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TNO report

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Review of potential issues for inland ship engines when reducing gasoil sulphur level to maximum 10 ppmm

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1. BP leaflet: ULSD for commercial and marine users
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Abbreviations and definitions

Biodiesel	Diesel grade made from FAME
CCR	Central Commission for Navigation on the Rhine
CEN	European Standardisation body (Comité Européen de Normalisation)
CO	Carbon monoxide
CO_2	Carbon dioxide
CWA	CEN Workshop Agreement; a kind of pre-standard, based on an agreement between major stakeholders, for a limited European area
DG-ENV	Directorate General (European Commission) in charge with environmental regulation
Diesel	Gasoil for diesel engines
DIN	Deutsches Institut für Normung
EGR	Exhaust Gas Recirculation
EN 590	European Norm for automotive diesel fuel
FAME	Fatty Acid Methyl Ester, normally based on a vegetable oil
Gasoil	Petroleum middle distillate with boiling range of 180 – 400 ˚C applied as a fuel for heat and power generation
HC	Hydro Carbons
HDS	Hydrodesulphurisation
NO_x	Nitrogen Oxides
ppmm	Parts per millions mass
Specification	Minimum requirements and test method to fulfil the demands of a specific application
S	Sulphur
SCR	Selective Catalytic Reduction
SO_2	Sulphur dioxide
Sulphur free	S content maximum 10 ppmm
ULS	Ultra low S; S level maximum 50 ppmm
ULSD	Ultra low S diesel; S level maximum 50 ppmm

Summary

The Dutch ministry of environment and spatial planning (VROM) asked TNO to review the potential consequences of the introduction of EN 590 sulphur free gasoil for the inland marine sector. This would be a 100% replacement for the current VOS (DIN) specification with a maximum sulphur level of 2000 ppm mass. EN 590 sulphur free gasoil has major advantages: a) it would lead to a reduction of SO_2 and particulate emissions for all ships, b) it is necessary for future engine emission control technologies such as EGR (exhaust gas recirculation) and exhaust after treatment systems (it is also specified by the engine manufacturers for modern, new engines), c) it would allow for cost effective retrofit after treatment systems such as diesel particulate filters (DPF) and selective catalytic reduction of NO_x (SCR deNO_x).

In Europe there is no general quality specification for marine gasoil. In most countries the marine gasoil quality aligns with off-road diesel or heating gasoil specifications.
In this study properties like lubricity, density, viscosity and lacquering tendency are discussed and the refining processing effects qualified. Although quite some changes emerge, most are positive or not creating incompatibility.

The overall conclusion of this study is that EN 590 sulphur free gasoil is compatible with all types of engines used for inland marine application. For engines sensitive to cylinder liner lacquering, this problem will tend to decline. However the balance in engine operating conditions and lubricant type may need adjustment.
The good compatibility of sulphur free gasoil is also supported by experience with marine fleets around the world which have already switched to sulphur free or to low S gasoil.

A special note needs to be made for Biodiesel components (or FAME) which are allowed in EN 590 sulphur free gasoil. Blending of Biodiesel, even in the range of 5%, will require extra maintenance and might create safety problems due to on board heating systems.
With this respect the (temporarily) introduction of B0-EN 590 sulphur free (zero bio component) for the marine sector might be considered.

1 Introduction

During the last decades, air pollution has become a very important issue. Due too ever increasing emissions of amongst others the industry and transport sector, the level of air pollution has increased dramatically and has become a serious health risk. In order to improve the air quality, stringent limit values for a number of emission components have been defined. To be able to meet these requirements, both the industry and the transport sector will have to reduce their emissions. Within the transport sector, the inland marine sector contributes significantly to the total traffic emissions. Although the inland navigation is an energy efficient mode of transport and therefore potentially environmental friendly, other transport modes like trucks have drastically reduced their emissions over the last decade.

To be able to meet the future stringent emission requirements the marine engine technology must be optimized regarding exhaust emissions. Only by combining engine technology with an appropriate fuel quality the emission targets can be fulfilled. For that reason, for modern engines latest fuel quality requirements like the EN 590 specification are prescribed by the engine manufacturers.

A very important quality parameter in the fuel specification is the sulphur content. Currently most of the gasoil delivered to inland marine customers is supplied from the heating gasoil pool with sulphur levels up to 2000 ppm mass (0,2 % m/m). Reducing the sulphur level will directly reduce emissions of SO_2 and particulates. Furthermore, current engine technology requires sulphur levels below 500 ppm mass and in near future exhaust gas after treatment like soot filters and de NO_x systems will be introduced demanding for sulphur free gasoils.
Although sulphur free gasoils are more expensive, the inland marine transport stakeholders are showing a growing willingness to adopt this gasoil grade as the fuel for their engines.
Before supporting the introduction of this gasoil, the ship owners need the assurance that such a step will not create any technical problem with the existing diesel engines. This study is meant to provide clarity on the technical consequences and potential harm related to a move to EN 590 sulphur free gasoil.

2 Variety in gasoil specifications

Gasoil as a refinery fuel grade is applied in a wide range of applications. In principle a split in on-road and off-road can be made. The on-road gasoil is marketed as diesel fuel. The off-road version can be applied for heating oil, off-road constructing vehicles, tractors, mining equipment, locomotives, ship engines and many other applications. During the 1980s the European road vehicle emission regulation was introduced and the fuel quality requirements, directly influencing the emissions, came on the agenda. The European Standardisation body CEN was given the role to establish a series of standards for automotive application. Later on also emissions of sea going vessels and inland marine gained European attention, however without leading to European inland marine gasoil standards. In a report from a DG-ENV consultant dated November 2001 [1] the inland marine gasoil volume is calculated to be in the order of 20 to 25% of the total off-road gasoil volume. When compared with the automotive diesel volume this is in the order of 4%, so very small. For that reason and from an economic perspective, inland marine gasoil is often derived from mean grade qualities like heating gasoil or agricultural grades to reduce costs of segregation, risk of contamination and tax fraud. This means that most inland marine gasoil delivery specifications are not dedicated to their specific requirements.
For sea going vessels, contrary to inland marine fuels, international ISO fuel standards have been established. The ISO 8217 covers, apart from heavy fuel oils, also gasoil qualities, however all with rather high S levels (1% m/m and above). Also for military applications a gasoil specification exists; Defence Standard 91-4 (equals NATO F-76) [2] setting the S level at max 0,2% m/m which is still pretty high and for other reasons not attractive for inland marine engines.
The only element specified for non-automotive gasoil at a European level is the maximum S content. In the European Directive 98/70/EC the gasoil S content is limited at max 0,2 % m/m (= 2000 ppm mass) and to be reduced to 0,1% m/m by 2008.

2.1 Vos specification

In the Netherlands a series of fuel quality incidents in inland marine during the late 80ties triggered a request by the sector for a better defined gasoil specification. The Dutch oil wholesale association NOVE took the initiative to start negotiations with the national oil refiners and establish the so called VOS specification (Vignet Olie Scheepvaart). By modifying their individual customer gasoil specification the oil refiners fulfilled the VOS specification so preventing the creation a new refinery gasoil pool. Later on when the German gasoil pool according to DIN 51603-1 became more important, alignment of the VOS spec with this grade was sought for by the refiners. The latest (2007) VOS specification [3] is now almost fully aligned with the German DIN specification. VOS includes some additional requirements for acid number, cetane index (min. 45) and a slightly higher flashpoint to be fulfilled in case of deliveries to seagoing vessels.
The drawback of the VOS specification is that it has no international status as established and maintained by the Dutch wholesale association.

2.2 CEN EN 590 automotive gasoil specification

European standards are established by the European Committee for Standardization CEN (fr. Comité Européen de Normalisation). It was founded in 1961 by the national standards bodies in the European Economic Community and EFTA countries. The main objective is to promote free trade between the members of the European community by having single standards for all technical goods. The standards developed by CEN are known as European Norm (EN).
The CEN EN 590 is the European standard for automotive gasoil (diesel). It specifies the minimum requirements and test methods. The sulphur limit, set by a European Directive is specified maximum 50,0 mg/kg (= ppmm) and an optional 10,0 ppmm (called sulphur free) for countries that like to pre-empt the mandatory change to 10 ppmm by 2009. Governments in many countries under which the Netherlands and Germany promoted the S free quality by tax incentives resulting in a complete move to S free diesel for on-road applications.

2.2.1 Bio component in EN 590

In the latest EN 590 issue (2004) the addition of 5% (V/V) fatty acid methyl ester (FAME) is allowed for. This is a bio component based on esters of vegetable oils like rapeseed oil and sunflower oil.
FAME is included to reduce the vehicle CO_2 emission. It has little effect in the harmful emissions like CO and NO_x. The emission of particulates tends to go down when adding FAME.
In some countries e.g. the Netherlands and Germany, the addition of bio components to automotive fuels is made mandatory. For all EU member states a target of minimum 5,75 % V/V in automotive fuels is set for the end of this decade. For 2020 the aim is 10% V/V.
To achieve these objectives it is most likely that the maximum FAME content in the EN 590 specification will go up in coming years.

2.3 Comparing EN 590, DIN 51603-1 and VOS

When comparing the EN 590, DIN 51603-1 and the VOS specifications the emerging differences are:

- Cetane Index (CI): The CI is a measure for the ignition quality of a fuel. This is important for compression ignition engines (diesel engines) but not for heating. For that reason this requirement is not included in the DIN specification. In the EN 590 and VOS specifications, a minimum cetane index of 46 and 45 is required.
- Sulphur content: In the DIN and the VOS specifications the upper limit for sulphur is defined as 0,2% m/m (2000 ppmm). In the EN 590 this is set on 50 ppmm and in the Rhine countries maximum 10 ppmm for on road diesel became the standard.
- Cold flow properties: For EN 590 each member state includes an appendix setting the cold flow requirements for their specific weather conditions. In the Rhine area in winter normally an operability down to -20 ˚C is guaranteed by selecting lighter refinery components and including cold flow additives. The DIN/VOS requirements are more relaxed. For marine application the more expensive EN 590 winter quality has no added value as the gasoil is normally stored below the waterline.
- Bio component: As mentioned before the EN 590 allows the inclusion of FAME. In the DIN specification the use of bio components is not permitted.

In the VOS specification these components are not addressed. In principle, for marine application, bio components have no added value. On the contrary, the volumetric energy content will reduce and the risk of contamination and deposit formation may increase. See also chapter 9.

2.4 Option for a dedicated European marine gasoil standard

Considering the differences in the VOS, DIN and EN590 fuel standards it may be desirable to establish a dedicated specification for European inland marine gasoil. Unfortunately this does not seem realistic due to the relatively small volumes involved. It is very unlikely that all stakeholders in such a process will align as a separated refinery gasoil pool is not attractive for economic reasons.
An attempt to establish a so called CEN Workshop Agreement (a fast route to a specification for a limited area) based on the current VOS specification may be considered by the CCR. A consult with the CEN standardisation body on this issue may be fruitful. However for the coming years this will not offer a solution.

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3 Sulphur not a beneficial quality parameter

Sulphur naturally occurs in crude oil in a wide variety of compounds. If the sulphur is not removed during the refinery process it will be converted to sulphur oxides in the engine combustion process.

3.1 Reactivity

Sulphur oxides may react with water from the air passing through the cylinder and form corrosive substances like sulphuric acid. Especially when the engine is cold the acid may condensate on the surface of the cylinder liner. The acid is neutralised by the alkali components in the lubricant in order to prevent corrosion of the liner. As this process is not always adequate, a direct relation is seen between fuel S content and engine lifetime, especially in ‘stop and go’ operation.
Sulphuric acid, although used in oil refining to extract impurities, is definitely not a cleaning agent in the combustion process. It is not soluble in the lubricant or the fuel and may only react under specific conditions with poly aromatic hydrocarbons (PAH) by forming a soap. When gasoil is desulphurised the poly aromatic hydrocarbon content will decline and the reactivity with PAH’s will decrease.

3.2 Heating value

Sulphur compounds slightly increase the heating value of the fuel. 1 kg of S, when completely burned, generates 9,25 MJ of energy. However, with S levels in the range of zero to 0,2 % m/m like in gasoil (about 10 gram S a litre) this heating value contribution is minor.

3.3 Emission aspects

Currently the sulphur content in gasoil is under pressure due to the emission aspects. Sulphur oxides contribute to acid rain and the emission of particles from the engine. It has also proved to be a poison for catalysts used in engine after treatment devices like particle filters and $deNO_x$ systems. Also engines equipped with cooled EGR would suffer from high sulphur levels, due to the formation of sulphuric acid in the EGR cooler. For these engines with advanced emission control an EN 590 sulphur free gasoil will be mandatory to prevent serious engine management issues.

3.4 Lubricity and deposit formation

Sulphur and its oxides do not directly support the lubrication properties of the fuel. Polaire impurities (traces of nitrogen and oxygen) in the fuel that are extracted in the desulphurisation process are responsible for the lubricity properties but not the sulphur itself. In combination with metals sulphur may contribute to deposit formation in which ash, soot and coke can be captured. These deposits may benefit exhaust valve seat recession rate, although the influence of the ash from burned lubricant is by far dominant in gasoil operation.
Based on above we can conclude that sulphur in fuel is not contributing to the fuel quality. On the contrary; reducing S content will favour engine durability and engine exhaust emissions.

4 Affected quality parameters and their technical impact

Sulphur in gasoil is mainly in the form of substances called benzo-and dibenzothiophenes. These can be broken down by a process called hydrodesulphurisation (HDS). When passing this process apart from S containing compounds also other molecules are affected. This results in a gasoil stream with different properties with consequences on the fitness for purpose. In this chapter we will elaborate on this aspect.

4.1 The HDS process

During the hydrodesulphurisation (HDS) process the S compounds are removed by converting them into hydrogen sulphide by reaction with hydrogen in the presence of a catalyst. The reactor operates at temperatures in the range of 300-380 ˚C and at a pressure of 30-50 bar with excess hydrogen supply. The lower the level of S in the product required, the higher the pressure in the reactor. This is called the severity of the process.
The HDS process is used in every major refinery, although other S reducing approaches are possible. For this study, related to the European market, we will focus on the HDS process and its consequences for the gasoil quality.
Apart from the effect on S level also other compounds are unwanted converted or removed, especially if process severity goes up. It will affect the amount of unsaturated hydrocarbons, like olefins and nitrogen from refinery process streams and poly aromatic hydrocarbons that will be converted in more saturated molecules. Also nitrogen from refinery process streams and oxygen-containing substances are strongly reduced.
Following Table provides an overview of possible impacts on gasoil quality and emissions.

Changes in refinery stream	**Impact on gasoil property**	**Impact on engine operation**	**Impact on engine emissions**
S ↓	S level ↓	None	SO_2 and particulates ↓
Traces of nitrogen and oxygen ↓	Lubricity ↓	Rotating fuel pumps at risk	Possible increase due too fuel pump wearing
	Conductivity ↓	None (safety)	
Aromatic content ↓	Cetane quality ↑	Smooth running especially during warming up. Less deposit	CO, NO_x, PM, Noise ↓
	Viscosity ↓	None	None
	Oxidation stability ↑	Cleaner fuel and filters	None
	Elastomer compatibility ↓	Fuel pump seals ↓	None
	Density ↓	Fuel consumption ↑ Improved combustion → cleaner engine	NO_x, PM ↓

The Table shows that most, but not all effects are positive. This is explained in the following paragraph. It is important to keep in mind that the impact of the HDS process on the gasoil properties depends on the severity of the HDS process and the specific characteristics of the refinery.

4.2 Lubricity

When low sulphur diesel was introduced in Sweden in the 1980s excessive wear and premature failures of fuel injection equipment occurred in some instances. Trace compounds that gave conventional diesel fuel its lubricity had been removed by the HDS process. The fuel pumps affected were all of the rotating type. This type relies on the fuel to lubricate the moving components of the pump. Rotating fuel pumps are normally only applied in passenger cars and light vans. Unit pumps, line pumps and common rail as used for HD engines and lubricated from the crank-case system have never reported any damage.
The lubricity problem was solved by the introduction of special lubricity additives. Furthermore new lubricity test methods were developed and lubricity “quality-parameters” were defined. For the EN 590 diesel specification a lubricity requirement was included and the EN ISO 12156-1 test was selected. This test, known as the High Frequency Reciprocating Rig (HFRR) test shows a good correlation with the specific wear phenomenon as seen in rotating fuel pumps. It is able to distinguish good and poor quality gasoils. The test measures the diameter of a wear scar formed on a standard ball bearing. The experts in the EN 590 drafting committee agreed that a gasoil producing a wear scar diameter of less than 460 µm under the condition of test has a lubricity which is satisfactory for use with old and new fuel pumps. Refineries now add a lubricity additive in case the EN 590 requirement is not fulfilled.
Since the introduction of the EN 590 diesel specification no damages have been reported anymore.

4.3 Conductivity

Conductivity is a safety issue and not included in the scope of this study. This aspect is managed by the fuel supplier and additives are used in case conductivity levels are too low.

4.4 Cetane quality

The cetane quality is expressed in the cetane number of a gasoil. High cetane fuels ignite more spontaneously after injection into the combustion chamber. In other words; the higher this number, the shorter the ignition delays. Especially during starting conditions and the engine warming up period it has a positive impact on the combustion quality and the noise produced. In some emission test also an emission benefit is recorded with engines running under full operation condition.

4.5 Viscosity

Gasoil viscosity may be slightly influenced by the HDS process. This may have an effect of increased bypass within the hydraulic mechanisms and result in slightly less fuel delivery.

Since the introduction of EN 590 this did not emerge as a problem in automotive applications and monitoring of the European fuel quality did not reveal refinery problems to meet the specification.

4.6 Gasoil stability

The HDS process will substantially reduce the unsaturated hydrocarbons. Especially these components tend to reduce the oxidation and thermal stability of the gasoil. Poor stability may result in the formation of gum and sludge during storage as well as deposit formation on injection nozzles and gumming of valves. Especially high speed direct injection engines as applied in automotive are vulnerable. By reducing the unsaturated components with the HDS process, low S gasoils have shown a positive contribution to the filter service live and the engine cleanliness.

4.7 Material compatibility

Aromatic constituents have a strong solubility which means that they easily penetrate in substances like rubbers leading to swelling of the rubber. Nitrile rubber shaft seals, successfully used for decades in fuel pumps, were subject to swelling due to fuel aromatics. Limited swelling was allowed for in the components design and such seals gave acceptable performance from -40 up to 120 ˚C. Research showed that changing to a lower aromatic environment caused these seals to shrink back to nearer their original size and, once slightly worn, they would no longer fit tightly. Pumps most likely to be affected are the older type VE rotary injection pumps of the type fitted to light duty diesel engines. New unworn seals presented less of a problem. Steps were taken by pump manufacturers to modify the specified material to minimize this effect in situations where operators were likely to run new equipment on both types of fuel.
It is obvious that the above action does not protect the existing, older fuel pumps in the field.
During the introduction of low sulphur diesel fuel in the US in 2001, reports of failures of elastomer compounds used in fuel systems leading to fuel leakage were received. These failures were probably caused by shrinkages as described above and related to refiners running very severe HDS processes. This resulted in substantial reduction in fuel aromatic content in some regions in the US market. The European oil industry has taken notice of these signals and monitors the total aromatic content in the various gasoil streams and products on the market. In general the gasoil delivered to the final customer will show only mild variations. Due to the mixing of fuel batches in the distribution chain the extremes will fade out. In Europe elastomer shrinkage never became an issue.

4.8 Density

Density is a measure for the energy content; the higher the density the more combustible molecules per litre and the other way around. Density is affected by treating a gasoil with the HDS process. Therefore the switch to EN 590 sulphur free will have a limited impact on the density

4.8.1 The impact of the HDS process

In the HDS desulphurisation process, heavy hydrocarbons like aromatics are converted in smaller molecules while the overall hydrocarbon hydrogen content is increased due to the increased saturating rate as well.

Especially the poly aromatics like tri and tri+ aromatic hydrocarbons, which are rather instable components, will substantially decline. Smaller hydrocarbons and more hydrogen coming available during combustion, will benefit a smooth and clean burning, leaving less unburned fuel remaining by the time the piston reaches top end centre.
By reducing the fuel aromatics the fuel density will be reduced. As density is a measure for the energy content, the lower density will affect the fuel volumetric heating value. On the other hand, due to the better saturation of the molecules there will be a small increase in the H/C ratio. On average, this will result in a higher heating value of the individual molecules. As this partly compensates for the loss, the overall effect will be a small (and likely negligible) reduction of the volumetric energy content.

4.8.2 *The impact of the switch to EN 590 sulphur free*

A step change from current heating gasoil quality, e.g. DIN 51603-1 (density maximum 860 kg/m3) to EN 590 sulphur free (density maximum 845 kg/m3) will most likely affect the average density. The refinery streams used for both grades are slightly different. The EN 590 sulphur free specification is tighter, leaving the refiner less room for flexibility. In the DIN grade the refiner may blend all kind of converted heavy gasoil components, which normally don’t contribute to the combustion properties. In the EN 590 this is much more restricted. Lighter, better combustible components will dominate and the resulting density will end at a lower level compared with the average DIN quality.
When looking at market surveys the average density of EN 590 sulphur free diesel is in the range of 830 - 835 kg/m3. In winter normally at the lower end, in summer slightly higher. The average DIN 51603-1 heating oil density is found in the range of 840 – 850. These are average values based on hundreds of samples taken from the German market. The density of individual gasoil batches may vary over the full range as given in the specification.
This means that the move from DIN heating oil quality to EN 590 will result in a measurable change in average density in the order of 10 kg/m3. Although the introduction of EN 590 will result in a cleaner combustion, the loss of energy content will most likely not be fully compensated by the improved H/C ratio. Overall a fuel consumption increase can be foreseen. The increase of the fuel consumption will approximately be 0,5% which is meaningful in the marine world.

5 Oil industry experts view

5.1 Find the experts

During the Round Table Discussion that took place in Strasbourg on 3 May 2007 the compatibility of S free gasoil with existing engines was discussed. In the presentation by the European Association of Internal Combustion Engine Manufacturers (Euromot) it was stated that most of the experience would be available from oil companies/refiners.
The oil industry has a direct interest in keeping customers satisfied when changing product composition and properties. For that reason major oil companies have own R&D facilities as well as an after sales organisation. So it is obvious that especially major oil companies are able to provide valuable knowledge in the area of compatibility. In the Netherlands Shell and Esso are in that position with own refineries and a great interests in the marine market. For this study we relied on the knowledge available with retired Royal Dutch Shell employees; Mr. J. Logtenberg and Mr. H.D. Kattenwinkel.
Mr. Logtenberg was a leading technical expert in the national and international marine market for over 30 year. He was charged with the development, market introduction and market support of marine engine oils and related fuels. He has been involved in solving liner lacquering and associated bore polishing problems right from the start of the first problems in 1986 in the Dutch fishing fleet as a field service engineer. Moving to the Shell world wide Marine Research Centre in Amsterdam in 1997 he was directly involved in the development of new products for medium and high speed marine engines.
Mr. Kattenwinkel was a technical expert in the fuel quality field for over 30 years, representing Shell in the European standard setting process (e.g. EN 590), debating the oil industry position with European car manufacturers. As the Shell European fuel technical expert he was also the Shell representative in the European Oil Industry Association (Europia) and several national oil industry organisations for quality related issues. As a consultant he is still active in the world of fuel quality.
A brain storming session was organised with Mr. J. Logtenberg and co-author Mr. H. D. Kattenwinkel. Both were challenged to raise all kind of technical problems that might emerge from a move to S free gasoil, especially in older engine types.

5.2 Questions for the experts

- *Q: Can S in gasoil be seen as a lubricant likewise specific S components added to gear oils to function as an extreme pressure (EP) additive reducing the chance of metal-to-metal scuffing and local welding?*
- A: S in fuel and its oxides formed during combustion will not fulfil such a role as the S chemistry in EP additives is very specific and the extreme loads activating such additive are not seen in engine parts in contact with fuels.

- *Q: Is S playing a role in valve seat recession by forming a protective coating on the valve seat likewise the function of lead in old gasoline engines?*
- A: The rate of valve seat recession strongly depends on engine speed (revs/min) and load. Especially smaller gasoline engines appeared to be sensitive when driving under such conditions.

Lead could, by forming a thin lead oxide layer condensing on the exhaust valve, provide protection as a kind of lubricant. Bigger engines and small engines under mild operation conditions proved not to be vulnerable. The same applies for diesel engines. In marine diesel engines the valve recession conditions are normally mild as speed is rather low. On the other hand the metal ash formed by burning highly additivated diesel engine oil will form a deposit on the valve seat. This will provide more protection than an S component would do. Most critical in this aspect are high speed gas engines (up to 3000 revs/min) using low ash oils and with specific high combustion temperatures as gas does not extract heat for evaporation. Gas engines are not common in inland marine.

-*Q: Are fuel pumps under threat when minimising gasoil S content*
- A: Only smaller rotating pumps as used in automotive engines came out to be vulnerable. This type of engine may be found as auxiliary engine on board of ships. The main engines will all have in-line pumps in which the sensitive parts are lubricated by engine oils. The older engines will have a fuel plunger pump for each cylinder, also separately lubricated and definitely not affected by fuel lubricity. Engines fitted with common rail fuel injection systems have not shown problems with low S-fuels. For the fuel system water and dirt are by far the major threats independent engine size and type.

-*Q: But the plungers in contact with the gasoil in the fuel pump and the injector nozzle, don't they suffer?*
-A: When talking about plungers moving in cylinders, these are shapes with common conformity. Their surfaces do not see peak loads and as such are not wear sensitive. This in contrast with e.g. a nock on a plate.

-*Q: May S level be related to cylinder liner lacquering tendency?*
-A: S level is definitely related to this phenomenon. The quality of high S gasoils is often marginal regarding ignition and combustion quality, resulting in incomplete combustion, soot formation and unburned fuel components on the cylinder liner together with the lubricant additives. This forms a glazy hard layer on the liners known as lacquer with all related problems. It seems to be a sensitive equilibrium between factors like operating condition, fuel quality and engine oil quality. Modern engine oils will help to solve the problem but it may take some time to find the right balance and select the best performing engine oil. The lubricant supplier is in the position to provide the service in this process. Desulphurisation, normally by hydro treating, will significantly improve the fuel quality and as such the combustion characteristics. A lower lacquering severity may be expected.

- *Q: How about bore polishing*
- A: Again here the root cause is found in incomplete combustion where heavy molecules and soot will deposit on the piston crown land above the piston top ring. The hard deposits polish the cylinder liner resulting in increased oil consumption and blow-by of hot combustion gases. Likewise with lacquering also here the S reducing refinery processes will assure better combustion quality.

- *Q: Two stroke engines like the old Bolnes engines with separate cylinder lubrication may be more vulnerable for changes?*
- A: There may be a sensitive balance in the combination of cylinder oil, the fuel used and operation conditions. Cylinder lacquering may be a threat, but this normally can be solved with help of the lubricant supplier selecting the best performing lubricant. High

TBN (high detergent) oils have proven to keep pistons clean and reduce ring wear in Bolnes engines.

- *Q: Is there any reason for concern when moving to S free and realising that ships may have an age of many decades?*
- A: The old engine and fuel pumps are more robust and running on lower speeds. This enabled the use of old fashion lubricants providing less protection compared with modern grades. As the fuel lubricity is not part of their design, there is no risk when moving to S free. The combustion will benefit from the cleaner low S fuel, so it will mean a positive change. Only rotating fuel pumps that may be used for smaller engines need protection. The lubricity requirement as included in the EN 590 specification will satisfy. So overall there are no reasons for concern.

6 Experiences in pre-empting countries

The experiences of other countries, which already introduced low sulphur marine gasoil, have been investigated as well. In this study the experiences gained in Sweden and California are considered.

6.1 Swedish experience

Transport by inland waterways in Sweden is small compared with Western Europe. Most of the engines are HD truck engines up to a cubic capacity of 15 litres. These engines proved to be fully compatible with sulphur free gasoils. Apart from EN 590 grades an Environmental Class 1 diesel is available which is extremely low in aromatics and density (around 0,81 kg/m^3) compared with conventional Swedish gasoils (around 0.84 kg/m^3). The use of this fuel raised complains about loss of power output. Another issue giving some rise in concern is the inclusion of bio components like FAME in gasoils. See also chapter 9. Market diesel may contain up to 5% FAME. Apart from the conventional gasoil a separate B0 grade with zero FAME is now available. This grade is preferred by marine customers.

6.2 Californian experience

In California a comprehensive diesel risk reduction plan started in the year 2000. One of the pillars of this plan was to require low S gasoil with max 15 ppmm sulphur for all diesel applications. The reduction plan first focussed on captive automotive fleets but will now extend to other California's diesel sources representing 85% of total. The other sources are found in sectors like harbour activities and rail transport. Now also regulation is in force or prepared to require clean low S gasoil for harbour craft, tug boats, commercial fishing vessels and vessels in coastal waters or near ports of call. Vessels having the ability to refuel out of state, requiring a regional or national approach to ensure the use of low S fuel are exempted from above requirements. In the whole fuel changing program, low S fuel compatibility is not an issue. See reference [4].

7 Experience with engines running on low S gasoil

Apart from the pre-empting countries also in other countries a substantial number of marine engines are running on ULSD already. This may have a variety of backgrounds like taxation regulations, logistic constraints, green initiative of local fuel suppliers and others. In this chapter a few of these cases are presented

7.1 European tax regulation

In Europe the minimum levels of excise duty that Member States must apply to mineral fuels are specified in European Directives (92/81/EEC, 92/82/EEC and 97/425/EC). Reduced rates of duty may be applied to gasoil used for specific purposes such as sale of gasoil to commercial marine. Low duty gasoil normally is coloured red and contains a fiscal marker e.g. furfural.
Reduced duty rates are not allowed for leisure marine. This means that in most European countries the leisure marine must use high tax rate gasoil, normally EN 590 automotive gasoil with S levels below 50 ppmm. Compared to the commercial marine engines, leisure marine engines only operate a small amount of hours a year. However, they represent a hug fleet with a relatively high rate of older engines. As the regulation applies since 1993 the leisure marine in principle represents a huge marine field test of ULSD.
A few countries (Belgium, Ireland, Finland and Malta) did have a derogation from the above mentioned Directives, allowing them to sell red gasoil to the leisure market for an extended period. For tax harmonisation reasons this derogation was under pressure and finally expired by 31 December 2006.
In the UK a huge campaign started under the name Red Alert using all media including internet [5] to draw attention to the consequences. Apart from a dramatic increase in fuel costs (threefold) the campaign communicated that the impact on industry, tourism and jobs would be detrimental. In the debate with the politicians all arguments that could help to withstand a change were presented. None of these arguments was related to potential technical problems. We can be sure that if any technical drawback was available the campaign organisation would have used this as an argument. Apparently none was found in spite of the wide experience gained in the countries already using ULSD in leisure marine.

7.2 Logistic constraints in New Zealand

In New Zealand the automotive diesel grade has been lowered in S content over time. By January 2006 ULSD (max. 50 ppmm) became the mandatory diesel grade for all types of use other than marine applications. However, due to supply logistic constraints, marine gasoil sold to marine users in New Zealand follows the automotive specification which means also maximum 50 ppmm S by January 2006. The BP owned Refinery Company issues an information leaflet (Appendix 1) to explain the situation and reassure the ship owners and operators that no technical problems were foreseen. This situation exists for more than one year now and we are not aware of any adverse effect.

7.3 Czech Republic

In the Czech Republic the inland marine fuel customers use the automotive EN 590 gasoil quality as they have no access to a special gasoil grade. This EN 590 quality has a sulphur content of maximum 10 ppmm since several years. Although the marine fleet in the Czech Republic is relatively small compared with the Rhine countries, no adverse effects on engines or operations have been reported so far.

8 Bio components

In Europe there is a drive to reduce CO_2 emissions by blending conventional fuels with renewable fuel components. Especially for automotive fuels the European Commission put pressure on Member States to introduce bio components. The European fuel quality standards allow for the addition of bio components. In the EN 590 it reads that up to 5% (V/V) of fatty acid methyl ester (FAME) may be included in automotive diesel fuel. The current practice is that in most European countries the diesel fuel on the market contains FAME. In some countries FAME is sold as a neat fuel under the name Biodiesel or B100.

8.1 Effect on marine gasoil fitness for purpose

The marine gasoil quality according to DIN 51603-1 does not contain any bio-component as the DIN standard does not allow for. It is most likely that when the marine gasoil would follow the EN 590 specification, bio components will be found. What may be the consequences? In principle it helps the environment by reducing CO_2 emission. On the other hand its quality impact may be negative.

- Separation of invaded water will be more difficult. This means that water may stay for longer time in emulsion making the fuel prone to microbial attack resulting in fuel system fouling. With good house keeping these aspect may be manageable. This means; more frequent checks for tank water bottoms, filter fouling, prevention of any ingress of water and the use of biocides in case of microbial contamination,
- Fuel consumption may tend to go up as the energy content is about 10 percent lower compared with conventional gasoil (38 rather than 43 MJ/kg). Theoretical a 5% V/V blend of FAME in marine gasoil will result in a 0,5% consumption increase. Together with the average lower density of EN 590 quality the overall effect may be measurable.
- Stability e.g. under storage and combustion may be an issue. Long term storage (more than a year), which may be practice in leisure marine, is not recommended.
- Experience related to marine engine cleanliness when using such components is limited.

Diesel engine manufacturers have released all their engines for EN 590 allowing for 5% (V/V) FAME and we can assume that older types of engines will not suffer when using up to 5%. In marine especially the house keeping aspects become more demanding. This to be seen as a sacrifice the customers have to make to the environmental problem. There is pressure by the European Commission on the European Standardisation body to raise the acceptable bio-component content in EN 590 to 10% V/V and even higher. This is under study with engine manufacturers. It can be anticipated that such EN 590 fuels will be introduced. It is difficult to oversee the technical drawbacks of such fuels as there is only limited experience available. Study is in progress to investigate higher FAME levels in automotive application. At a later stage the application in marine will be addressed. A good alignment with the marine engine manufacturers is required to anticipate these developments.

9 On board heating systems

When ULS heating gasoil was scheduled to be introduced in Germany the German burner manufacturers found out that with this fuel a very typical corrosion phenomenon took place in the flame tube of latest technology burners. This was identified as ‘’high temperature corrosion’’. A list was established and distributed to warn the customers for this combination. However extended testing revealed that the phenomenon was not related to the gasoil low S level. In 2004 the message was issued that the non compatibility list was withdrawn and all types from now on were released for ULS heating gasoil. Information to be found on the web site of the German Technical Institute TWO [6].

9.1 Bio components in heating gasoil

The actual German Standard DIN 51603-1, like most other heating oil standards in Europe, does not allow for bio components. In case inland marine will switch to EN 590 quality this quality will contain up to 5% V/V FAME. In Germany a comprehensive study is in progress to investigate the effect of bio components in heating gasoil on the compatibility with seals, hoses and non Ferro metals as applied in burners as well as the storage stability and the impact on emissions (see appendix 2). This work may result in a new heating oil specification allowing for a limited amount of FAME for all existing burners, but this may take some time. To get a clear answer on the question whether or not EN 590 with FAME can be used in on board heating systems an additional study is required to investigate the different brands and types of heating devices and discuss the best approach with the manufacturers. This is not covered by the scope of this study. It is important to realise that only limited experience with FAME in heating gasoil is available and all considerations as addressed in chapter 9.1. will also apply here.

10 Conclusions

The overall conclusion of this study is that changing from the current VOS (DIN) specification gasoil (S content maximum 2000 ppm mass) to EN 590 sulphur free gasoil for the entire Dutch inland marine fleet will not cause significant problems. On the contrary some typical engine wear issues will improve.

More in detail, the conclusions are as follows:

- A European standard for inland marine gasoil does not exist. The marine fuel delivered in European countries originates from different refinery gasoil pools. In the Rhine area this is predominantly the heating gasoil pool according to DIN 51603-1, which specification is almost equivalent to the Dutch VOS specification.
- EN 590 sulphur free is specified by the manufacturers for most inland marine engines. This is the same as specified for all on road diesel vehicles in Europe. For future engines with advanced emission control such as cooled EGR and exhaust after treatment systems, EN 590 sulphur free will be mandatory to prevent serious engine and exhaust after treatment durability issues.
- The good compatibility of sulphur free gasoil is also supported by experience with marine fleets around the world which have already switched to sulphur free or to low S gasoil. This is also supported by the fuel properties and analysis of potential engine wear issues.
- EN 590 sulphur free gasoil compared to VOS gasoil will have a higher cetane number and improved stability. A reduction in lubricity properties is fully compensated by the included lubricity additives.
- Elastomer compatibility is slightly different. Basically EN 590 sulphur free has a lower impact on the elastomers than the VOS (DIN) gasoil, however some seals in some engines which have always been running with VOS gasoil might pose a problem when switching to the EN 590 sulphur free. Although these problems have been reported from the United States they were so far never seen in Europe.
- The typical engine wear issues; cylinder liner lacquering and bore polishing are expected to improve with the use of EN 590 S free due to the more complete combustion. The sensitive balance between operation conditions and lubrication oil in preventing these phenomenons as experienced in several engines may need a new adjustment by testing other engine oil or cylinder oil formulations. Valve seat retention and wear of the fuel injector pump are not expected to be affected by the change of fuel.
- A switch to EN 590 sulphur free will have an impact on the average fuel density. As a consequence fuel consumption will increase in the order of 0,5% and maximum power output will be reduced by about 0,5%.
- The blending of up to 5% V/V Biofuel (FAME), common practice in automotive diesel, will increase fuel consumption with another 0,5% and require additional maintenance discipline to prevent fuel system fouling and deposit formation.
- Biofuel blend might cause problems for on board heating systems such as with seals, hoses and deposit formation. This can lead to a safety problem.
- The (temporarily) introduction of B0-EN 590 sulphur free (zero bio component) for the marine sector might be considered.

The creation of a dedicated sulphur free gasoil standard for inland marine application would potentially offer technical and economic advantages. This should be based on EN 590 sulphur free, but without FAME and reduced requirements on some aspects such as cold flow properties in winter.

A European standard is not realistic, but a CEN Workshop Agreement between major stakeholders and for a limited area might be feasible.

11 References

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12 Signature

Delft, 29 June 2007

TNO Science and Industry

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50 PPM SULPHUR DIESEL

What does it mean for commercial and marine users?

Introduction

New Zealand ADF (automotive diesel fuel) used to be manufactured to a limit of 3000 ppm sulphur. From 2002 onwards, sulphur levels were reduced to 1000 ppm in Auckland and 2400 ppm in the rest of New Zealand. Then in August 2004, the maximum level was lowered to 600 ppm across New Zealand. In January 2006, 50ppm sulphur diesel (ULSD) became the mandatory diesel grade for all types of use other than marine applications. However, due to supply logistics constraints, MGO (marine gas oil) sold to marine users in New Zealand will almost always be the 50 ppm sulphur ADF grade.

The NZ Refining Company (NZRC) manufactures most of New Zealand's diesel and completed a major upgrade in 2005 that allows it to meet the 2006 specification. NZRC began producing diesel to this specification in September 2005.

Composition

Sulphur in diesel is mainly in the form of substances called benzo- and dibenzothiophenes. These can be broken down by reacting gas oil refining streams with hydrogen in the presence of a catalyst under high temperature and pressure conditions. This process is called hydrodesulphurisation. The NZRC upgrade included the installation of a new and more capable unit for carrying out this process.

Reducing sulphur in diesel need not affect the bulk composition of the diesel greatly but three important effects can arise. Some less stable components are removed, the aromatic content (especially poly-aromatic hydrocarbons, PAH) of the diesel can be reduced and trace nitrogen and oxygen-containing substances that give diesel good lubricity are also reduced.

The first two of these effects are beneficial. The resulting fuel is more stable to oxidation, and its cetane quality is improved. One downside of lower aromatics is the effect this can have on injector pump seals in direct contact with the fuel.

The last of these effects is detrimental to injector pumps that rely on the fuel to lubricate their moving components.

Performance

50 ppm sulphur diesel must meet a cetane index specification of 51 minimum. The new product is expected to have a cetane index of around 55 – 57 which is quite a high value.

High cetane fuels are faster burning fuels. The fuel ignites spontaneously as soon as it is injected into the combustion chamber. Provided the fuel is injected smoothly and forms a well-controlled spray pattern, it will burn smoothly leaving little or no unburned fuel remaining by the time the piston reaches top dead centre. The benefits are a cleaner engine, less engine stress, improved fuel economy and reduced emissions.

Cold starting in winter is another benefit. Outdoor equipment in the colder parts of New Zealand in winter require a high cetane fuel for easy starting and avoidance of white smoke.

Emissions

Low sulphur diesel was introduced in many OECD countries in the mid to late 1990s in order to reduce particulate emissions. Fine particulates, often referred to as PM_{10} or $PM_{2.5}$ are now known to exacerbate respiratory and cardiovascular conditions. This can lead to hospital admissions and even early deaths in a few cases.

Particulates are reduced by reducing the sulphur content of the fuel but the real benefit of 50 ppm sulphur diesel is that regenerative particulate filters can be fitted to engines without the risk of a reduction in performance over time.

Engine Protection

Low sulphur diesel has benefits for engines. Sulphur oxides generated during combustion can react with water vapour to generate sulphurous and sulphuric acids. Modern heavy-duty engine lubricants contain alkalis to neutralise these acid gases but the risk of premature engine wear such as corrosive ring wear is reduced if low sulphur fuel is used.

Other than particulates, the emission gases of most concern for diesel engines are oxides of nitrogen (NOx). These are produced from air (nitrogen and oxygen) in the combustion chamber. The hotter the engine and the greater the residence time of the combustion gases, the more NOx is formed.

Fuel composition can only play a minor role in helping reduce NOx directly. Manufacturers of modern engines often retard injection timing to reduce residence times. Unfortunately, the additional soot generated by doing this exacerbates engine wear and shortens engine lubricant life. Provided fuel injectors and pumps are in good order, high-cetane fuels will burn more completely under these conditions, resulting in less soot. The benefits are less engine wear and longer oil life relative to conventional diesel.

'No Harm' Properties

Lubricity

'No harm' properties are properties that ensure the fuel will not harm engines and equipment during storage and use. When low sulphur diesel (LSD) was introduced in the USA in the early 1990s, excessive wear and premature failures of fuel injection equipment occurred in some instances. Trace compounds that give conventional diesel its lubricity had been removed by the de-sulphurising process.

The problem was solved using special lubricity additives and a family of new lubricity tests. All diesel supplied in New Zealand is tested using the standard High Frequency Reciprocating Rig (HFRR) test to ensure good lubricity. This test is called IP 450. ASTM 6079 is a similar test, (see Appendix for further information.) If the wear scar diameter (wsd) in the HFRR test applied to the base fuel is greater than 460 μm (ie 0.46 mm), a lubricity additive is used.

NZRC now add a lubricity additive to all the 50 ppm sulphur diesel they produce and are currently achieving results of 250 to 370 μm wsd on most batches, ie well below the maximum 460 μm limit.

Seal shrinkage

A quite different problem can also occur. Some types of diesel injector pumps operate under quite high positive pressures and are equipped with seals to prevent leakage of the fuel. The seals absorb fuel and expand, depending on the solvency (aromatics content) of the fuel. As these seals age, they tend to loose their elasticity. The pumps most likely to be affected are older type VE rotary injector pumps of the type fitted to light duty diesel vehicles. Provided the composition of the fuel doesn't vary much from one tank fill to the next, the seal will usually hold good. However, if the solvency of the fuel reduces suddenly, the seal can shrink and a fuel leak may occur.

At the present time, 50 ppm sulphur diesel contains over 14% of aromatic hydrocarbons. Although aromatics have come down by five percent or so relative to the old ADF, this is unlikely to cause significant numbers of premature seal failures.

Most custom designed marine engines are not susceptible to this problem. If unsure, diesel powered, small boat owners are recommended to contact their engine manufacturers to find out whether they are vulnerable to this potential problem. Most makes and models will not be vulnerable.

If a diesel vehicle engine has been fitted to an inboard or stern drive boat, it would be worth checking on the type of injector pump used.

Larger marine engines are not vulnerable to this problem.

Other Properties

In other respects, 50 ppm sulphur diesel is similar to the previous ADF grade. On average, its density will be a little lower than the density of the old ADF. It is subject to a maximum of 0.85 kg/L. Average density (0.835 kg/L) is well suited to engine factory injector settings. Properties such as flash point, distillation, viscosity and cleanliness are no different from those of the old ADF.

Water separation properties are not expected to change. Purifiers will operate effectively as with the old ADF or MGO. The same care should be exercised to avoid microbial growth. This required keeping the fuel well drained of free water and inspecting and cleaning boat fuel tanks and storage tanks regularly.

The cold flow properties of ADF sold in New Zealand are tuned to the location and the season. Winter grade ADF is manufactured as early as January to ensure that the cold flow properties have passed through to customers' tanks before winter. Cold flow properties will always be better than those guaranteed by the MGO specification.

Marine Crankcase Oils

Marine crankcase oils are formulated to absorb acid gases generated during combustion. A proportion of these arise from the sulphur in the fuel. Most engine manufacturers currently do not alter lubricant recommendations and oil change intervals when running on low sulphur fuels. If in doubt contact the engine manufacturer.

For a lubricant recommendation for your engine refer to the lubricants selector on our website http://www.bp.co.nz/business/index.html or contact the BP Technical Helpline on 09 623 9451.

V2 January 2006

Appendix: Diesel Lubricity

When low sulphur diesel was first introduced into the USA in the early 1990s, fuel injection equipment that relied on the fuel for lubrication suffered from a high level of failure. ADF contains trace quantities of polar substances that give the fuel its lubricity. The refinery processes designed to remove sulphur from the fuel by breaking down molecules containing sulphur also remove these polar substances.

A task force made up of manufacturers of injection equipment, oil companies and petroleum additive suppliers urgently studied the problem. New fuel injection pumps and fuel control units were introduced that were resistant to wear from low sulphur fuels. At the same time, standard methods were developed to test diesel fuels for lubricity. Among the methods developed were the scuffing load BOCLE (Ball-on-Cylinder Lubricity Evaluator), the HFRR (High Frequency Reciprocating Rig) test, the Stanadyne rotary distributor pump test and the BOTD (Ball-on-Three Disc) test.

Through round robin testing among task force members, the HFRR test method was found to give results that matched the actual behaviour of fuels with susceptible equipment and to be cost effective as well. In 1996, a standard form of the HFRR test was published by the Co-ordinating European Council (CEC) and became the CEC F-06-A-96 test. The ASTM (American Society for Testing and Materials) adopted this test method in modified form as, ASTM D6079 and the International standards Organisation as the method, ISO12156 (IP450).

The test measures the diameter of a wear scar formed on a standard ball bearing. The participants all agreed that fuel which produces a wear scar diameter of less than 460 µm under the conditions of the test has a lubricity which is a satisfactory for use with older diesel fuel injection equipment as well as new.

Since then, the test rig has been made widely available and many refineries that manufacture low sulphur diesel have obtained this equipment. The laboratory at the Refinery (IPL) has this equipment.

At the same time, the world’s leading petroleum additive suppliers such as Infineum, Ethyl and BASF were developing lubricity-improving additives for use in low sulphur diesel fuel. It is now common for refineries to use these additives at dose levels that provide a safe margin of lubricity. The lubricity of the fuel is then confirmed by HFRR testing.

Abb. 3: Prüfverfahren ATES FAME
(Anwendungstechnische Eigenschaften von FAME)

Insbesondere die nur in der Ölheizungstechnik verwendeten Bauteile, wie z. B. die Ölbrennerpumpen, erfordern neue umfangreiche und detaillierte Untersuchungen. So wird in einem weiteren IWO-Projekt auf Pumpenprüfständen der Einfluss von Biobrennstoffen auf die Betriebssicherheit der Ölbrennerpumpe untersucht.

Wechselwirkungen mit Werkstoffen

Eine aus dem Automobilbereich bekannte besondere Eigenschaft von Biobrennstoffen ist die Wechselwirkung von FAME auf Kunststoffe. Da gerade in der Ölheizungstechnik und bei der Heizöllagerung sehr verschiedene Kunststoffe und Installationsmaterialen verwendet werden, muss auch aus Gründen des Gewässerschutzes die Beständigkeit der Werkstoffe untersucht werden. Hierzu wurde im November 2006 eine Langzeituntersuchung zur Beständigkeit der Werkstoffe gestartet. Es werden fast 7.000 Prüfkörper aus zwölf verschiedenen Kunststoffen in verschiedenen Mischungen und Reinkomponenten für mindestens 24 Monate eingelagert. Während des Untersuchungszeitraums werden kontinuierlich Prüfkörper entnommen und auf Schädigungen analysiert und die Werkstoffeigenschaften z. B. im Zugversuch untersucht.

Hiermit werden wesentliche Voraussetzungen dafür geschaffen, eine spätere Zulassung verschiedener in der Ölanlage eingesetzter Komponenten auch für den neuen Brennstoff zu ermöglichen.

Normung

Auf europäischer Ebene existiert bereits eine Norm, die EN 14 213, die die Anforderungen an Fettsäuremethylester (FAME, umgangssprachlich auch als Biodiesel bezeichnet) als Brennstoff und als Mischkomponente für Heizöl EL festlegt.

Die deutsche Heizölnorm für Standard- und schwefelarmes Heizöl EL, die DIN 51 603-1, erlaubt diese Beimischungen bislang nicht. Diese Norm wird bis auf Weiteres mit dieser Vorgabe bestehen bleiben. Zusätzlich wird eine neue Vornorm (DIN V 51603-6) für ein Heizöl erarbeitet, das auch Biokomponenten enthalten darf. Ziel des zuständigen Arbeitskreises ist es, einen Brennstoff zu normieren, der in den bestehenden 6,4 Millionen Ölheizungen eingesetzt werden kann.

Die aus allen vorgenannten Projekten und Untersuchungen gewonnenen Erkenntnisse gehen in den Entwurf dieser Vornorm ein. Denn nur genormte Brennstoffe gewährleisten einheitliche Qualitätsstandards und eine sichere Verwendung in der Gerätetechnik sowie eine Zulassung als Regelbrennstoff in der BImschV.

Wichtige Argumente für flüssige Energieträger im Wärmemarkt – heute und in der Zukunft

- **Hohe Versorgungssicherheit durch große Reserven, flexible Versorgungsstrukturen sowie durch die gesetzliche und individuelle Bevorratung**
- **Flüssige Biobrennstoffe**
- **Hohe Effizienz durch Öl-Brennwerttechnik plus Solarthermie**
- **Niedrige Emissionen**
- **Hohe Wirtschaftlichkeit durch freien Wettbewerb zwischen den Energieanbietern**

30330/01/5/02/07, Stand Februar 2007. Alle Angaben sind freibleibend!

IWO informiert:

Forschung und Entwicklung für neue flüssige Brennstoffe

- **Ölheizungsanlagen mit Biobrennstoffkomponenten im Feldversuch**
- **Untersuchungen zur Langzeitlagerung**
- **Wechselwirkungen zwischen neuen flüssigen Brennstoffen und eingesetzten Materialien**
- **Normung**

IWO
Institut für wirtschaftliche Oelheizung e.V.

Forschung und Entwicklung für neue flüssige Brennstoffe

Nachhaltigkeit durch Energieeffizienz und erneuerbare Energien

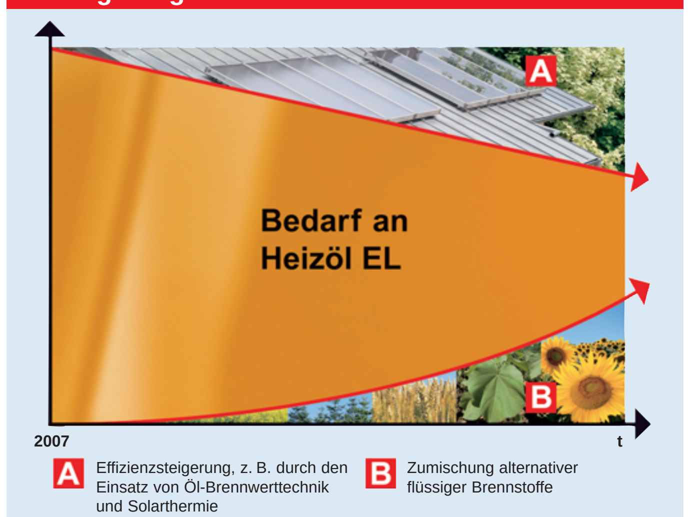
Zur Reduzierung des Primärenergiebedarfs im Wärmemarkt gibt es grundsätzlich nur zwei Möglichkeiten: die Steigerung der Energieeffizienz und damit verbunden die Reduzierung des Bedarfs insgesamt sowie die Abdeckung des Energiebedarfs durch erneuerbare Energien.

Gerade im Wärmemarkt lassen sich durch die Modernisierung der Anlagentechnik, vor allem durch Öl-Brennwerttechnik plus ergänzender thermischer Solarunterstützung, große Energieeinsparpotenziale erschließen.

Eine weitere Reduzierung des Rohölbedarfs ergibt sich, wenn – wie bereits beim Dieselkraftstoff praktiziert – Heizöl EL nicht mehr allein aus Rohöl hergestellt wird, sondern auch Anteile von Biokomponenten enthalten kann.

Die größten Potenziale ergäben sich, wenn diese weiterentwickelten flüssigen Brennstoffe in den bestehenden 6,4 Millionen Ölheizungsanlagen in Deutschland eingesetzt werden könnten. So entspräche eine Beimischung von z. B. 5 % Pflanzenölmethylester zum Heizöl EL einer Zahl von 320.000 Anlagen, die mit Biobrennstoffen betrieben würden.

Reduzierung des Bedarfs an fossilen Energieträgern

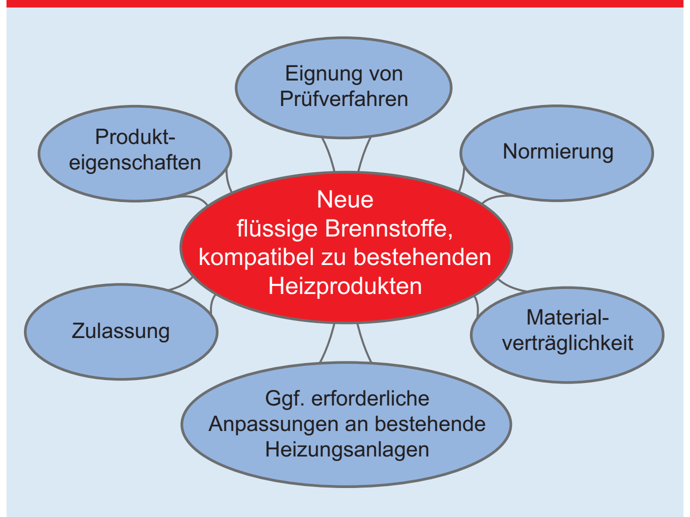


Nur wenn die bestehenden, gegebenenfalls geringfügig modifizierten Anlagen emissionsarm und zuverlässig mit den neu entwickelten Brennstoffen weiter zu betreiben sind, können regenerative flüssige Brennstoffe im Wärmemarkt wirklich an Bedeutung gewinnen.

Technische und ordnungsrechtliche Fragestellungen

Um diese Potenziale auszuschöpfen, sind von der Mineralölwirtschaft gemeinsam mit der Heizgeräteindustrie und den Herstellern von Komponenten verschiedene Projekte gestartet worden.

Fragestellungen „flüssige Biobrennstoffe“



Prüfstands- und Felduntersuchungen

Ein neuer Brennstoff, der in allen Ölheizungen verwendet werden kann, muss vergleichbare produkt- und anwendungstechnische Eigenschaften wie das klassische Heizöl EL aufweisen. D. h. beispielsweise, er muss mindestens genauso schadstoff- und emissionsarm verbrennen. Dies gilt auch für den Start und das Abschalten des Brenners. In ersten orientierenden Parameterstudien auf dem Prüfstand wurden verschiedene Konzentrationen von FAME (**F**atty **A**cid **M**ethyl **E**ster – Fettsäuremethylester – besser bekannt als Biodiesel) und Pflanzenöl dem Heizöl zugemischt, um zu ermitteln, welche Konzentrationen unter Beibehaltung der niedrigen Emissionen zugegeben werden könnten.

Abb. 1: Feldanlage mit Messtechnik

Da neben den verbrennungstechnischen Eigenschaften in der Praxis auch viele andere Faktoren wesentlich für den problemlosen Betrieb einer Heizungsanlage sind, werden seit dem Frühjahr 2006 vom IWO zwölf Feldanlagen mit verschiedenen Brennstoffmischungen betrieben. Als Basisbrennstoff wurde ausnahmslos schwefelarmes Heizöl verwendet, dem verschiedene FAME-Konzentrationen vor der Belieferung zugegeben wurden. In den meisten Anlagen wird ein Heizöl mit einem Anteil von 5 % FAME eingesetzt. Einige Anlagen werden auch mit 20%igen FAME-Anteilen betrieben.

Seit Ende 2006 ist eine große Zahl weiterer Anlagen in Kooperation mit führenden Heizgeräteherstellern hinzugekommen. Knapp 30 Anlagen und zusätzlich einige Anlagen im europäischen Ausland werden mit 5 % FAME im Heizöl betrieben.

Einfluss der Installation

Über diese Feldanlagen hinaus werden Untersuchungen zum Einfluss der Installation durchgeführt. Hierbei wird geprüft, ob die neuen Brennstoffe ggf. Änderungen an der Installation der Ölheizungsanlage, z. B. die Umrüstung der Ölversorgung auf ein Einstrangsystem, erforderlich machen.

Langzeitlagerung

Charakteristisch für die Ölheizung ist die individuelle Bevorratung des flüssigen Brennstoffs über vergleichsweise lange Zeiträume. Eine wesentliche Anforderung an neue flüssige Brennstoffe ist daher auch die Stabilität, so dass nach langer Lagerzeit ein qualitativ hochwertiges Produkt im Kundentank vorliegt. Da die Lagerung beim Kunden allerdings sehr individuellen Einflüssen unterliegt und somit Einfluss auf die Qualität des Brennstoffs besitzt, werden in Langzeituntersuchungen zur Lagerung und Produktqualität unter definierten Bedingungen in Klimaschränken die verschiedensten Mischungen und Reinkomponenten für mindestens 24 Monate eingelagert und untersucht. Während dieser 24 Monate werden nach genauen Entnahmezeitplänen immer wieder Proben entnommen, um die Qualität zu analysieren.

Abb. 2: Projekt Langzeitlagerung

Neue Analyseverfahren und Prüfverfahren

Da neue Brennstoffe aber auch Produkteigenschaften aufweisen können, für die bisherige Analyseverfahren nicht ausreichen, wie z. B. die Bestimmung der Konzentration einer Komponente im Heizöl EL, werden diese entsprechend weiterentwickelt.

Darüber hinaus werden Prüfverfahren zur Bestimmung von Qualitätsmerkmalen von Biobrennstoffkomponenten wie z. B. die Oxidations-, thermische und Langzeitstabilität entwickelt.