Paper on the impact of storing and using blends of diesel with biofuels onboard warships presented at INEC 2008 in Hamburg, Germany.

Future Fuels Onboard UK Warships

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SYNOPSIS

The market for diesel fuel is changing as the automotive sector seeks to include a biodiesel component to the fossil fuels it consumes and this will in turn affect the market for marine fuel even though marine fuels will not be targeted in the short term.

This trend will continue throughout other consumer sectors and across the world to the extent that by 2050 for the shipping sector, the Marine Gas Oil (MGO) fuel offered at many ports may include biodiesel as matter of course, whether this is by deliberate addition principally for automotive use or by contamination. This could particularly be the case in Africa and South America where the pressure to use indigenous biodiesel is greatest.

UK warships and auxiliaries need to operate worldwide and any changes to the fuel infrastructure at ports needs to be considered early so that the necessary changes to onboard machinery and operations can be identified and their impacts assessed.

This paper considers the impact of storing and using blends of diesel with biofuels onboard warships. The biodiesel could be derived from any natural feedstock and could be of variable quality at point of delivery despite the emergence of international standards.

The key areas of study were the storage stability (hot and cold temperatures), onboard treatment and fuel management to ensure a fuel of sufficient quality is supplied to the engines.

The impact of biodiesel fuels on ship performance was also assessed with specific reference to fuel consumption (endurance) and power (top speed).

Potential problems arising from the use of biodiesel could include a reduction in the reliability of equipment and common-mode failure sin the power and propulsion systems. Safety and availability can be affected by the greater risk of microbial induced corrosion (i.e. such as sulphur-reducing bacteria). Solutions to these problems are presented together with an estimate of the impacts associated with the changes to the warship.

INTRODUCTION

Objective

This paper seeks to determine the impact of future marine fuels on warship usage. It seeks to determine:

1. The ship impact;
2. The operational risks to machinery;
3. The available measures.

Context

Although there is an on going requirement for the world's navies to seek to meet IMO and other local emissions requirements, there is also a pressing need to be able to operate worldwide in an economy where fossil-based distillate fuels may become scarcer and increasingly mixed with fuels which are synthetic or derived from biomass. In the near term the most common of these is likely to be biodiesel.

The constituents of biodiesels vary greatly and they are a function of their source which could be fruit and seeds from a wide range of plants. Biodiesel is defined by the World Customs Organization (WCO) as "a mixture of mono-alkyl esters of long-chain [C16-18] fatty acids derived from vegetable oils or animal fats, which is a domestic renewable fuel for diesel engines and which meets the specifications of ASTM D 6751. (Ref.1)".

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The fuel can be used in standard compression-ignition (i.e., diesel) engines with small or no modifications. It is biodegradable, non-toxic, and essentially free of sulphur, aromatic hydrocarbons (such as carcinogenic benzene).

The specification of the fuel will be altered by the type of biodiesel used and the degree to which it is mixed with the other fuel. This paper explores how such biodiesel when mixed with the standard UK naval fuel, F76, and other low-sulphur fuels may affect the resulting quality of fuel produced.

Given that the fuel quality may be altered the extent to which this affects the safe and reliable operation of the engines will be reviewed. The scope for the provisions of onboard equipment to rectify the fuel and make it suitable for use will then be explored.

Information Sources

This paper has been developed from background research conducted by BMT as part of their technology watch activities. Such material has been used by the authors with the research conducted by Lt Roy Casson for his MSc project at UCL (Ref. 2) to provide the perspective presented in this paper.

WORLD FUEL CONTEXT

In simple terms, the world fuel context could be summarised thus:

- The world needs ever more energy to consume;
- Driven by government policy – energy is big business which is global and has huge political implications.
- Fossil fuels are affordable at present but the increasing price will allow other sources to become more cost-effective;
- Public policy and public opinion increasingly demands a more sustainable approach to energy production;
- Biofuels are more expensive and less energy efficient to produce.

Therefore, the world's economies need energy to burn and the low cost in energy terms of fossil-fuels will give way to means which are more energy intensive (i.e. less efficient) as we will always need energy.

Public opinion is influenced by the issues of deforestation for growing palm oil as well as the increasing price of human and animal food stocks due to the increased demand for land for biomass derived fuel.

This paper does not address the public policy and public opinion issues: although these economic and social issues are pressing and do require a concerted and collective global agreement to solve them, they are not a direct issue for naval operations and so they will not be addressed any further here.

Due to the extra energy required to be expended in their production, energy-wise, biodiesels are over four times more costly to produce per unit energy than their natural fossil fuel equivalents. However they do yield one third the carbon dioxide providing renewable energy is used to make them (Ref. 3). There is therefore a poor net energy yield from the use of biodiesel energy sources.

RANGE OF FUELS

The best future fuel for transport applications may lie with so called "Second Generation" solutions such as the Fischer-Tropsch Process (FTP) which was developed by the Germans in WWII and which has since been developed further by South Africa. The FTP uses low grade fossil-fuel derivatives to create synthetic high quality petroleum oil. The method is not currently efficient and is far from being in widespread production (Ref. 4).

There is also much promise for oil sand shales in North America where their bitumen type material is transformed into a range of crude oils through a hydrogen-addition process. The process is energy intensive and does raise environmental issues but would have a speed which would get fuel from the mine to the motorist within seven days.

The hydrogen economy is still not here and although it is progressing with much state-help in France when used with natural gas (Ref. 5) there is not yet a ground swell of industrial change in its favour. The use of hydrogen fuel onboard ships would result in a very bulky design and would not be a retro-fit for current engines.

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For the merchant marine the use of boil-off LNG to propel LNG carriers has been successful but the use of stored bunker LNG for other forms of propulsion is not a feasible prospect due to the volume and dedicated machinery that would be required.

The world needs fuel to supply power for transport whatever the price and for the marine world, the ships need to keep moving and increasingly, with better green credentials. Hence one scenario is that biodiesel may be likely to be used in greater quantities with medium speed diesels in the merchant marine as it is already used with ultra-low sulphur diesel in the automotive world. However it is already difficult to supply automotive use with 5% so this will be some way off.

The feedstock for biodiesel is an opportunity crop in poorer parts of the world as the range of crop sources can allow for each locale to select the crop which suits its climate. However in poor areas there is also pressure for food crops and there is already an increase in food prices due to the dual purposes that the land can be put to. There are four methods of creating biodiesel from the feedstock and of these transesterification is the most common.

NAVAL CONTEXT

The naval distillate F76 to Def-Stan 91-4 (Ref. 6) is the datum designated fuel for UK RN ships machinery. The set of specific performance in this standard allows for latitude in fuel specification to reflect the variation in fossil-fuel supplies.

The reliable storage and use of fuels onboard warships is a key element in its ability to operate worldwide. There is much co-operation and sharing of information on naval fuels for this reason and the standards to be adopted has been widely researched (Ref.7).

Warships will take bulk F76 fuel from NATO/ABCANZ sources such as replenishment tankers and designated refuelling jetties/barges.

It is recognised that the supply of F76 to the Def-Stan is limited and STANAG 1385 (Ref.8) provides a much wider range of fuel specifications to reflect the variants in national supply within NATO. However the common thread between both these standards is their ability to provide a reliable guarantee that the fuel will be of adequate quality for gas turbine operations. The main differences between the two standards are:

1. Lower cetane requirement: 40 min;
2. Lower flash point: 60°C min;
3. No filterability or cleanliness requirement;
4. Higher sulphur limit: 1% m/m;
5. Water separation (demulsibility) is measured by a different method.

MGO DMA

If F76 or fuel to the STANAG cannot be met, NATO warships are permitted to embark via spot bunker Marine Gas oil (MGO) to Distillate Marine Grade A, DMA MGO (Ref.9) as an emergency substitute fuel from designated suppliers around the world. Such fuels whilst still distillate may contain additional trace element quantities which may affect GT engine operations.

If DMA is not available then the next best permissible source as recommended by the UK MoD can be considered if refuelling is absolutely necessary. Such fuel is then usually stored separately and then burned as a first priority before any other better fuel is consumed

ULSD

In some cases, the next best permissible source may be automotive Ultra Low Sulphur Diesel (ULSD) fuel (< 15ppm S). In Europe this would be to BS EN 590 (Ref. 10) and its equivalents. EN590 may contain up to 5% biodiesel to meet environmental legislation.

Lower sulphur fuel will have a lower aromatics content which may allow fuel degrading microbes to thrive. However, there are preventive and mitigating measures which can be introduced such as biocides.

If a 100% biodiesel fuel (B100) meets ASTM D 6751, then most blends of B20 or lower will meet the US D 975 parameters for automotive diesel fuel (Ref 11).

For most biocides the required dosage rate is about 5 litres to treat 10,000 litres. Therefore this would represent a need to have a 5 litre dose for a 200 tonne embarked fuel load of B5 ULSD.

OPERATING SITUATION

So what happens when ships take on fuels with biodiesel content? There is no known documented information at this time but without suitable measures the low sulphur content may allow microbes to prosper and feed on the biofuel content.

Even if the biofuel content is 5 % this is still a sizeable quantity of feedstuff for a 200 tonne fill-up.

Spot fuel from non-standard suppliers will always be stored separately to F76 and used first. However the embarked quantities can still be large (i.e. 200 tonnes) and the risk of deleterious impact on machinery is real.

Therefore, it is quite possible that biodiesel fuel will be embarked for no good reason. An awareness of the issues is therefore a cogent requirement!

BIODIESEL

Manufacture

Biodiesel is a Fatty Acid Methyl Ester (FAME) derived from its feedstock (a triglyceride) through the transesterification process. This involves addition of methanol and a catalyst, sodium hydroxide. The resulting solution yields the FAME and glycerol which can be used for other industrial applications.

At the end of the transesterification process, the glycerol and ester separate into layers with the heavier glycerol at the bottom. This process happens due to gravity although the use of a centrifuge accelerates this process. Glycerol can be used in the pharmaceutical and cosmetic industries. The engine combustion benefits of this process are the lowered viscosity, the removal of glycerides, the lowered boiling point, flash point and pour point.

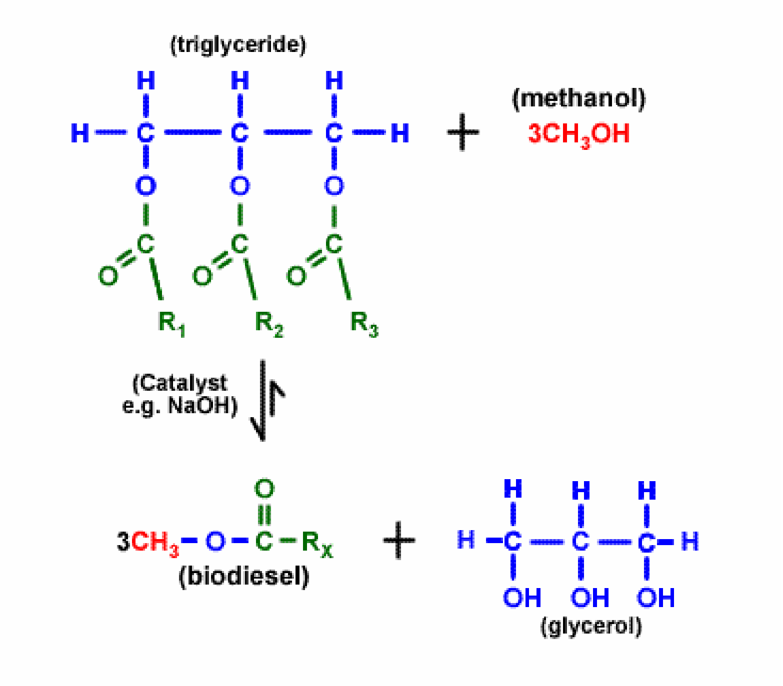

Figure 1 - Biodiesel Process

Biodiesel is carbon neutral over its lifecycle but often the energy expended to grow the feedstock can be considerable. Fertiliser has an energy burden and the energy consumed when processing the feedstock is significant when much of the process is small batch. There is little scope for future manufacturing reductions as the technology and its implementation are mature but if the fuel is produced local to its point of consumption then it will have a lower transport cost.

Biofuel has a number of advantages onboard ship: lower sulphur emissions, increased lubricity and usually, a similar cetane number.

1. On the debit side there are a number of disadvantages:
2. Reduced energy density:13% less, leading to:
    - (i) 13% reduction in endurance distance;
    - (ii) 5% reduction in top speed.
3. Not currently cost-effective compared to fossil petroleum fuel;
4. Water separation problems and microbial contamination;
5. Increased fuel maintenance and management issues;
6. Potential combustion problems in GT engines;
7. Poor storage stability, especially when in contact with metals commonly found in fuel systems.
8. Poor thermal stability during combustion.

Feedstocks

The primary biodiesel feedstocks are rape (canola), soy and palm oil. The first two are preferred due to their better low temperature performance with a cloud point which is below zero °C.

There are issues with sustainable land-use both in developed and developing nations and the well defined issue with palm oil from farmland created from felled rainforest is one example (Ref. 12).

The range and standard of biodiesel throughout the world is very broad as the creation of biodiesel is largely uncoordinated and deregulated. The fuel can actually be made from everything between chocolate and chip pan fat through to refined canola (rapeseed oil). One promising source is the seed from the jatropha curcas tree. This plant can be raised on marginal soils in a wide range of climates. BP are working with D1 oils to create a fuel infrastructure based on this feedstock which is sustainable and renewable (Ref.13).

It is the rapeseed oil feedstock which when converted to Rape Methyl Ester (RME) oil which could be considered to be one of the best sources of biodiesel from a European perspective and it is one of the feedstocks most likely to allow the international standard, EN14214:2003 to be achieved (Ref 14). In the US, biodiesel is to be to ASTM D 6751 (Ref. 1)

The other favourable feedstocks are sunflower oil and linseed oil due to their low cloud point. There are many feedstocks which are never likely to be used for a reliable warship fuel: one example is palm oil which has a pour point of 12°C. Therefore for the purpose of this study, some metric to allow the assessment of feedstocks against F76 needs to be derived.

Blended Fuel

The key fuel parameters for naval use will now be explored and the features of F76 and MGO diesel fuel described in the context of a petroleum fuel mix with biodiesel. The increasing use of ULSD often with a biodiesel component of up to 5% has led to an interest in this area and for that reason the blend of biodiesel with ULSD has been considered here.

This may be the way forward for the foreseeable future – due to the lack of biodiesel, despite some trials with 50% and 100% bio product.

The key features of ULSD, F76 and other principal marine fuels have been incorporated in Table I.

Data Comparison

Table I shows the key parametric values (where known) for:

1. F76 to Def-Stan 91-4 & STANAG 1385
2. DMA MGO to ISO 8217: 2005;
3. Biodiesel to the standard EN14214:2003,
4. Biodiesel to the standard ASTM D 6751;
5. Neat biodiesel (B100) from rape methyl ester (RME) feedstock
6. Automotive Petroleum Diesel to BS EN 590;
7. ULSD (B5).

Table I - Principal Fuel Parameters

Fuel > ***Parameter V***	***F76*** ***Def-Stan 91-4***	***F76 to*** ***STANAG 1385***	***DMA MGO*** ***to BS ISO 8217: 2005***	***Biodiesel (FAME) to*** ***EN 14214: 2003***	***B100*** ***Canola***	***ASTM*** ***D6751***	***Automotive Diesel*** ***BS EN 590*** ***:1999***	***ULSD***
Density at 15°C kg/m^3	820-880	820-887	890	860 to 900	890	-		
Flash point, Minimum, °C	61	60	60	<101	153	> 130	55	>130
Sulphur Content, Maximum	0.1%	1%	1.5	< 10ppm	0.1	15ppm	50ppm	<=0.05% (500ppm)
Cetane Number, Minimum	45	40 (Index 43)	40	> 51	49 to 62	> 47	>51	> 47
Cloud point, Maximum	-1°C	-1°C	-	-	-3 to 1°C	* report	-	-10°C
Pour point, maximum	-6°C	-6°C	0°C	-		-		-17°C
Energy Content MJ/kg	-	42.7	42	-	37.2	-		
Kinematic Viscosity mm^2/s 40°C	1.7 to 4.3	1.7 to 4.3	6.0	3.5 to 5.0	5 to 7	1.9 to 6.0	4.5	1.9 to 6.0
Oxidation Stability Rancimat test / mg/m^3			-	>6hours At 110°C		-	N/A 25g/m^3	3 Cu strip corrosion
Water Content			-	<500ppm		<500ppm	<200ppm	<=0.050%

Flash point

The minimum flash point (FP) of naval marine fuels is prescribed by the IMO SOLAS convention which states that fuels with flash points below 60°C cannot be stowed below decks (Ref.15). Therefore F76 has been formulated to ensure the FP is at 61°C so that it can be handled safely with the minimum risk of fire.

100% RME biodiesel has an FP of 150°C or over and therefore B100 or any other blend should therefore be a safer fuel to handle and store compared to F76 with respect to fire hazard. However it has been postulated that biofuels which have degraded (i.e. to methanol) may be more susceptible to inflammability.

Sulphur Content

F76

The current maximum allowable sulphur limit of 0.2% is often much higher than seen in practice and in 2008 this limit will come down to 0.1% in-line with the general practice with other distillate fuels. The STANAG limit will be retained at 1% for the time being.

As sulphur compounds can act as anti-oxidants, the allowance for progressively less sulphur needs to be made with no degradation of the storage stability. It is expected that anti-oxidants will be added to mitigate this effect.

Biodiesel

In a limited presence, sulphur has benefits for lubricity but this can also be managed by additives. However in ULSD where the sulphur proportion is usually less than 15ppm, it has been stated that the lack of sulphur can remove a potential biocide and source of lubricity. If the ULSD containing microbes is then blended with biodiesel containing the “food”, microbiological growth (MBG) can proceed more quickly (Ref.16).

The risk with MBG is the precipitation of particulates and fibrous organic matter which can then clog up filters and coalescers and especially with the latter: limit their effectiveness. As has been stated above the treatments available vary but the dose of biocide is typically 5 litres per 10,000 litres of biodiesel fuel which for a 200 tonne load of B5 ULSD requires a dose of 5litres.

Way Forward

For blended ULSD, biocides will have to be added to the ULSD to ensure that MBG is constrained. The warship may not always be able to assume that a biocide has already been introduced and may have to carry a source onboard.

Water Content

The Risks

Water content in fuel and specifically the sodium impurities from sea water can cause corrosion of the combustors in a relatively short time if they are not suitably managed.

The most significant source of sodium contamination is from sea water which contains approximately 14,000 ppm of sodium. Sodium salts can cause corrosion in an engine control system which uses fuel as its process fluid and they can also have a marked effect on the rate of gas turbine blade corrosion.

Water content in fuel is therefore to be very low to avoid engine and ancillary equipment corrosion. Some distillate fuels (DMB & DMC) allow up to 0.3% water and this recognises that some water is likely to be present.

Precautions

All fuel contains water and any accumulation should be avoided and provide husbandry to remove the opportunity for fuel constituents to have miscibility with water.

Water, above the fuel saturation point, is present in a physical form and can be separated by various techniques including gravity settling and filtration. This ‘free water’ requires minimizing within the system and is required to be less than 30 parts per million (ppm) on delivery to an aircraft/engine.

Free water’ may be present in the fuel supplied to a ship but fuel stowed in a ship may also be contaminated by ‘free water’ in the following ways (Ref.17)

1. Absorption from or mixing with layers of water under the fuel in tanks, pipes or system components;

2. Absorption from humid air above the fuel in a tank;

3. Condensation from humid air above the fuel in a tank when temperature changes occur;

4. Contamination from defective tanks or incorrectly operated systems.

Positive displacement pumps are preferred to centrifugal pumps to restrict the emulsification of water and assist in the removal of such contamination.

The process of leaving fuel to stand in a tank to allow water droplets to collect at the bottom by gravity separating is known as ‘settling’. Most ‘free water’ in fuel will be in droplet form which is larger than 50 mm and will separate from the fuel by ‘settling’. Water separated by ‘settling’ will form a layer at the bottom of the tank and can be removed either by draining, or by pumping using a system provided for this purpose. The ‘settling’ process can however be impeded by ship movements.

F76

Annex A of Ref 6 provides a method for determining the water reaction of diesel fuels, i.e. how much water it absorbs. This method is still being trialled but the F76 standard does require the fuel to have good water separation characteristics. The UK MoD standard also specifically states that F76 is not to contain vegetable oil or fatty acid methyl esters (FAME).

ULSD

ULSD is not generally tested for water separability although there is no permissible limit in BS EN 590. EN590 is a British standard which has equivalents throughout Europe: world-wide ULSD standards may vary considerably.

If the ULSD contains a biodiesel extender, then water separability could be exacerbated. Automotive diesel fuel may also contain detergents and additives which would affect water separability.

Biodiesel

Unfortunately biofuel is known for being highly hygroscopic although it is not known to be miscible with water. The water content can be as high as 1200ppm in biodiesel although the EN standard states a limit of 500ppm. There is therefore scope for its removal by centrifuge and to a limited extent, coalescers.

The absorbed water would be burned in the engine and if it was sea water then the sodium could lead to engine damage.

This aspect is a principal cause for concern with the use of blends of biodiesel onboard a warship.

Miscible water content is known to damage coalescers as an emulsion-type film stops the fibres from absorbing the separated water. One promising approach to remove water is the adoption of zeolite columns. However an additional carry-on of coalescers would be prudent measure.

Cloud Point

As the fuel cools it will reach a temperature known as the Cloud Point (CP) where it becomes cloudy and opaque due to the formation of micro crystals. This condition presents the danger of blocked fuel filters, plugs and fuel lines at the cold temperatures.

This feature indicates the likely coalescing of the long chain molecules in the FAME and is a measure of the refinement of the fuel. The CP is thus an important measure for cold temperature operations. Although additives can help it is considered unlikely that they would be required for naval operations.

The maximum allowable CP for F76 is -1°C but DMA often has middle-distillate flow improvers (MDFI) added to improve the low temperature properties. Data for UK MoD spot fuels has shown that the MDFI content can vary between zero and 136 ppm with an average of 20ppm.

RME (Canola biodiesel) has a CP which is between -2 and 0°C: as ULSD has a CP of -10°C, a ULSD biodiesel blend would require a high proportion of biodiesel to cause the FP to be out of F76 specification.

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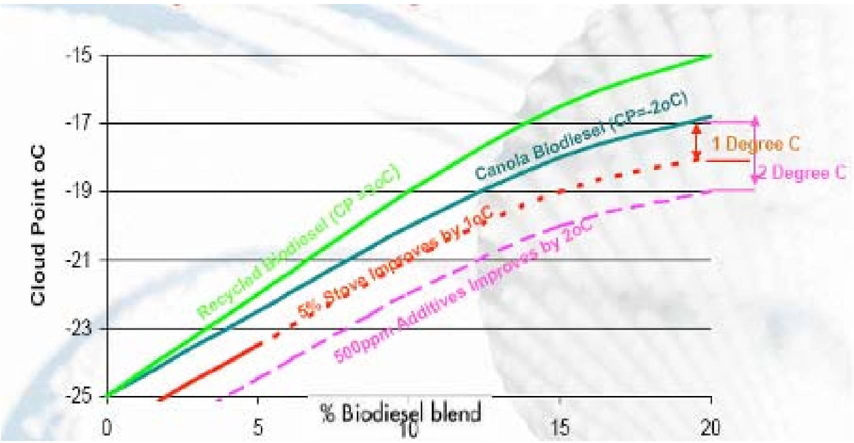

Figure 2 - Variation of Cloud Point with Blend

Figure 2 shows how the use of a higher blend of biodiesel can increase the CP.

ENGINE OPERATING ISSUES

Gas Turbine Engine Requirements

GT engines require fuel supplied to within 1 micron at flow rates up to 6 tonnes per hour.

To operate reliably gas turbines require fuel to a purity and quality which is better than required by medium speed diesel engines. Particulate contamination is to be less than 10ml/litre (Ref.18).

If the filtration is out of specification then the injectors can have accumulations and quickly block up. This can lead to engine shut-down or worse filter failure and a block of sediment entering the fuel burners.

Gas turbines benefit when they run on fuel with a low aromatic content as this has a positive effect on engine life by decreasing the soot emissions and flame radiation in the combustor region of the engine and thus allowing a prolonged life for the hot section.

Biodiesel also contains phosphorous and this can lead to its acting as a solvent on some system fuel components such as natural rubber gaskets and hoses breaking them down over time (Ref. 19). In general a “B5” blend (5% Biodiesel and 95% petroleum Diesel) is considered as unlikely to have any noticeable effect on current equipment however blends greater than 5% will have varying degrees of impact.

Cetane number

The cetane number (CN) is a measurement of ignition delay: the time between when the fuel is injected and the combustion process begins. The higher the CN, the shorter the delay The F76 specification requires a minimum cetane number of 45 and the STANAG requires a minimum of 40. As the ULSD value is 53 and the RME value is 61, this should not lead to an engine combustion timing issue.

Viscosity

The viscosity of DMA and RME is 50% greater than that of F-76 at 40°C. However if DMA has been used successfully onboard warships designed to UK standards then the pressure drops should not present an operating issue. Reduced flows would be a potential power limiting issues for a gas turbine engine but that would only become an issue in very cold engine room temperatures.

Storage Stability

The storage of fuel is a crucial aspect for naval use as the fuel may be stored ashore, in tankers and in bunker tanks for some considerable time before use. As warships will always seek to maintain their bunkers at least 75% full at any one time, there is always fuel onboard which has to be stored in a stable state for periods of over 6 weeks.

Notwithstanding the disintegration of biofuel through microbiological means there is also the scope for in-built organic decay through exposure to air and due to heat-accelerated means. The storage stability is usually denoted by the oxidation number which has units of mg/100 ml of total insoluables and a limit of 3mg/100ml is provided in Ref.18.

Good fuel management is required but as Westbrook (Ref. 21) has shown, for some blends there is scope for storage for several months and even as much as a year. As the fuel storage may be on a ship in arctic or tropical temperatures the variability of this effect is difficult to estimate.

F76

A key feature of F76 is its ability to be stored for extended periods with negligible risk of damage through oxidation. It is expected that F76 would be storable for 12 months before any appreciable risk of oxidation became apparent. The exact time would be dependent on temperature and any impurities such as water and microbial contamination.

MGO DMA

Marine Gas oil (MGO) to Distillate Marine Grade A

There is no specific storage stability performance parameter for DMA. Automotive Distillate Fuels are tested to D4625 (Ref. 20).

The stability is likely to be variable around the world. An analysis of spot fuels taken on by UK naval craft has shown a variability between zero and 1.8 on the UK MoD calorimetric storage stability test with an average of 0.1

Biodiesel

A key concern of any fuel that has biodiesel content is its storage stability, especially in hot temperatures. Although there has been testing of neat biodiesel (Ref.21) the impact of lower proportions is less clear. The latest available results from the NREL (Ref.22) where a set of different of endurance tests were performed on B100, blends and pure diesel fuel indicate that B5 performance should be acceptable for up to one year based on accelerated B100 testing.

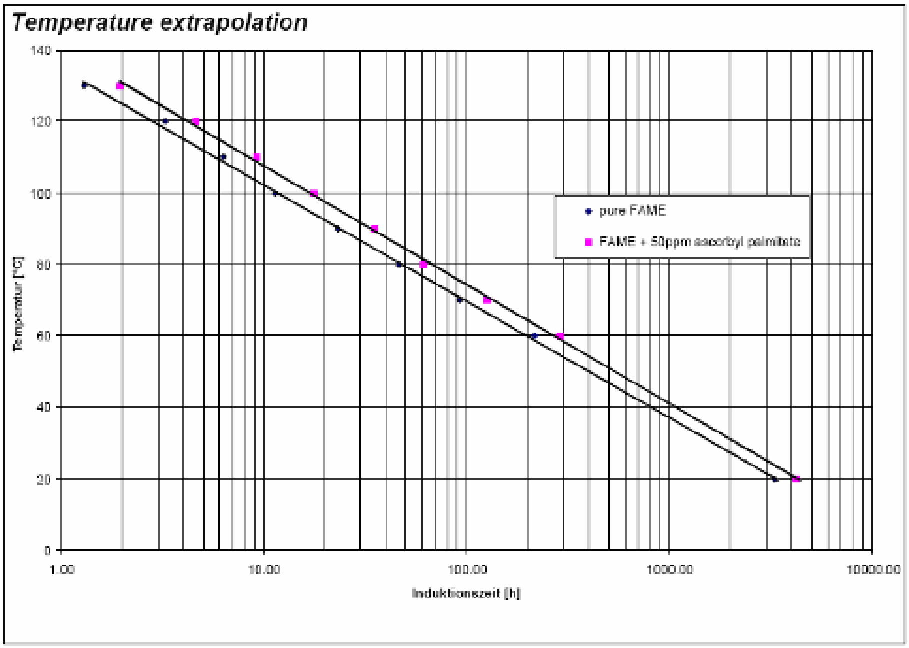

Figure 3 - Variation of FAME Stability with Temperature

Figure 3 from Metrohm (Ref. 23) shows how the addition of an anti-oxidant can affect the stability of a fuel across a range of temperatures. The anti-oxidant dose indicated has allowed an effective temperature increase of 3°C to be accommodated. The figure also shows that for 100% RME, a storage life of 3000 hours (i.e. 125 days) is achievable at 20°C for laboratory conditions (i.e. no water content) with this time reduced to 1000 hours (41 days) for an ambient temperature of 35°C. This shows how important an awareness of temperature is when considering how to consume and store fuel with biodiesel components onboard.

Measures

Although there is limited evidence that limited blends are stable for short periods the results do not go any distance to indicating stability for extended periods and a pro-active means of ensuring stability is necessary.

Such active methods might include one or more of the following:

1. Immediate use of such blended fuel;
2. Recycling and stripping tanks to collect and dispose of waste deposits;
3. Filtering to remove organic deposits from decay;
4. Onboard treatment;
5. The addition of a stabiliser.

Anti-Oxidants

Anti-oxidants will help to prevent the formation of lacuer and insoluble materials within the biodiesel. Anti-oxidants are usually added at the refinery with most biodiesel stabilisers having a dose rate of 0.5% by volume. This for a 200 tonne embarkation of B5 ULSD, the required dose would be 58 litres.

CONCLUSIONS

Ship Impact

Due to its reduced specific energy content, the use of 100% RME biofuel would lead to a reduction in a ship's operational endurance of up to 13% and a loss of top speed of 5% (say 1 knot). With a 5% blend in ULSD this impact would be negligible and the cetane number could be comparable to that for DMA.

Storage stability is operationally vital and if water is present in a biofuel blend it is vulnerable to microbial attack and/or the reversion of the FAME to fatty acids. Also water can hydrolyse certain stabilisers and thus inactivate their interceptive character.

The Way Ahead

It would appear that the risks associated with the use of biodiesel blends in ULSD can be managed onboard through the following measures:

1. Proactive water isolation and removal management (Ultimately an active means of water removal);
2. The judicious use of biocides;
3. The addition of anti-oxidants if this is deemed to be required;
4. Fuel management (fuel located adjacent to machinery spaces)
5. Pro-active managed fuel usage;
6. Health Monitoring: increased sampling;
7. Onboard analysis: greater use of spectroscopy etc. onboard;
8. Possible off-line treatment for solid removal

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