Lloyd's Register

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Use of new fuel types for ECA-SOx compliance

FOBAS guidance for ship-owners and operators

Contents

1. Executive summary

Since 1st January 2015, ships entering emission control areas for SOx (ECA-SOx) are required to comply with MARPOL Annex VI regulation 14.4.3 which limits the sulphur content of bunker fuels used to 0.10% m/m. To comply with the regulation, ship owners and operators have mainly used the compliant fuels (S <0.10%m/m) option however other alternatives such as liquefied natural gas, methanol, bio-fuels and abatement technologies are also becoming popular.

Of the ships opting for 0.10% sulphur fuels to comply with ECA-SOx regulation; the majority used conventional marine gas oils however the use of New ECA Fuels (NEF) sometimes referred to as Hybrid fuels is on the rise. FOBAS issued a guidance document on use of these new fuels in December 2014. The purpose of this document is to update and look back at the performance of these NEFs and address a few pertinent issues such as operational challenges, best practice approach, availability and fuel quality.

Our data suggest that quality of NEFs vary, even from same supplier and therefore it is necessary that such fuels are analysed promptly before putting into use. Secondly, the majority of reported problems in using such fuels are mainly excessive sludging at purifiers and/or frequent filter blockages. Furthermore, known issue of NEFs incompatibility with other fuels is well known and this aspect should be managed as such. Overall, if such fuels are managed properly then there are may be some economic and operational benefits in using such fuels.

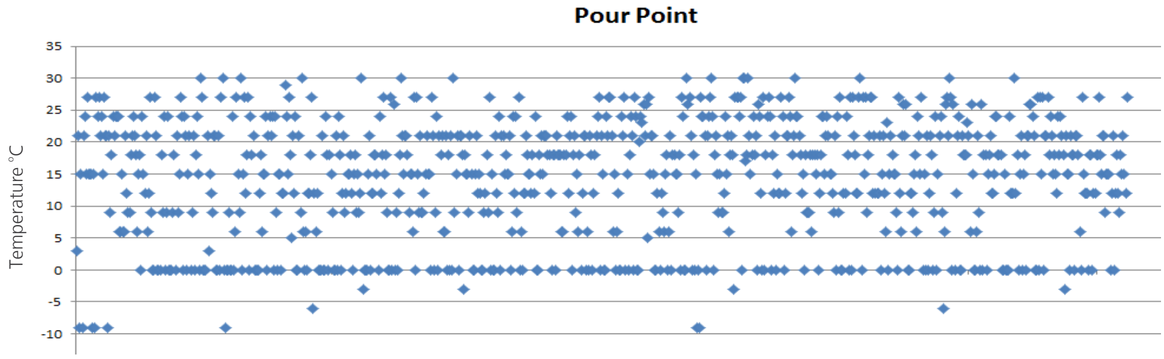
2. New ECA Fuel (NEF) quality

Since the launch of NEFs, FOBAS has tested fuels with various grades and formulations from suppliers around the world. Section 3 provides more detail on the availability of these new fuels however it has been observed that ARA (Amsterdam, Rotterdam, Antwerp) is the main region where most NEF bunkering activity takes place. It has also been observed that the majority of NEFs for the most part fall within the ISO 8217 requirements for Residual Marine (RM - RMD80/RMB30/RMA10) whilst only a few supplies falls within the Distillate Marine (DM) category.

For fuel buyers, it poses a unique challenge of managing operational risk of relatively unknown fuel blends against the monetary benefit stemming from the price differential between conventional gas oil and NEFs. Some of these challenges have been highlighted in Appendix A at each stage from fuel purchasing to combustion at engine or boiler. However, NEF formulations are becoming more established with time in various regions with well-known bunker suppliers. Having said that, the extreme variability in fuel formulations between different NEFs when compared with regular fuels requires a cautious approach from fuel purchasing through to the combustion at engine or a boiler.

2.1 Cold flow properties

Most of the NEFs are particularly waxy in nature as exhibited by their pour point (the lowest temperature at which a fuel will continue to flow). The graph below indicates pour point data of NEF samples analysed by FOBAS during last year.



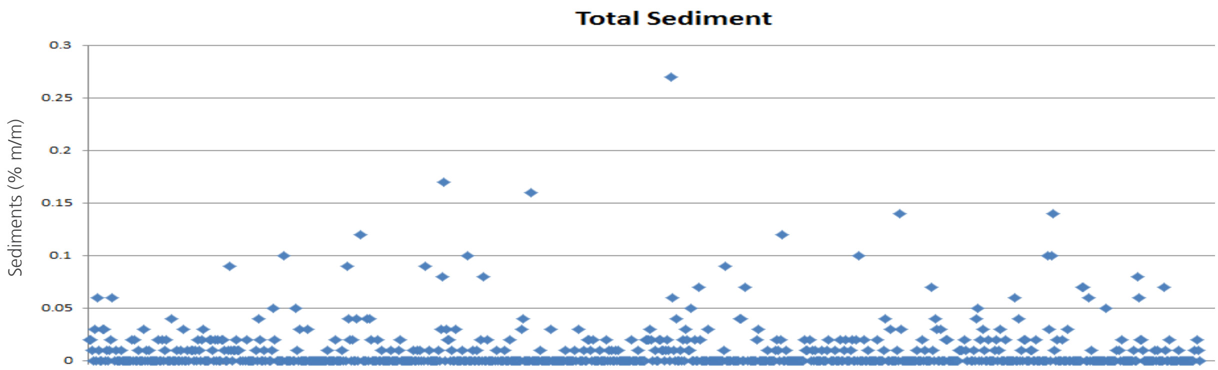
The data indicates a wide temperature range from +30°C to sub-zero pour points of these fuels. This seems to suggest that most of the blend components of NEF are paraffinic in nature. This will be down to the crude source and blending components.

The general rule is to maintain any fuel oil no lower than 7°C above its tested pour point. Based on the data, it appears that most of these fuels would have required heating arrangement in the storage tank particularly if the ship is operating in colder climate to maintain trouble free operations.

It has also been observed that many NEFs were categorised as ISO-F-RMD80 grades due to high pour points although other parameters may be complying with the ISO-F-RMB30 or lower grades. This would have no or little impact on overall quality standard as both grades have similar quality limits within ISO 8217.

2.2 Stability and compatibility

Understanding the stability of the fuel and compatibility with other fuels are critical considerations when dealing with NEFs. Stability of marine fuels is determined through ISO 10307-2 (Total sediment aged) test as per ISO 8217 standard requirement. FOBAS data on total sediment (graph below) predominantly indicates only a few NEF samples exceeded the 0.10 % m/m limit in last 12 months. This shows the majority of the fuels are stable with low sedimentation tendency however, as best practice, if the fuel is going to be stored for longer periods, it should be verified through fuel system sampling and analysis to determine if there is any deterioration in stability over time or due to extended heating.

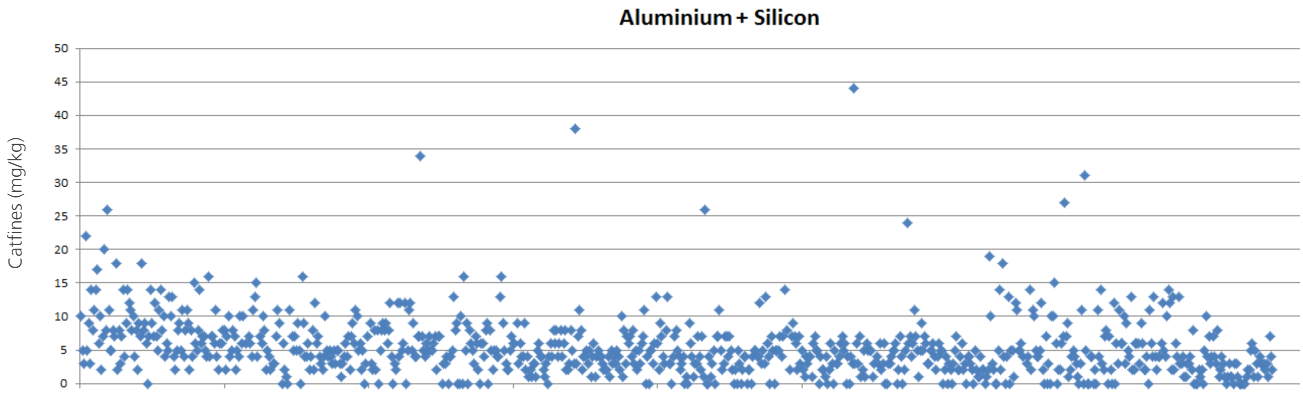


Even with NEFs with low tested total sediment, there have been reported instances of abnormal sludge generation during purification and frequent filter blockages. Further investigations into some of the instances revealed incompatibility between other fuels as likely cause of the reported operational problem.

Because of their paraffinic (waxy) nature of NEFs, the risk of incompatibility between NEFs and conventional residual fuel oils is relatively high. Provided that the mixed proportions are at a low ratio, serious issues should not be expected; as always, minimising the quantities involved is a good policy. As standard practice, the fuel should be passed through the ship's treatment system (purifiers) before use, which means that the fuel will be passed to the settling tank first. Consequently, if a conventional residual fuel has previously been used, the changeover to NEF must properly be managed and monitored, and should be undertaken in a low-risk location. Moreover, fuel storage tanks being loaded with NEFs must be as empty as possible and a compatibility test must be carried out before any attempt is made to mix these fuels with other conventional fuel blends. In fuel service systems, the minimum quantity of fuel in service tank is governed by other regulations such as class and therefore during changeover such consideration should also be taken into account.

2.3 Catfines

FOBAS data indicates the majority of the NEF samples contained low catfines (Al+Si <15mg/kg) well within the ISO 8217:2012 grades (RMB30 / RMD80) limit of 40 mg/kg. Only in few instances, Al+Si concentration were noted above 15 mg/kg.

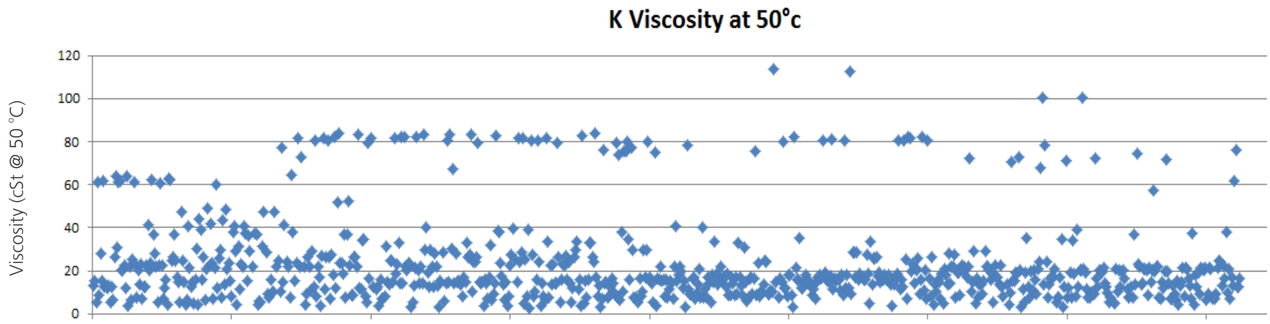


Nonetheless, these fuels still require to be passed through the purifier to ensure engine manufacturer's requirements for water and catfines are achieved. Based on the tested viscosity and density of the fuels, the purifier manufacturer's recommendations on flow rate, temperature (see table in section 2.4) and selection of gravity disc (if applicable) should be followed to achieve optimum separation efficiency.

2.4 Viscosity and lubricity

Viscosity and lubricity are two of the key challenges that the NEFs aim to address, when considering an alternative distillate fuel oil.

When changing over from residual fuel oil to distillates, viscosity has to be carefully controlled (along with the fuel temperature to reduce the risk of thermal shock) in order to maintain sufficient hydrodynamic lubrication film between the moving surfaces of the fuel pump and injectors. NEFs exhibit higher viscosities compared to distillate fuels and lubricity is generally not a concern with most NEF types because of their residual and higher viscosity nature. Therefore, at normal operating temperatures, NEFs are expected to maintain hydrodynamic film lubrication, eliminating the need for any fuel coolers or chillers.



FOBAS data indicates average viscosity for NEFs is around 20cSt @ 50°C as per above graph. However due to the large spread between the minimum and maximum viscosity of NEFs, it is imperative to determine the viscosity as loaded and make appropriate operational adjustments, temperature and flow rates to ensure smooth engine operation.

One of the frequently asked questions concerns the optimum temperature at purifier and engine inlet for these fuels. These fuels can have slightly different viscosity indices from conventional marine residual fuels hence few suppliers such as ExxonMobil[1] have come out with viscosity-temperature graphs for their specific products. Nevertheless, following table has been prepared to give an indication of the typical values for the NEF viscosity and corresponding temperatures at separators and engine inlet.

Viscosity (cSt) @50°C	Separation Temperature (°C)	Typical Engine Injection Temperature (°C) – 10~15cSt
10		37~50
15		50~63
≤ 20	40	52~72
21~30	50	60~84
31~40	60	71~92
41~50	70	78~98
51~70	80	84~107
71~90		92~113

Note: The separation temperatures in the table above have been advised by purifier manufacturer GEA Westfalia (GmbH) however it is advisable for ship operators to check relevant temperature settings and throughput rates with the specific purifier manufacturers for optimum separation efficiency when processing NEFs.

In most cases, the minimum temperature needed to avoid solidification problems will be more than sufficient for transfer however for injection temperatures, it is vital to ensure that the viscosity control system is working correctly ensuring that the fuel is not being overheated but meeting the required injection viscosity setting. Viscosity at different temperatures can also be calculated through FOBAS fuel management toolkit which can be downloaded free of charge via link http://www.lr.org/en/services/fuel-testing/FuelManagementToolkit.aspx.

2.5 Combustion performance

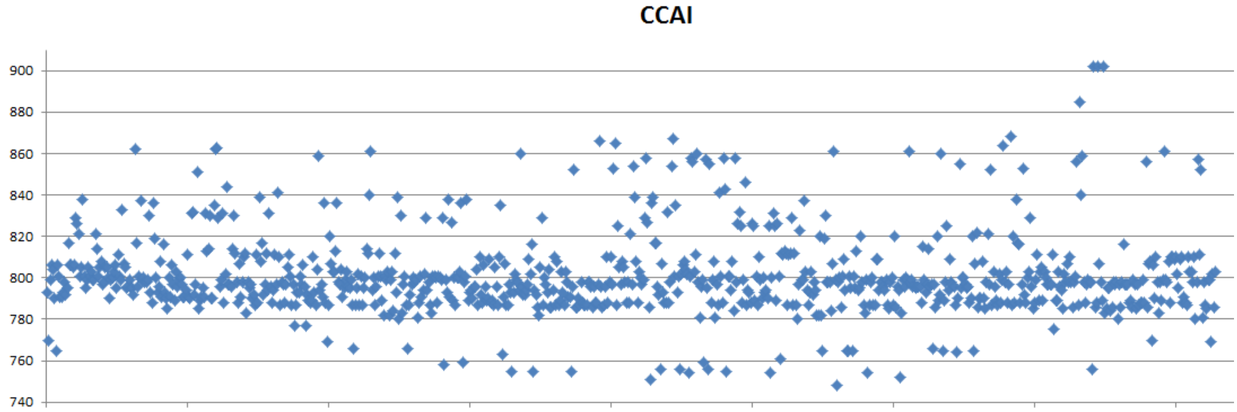
The ignition and combustion characteristics of a marine fuel in a diesel engine are dependent on the particular engine type, design, operating condition, load profile and the chemical properties of the fuel oil. As NEFs are mainly blended products, the Calculated Carbon Aromaticity Index (CCAI)[2] value may not reflect the true combustion characteristics of the fuel however this can be an indicator for fuels ignition delay. CCAI has been included in ISO 8217 as a standard parameter mainly in order to avoid fuel oils with uncharacteristic density-viscosity relationships. Some engine manufacturers apply a maximum CCAI limits on fuels to be used on their engines hence where applicable these limits needs to be considered when

[1] Graph for viscosity-temperature relationship can be accessed via link https://lubes.exxonmobil.com/MarineLubes-En/Files/viscosity-temp-chart.pdf

[2] CCAI is an index to reflect ignition and combustion property of the marine fuels simply calculated from density and viscosity of the fuel

ordering marine fuels. CIMAC (International Council on Combustion Engines) issued a guidance document[3] which indicates that medium speed engines are more susceptible to combustion problems compared to the large slow speed two stroke engines. Moreover, low load engine operation can be a significant factor in exacerbating operational issues related to fuels' poor ignition and combustion characteristics.

ISO 8217 standard applies a CCAI limit of 860 (RMB30, RMD80) for these typical light residual fuels. FOBAS data indicates that most of the NEFs exhibit satisfactory CCAI (<860) however there have been instances of extremely high (>880) CCAI results from high density fuels with relatively low viscosity which may also point to blending failure.



It is vitally important to check the engine operations manual for any CCAI limit and as best practice approach place specific requirements in the bunker purchase clause. An uncharacteristic blend (high density-low viscosity) can be problematic especially on 4 stroke engines and detailed fuel combustion performance assessment can be carried out through an 'FIA100/FCA' test. Based on the fuels ignition characteristics, fuels injection setting may require adjustment (advanced or delayed) for optimum combustion performance.

3. Changeover procedure

Changeover from residual fuels to distillates and equally from distillates to residual fuels, along continuous operation of engines on low-viscosity distillates are two challenges that NEFs aim to address.

Most NEFs have a high enough viscosity to tolerate the temperature fluctuations within the fuel system during changeover, without going below the minimum viscosity requirement. But care still needs to be observed if temperatures and corresponding viscosities are not controlled correctly and the resulting issues such as loss of power and engine starting problems could occur due to fuel pump leakage – both commonly reported fuel-related problem during changeovers to distillates.

As a general rule to avoid the risk of thermal shock when changing over to low sulphur fuels, the change of temperature gradient should not be more than 2 °C per minute as any sudden changes in temperature can thermally load fuel pumps and/or injectors and cause them to seize.

Most NEFs are likely to exhibit solvent characteristics / cleaning effects, just like regular distillate fuels, hence there is a risk of increased sludge deposition in filters due to carry over of sediments accumulated in

[3] Study can be accessed through link
http://www.cimac.com/cms/upload/Publication_Press/WG_Publications/CIMAC_WG07_2011_Guideline_Fuel_Quality_Ignition_Combustion.pdf

the fuel system tanks and pipelines. Attention should be given to the filter pressure differential and standby filters should be kept in clean condition ready for switch if needed.

4. Operational problems

Since 0.10% sulphur ECA-SOx regulation came into force in January 2015, the general feedback from FOBAS clients using NEFs has been satisfactory. It appears that by taking appropriate and vigilant fuel management actions, ships have been able to reduce the risks to low and manageable levels. Nevertheless, on few occasions, problems were reported to us, some relevant case studies can be found in Appendix C with generally the problem has been relate to sludge generation at various points of the fuel system.

5. Availability

Around the start of 2015 these new fuels became increasingly more available. As experience has been gained in storing, handling and using these new fuels, the demand for such fuels has risen. Rotterdam's sales reached 800,000 to 900,000 Mt in 2015, and are expected to reach similar levels in 2016[4].

Availability is an important consideration when using new fuels. For better management, consistency and in order to avoid compatibility issues, it is best practice to bunker same product in all ports the vessel is calling at, so that no other types of fuels are needed to comply with ECA-SOx requirement. The world map below indicates the sources of NEF samples sent to FOBAS for analysis.

The map indicates major NEF bunkerings took place in ports within European ECA-SOx with some activity along US east coast. In the Far East, Korea and now China have seen an increase in bunkering activity of new low sulphur products. It is expected that with the introduction of Chinese emission control areas, the suppliers in the region will produce more new blends to comply with the local regulations. Further details on the suppliers and availability in different ports have been provided in Appendix B.

6. Procurement

The NEFs are produced to meet the 0.10% sulphur regulation for use within ECA-SOx and because they are complex petroleum derived blends, they do not exactly match 'table 1' or 'table 2' grades of the ISO 8217 standard in the traditional sense.

[4] http://www.platts.com/latest-news/oil/london/rotterdam-sales-of-ulsfo-seen-close-to-1-mil-26360884

Nevertheless, it is strongly recommended that NEFs are ordered against the ISO 8217 specification considering the maximum, and where applicable, minimum limits of the tested parameters acceptable to the ship. The benefit of using ISO 8217 lies principally in the 'general requirements' aspects contained in section 5 of the standard. When ordering with reference to ISO 8217, it should be ensured that any exceptions to the nominated ISO 8217 grade being offered by the supplier are clearly stated; these exceptions will be based on the available specification data from the fuel supplier.

7. General guidelines

Further to the guidance given in this document, the following are some general considerations for on-board NEF use:

– It is recommended to seek views / 'no objection' statements from specific engine and auxiliary boiler manufacturers in which the fuel will be consumed.

– In addition, seek comments from the suppliers of: the lubricants used in the machinery; the fuel oil treatment system (separators / filters); and the bilge system components (oily water separators and oil discharge monitors).

– NEFs would not be expected to react with any of the metals / alloys / seals normally found in fuel oil systems or combustion space.

– There is no information to indicate that NEFs would have anything other than the usual temperature / cold flow characteristics; some waxy products, if in motion, will be retained in a liquid state at temperatures well below the pour point, which refers to the static condition. **Note:** the minimum temperature (7 °C above the tested pour point) needs to be maintained not just in storage, but throughout the entire fuel system, including connections to pressure sensors, instrumentation and drain lines. Therefore, the risk of solidification posed by any of the fuel system components should be evaluated under expected service conditions.

– As a best practice, obtain and review the product specification from supplier and discuss with FOBAS if assistance in required in making a decision to purchase a particular blend.

– The selection of cylinder lube oil (for 2 stroke engines) and system oils (4 stroke medium speed engines) will be critical for all 0.1%m/m sulphur fuels. Specific engine manufacturer's guidelines need to be consulted; moreover CIMAC has issued guidelines[5] looking at the impact on lubrication requirements of future fuels.

8. Compliance

The revised MARPOL Annex VI ECA-SOx regulations and EU 'at berth' regulations require only that the fuel being used has a maximum sulphur content of 0.10% m/m, so use of NEFs is permitted in order to comply. However, the situation is different with the California Air Resources Board (CARB) regulations. The California OGV Fuel Regulation requires that the fuel must not only have a sulphur content of 0.1% m/m or lower, but must also meet the specifications for distillates (marine gas oil or marine diesel oil). Therefore, vessels using new ECA fuels to comply with the Annex VI ECA-SOx regulations do not automatically comply with the OGV Regulation; to do so they must obtain a 'Temporary Experimental' or 'Research Exemption'. For further details on how to apply for ARB exemptions, please visit the ARB website http://www.arb.ca.gov/ports/marinevess/ogv.htm.

[5] http://www.cimac.com/cms/upload/workinggroups/WG8/CIMAC_WG08_2014_05_Guideline_Fuel_Scenarios_Impact_Lubrication.pdf

Appendix A – Operational matrix for using compliant fuel in main engines within ECA-SOx

Fuel System Stage	Major Concerns
Bunker requisition/ Bunkering operation	• Availability of compliant fuel [0.1% Sulphur Fuel Oil (SFO)] in increased volumes required • Any limitation on rate of bunker loading due to manifold size/pipework used for loading compliant fuel • Separate bunker lines of combined HSFO/0.1%SFO • Risk of cross contamination with HSFO if using same bunkering lines both for HSFO and 0.1% SFO (Sulphur fuel oil)
Fuel Storage/Transfer	• Low tolerance margin of 0.1%SFO contamination with HSFO causing fuel to become non-compliant on-board • Tank cleaning challenges of existing HSFO tanks to increase 0.1%SFO tank capacity • Crew competence/awareness in managing the fuel change over • Incompatibility between HSFO and 0.1%SFO causing filter blockages. Moreover, compatibility issues of 0.1%SFO with the MGO 0.1% fuels where fuels are possibly loaded in same tank in tandem • Unavailable storage/transfer heating arrangement for fuels with high pour point • Fuel quality issues during long storage such as with FAME (Fatty Acid Methyl ester), Fuel Stability, Microbial Contamination.
Settling /Service Tanks	• Certain temperature range, risk of overheating or under heating
Purifiers/Filters	• Filter blockage may occur especially at the time of fuel change-over or during circulation due to potential solvency nature of the fuel • Excessive sludge generation at filters/purifiers could result in fuel supply restriction
Viscosity Controller/ Service system Change Over Point	• Overheating and/or thermal shock • Leaky 3-way C/O valve with the risk of HFO contamination • Unsatisfactory or poorly executed fuel change over procedure • Fuel starvation due to filter blockage at the time of change-over • Flushing time required
Fuel Pumps/Injectors/ Exhaust Valve	• Excessive fuel temperature can also cause gassing up or vapour lock. Moreover, loss of hydrodynamic film between barrel and plunger assembly • Fuel leakage and insufficient pressure from worn fuel pump/injectors and old seals • Excessive wear at exhaust valves
Combustion/Engine Performance	• Engine knock • Cylinder lubrication with inappropriate base number (BN) • Possibly low energy content

Note: Above information is for guidance only and we expect ship operators to perform a risk assessment to evaluate and make decisions based on the operational and technical profile of individual vessel or group of vessels.

Appendix B – Major suppliers[6] in key areas

Supplier	Product	Availability
ARGOS	RMB30, RMD80	ARA Region
AS BALTIC MARINE	RMA30, RMD80	Tallin, Muuga (ESTONIA)
ATLAS (Neva)	RME180, DMC	St Petersburg
BALTIC (Marine Bunkers)	RMB30, RMD80	Tallinn, Ust Luga
BOMINFLOT	RMB30, RMD80	Tallinn, Muuga, Riga
BP	RMD80	Rotterdam
ExxonMobil	RMD80, RME180	ARA region, Southampton UK
FAST Bunkering	RMD80, RMB30	Riga, Ventspils (Latvia)
FRIEDRICH G. FROMANN	RMD80	Hamburg, Bremen, Cuxhaven
Gazpromneft Marine Bunkering	RMD80	Various ports in Russia mainly Primorsk
GS Caltex	RMA10, RMD80	South Korea (Yosu, Busan, Kwang Yang)
Lukoil	RMD80	Large supplier in Russian ports
Maersk Oil Trading	RMD80	ARA Region, USA (Newark, Elizabeth)
Monjasa	RMD80	Mainly Denmark (Skagen, SKAW)
NNK-Bunker	RMB30, RMD80	Vostochnyy, Vladivostok, Nakhodka
Oil Chart	RMD80	ARA Region
Peninsula Petroleum Ltd	RMD80	ARA Region
Preem AB	RMD80	Sweden (Brofjorden)
Primorsk-Resursy	RMD80	Primorsk
Saurix Kuras	RMD80	Klaipeda
Shell	RMD80	Mainly ARA region
SK Energy	RMD80	Rotterdam, Singapore, Yeosu
SK Trading International	RMA30, RMD80	Mainly South Korean ports
ST1 Energy AB	RMA30, RMD80	Gothenburg
Stena Oil Co	RMD80	ARA region and varios ports in Sweden and Denmark
Topoil	RMA30, RMD80	Various ports in Scandinavia
Total	RMA30, RMD80	ARA region
Trefoil	RMD80	ARA region
UNI Oil	RMD80	Fredericia & Aarhus (Denmark)

[6] This list is not exhaustive and only highlights major suppliers in above mentioned regions/ports based on FOBAS data

Appendix C – Case studies on reported operational issues on new ECA fuels

Case 1 – A ship bunkered a fuel (RMD80) from a Russian port and after a few days, loaded another batch of fuel (RMD80) from ARA region. Assuming the two fuels are of same grade, the ARA fuel was bunkered 'on top' of the Russian fuel in same storage tank. Once the ship started using the fuel from that storage tank with mixed fuel, straight away they encountered major sludging problems at the purifier and also filter clogging. FOBAS was asked to investigate the matter. Pictures below were sent by the vessel indicating the extent of problem.

Filter Clogging

Purifier sludge

The compatibility test in the lab was performed which gave a satisfactory rating however TSP (Total Sediment Potential) test of the 50:50 blend came out above average which indicated certain level of instability of blend product. There was suspicion that the disintegration of residual components within the fuel manifested itself during separation process under the influence of the centrifugal force. Because the fuel was mixed with another fuel, the ship had to carefully manage the remaining quantity of mixed fuel through focussed on-board fuel management and advice from FOBAS. Some adjustments to the purifier reduced the sludge generation helping ship to consume the fuel.

Case 2 – Another ship loaded NEF from a Russian port and straight away reported heavy sludging at the purifiers. Analysis on manifold drip sample was satisfactory with nothing untoward observed during the standard testing. Following this an acid number test gave a result of 1.12 mg KOH/g which can be considered above average.

FOBAS was asked to perform in-depth FTIR/GCMS analysis to determine the root cause of problem and the nature of acidic components in the fuel. The results indicated the presence of anomalous components such as alkyl benzene, naphthalene and 'atypical' asphaltenes alongside some other components which are not considered to originate from the refinery process. Based on the extended analysis, it was concluded that fuel is likely to be the contributory factor in the reported operational problems. The client was asked to inform the supplier and record any corrective action which the supplier may have offered.

Case 3 – A ship bunkered NEF (RMD80) from a port on US east coast. This particular client is on the regular ISO 8217 standard fuel testing programme including acid number on all residual based fuels. The acid number test performed on this sample resulted in 2.17 mg KOH/g which can be considered high. Further FTIR/GCMS analysis was requested to determine the nature of acids present in the fuel.

FTIR/GCMS analysis found fatty acids along with naphthenic acids. It was suspected that the source of the majority of fatty acids is 'vegetable oil based'. Nevertheless, ship was advised about the unusual blend and issues that might appear with using fuels with the presence of fatty acids. The ship decided to take a cautious approach and put the fuel in use but keeping suppliers on notice. The ship consumed the fuel without reporting any problems.

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