of tanks.

Why are there no Cold Flow Improvers (CFI) for VLSFO?

Cold Flow Improvers (CFI) are created to target the most common N-Paraffins within a fuel. For MGO, this is relatively simple due to consistency in production and therefore in the n-paraffin distribution.

VLSFO quality is far more variable. Our research into n-paraffin distribution of VLSFO has shown that they not only differ from MGO, but significantly differ from each other. This means a cold flow improver designed for MGO will most likely not work on VLSFO, whilst CFI products designed for one VLSFO may not be effective in others.



The graph above gives an example of two VLSFOs with completely difference n-paraffin profiles. CFI products are designed to target a specific range as illustrated by the treat range. We can see CFIs for the typical MGO will have limited to no impact on VLSFO 1 or VLSFO 2 as most n-paraffins for these fuels exist outside of the treat range.

Solution?

It would be possible to produce a specialist CFI to treat the n-paraffins of a single VLSFO, however the prospect of treating all VLSFOs with a single CFI is not practicable. In theory a single CFI could be designed to impact the entire n-paraffin range found in VLSFOs however, such a treatment would require very high treat rates and prove prohibitively expensive and of little practical use.

The most practical way to prevent cold flow issues when using VLSFO is to ensure sufficient heating in fuel tanks, maintaining temperatures inline with or close to the Wax appearance temperatures wherever practical.

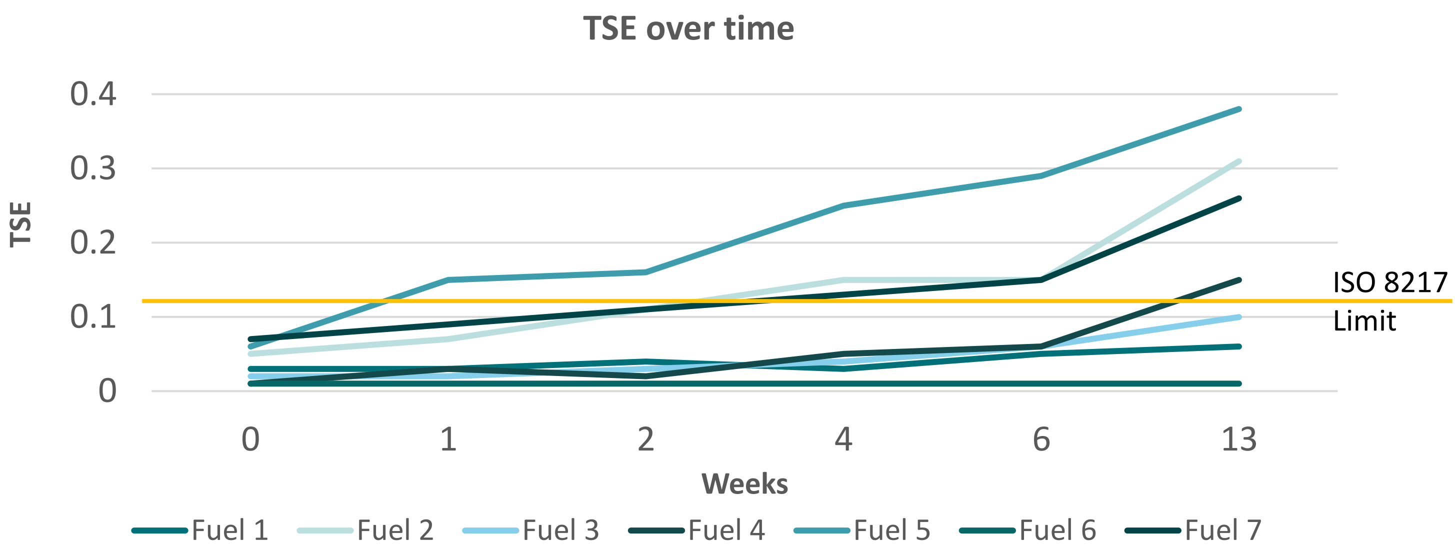
Residual fuels are often highly viscous and require heating to bring their viscosity down to a level where effective pumping and injection is possible. For HSFO, fuels were stored unheated and then before use brought up to temperature, however VLSFO will require continuous heating in storage to prevent cold flow issues in colder climates.

However, much like heating an MGO, heating lighter VLSFOs over time is not advised due to the onset of **ageing** common when lighter or FAME components are heated in the long term. The next section will cover third party and Innospec advice on heating VLSFO to prevent Cold Flow issues and how the negative consequences of doing so can be overcome.

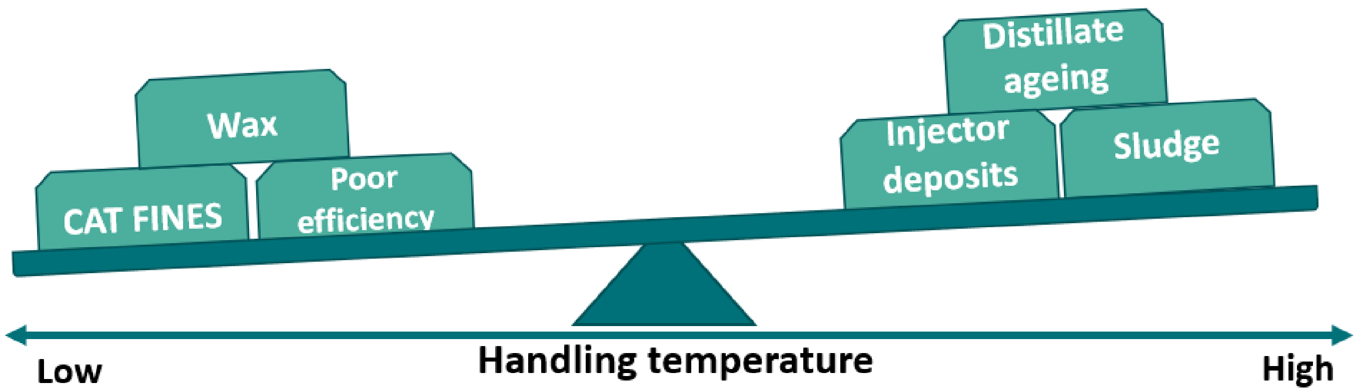
Considerations when heating VLSFO

Heating VLSFO to prevent cold flow issues will cause unintentional issues related to distillate ageing i.e. the rapid change in fuel quality due to chemical reactions in the lighter fractions of the fuel.

A study into the storage stability of VLSFO from global ports shows how the sediment present in VLSFO increases over time when a fuel is stored at slightly elevated temperatures (50°C). The Total Sediment Existent (TSP) increases with time across most fuels, and rapidly increases in most cases to exceed the ISO 8217 limits within weeks.



The increased sedimentation would manifest as excessive sludge, filter blocking and centrifugal purifier maintenance. However these are only symptoms of ageing and other issues besides might be expected, such as reduced fuel efficiency, poor combustion and contamination of future bunkers.



There is clearly a gentle balance to be maintained when handling VLSFO that did not previously exist when using HSFO. If temperatures are too low there is the risk of cold flow issues, poor separation efficiently etc. Too high and fuel will age, leading to excess sludge and deposits. Diligent monitoring and house keeping is one of the best ways to combat this, ensuring that storage temperatures are maintained high enough to prevent wax but not so high that the ageing process is unduly accelerated.

At this time there is little information on how low is too low, or how high is too high. Chemical treatments are available that retard the chemical ageing process and mitigate against the consequences of aged fuel.

Case Story 1: Wax sludge experienced in cold climate

Example of solid wax deposits on tank bottoms

Bunker Grade, Quantity: VLSFO IFO380, 2000MT

ISO 8217: Met

Viscosity, Pour Point: 28cSt, 6°C

WAT, WDT: Not tested

Issue: Sludge clogging backwash filters and overloading purifier. Heavy sludge left behind at bottom of bunker tank unable to be dissolved.

It was during the winter season and the container ship was transiting through a cold climate region. There was no issue faced when the first 200MT of fuel was consumed but soon after, the vessel started to experience sludge issues. Some fluctuation was also observed at the viscometer.

Why did this happen? Where heating is insufficient, especially when the vessel transits through cold climates, the fuel can separate into layers. Initially, lighter components will enter the fuel system and leaves behind the heavier components. Even with the highest possible temperature that can be achieved in bunker tanks, the sludge that remains at the bottom of the tank will not dissolve.

Case Story 2: Wax sludge experienced with on spec pour point fuel, WAT/WDT unknown

Port: South Korea
Bunker Grade, Quantity: VLSFO IFO380, 400MT
ISO 8217: Met
Viscosity, Pour Point: 33cSt, 15°C
WAT, WDT: Not tested
Issue: High generation of sludge overloading the purifier.

In this case, the sludge appeared to have both the consistency of waxes and asphaltene sludge. Hence, to eliminate the possibilities, the vessel carried out a trial and error at the purifier by increasing the separation temperature in steps of 5 °C from the recommended separation temperature which was 60 °C. When the separation temperature was maintained at 75 °C, the sludge generated was observed to be minimal and therefore, the sludge is likely waxes.

Sometimes, purifying at the recommended temperature is insufficient when the fuel has a higher risk of experiencing cold flow issues. At any point of time, if the temperature falls below WAT, wax crystals will form and they can only be dissolved by increasing the heating temperature to above WDT.

However**,** excessive heating either by high temperature or long-term heating can accelerate the distillate ageing process. Hence, correct heating must be applied.

Case Story 3: Wax sludge experienced with low pour point fuel, high WAT/WDT

Port: Singapore
Bunker Grade, Quantity: VLSFO IFO380, 800MT
ISO 8217: Met
Viscosity, Pour Point: 57cSt, 3°C
WAT, WDT: 74 °C, >75 °C
Issue: High generation of sludge overloading the purifier

Waxy fuel blocking centrifugal purifier drains

The vessel suspected waxes due to the softer appearance of sludge that was clogging the purifier and hence, requested for the fuel lab to carry out WAT, WDT testing with the fuel. From the results, it is likely that waxes have formed in the bunker tank as the fuel's temperature at storage fell below its' WAT result. In an attempt to dissolve the waxes before consuming the fuel, the vessel increased the storage temperature to as close to WDT as possible, managing to achieve only 50 ℃ inside the bunker tanks. The sludge issue did improve for the next 48hrs before it took a turn and worsened.

Why did this happen? This is an example where issues and solutions overlap. In this case, the temperatures required to dissolve the waxes (WDT) were extremely high which brought a new problem into the equation- an irreversible distillate ageing process through thermal instability. In addition, distillate sludge can similarly clog filters and purifiers.

The fuel's resistance to oxidation and thermal instability can be improved significantly with the help of fuel additives. However, if the distillate ageing process has already started then it cannot be reversed. Its' effectiveness will only be to stabilise the fuel and the chances is dependent on the extent the fuel has aged. Hence, pre-combustion additives are always recommended to be dosed at an early stage- into the storage tanks before bunkering.

To explain the disparity between pour point and WAT in this case, we will need to revisit the n-paraffins distribution graph. In the presence of a higher concentration of lighter n-paraffins, this leads to uneven precipitation due to the gradual precipitation of the heavier or longer carbon chains that also exists in this fuel.

Please contact your local sales representative for more information.
email: CSC.americas@innospecinc.com CSC-emea@innospecinc.com CSC.asiapacific@innospecinc.com

For technical support or questions please email: marine.technical@innospecinc.com

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