FEBIMA

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Belgium

Report 2020/003688

Report on the investigation into a serious injury on board

mv MINERAL TEMSE

at the South Atlantic Ocean with one victim on May 5th 2020.

Federal Bureau for the Investigation of Maritime Accidents

1. CONTENT

2. LIST OF ILLUSTRATIONS

3. Glossary of abbreviations and acronyms

%	Percent
% m/m	mass percent
% V/V	Volume Percent
°	Degrees
AO	Amongst Others
C	Celsius
Co. Ltd.	Limited Company
E	East
ETA	Estimated Time of Arrival
ETC.	Et Cetera
FO	Fuel Oil
FW	Fresh Water
h	Hour
IMO	International Maritime Organization
ISO	International Organization for Standardization
KG	Kommanditgesellschaft (Limited Company)
kg	Kilogram
kW	Kilo Watt
Lbpp	Length Between Perpendiculars
LOA	Length Over All
LT	Local Time
m	Metres
M/v	Motor Vessel
m^3	Cubic Metre
mg	Milligram
mg KOH/g	Milligrams of Potassium Hydroxide per Gram
MLC	Maritime Labour Convention
mm^3	Cubic Millimetre
MPT	Mixed Partial Thickness
mT	Metric Tons
N°	Number
Nm	Nautical Mile
Nv	Naamloze Vennootschap (Limited Company)
PAS	Publicly Available Specifications
PPE	Personal Protective Equipment
RMG	Residual Marine Fuel Oil
S	South
s	Second
SMS	Safety Management System
TBSA	Total Body Surface Area
UTC	Universal Time Co-ordinated
VLSFO	Ver Low Sulphur Fuel Oil

4. Marine Casualty Information

4.1 Resume

By opening the inspection plug of the sludge discharge line of a switched-off fuel oil separator on board, hot sludge oil gushed out of the opening onto the engineer on duty.
The engineer was wearing loose shorts and a t-shirt.
Large parts of his hands, arms and legs were covered with hot sludge, causing burns on 12% of the engineer's body surface.

4.2 Classification of accident

According to Resolution A.849(20) of the IMO Assembly of November 27th 1997, Code for the investigation of Marine Casualties and Incidents, a marine casualty means an event that has resulted in any of the following:

- the death of, or serious injury to, a person that is caused by, or in connection with, the operations of a ship; or
- the loss of a person from a ship that is caused by, or in connection with, the operations of a ship; or
- the loss, presumed loss or abandonment of a ship; or
- material damage to a ship; or
- the stranding or disabling of a ship, or the involvement of a ship in a collision; or
- material damage being caused by, or in connection with, the operations of a ship; or
- damage to the environment brought about by the damage of a ship or ships being caused by, or in connection with, the operations of a ship or ships.

A serious injury means an injury which is sustained by a person in a casualty resulting in incapacitation for more than 72 hours commencing within seven days from the date of injury. Consequentially, the incident was classified as a

MARINE CASUALTY - SERIOUS INJURY

The maritime labour Convention states in Regulation 5.1.6 that each Member shall hold an official inquiry into any serious marine casualty, leading to injury or loss of life, that involves a ship that flies its flag. The final report of an inquiry shall normally be made public.
The Belgian law of June 2nd 2012 regarding the Federal Bureau for the Investigation of Maritime Accidents authorizes FEBIMA to perform such inquiries.

4.3 ACCIDENT DETAILS

Time and date	May 5th 2020, 20:34 hours LT
Location	29° 41,98'S 013° 40,20' E South Atlantic Ocean, app. 350nm NW of Cape Town
Persons on board	21
Deceased	0

5. SYNOPSYS

5.1 NARRATIVE

All times in LT, UTC+2, unless specified.

On March 17th 2020, mv MINERAL TEMSE had bunkered very low sulphur fuel oil, VLSFO in short, in Gibraltar before heading to Bahrain via the Cape of Good Hope, with an ETA on May 26th 2020.

A fuel sample was taken during bunkering and the sample was analysed on 20 March 20th 2020. No anomalies were detected.

Mv MINERAL TEMSE was authorized to sail with an unmanned machinery space. Alarm panels were installed in different locations, including the cabins of watchkeeping engineers.
During the daily working hours, engineers were present inside the engine, but outside these working hours, the engine room was only entered to make a safety round or to check equipment after an alarm had been generated on the alarm panel.

Upon entering and leaving the engine room, outside the working hours, the officer of watch on the bridge had to be informed and an entry in the deck log book was to be made.
During the stay in the engine room, the officer of watch was called every 20 minutes by the engineer on duty and it was not allowed to execute more detailed inspections, maintenance or repairs without someone else present in the engine room.
A motorman on duty could be called for assistance in case such works had to be carried out outside the daily working hours.
Safety instructions on the door to the engine room, as indicated in
Figure 1, were showing these instructions.

Figure 1 - Entrance door to engine room with instructions

The vessel was equipped with two centrifugal fuel oil separators[1], cleaning the fuel at a temperature around 40°C.

The sludge that was produced during this process was discharged from the separator through a pressure less discharge line.

An inspection opening covered by a plastic cap, as shown in Figure 3, made it possible to verify the condition of the discharge line.

In Figure 2, the sludge discharge line is represented after the accident had taken place.

[1]Marine fuel oils contain very small, unfilterable particles of impurities (including water) that can damage the vessel's engines. To remove these particles, the fuel oil is sent through a separator. The working of most separators is based on the use of the centrifugal force. The variety of particles together forms a slushy mass, called sludge.

Figure 2 - Fuel oil separator and sludge discharge line after the accident

On April 15th 2020 the vessel started to consume the VLSFO that was bunkered in Gibraltar and from that date, the sludge discharge line of the oil separator on board got clogged frequently, generating a "*separator fail*" alarm on the alarm panel.

After consulting the vessel's superintendent, it was agreed that the oil separator had to be cleaned twice a day. One of the two separators had to be kept in standby modus in case a switch over from the running separator to the standby separator was necessary after a "*separator fail*" alarm was generated.

On May 5th 2020 around 20:18 hours, the engineer on duty received a "*Separator N°1 fail*" and a "*Fuel oil bowl leak*" alarm on the computer. Experience learned that this was a consequence of the contamination of the separator bow[2]l as the discharge line of the separator got clogged.

The engineer informed the bridge that he was going to the engine room alone.
He did not put on his coveralls and entered the engine room where he switched off separator N°1 and switched on separator N°2.
Thereafter, he opened the plug of the inspection hole of the sludge discharge line in order to verify the condition.

[2]See *Figure 9 - Sludge accumulated inside the separator* and *Figure 10 - Sludge discharge phase of a separator*

Figure 3 - Plastic plug covering the inspection hole of the sludge discharge line

Upon opening the plug, hot sludge oil gushed out of the inspection hole and covered the arms and legs of the engineer.

Figure 4 - Sludge gushed out of the inspection opening

The engineer called the on duty motorman for help and informed the bridge that he got burned by hot sludge. At 20:34 hours the officer of watch received the call from the injured engineer. The master, who was on the bridge to check the ship's correspondence, ordered the officer of the watch to muster the emergency team, including the chief mate and the second mate.

At 20:35 hours the injured engineer was calling to the chief engineer, when the third engineer arrived in the engine room.

The third engineer helped the injured engineer to wash off the sludge at the washstand inside the engine room.

Before going to the engine room, the chief engineer called the electrician.

In the engine room ,the chief engineer met the third engineer and the injured engineer at the washstand.
He ordered the third engineer to take over the watch from the injured engineer, to check the affected area and to verify the parameters and condition of the working separator N°2. The third engineer checked all parameters, but no anomalies where found.

Meanwhile the electrician had arrived in the engine room. The chief engineer and the electrician escorted the injured engineer to the ship's sick bay.

At 20:38 hours the master went down from the bridge and met with the injured engineer, the electrician and the chief engineer at the upper deck, near the hospital.

At the same time, the second officer arrived at the sick bay.

Inside the sick bay, the dirty clothes of the injured engineer were removed and he was put in the bath tub filled with cold water, during ten minutes to cool down the burnt skin.
Meanwhile, the second officer prepared the necessary medicines, ointments and materials to threat the injured body parts.
Around 20:45 hours the chief officer also arrived in the sick bay.

Figure 5 – Legs of the engineer covered with sludge

At 20:51 hours, the cooling down of the burnt skin was stopped and the burns were treated with the necessary ointments and covered with sterile gaze. The medical team tried to remove the sticky sludge from the non-affected skin with soapy water. Medicines to mitigate the pain were dosed according to the doses from the medical guide for ships.

At 21:25 hours, the telemedical maritime assistance service MEDICO in Cuxhaven ,Germany, was called for medical consultation and further assistance.

From 21:45 hours onward, and as per doctor's recommendation, medicine was dosed to the injured engineer every 6-8 hours and essential wound care was administered.

On 6 May 2020, in consultation with MEDICO Cuxhaven and the shipowner, the master decided to call at the nearest port, Cape Town, approximately 250nm from the position of the vessel at that time, in order to evacuate the patient.

On 7 May 2020 the patient was evacuated from the vessel and transferred to a hospital in Cape Town, where the patient was diagnosed with 12% total body surface area mixed partial thickness burns, which were covered in sludge, involving both arms and legs.

6. Factual information

6.1 Vessel's details

Figure 6 - Mv MINERAL TEMSE

Type: Capesize Bulk Carrier

Flag: Belgium

Port of registry: Antwerpen

Call Sign : ONJO

IMO N°: 9435052

Shipyard : New Times Shipbuilding Co. Ltd., China

Date of delivery : 21/07/2010

Keel laid: 10/12/2008

Current owner: CMB nv

Current Manager: Oskar Wehr KG

LOA: 291.80m

LBPP: 282.20m

Breadth (Moulded): 45.00m

Depth (Moulded): 24.75m

Draught summer: 18.273 m

Gross tonnage: 92,079

Net tonnage: 58,672

Displacement: 202,616.80 tons

Deadweight (summer): 175,396.60 tons

Holds/Hatches: 9/9

Hatch cover type: 2 covers side rolling

Main Engine Type: Diesel

Main Engine Maker: Hyundai

Main Engine Model: MAN B&W 6S70MC6

Engine power: 16860 kW x 91rpm

Full speed (ballast): 15.5 knots

Full speed (laden): 15.5 knots

Propeller: Fixed, right hand

7. ANALYSES

7.1 FUEL QUALITY

On March 17th 2020, the vessel bunkered 1097 mT VLSFO RMG 380 with 0.46% m/m sulphur content from MINERVA bunkering ltd. in Gibraltar.

From April 15th 2020 onward, the vessel was consuming this fuel and during the consumption the sludge discharge line of the fuel oil separators was clogged regularly. Figure 7 shows the clogged sludge discharge line.

Figure 7 - Completely blocked sludge discharge line of separator N°1

An oil sample taken during the bunkering was analysed by VPS, Veritas Petroleum Services, on March 20th 2020. According to the analysis report, the fuel met the specifications of ISO 8217 Fuel Standard for marine distillate fuels. The values are shown in

Figure *8*.

MINERAL TEMSE

Test Results

Test Results	Unit	Test Results	RMG380	Test Method
Density @ 15°C	kg/m³	932.0	991.0	ISO 12185
Viscosity @ 50°C	mm²/s	143.8	380.0	ISO 3104
Water	% V/V	0.07	0.50	ASTM D6304-C
Micro Carbon Residue	% m/m	6.39	18.00	ISO 10370
Sulfur	% m/m	0.45	0.50	ISO 8754
Total Sediment Potential	% m/m	0.01	0.10	ISO 10307-2
Ash	% m/m	0.01	0.10	LP 1001
Vanadium	mg/kg	10	350	IP 501
Sodium	mg/kg	9	100	IP 501
Calcium	mg/kg	8	30	IP 501
Zinc	mg/kg	<1	15	IP 501
Phosphorus	mg/kg	3	15	IP 501
Pour Point	°C	<0	30	ISO 3016
Flash Point	°C	>70.0	60.0	ISO 2719-B
CCAI (Ignition Quality)¹	-	841	870	ISO 8217
Aluminium + Silicon	mg/kg	9	60	
Acid Number	mg KOH/g	0.2	2.5	ASTM D664
Total Sediment Existent	% m/m	0.01		ISO 10307-1
Aluminium	mg/kg	4		IP 501
Silicon	mg/kg	5		IP 501
Iron	mg/kg	11		IP 501
Nickel	mg/kg	6		IP 501
Magnesium	mg/kg	<1		LP 1101
Potassium	mg/kg	<1		LP 1101
Asphaltene	% m/m	1.0		ASTM D3279
Net Specific Energy¹	MJ/kg	41.83		ISO 8217
GC/MS Screen Headspace	-	Pass		LP 3404-Headspa Screen
Separability Number	% Trans	0.3		ASTM D7061

¹ Calcu

Temperature

Injection	60 °C for 10 mm²/s, 50 °C for 15 mm²/s, 40 °C for 20 mm²/s, 35 °C for 25 mm²/s
Transfer	Transfer : Heating may be required in cold climates.

Figure 8 - Extract from fuel analysis report

RMG 380 is a residual marine fuel oil. Residual fuel oil is one of the lowest value petroleum products and the main type of fuel used for propulsion on board ocean going ships. It is processed from the remaining residues of the refining process of other oil products. The sulphur content of residual fuel oil can be reduced by further processing.

The ISO 8217 norm[3] specifies the requirements for different types of distillate and residual fuels, including RMG 380, for use in marine diesel engines and boilers, prior to conventional onboard treatment, such as settling, centrifuging and filtration, before consumption. The requirements

[3] See Annex 3 for the requirements of ISO8217:2017.
The tables taken from ISO 8217:2017 - Petroleum products — Fuels (class F) — Specifications of marine fuels, are reproduced with the permission of the International Organization for Standardization, ISO. This standard can be obtained from any ISO member and from the Web site of ISO Central Secretariat at the following address: www.iso.org. Copyright remains with ISO.

guarantee a certain fuel quality. The receiver usually has the delivered fuel sample tested and analysed for quality comparison.

Refineries can process residual fuels by blending with distillates until a product is obtained that meets the requirements of ISO 8217.

The IMO 2020 regulations state that the maximum sulphur content in marine fuel is limited to 0.5% m/m from January 1st 2020, where it was 3.5% m/m before.
Due to these new IMO regulations, the demand for fuel oil with less than 0,5% m/m, such as RMG 380, increased. The refineries were challenged to use more and other refinery residues to fulfil the need for low sulphur fuel. This led to many new blends of VLSFO that apperared on the market.

Although the blends corresponded to ISO 8217 requirements, other fuel oil characteristics introduced new risks on board such as:

- Instability of fuel : the ability of blended fuels to breakdown and precipitate asphaltenic sludge when handled or stored; The total sediments method (tested in ISO 8217) gives an indication of the amount of sludge that can be formed. The lower the result, the better.
- Incompatibility between different batches of VLSFO: Mixing different blends of fuel can have an impact to the stability and the cold flow properties of the fuel. Compatibility of different blends can be determined.
- Differences in viscosity: This has impact the temperature to threat the fuel on board.
- Differences in density: This can be important for certain fuel cleaning systems: the gravity discs in fuel separators need to be adapted to the density of the fuel to separate the water that is contained in the fuel.
- Unexpected cold flow properties: At a certain temperature, wax crystals that can block filters and pipes are being formed in the fuel. The temperature at which these crystals are formed is different for every blend. The difficulty is to find the right temperature at which the viscosity is good without forming wax crystals.
- Poor ignition and combustion characteristics: this can cause engine damage and breakdown in extreme properties
- Risk of more catalytic fines of the refinery process (Aluminium and Silicon) in the fuel: these are small, very hard particles which can wear the engine fast. They can be detected during sample analysis and are removed during the cleaning process of the fuel in a.o. separators.

These risks were assessed by the industry before IMO 2020 came in vigour. In 2019, International standard *ISO/PAS 23263:2019 Petroleum products- Fuels class F- Considerations* *for fuel suppliers an users regarding marine fuel quality in view of the implementation of maximum 0.50% Sulphur in 2020* was issued[4].

A lot of information regarding these risks was spread, as indicated by the circular of Veritas Petroleum Services in

Annex *1*.

The amount of sediments and catalytic fines was not high in the bunkered fuel, since the fuel was not mixed with other fuels and since the problems occurred in the fuel oil separator at a temperature of around 40°C, the clogging of the sludge discharge line of the separator on board mv MINERAL TEMSE can possibly be assigned to cold flow properties of this specific blend of VLSFO RMG380.

7.2 SEPARATOR ALARM

The working temperature of the fuel oil separator on board at the time of the accident was 42°C. The sludge discharge line of the separator was not heated and in normal working condition. There was no pressure on the sludge discharge line when the separator was switched off.

On May 6th 2020, at 20:14 hours, two separator alarms were generated, *Separator No.:1 fail* and *FO Bowl leakage*. These alarms popped up regularly since the consumption of the fuel oil that was bunkered in Gibraltar on March 17th 2020. It was known that these alarms were the result of a blockade in the sludge discharge line and the contamination of the separator bowl since sludge could no longer be removed from the bowl when the discharge line was blocked.

Figure 9 and

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[4] ISO/PAS 23263:2019 addresses quality considerations that apply to marine fuels in view of the implementation of maximum 0,50 mass % S in 2020 and the range of marine fuels that will be placed on the market in response to the international statutory requirements to reduce exhaust gas emissions. It defines general requirements that apply to all 0,50 mass % sulfur (S) fuels and confirms the applicability of ISO 8217 for those fuels.

It gives technical considerations which might apply to particular fuels for the following characteristics:

— kinematic viscosity;
— cold flow properties;
— stability;
— ignition characteristics;
— catalyst fines.

Additionally, it provides considerations on the compatibility between fuels and additional information on ISO 8217:2017. This document can also be used in conjunction with earlier editions of ISO 8217 in the event an earlier edition is referenced in the commercial agreement between parties.

Figure 10 represent the removal of sludge from the separator to the discharge line in normal working conditions.

During the cleaning process of the fuel oil in the separator, solids were accumulated on the outer side of the separator bowl due to the centrifugal force. This is represented in Figure 9. The sludge discharge opening is closed.

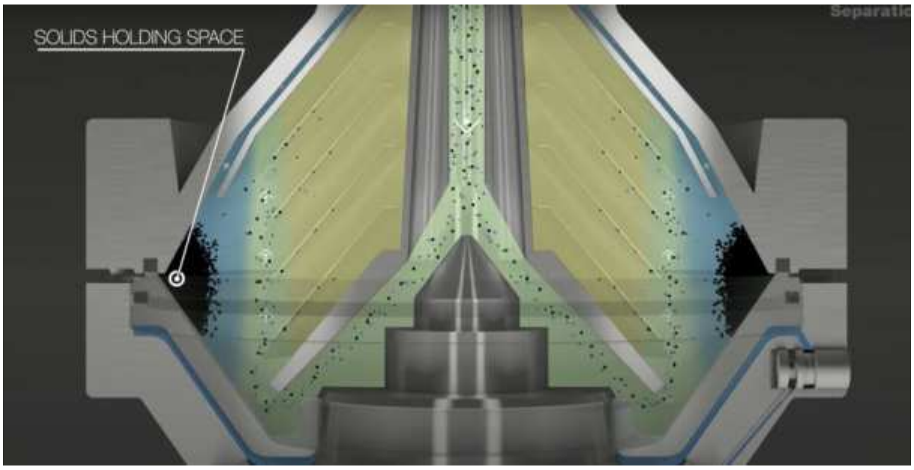


Figure 9 - Sludge accumulated inside the separator

Source: Marinersight youtube channel

At regular intervals, the sludge is removed from the bowl through the discharge line, as represented in

Figure 10. Solids and water flow into the sludge discharge line.

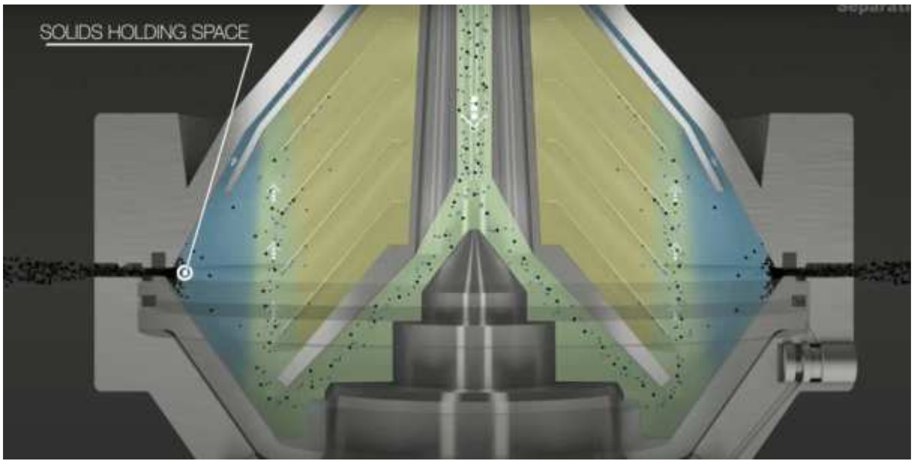


Figure 10 - Sludge discharge phase of a separator

When the discharge line is blocked, sludge can no longer be removed from the bowl and the bowl becomes contaminated. When that happened, an alarm was triggered. In this case a *Separator Fail* alarm and a *FO Bowl Leakage* alarm were triggered.

In the time between the clogging of the sludge discharge line and the triggering of the *Separator Fail* and *FO Bowl Leakage* alarms, pressure inside the discharge line built up and the temperature rose.

After switching off the separator, the pressure built-up between the blockade and the bowl opening did not decrease since the discharge line was completely blocked.

The discharge line was not equipped with a pressure gauge, since the sludge inside the discharge line is normally not under pressure. It was unusual and unexpected that the sludge was under pressure after switching off the separator.

The inspection plug as indicated in Figure 3 was opened very soon after switching off the separator. The sludge was still hot in the time between the clogging of the discharge line and the generated alarm. Exact temperatures were not measured.

As a result of the blockade, hot sludge gushed out of the inspection hole after opening the plug.

7.3 SLUDGE

Sludge can be defined as a thick, soft, wet viscous mixture of liquid and solid components, usually the product of an industrial or refining process.

Inside a fuel oil separator on board a vessel, the cleaning of fuel oil generates sludge. In this case, it was a collection of solid particles, water, chemicals,… that was removed from the fuel oil during a centrifugal process.

The exact chemical composition of sludge generated during the cleaning of fuel oil on board was not known, but it can be assumed that the toxic, carcinogenic and caustic substances present in VLSFO were also present in sludge derived from this VLSFO.

The safety data sheet for residual fuel oils of this supplier, mentioned skin irritation as a hazard.
According to medical advice, prolongated direct skin contact with sludge derived from this fuel, could cause chemical burns as well, even at temperatures around 40°C.

It can be assumed that the direct skin contact with sludge during several hours, or even days for some parts where it was not possible to remove the sludge from the skin, contributed to the severity of the burns.

Figure 11 - Hand of victim covered with sludge

7.4 SAFETY PROCEDURES

On board mv MINERAL TEMSE, the engineer on duty is in his cabin outside the working hours, where he can monitor the engine room alarms on an alarm panel. In case an alarm sounds, the engineer acknowledges the alarm on said panel and goes to the engine room to verify the situation.

Prior to entering the unmanned engine room, the engineer has to call the officer of watch on the bridge. Inside the engine room the duty officer has to be called every 20 minutes, a so called "safety call" since the engineer is alone in the engine room.

Upon leaving the engine room, the duty officer has to be informed again. Records of entries and exits in the unmanned engine room were recorded in the deck logbook.

Executing maintenance jobs, repairs or technical investigation of equipment in the engine room was not allowed when being alone. In case a generated alarm required additional work, the duty motorman had to be called to assist the engineer.

When the accident occurred, the engineer was alone in the engine room. The officer of watch on the bridge was informed, but no second person was present when the engineer opened the inspection plug of the sludge discharge line.

7.5 PERSONAL PROTECTIVE EQUIPMENT

The engine room was identified as a PPE zone. This means a zone were personal protective equipment needed to be worn all the time.

Figure 12 shows the label on the entrance door of the engine room indicating that appropriate PPE has to be worn.

Figure 12 - PPE zone identification

The engine changing room is the place where every engineer has a personal locker containing the necessary PPE, as indicated in Figure 13 .
This changing room was located in front of the engine room. Coming from inside the accommodation, one was to pass the engine changing room prior to entering the engine room.

A simulation on board indicated that putting on an overall, gloves and head protection only takes 20 seconds extra time.

Figure 13 - Engine changing room

During regular safety meetings on board and during toolbox meetings prior to start the daily jobs, the crew was made aware to wear appropriate PPE.

Master, chief engineer, chief officer and bosun did randomly check if all crew was wearing proper PPE during the daily working hours on board. During the weeks prior to the incident, no violations against PPE procedures were noticed on board.

At the time of the accident, the victim was wearing loose short pants and a t-shirt , no gloves, no overall and no helmet.

A long sleeved overall and leather gloves would have protected the skin of the engineer when the sludge gushed out the discharge line. The impact of the temperature of the sludge would have been less severe and the amount of sludge coming into contact with the skin would have been reduced to an absolute minimum. As an overall and gloves could have been removed immediately, the time of contact between skin and sludge would have been reduced as well.

It can be concluded that wearing a long sleeved overall would have resulted in less severe burns.

7.6 RISK ANALYSES

Since April 15th 2020, the vessel was consuming the VLSFO that was bunkered in Gibraltar. As from this date forward, the sludge discharge line of the fuel oil separator got clogged regularly.

The superintendent of the vessel was consulted and it was agreed that one separator had to be kept stand- by in good order, to be able to switch between separator N°1 and separator N°2 in case an alarm was generated.
It was also agreed to clean the separator in use twice a day in order to prevent clogging as much as possible.

No risk assessment and/or additional safety procedures were made based on this situation and the additional maintenance that had to be done.

8. CONSEQUENCES OF THE ACCIDENT

On May 7th 2020, the vessel was derived towards the port of Cape Town to evacuate the victim. At the hospital it was stated that the victim suffered from 12% total body surface area ,TBSA, mixed partial thickness ,MPT, burns, which were covered in grease, involving both arms and legs.

Right forearm and hand: 4% TBSA MPT burn.

Left forearm and hand: 4% TBSA MPT burn. Deep partial thickness burn on forearm skin.

Right thigh and leg: 1% TBSA superficial partial thickness burns.

Left knee: 3% TBSA MPT burn. Lateral aspect of knee had a deep partial thickness burn.

Figure 14 - Burns on left knee

9. CAUSE OF THE ACCIDENT

Due to the cold flow characteristics of a certain blend of RMG 380 VLSFO, the separation of this fuel at +-40°C caused a blockade of the sludge discharge line.

The heating and pressurizing of the sludge in the discharge line in case of a complete blockade was not detected as a risk and so the inspection plug was opened very soon after the separator was switched off.

Safety rules were not strictly followed outside the daily working hours in the engine room. The victim was not accompanied when inspecting the sludge discharge line and he was not protecting his skin with the necessary PPE.
The hot and sticky sludge came into direct contact with the skin of the victim, aggravating the consequences of this accident.

10. SAFETY ISSUES

The cold flow properties of this blend of VLFSO most probably led to the regular clogging of the fuel oil separator on board, as discussed in part 7.1 Fuel Quality. Action was taken to keep the fuel cleaning process running as good as practically possible, but the source of the burden had not been dealt with.

Although the temperature at which wax crystals appear in blended fuel is very difficult to determine with sufficient accuracy, Veritas Petroleum Services, the same company that analysed the fuel sample of mv MINERAL TEMSE, developed a test method to determine the wax appearance temperature of a certain blend of VLSFO, see Annex 2.

A more detailed analysis of the fuel regarding cold flow properties could have solved the separation problems with this blend of VLFSO.

Safety procedures to prevent working alone in the engine room and to wear the necessary PPE were ignored, what indicates a lack of safety responsibility on board.

Regular clogging of the sludge discharge line of the separator occurred during the consumption of this batch of fuel oil on board. It was decided to clean the separator two times a day. This was not a standard job on board, but no further risk assessment or safety measures had been implemented to mitigate the risks associated to this job.

11. ACTIONS TAKEN

On May 7th 2020, extra crew training was given on board regarding personal protective equipment and safety precautions during routine work on deck and/or in the engine room. All crewmembers confirmed their participation.

Disciplinary measures are implemented on board in case of a breach of safety procedures: first a verbal warning will be given and in case of re-occurance, a written warning or caution letter will be issued. In case of coarse violation of safety procedures, a caution letter will be issued immediately.

The company will compile and issue a more comprehensive and specific Personal Safety Manual as part of our MLC manual. The Personal Safety Manual will particularly focus on PPE and streamline existing procedures.

The company will focus on the implementation of PPE procedures during internal audits.

The implementation of additional procedures as part of the SMS will be discussed by the company. Due to the fuel characteristics of different blends of VLSFO, additional job instructions might be necessary.

12. ANNEXES

VPS Circular

Veritas Petroleum Services

20 September 2019

ISO PAS 23263 & The Joint Industry Guidance

On Wednesday 18th September 2019, the International Standards Organisation (ISO) released their Publicly Available Specification (PAS). The document; "ISO/PAS 23263:2019 Petroleum products — Fuels (class F) — Considerations for fuel suppliers and users regarding marine fuel quality in view of the implementation of maximum 0.50 % sulphur in 2020" has now been published and is available to purchase from the ISO website on this link: https://www.iso.org/standard/75113.html

Please note, the document is covered by strict copyright and therefore individuals are urged to purchase their own copy, to avoid any possible infringement.

PAS 23263, confirms ISO 8217 specifications still apply to fuels meeting the 0.50% sulphur limit, and provides specific considerations and technical advice on fuel characteristics that might apply to particular fuels for viscosity, cold flow properties, stability, ignition characteristics and cat-fines. In addition, it provides information on how to consider compatibility between fuels.

It is worth highlighting that this document is not a new specification for 0.50% S VLSFOs, so such fuels should still meet the ISO8217 specifications, with fuel ideally being purchased against ISO8217:2017. The fuels can still be classified as distillate marine (DM) or residual marine (RM) in accordance with Table 1 or Table 2 of ISO8217 respectively.

VPS have already tested hundreds of 0.50% S VLSFOs, which to date have been bunkered across 39 ports globally. These fuels have so far shown the following properties:

Density 882 - 998Kg/m3
Viscosity 6 Cst - 510 Cst
Cat-fines 2ppm -82 ppm
Elevated Pour Points and TSP results
Average Net Energy of 41.5 KJ/Kg
Generally compliant Sulphur levels of <0.50%

The above highlight the diverse and wide-ranging properties these new fuels exhibit and why additional considerations should be made when using such fuels, especially for the first time.

It is vitally important that you, as a fuel user, understand these new fuels with regard to quality and fuel management implications.

VPS can provide our **Additional Protection Service (APS)** which including ISO8217 test parameters offers additional tests which will provide much more information and understanding of your fuels with respect to quality, operational assistance, asset protection and damage prevention, as well as helping to ensure legislative compliance.

In addition to the ISO PAS 23263, additional guidance can be obtained via the **Joint Industry Guidance, "The Supply & Use of 0.50% Sulphur Marine Fuels**, which was published in August 2019 and available free-of-charge from numerous websites including:

www.ibia.net and https://www.cimac.com/press-media/news/joint-industry-guidance-on-the-supply-and-use-of-0.50-sulphur-marine-fuel-kopie.html
The JIG document is designed to be understood by senior technical staff on board ships, operational staff within shipping offices and those within the fuel supply chain and support services. The JIG should be used as part of both risk and technical assessment.

VPS have been informed the JIG document should be further supported by e-learning material which is to be made available before the end of 2019. Information for which should be provided via the authors of the guidance document in due course.

Whatever your fuel choice going into 2020, please note VPS are available to support and advise you in order to help make IMO2020 as smooth and as trouble-free as possible.

For details on **The Additional Protection Service (APS)**, VLSFO testing and advisory services, kindly email us at info@v-p-s.com or contact your Account manager. More contact details can be found at www.v-p-s.com.

Annex 1 - Circular VPS

VPS WHITE PAPER:
AN AUTOMATIC TEST METHOD FOR WAX APPEARANCE TEMPERATURE OF VLSFOS

Article by Dr. Malcolm Cooper & Dr. Joshua Sun

Summary

Wax Appearance Temperature (WAT) or cloud point, hereinafter referred to as WAT, is the temperature at which wax crystals appear when fuel is cooled. This ultimately results in wax precipitation causing the fuel to stop flowing, which has a detrimental impact on operability as it may block filters and pipes, causing fuel starvation and engine problems. Providing that the fuel temperature does not fall below the WAT it will not wax, so measuring this temperature is critical in managing risk.

The measurement of the WAT of Very Low Sulphur Fuel Oils (VLSFOs) is problematic because although various manual and instrumental methods are available, the opacity of the fuel produces unacceptably wide errors. Whilst pour point may be used as a useful cold-flow property, the definitive indicator used to identify wax precipitation is the WAT.

VPS has developed an in-house method for the measurement of WAT for VLSFOs. The technique is based on ASTM D5773 and involves direct detection of light scattered by wax crystals using the same technology that has been used to measure the WAT of crude oil for some years. Significant work has been carried out to modify the equipment instrumentation and optimise experimental conditions for VLSFO fuel types. It is sensitive, precise and reasonably quick in delivering results. The method has been validated by correlating results of a series of distillate samples with an existing method and repeatability has been assessed on several VLSFO samples across a wide temperature range (10°C to 65°C). The WAT of many VLSFO samples bunkered over the past months has been measured and graphed. The wide variation of these results indicates the importance of measuring this parameter to mitigate cold-flow operability problems for VLSFOs.

VLSFO Cold-Flow Problems

Compliance with the 2020 IMO 0.5% sulphur cap has driven the introduction of new 0.5% VLSFOs produced by blending low sulphur distillates with conventional Heavy Fuel Oil (HFO). The chemical composition of these new VLSFO blended fuels is variable but strikingly different to HFO, as shown in the table of typical compositions shown below.

Table 1 – Chemical Composition of Various Fuel Types

Chemical Composition	Typical HFO	Typical Distillate	0.5% VLSFO blend
Sulphur	3.5%	<0.1%	0.5%
Saturates	ca 21%	ca 75%	ca 69%
Aromatics & Polar Aromatics	ca 64%	ca 25%	ca 29%
Asphaltenes	ca 14%	ca 0%	ca 2%

Reference for Typical compositions: https://www.ncbi.nlm.nih.gov/books/NBK531265

The increased paraffinic content (saturates) arising from the distillate composition of the new blended 0.5% VLSFOs increases the likelihood of wax precipitation compared to HFO fuels. The temperature at which wax precipitation starts is dependent upon the chemical composition which varies significantly from fuel to fuel. Measurement of the temperature at which wax precipitation starts (the WAT, which is the temperature at which wax crystals appear) is important to determine the cold-flow risk of VLSFO fuels.

Current Methods for Measurement of Cold-Flow Properties

There are 3 test methods used to evaluate the cold-flow properties and likelihood of formation of wax crystals in fuel. For distillates all 3 methods can be applied as they are clear fuels, but for HFO and VLSFOs only pour point has been applied due to the high opacity of these fuels.

- Cloud Point (CP) – The temperature at which wax crystals start to form in the fuel, detected by visually seeing the fuel shift from being transparent to cloudy (ISO3015) or using instrumentation (ASTM D5773 using a light source in the visible wavelength).
- Pour Point (PP) – The lowest temperature at which the fuel will continue to flow when cooled, detected visually (ISO3016) or using instrumentation (ASTM D5949, ASTM D6749-02).
- Cold-filter Plugging Point (CFPP) – The lowest temperature at which a fuel of known volume continues to flow within a specified time (60 seconds) when drawn by vacuum through a standardised filter (45 micron) (ASTM D6371).

Table 2 – Repeatability & Reproducibility of Cold-flow Property Measurement Methods

Cold-Flow Property	Measurement Technique	Method	Repeatability °C (95% CL)	Reproducibility °C (95% CL)
Cloud point	Visual	ISO3015:2019	2	4
	Instrument - visible light source	ASTM D5773	1.3	2.5
Pour Point	Visual	ISO3016:2019	3	9
	Instrument (Phase Tech) model 70	D5949-16 *	1.6	3.2
	Instrument (Phase Tech) models 30, 50, 70	D5949-16 *	2.9	6.3
	Instrument (Tanaka)	D6749-02 (2018) *	1.1	2.2
CFPP		ASTM D6371-17 IP309/IP612	1.8	

* - These methods have not been verified for residual fuel oils

Cloud point is the definitive cold-flow property measure, since this indicates the temperature at which wax crystals start to form. The fuel will continue to flow at temperatures above the cloud point. Current test methods do not enable cloud point to be measured for opaque fuels as stated below:

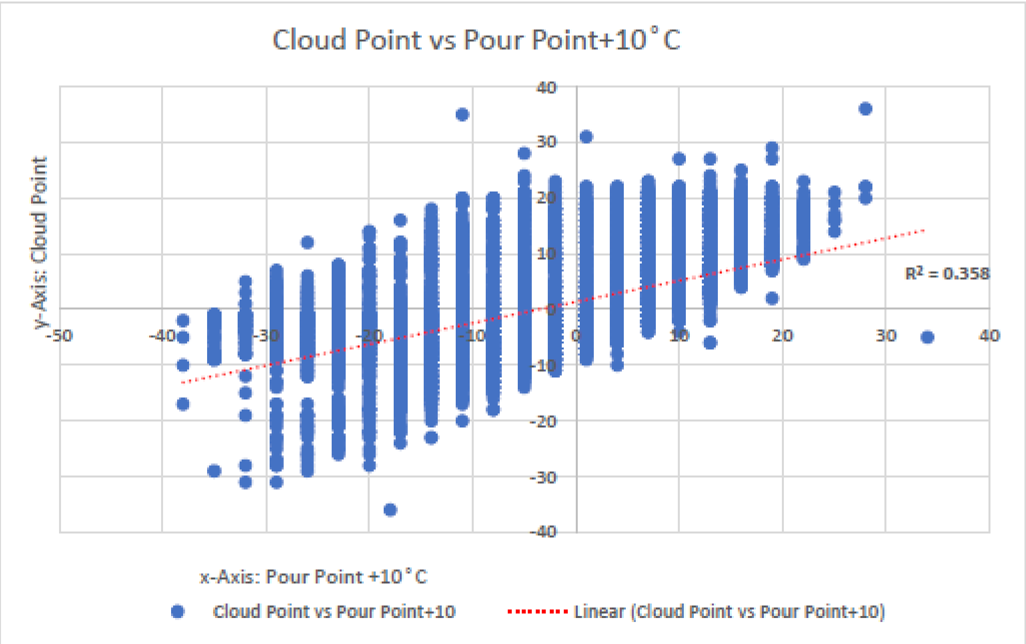
- ISO3015 (visual method) states that 'it may only be used for the determination of the cloud point of petroleum products which are transparent in layers 40 mm in thickness'
- ASTM D5773 (using a light source in the visible wavelength) states in the scope that 'This test method covers the determination of the cloud point of petroleum products and biodiesel fuels that are transparent in layers 40 mm in thickness by an automatic instrument using a constant cooling rate'

Pour point identifies the temperature at which the marine fuel ceases to flow making the fuel unusable. This is currently the only method of measuring the cold-flow properties of opaque fuels (such as HFO, as indicated in ISO8217). The visual method (ISO3016) has very poor repeatability and reproducibility whilst the automated methods (ASTM D5949-16, ASTM D6749-02) have not been verified for residual fuel oils.

A fundamental problem with the measurement of pour point to assess the risk of fuel waxing is that once the pour point is reached, the fuel has stopped flowing and started to solidify already creating problems. For this reason, the recommendation by CIMAC is to keep the fuel at 10°C above the pour point. However, since the definitive cold-flow property measure is cloud point (the temperature at which wax crystals form) it is useful to understand the correlation between pour point and cloud point.

Many distillate samples have been measured for both cloud point and pour point over the past few years by VPS. A graphical representation of the correlation between cloud point and pour point on distillate samples has been produced below. This data (>15,000 data points) shows a poor correlation with a measure of R^2=0.358, as indicated in the graph below. This demonstrates that pour point is a poor indicator of the cloud point (i.e. wax formation temperature) of fuel. This is perhaps unsurprising since pour point is affected by additives in the fuel, whereas cloud point is not as this is a fundamental fuel property.

Figure 1 - Correlation of Cloud Point Vs Pour Point on Distillate Samples



The cold-flow properties of HFO are based on pour point because there are currently no methods available to measure cloud point due to opacity, and CIMAC guidance is to maintain a temperature at pour point+10°C to prevent problems. However, there is no correlation between pour point and cloud point as indicated in Figure 1 above. This illustrates the need for an accurate method for the measurement of cloud point in opaque fuels.

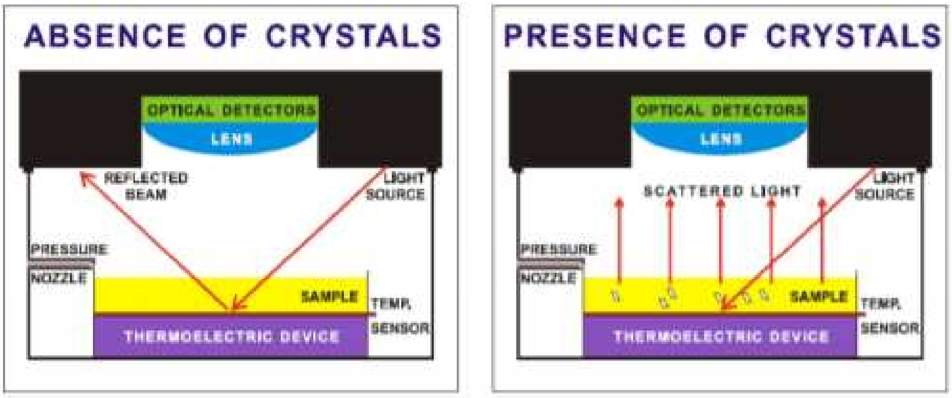
VPS Method (VPS-LP1307) for Measurement of WAT/Cloud Point of VLSFOs

VPS has developed an in-house method for the measurement of WAT of VLSFOs based on ASTM D5773 with instrumentation using non-visible light. Significant work has been carried out to modify the equipment instrumentation and optimise experimental conditions for VLSFO fuel types.

However, the underlying principles of this method have been applied in the measurement of wax crystal formation (WAT) in opaque crude oils in the Upstream sector for some years. This technology works on opaque oils because the light source is outside the visible spectrum. This method is used to help companies engaged in crude oil production, storage and transportation to define acceptable operational limits to prevent wax crystals forming which may restrict flow or create total blockage.

The operating principle of the instrument is an optical light scattering technique which detects phase changes of crude oil with high levels of sensitivity and accuracy. The presence of wax crystals is detected in the fuel by measuring the scattering of a light source as in the diagram below. Since it is an instrumental technique the measurement is not subjective. The phase change detected is the temperature at which a crude oil sample first precipitates solid wax as it is being cooled, which is termed WAT. Similarly, the Wax Disappearance Temperature (WDT) is the temperature at which the last wax solids are melted into liquid when the oil is warmed.

Figure 2 - Wax Crystallisation Detection Method (ref. Phase Technology)



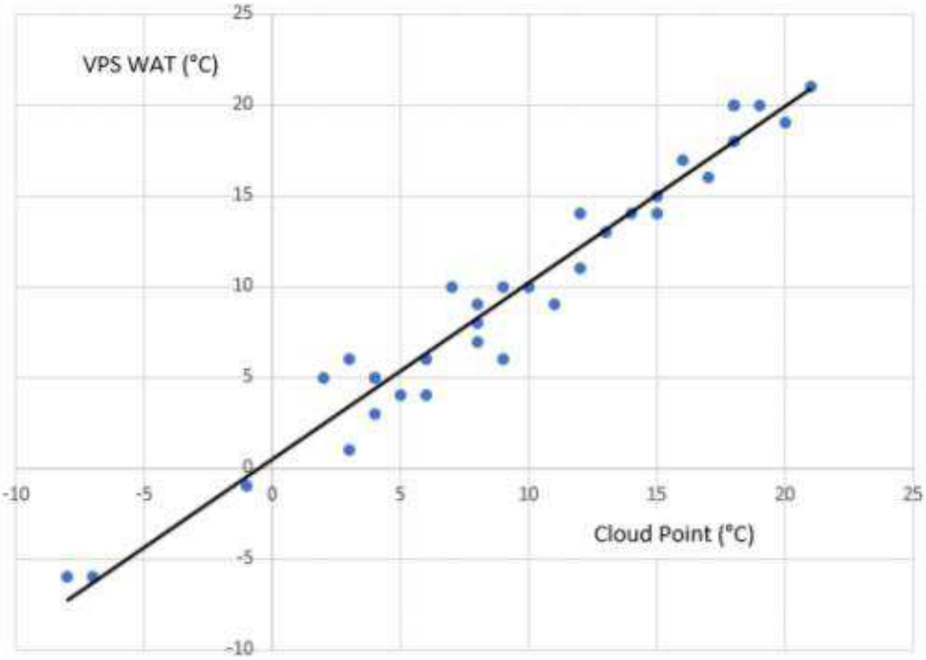
VPS has developed an improved method of measuring the formation of wax crystals in VLSFOs (VPS method LP1307). Significant work has been carried out to modify the equipment instrumentation and optimise experimental conditions for VLSFO fuel types. The method is sensitive, precise and reasonably quick in delivering results.

Validation of VPS Method (VPS-LP1307) for Measurement of WAT of VLSFOS

Several clear distillate blends have been tested using the new VPS method (VPS-LP1307) with instrumentation using non-visible light. These results were compared to the standard method using instrumentation with visible light. Very good correlation between the results was obtained with a measure of R^2=0.98, as indicated in the graph below.

In addition to the WAT, the method provides a measurement of the WDT. This is very useful as it is the temperature at which the last wax solids are melted into liquid when the oil is warmed. As such it provides an indication of the temperature that the fuel must be heated to in order to fully dissolve any wax solids that have precipitated.

Figure 3 - Graph of WAT Using Method VPS (VPS-LP1307) Versus Cloud Point



Repeatability of VPS Method (VPS-LP1307) for Measurement of WAT/Cloud Point of VLSFOs

Four different fuels that had been bunkered in the ports of Singapore, Rotterdam and Houston were tested multiple times (x12) using the newly developed VPS method (VPS-LP1307). These four different fuels each had very different WAT across the temperature range of 10°C to 65°C. The table below summarises the repeatability of these results, which shows that this method is very repeatable across the full range of temperatures.

WAT/Cloud Point	65°C	45°C	30°C	10°C
Repeatability	1.3°C	1.2°C	1.5°C	1.7°C

Results of WAT and WDT Measurement of VLSFO Samples Using VPS Method (VPS-LP1307)

A number of VLSFO samples (87 in total) bunkered over the past few months across ports in Singapore, Rotterdam, Houston and Fujairah have been tested using the new method. The graph below shows the spread of results. The WAT point results show a very wide range for VLSFO fuels already on the market and a number of these are at elevated temperatures. This demonstrates the importance of measuring WAT for the VLSFO fuels. The WDT results indicate the temperature that these fuels would need to be heated to in order to melt all wax solids if the fuel temperature has fallen below the WAT causing waxing.

Figure 4 – Graph of WAT Distribution for VLSFO Fuels Bunkered to Date in 2019

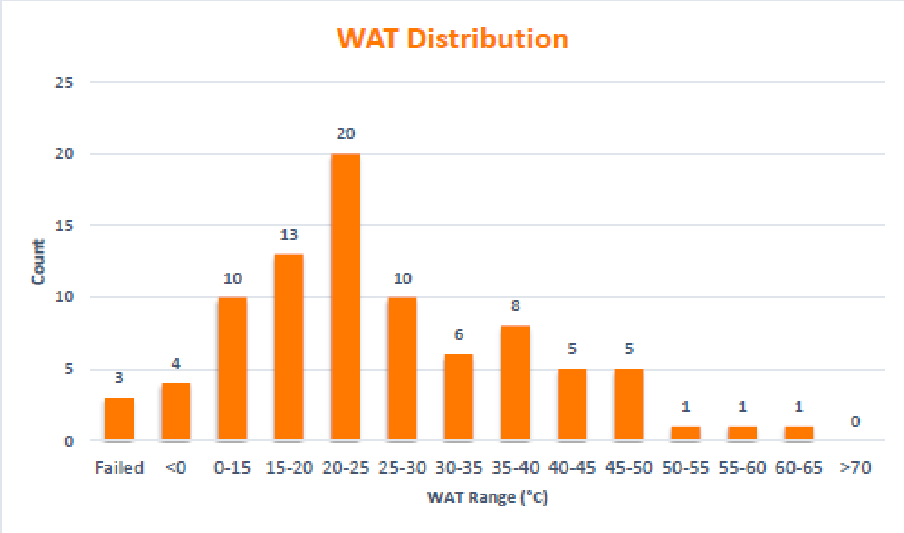
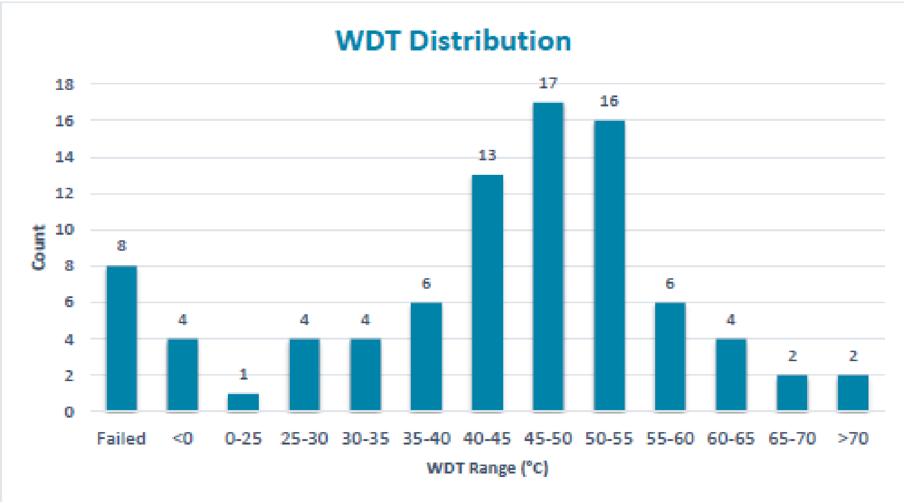


Figure 5 – Graph of WDT Distribution for VLSFO Fuels Bunkered to Date in 2019



Summary

VPS has carried out extensive research and developed this new method, VPS-LP1307 for identifying the WAT on VLSFO opaque fuels. The method is sensitive, precise and has a reasonably quick analysis turnaround time. The measurement of WAT is critical in mitigating the risk of cold-flow problems when handling VLSFO fuels. Additionally, this method enables the measurement of WDT.

Annex 2 – VPS test method for wax appearance temperature

Characteristics	Unit	Limit	Category ISO-F-											Test method(s) and references
			RMA	RMB	RMD	RME	RMG				RMK			
			10	30	80	180	180	380	500	700	380	500	700	
Kinematic viscosity at 50 °C	mm^2/s[a]	Max	10,00	30,00	80,00	180,0	180,0	380,0	500,0	700,0	380,0	500,0	700,0	ISO 3104
Density at 15 °C	kg/m^3	Max	920,0	960,0	975,0	991,0	991,0				1010,0			ISO 3675 or ISO 12185; see 7.1
CCAI		Max	850	860	860	860	870				870			See 7.2
Sulfur[b]	mass %	Max	Statutory requirements											ISO 8754 or ISO 14596 or ASTM D4294; see 7.3
Flash point	°C	Min	60,0	60,0	60,0	60,0	60,0				60,0			ISO 2719; see 7.4
Hydrogen sulfide	mg/kg	Max	2,00	2,00	2,00	2,00	2,00				2,00			IP 570; see 7.5
Acid number[c]	mg KOH/g	Max	2,5	2,5	2,5	2,5	2,5				2,5			ASTM D664; see 7.6
Total sediment – Aged	mass %	Max	0,10	0,10	0,10	0,10	0,10				0,10			ISO 10307-2; see 7.9
Carbon residue – Micro method	mass %	Max	2,50	10,00	14,00	15,00	18,00				20,00			ISO 10370
Pour point (upper)[d] winter	°C	Max	0	0	30	30	30				30			ISO 3016
Pour point (upper)[d] summer	°C	Max	6	6	30	30	30				30			
Water	volume %	Max	0,30	0,50	0,50	0,50	0,50				0,50			ISO 3733
Ash	mass %	Max	0,040	0,070	0,070	0,070	0,100				0,150			ISO 6245
Vanadium	mg/kg	Max	50	150	150	150	350				450			IP 501, IP 470 or ISO 14597; see 7.14

[a] $1\ mm^2/s = 1$ cSt.

[b] The purchaser shall define the maximum sulfur content in accordance with relevant statutory limitations. See Introduction.

[c] See Annex E.

[d] The purchaser should confirm that this pour point is suitable for the ship's intended area of operation.

Table 2 *(continued)*

Characteristics	Unit	Limit	Category ISO-F-											Test method(s) and references
			RMA	RMB	RMD	RME	RMG				RMK			
			10	30	80	180	180	380	500	700	380	500	700	
Sodium	mg/kg	Max	50	100	100	50	100				100			IP 501, IP 470; see 7.15
Aluminium plus silicon	mg/kg	Max	25	40	40	50	60				60			IP 501, IP 470 or ISO 10478; see 7.16
Used lubricating oil (ULO): Calcium and zinc or Calcium and phosphorus	mg/kg		Calcium >30 and zinc >15 or Calcium >30 and phosphorus >15											IP 501 or IP 470, IP 500; see 7.17

[a] 1 mm^2/s = 1 cSt.

[b] The purchaser shall define the maximum sulfur content in accordance with relevant statutory limitations. See Introduction.

[c] See Annex E.

[d] The purchaser should confirm that this pour point is suitable for the ship's intended area of operation.

Annex 3 - ISO 8217:2017