Action code: **Immediately**

Updated Quality of Fuel Oil

March 2010

SL10-527/SIC

Concerns

Owners and Operators of MAN Four-stroke Diesel Engines Type All.

Dear Sirs

For your kind reference, we hereby forward as attachment our updated HFO quality recommendations covering MAN Four-Stroke GenSets.

Please distribute and update manuals with the forwarded information.

In case you may have any questions to the above, please contact PrimeServ Holeby at PrimeServ-hol@mandiesel.com

Yours faithfully

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Prerequisites

MAN Diesel four-stroke engines can be operated on any crude-oil based heavy fuel oil meeting the requirements listed in Table 1, provided the engine and the fuel treatment plant are designed accordingly. In order to ensure a well-balanced relation between the costs for fuel, spare parts and maintenance and repair work, we recommend bearing in mind the following points.

Heavy fuel oil (HFO)

Provenance/refining process

The quality of the heavy fuel oil is largely determined by the crude oil grade (provenance) and the refining process applied. This is the reason why heavy fuel oils of the same viscosity may differ considerably, depending on the bunker places. Heavy fuel oil normally is a mixture of residue oil and distillates. The components of the mixture usually come from state-of-the-art refining processes such as visbreaker or catalytic cracking plants. These processes may have a negative effect on the stability of the fuel and on its ignition and combustion properties. In the essence, these factors also influence the heavy fuel oil treatment and the operating results of the engine.

Bunker places where heavy fuel oil grades of standardised quality are offered should be given preference. If fuels are supplied by independent traders, it is to be made sure that these, too, keep to the international specifications. The responsibility for the choice of appropriate fuels rests with the engine operator.

Specifications

Fuels that can be used in an engine have to meet specifications to ensure a suitable quality. The limiting values for a heavy fuel oil are listed in Table 1 Fuel oil specifications and associated characteristic values.

Please note the entries in the last column of Table 1 Fuel oil specifications and associated characteristic values, because they provide important background information.

Several international specifications for heavy fuel oils are existing. The most important specifications are ISO 8217-2005 and CIMAC-2003. These two specifications are more or less equivalent. Table 2 CIMAC Recommendations for residual fuels for diesel engines (as bunkered) shows the specifications CIMAC-2003. All qualities of these specifications up to K700 can be used provided the fuel treatment system is designed for these fuel grades e.g. fuels with a maximum density of 1010 kg/m^3 can only be used with modern separation.

Important

Fuel oil characteristics as stated in analysis results - even if they meet the above mentioned requirements - may be not sufficient for estimating the combustion properties and the stability of the fuel oil. This means that service results depend on oil properties which cannot be known beforehand. This especially applies to the tendency of the oil to form deposits in the combustion chamber injection system, gas passages and turbines. It may, therefore, be necessary to rule out some oils that cause difficulties.

Blends

The admixing of engine oils (ULO:used lube oil), of non-mineral oil constituents (such as coal oil) and of residual products from chemical or other processes (such as solvents, polymers or chemical waste) is not permitted. The reasons are, for example: the abrasive and corrosive effects, the adverse combustion properties, a poor compatibility with mineral oils and, last but not least, the negative environmental effects. The order letter for the fuel should expressly mention what is prohibited, as this constraint has not yet been incorporated in the commonly applied fuel specifications.

The admixing of engine oils (ULO: used lube oil) to the fuel involves a substantial danger because the lube oil additives have an emulsifying effect and keep dirt, water and catfines finely suspended. Therefore, they impede or preclude the necessary cleaning of the fuel. We ourselves and others have made the experience that severe damage induced by wear may occur to the engine and turbocharger components as a result.

General

A fuel shall be considered to be free of used lube oil (ULO) if one or more of the elements Zn, P and Zn are below the specific limits (Zn: 15 ppm; P: 15 ppm; Ca: 30 ppm).

The admixing of chemical waste materials (such as solvents) to the fuel is for reasons of environmental protection prohibited by resolution of the IMO Marine Environment Protection Committee of 1st January 1992.

Fuel-system related characteristic values				
Viscosity (at 50° C)	mm²/s (cSt)	max.	700	»Viscosity/injection viscosity«
Viscosity (at 100° C)		max.	55	»Viscosity/injection viscosity«
Density (at 15° C)	g/ml	max.	1.010	»Heavy fuel oil treatment«
Flash point	°C	min.	60	»Flash point (ASTMD-93)«
Pour point (summer)		max.	30	»Low temperature behaviour (ASTM D-97)«, and »Pump ability«
Pour point (winter)		max.	30	»Low temperature behaviour (ASTM D-97)«, and »Pump ability«
Engine–related characteristic values				
Carbon residues (Conradon)	% wt.	max.	22	»Combustion properties«
Sulphur			5 4.5 in marine operation	»Sulphuric acid corrosion«
Ash			0.20	»Heavy fuel oil treatment«
Vanadium	mg/kg		600	»Heavy fuel oil treatment«
Water	% vol.		1	»Heavy fuel oil treatment«
Sediment (potential)	% wt.		0.1	
Supplementary characteristic values				
Aluminium and silicon	mg/kg	max.	80	»Heavy fuel oil treatment«
Asphalts	% wt.		2/3 of carbon residues (Conradson)	»Combustion properties«
Sodium	mg/kg		Sodium < 1/3 vanadium, sodium < 100	»Heavy fuel oil treatment«
Cetane number of low–viscosity constituent minimum 35				»Ignition quality«
Fuel free of admixtures not based on mineral oil, such as coal oils or vegetable oils; free of tar oil and lubricating oil (used oil), free of any chemical waste and of solvents or polymers				

Table 1 *Fuel oil specifications and associated characteristic values*

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General

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Characteristics	Unit	Limit	CIMAC A30	CIMAC B30	CIMAC D80	CIMAC E 180	CIMAC F 180	CIMAC G 380	CIMAC H 380	CIMAC K 380	CIMAC H 700	CIMAC K 700	Test method reference
Density at 15 ûC	kg/m³	max.	960.0	975.0	980.0	991.0		991.0		1010.0	991.0	1010.0	ISO 3675 or ISO 12185
Kinematic viscosity at 50 ûC	mm²/s[1]	max.	30.0		80.0	180.0		380.0			700.0		ISO 3104
		min.[2]	22.0		-	-		-			-		ISO 3104
Flash point	°C	max.	60		60	60		60			60		ISO 2719
Pour point (upper) -winter quality -summer quality -	°C	max. max.	0 6	24 24	30 30	30 30		30 30			30 30		ISO 3016 ISO 3016
Carbon residue	% (m/m)	max.	10		14	15	20	18	22		22		ISO 10370
Ash	% (m/m)	max.	0.10		0.10	0.10	0.15	0.15			0.15		ISO 6245
Water	% (V/V)	max.	0.5		0.5	0.5		0.5			0.5		ISO 3733
Sulfur [3]	% (m/m)	max.	3.5		4.00	4.50		4.50			4.5		ISO 14596 or ISO 8754
Vanadium	mg/kg	max.	150		350	200	500	300	600		600		ISO 14596 or IP 501
Total sediment potential	% (m/m)	max.	0.10		0.10	0.10		0.10			0.10		ISO 10307-2
Aluminium plus silicon	mg/kg	max.	80		80	80		80			80		ISO 10478
Used lubricating oil (ULO)			**The fuel shall be free of ULO.** A fuel shall be considered to be free of ULO if one ore more of the elementsl Zinc, Phosphorus and Calcium are below or at the specified limits. **All** three elements must exceed the same limits before a fuel shall be deemed to contain ULO.										
Zinc	mg/kg	-	15										IP501 or IP470
Phosphorus	mg/kg	-	15										IP501 or IP500
Calcium	mg/kg	-	30										IP501 or IP470

1) 1 mm2/s = 1cSt
2) Fuels with density close to the maximum, but with very low viscosity, may exhibit poor ignition quality.
3) A sulphur limit of 1,5% mm will apply in SOx Emission Control Areas designated by the IMO, when its relevant Protocol comes into force. There may be local variations.

Table 2 CIMAC Recommendations for residual fuels for diesel engines (as bunkered)

General

Leaked oil collectors

Leaked oil collectors into which leaked oil and residue pipes as well as overflow pipes of the lube oil system, in particular, must not have any connection to fuel tanks. Leaked oil collectors should empty into sludge tanks.

Supplementary remarks

The following remarks are thought to outline the relations between heavy fuel oil grade, heavy fuel oil treatment, engine operation and operating results.

Selection of heavy fuel oil

Economic operation on heavy fuel oil with the limit values specified in Table 1, is possible under normal service conditions, with properly working systems and regular maintenance. Otherwise, if these requirements are not met, shorter TBO's (times between overhaul), higher wear rates and a higher demand in spare parts must be expected. Alternatively, the necessary maintenance intervals and the operating results expected determine the decision as to which heavy fuel oil grade should be used.

It is known that as viscosity increases, the price advantage decreases more and more. It is therefore not always economical to use the highest viscosity heavy fuel oil, which in numerous cases means the lower quality grades.

Heavy fuel oils ISO-RM A/B 30 or CIMAC A/B 30 ensure reliable operation of older engines, which were not designed for the heavy fuel oils that are currently available on the market. ISO-RMA 30 or CIMAC A30 with a low pour point should be preferred in cases where the bunker system cannot be heated.

Viscosity/injection viscosity

Heavy fuel oils if having a higher viscosity may be of lower quality. The maximum permissible viscosity depends on the existing preheating equipment and the separator rating (throughput).

The specified injection viscosity of 12-14mm2/s (for GenSets 16/24, 21/31, 23/30H, 27/38 and 28/32H: 12 - 18 cSt) and/or fuel oil temperature upstream of the engine should be adhered to. Only then will an appropriate atomisation and proper mixing, and hence a low-residue combustion be possible. Besides, mechanical overloading of the injection system will be prevented. The specified injection viscosity and/or the necessary fuel oil temperature upstream of the engine can be seen from the viscosity/temperature diagram.

Heavy fuel oil treatment

Trouble-free engine operation depends, to a large extent, on the care which is given to heavy fuel oil treatment. Particular care should be taken that inorganic, foreign particles with their strong abrasive effect (catalyst residues, rust, sand) are effectively separated. It has shown in practice that with the aluminium and silicon content > 15 mg/kg abrasive wear in the engine strongly increases.

The viscosity and density will influence the cleaning effect, which has to be taken into consideration when designing and setting the cleaning equipment.

- **Settling tank**

The heavy fuel oil is precleaned in the settling tank. This precleaning is all the more effective the longer the fuel remains in the tank and the lower the viscosity of the heavy fuel oil is (maximum preheating temperature 75° C to prevent formation of asphalt in the heavy fuel oil). One settling tank will generally be sufficient for heavy fuel oil viscosity below 380mm^2/s at 50° C. If the concentration of foreign matter in the heavy fuel oil is excessive, or if a grade according to ISO-F-RM, G/H/K380 or H/K700 is preferred, two settling tanks will be required, each of which must be adequately rated to ensure trouble-free settling within a period of not less than 24 hours. Prior to separating the content into the service tank, the water and sludge have to be drained from the settling tank.

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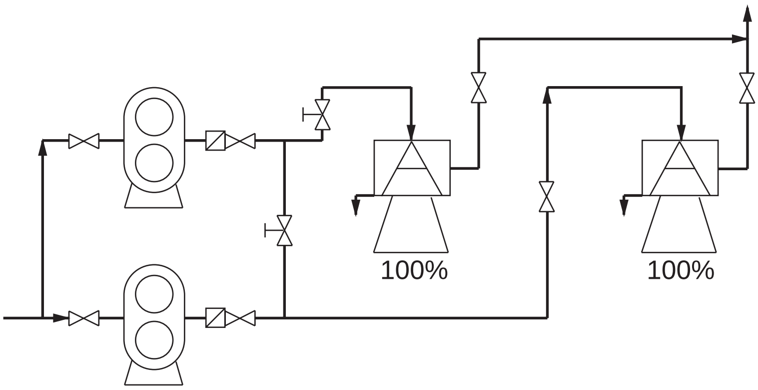
- **Separators**

A centrifugal separator is a suitable device for extracting material of higher specific gravity, such as water, foreign particles and sludge. The separators must be of the self-cleaning type (i.e. with automatically induced cleaning intervals).

Separators of the new generation are to be used exclusively; they are fully efficient over a large density range without requiring any switchover, and are capable of separating water up to a heavy fuel oil density of 1.01 g/ml at 15° C.

Table 3, shows the demands made on the separator. These limit values which the manufacturers of these separators take as a basis and which they also guarantee.

The manufacturer' specifications have to be adhered to in order to achieve an optimum cleaning effect.



Marine and stationary application; connected in parallel

1 separator for 100% throughput

1 separator (standby) for 100% throughput

Figure 1 *Heavy fuel oil cleaning/separator arrangement*

Layout of the separators is to be in accordance with the latest recommendations of the separator manufacturers, Alfa Laval and Westfalia. In particular, the density and viscosity of the heavy fuel oil are to be taken into consideration. Consulting MAN Diesel is required if other makes of separators come up for discussion.

If the cleaning treatment prescribed by MAN Diesel is applied, and if the correct separators are selected, it can be expected that the results given in Table 3, for water and inorganic foreign particles in the heavy fuel oil are reached at the entry into the engine.

The results obtained in practical operation reveal that adherence to these values helps to particularly keep abrasive wear in the injection system and in the engine within acceptable limits. Besides, optimal lube oil treatment must be ensured.

Definition	Particle size	Quantity
Inorganic foreign particles incl. catalyst residues	< 5 µm	< 20 mg/kg Al+Si content <1 5 mg/kg
Water	-	< 0.2 % by volume

Table 3 *Obtainable contents of foreign matter and water (after separation)*

General

• **Water**

Attention is to be paid to very thorough water separation, since the water is not a finely distributed emulsion but in the form of adversely large droplets. Water in this form promotes corrosion and sludge formation also in the fuel system, which has an adverse effect on the delivery and atomisation and thus also on the combustion of the heavy fuel oil. If the water involved is sea water, harmful sodium chloride and other salts dissolved in the water will enter the engine.

The water-containing sludge must be removed from the settling tank prior to each separating process, and at regular intervals from the service tank. The venting system of the tanks must be designed in such a way that condensate cannot flow back into the tanks.

• **Vanadium/sodium**

Should the vanadium/sodium ratio be unfavourable, the melting temperature of the heavy fuel oil ash may drop into the range of the exhaust valve temperature which will result in high-temperature corrosion. By precleaning the heavy fuel oil in the settling tank and in the centrifugal separators, the water, and with it the water-soluble sodium compounds can be largely removed.

If the sodium content is lower than 1/3 of the vadium content, the risk of high-temperature corrosion will be small. It must also be prevented that sodium in the form of sea water enters the engine together with the intake air.

If the sodium content is higher than 100 mg/kg, an increase of salt deposits is to be expected in the combustion space and in the exhaust system. This condition will have an adverse effect on engine operation (among others, due to surging of the turbocharger).

Under certain conditions, high-temperature corrosion may be prevented by a fuel additive that raises the melting temperature of the heavy fuel oil ash (also refer to "Additives to heavy fuel oils".

• **Ash**

Heavy fuel oils with a high ash content in the form of foreign particles such as sand, corrosion and catalyst residues, promote the mechanical wear in the engine. There may be catalyst fines (catfines) in heavy fuel oils coming from catalytic cracking processes. In most cases, these catfines will be aluminium silicate, which causes high wear in the injection system and in the engine. The aluminium content found multiplied by 5 - 8 (depending on the catalyst composition) will approximately correspond to the content of catalyst materials in the heavy fuel oil.

• **Homogeniser**

If a homogeniser is used, it must not be installed between the settling tank and the separator on any account, since in that case, harmful contaminants, and in particular seawater, cannot be separated out sufficiently.

Flash point (ASTMD-93)

National and international regulations for transport, storage and application of fuels must be adhered to in respect of the flash point. Generally, a flash point of above 60° C is specified for fuels used in Diesel engines.

Low temperature behaviour (ASTM D-97)

• **Pourpoint**

The pour point is the temperature at which the fuel is no longer fluid (pumplike). Since many of the low-viscosity heavy fuel oils have a pour point greater than 0° C, too, the bunkering system has to be preheated unless fuel in accordance with CIMAC A30 is used. The entire bunkering system should be designed so as to permit preheating of the heavy fuel oil to approx. 10° C above the pour point.

Pump ability

Difficulties will be experienced with pumping if the fuel oil has a viscosity higher than 1,000mm^2/s (cSt) or a temperature less than approx. 10° C above the pour point. Please also refer to "Low temperature behaviour (ASTM D-97)".

Combustion properties

An asphalt content higher than 2/3 of the carbon residue (Conradson) may lead to delayed combustion, which involves increased residue formation, such as deposits on and in the injection nozzles, increased smoke formation, reduced power and increased fuel consumption, as well as a rapid rise of the ignition pressure and combustion close to the cylinder wall (thermal overloading of the lube oil film). If the ratio of asphaltenes to carbon residues reaches the limit value 0.66, and the asphaltene content also exceeds 8 %, additional analyses of the heavy fuel oil by means of thermogravimetric analysis (TGA) must be performed by MAN Diesel to evaluate the usability. This tendency will also be promoted by the blend constituents of the heavy fuel oil being incompatible, or by different and incompatible bunkering being mixed together. As a result, there is an increased separation of asphalt (also see "Compatibility").

Ignition quality

Cracked products which nowadays are preferred as low-viscosity blend constituents of the heavy fuel oil in order to achieve the specified reference viscosity may have poor ignition qualities. The cetane number of these constituents should be > 35. An increased aromatics content (above 35 %) also leads to a decrease in ignition quality.

Fuel oils of insufficient ignition qualities will show extended ignition lag and delayed combustion, which may lead to thermal overloading of the oil film on the cylinder liner and excessive pressures in the cylinder. Ignition lag and the resultant pressure rise in the cylinder are also influenced by the final temperature and pressure of compression, i.e. by the compression ratio, the charge-air pressure and charge-air temperature.

Preheating of the charge-air in the part-load range and output reduction for a limited period of time are possible measures to reduce detrimental influences of fuel of poor ignition qualities. More effective, however, are a high compression ratio and the in-service matching of the injection system to the ignition qualities of the fuel oil used, as is the case in MAN Diesel trunk piston engines.

The ignition quality is a key property of the fuel. The reason why it does not appear in the international specifications is the absence of a standardised testing method. Therefore, parameters such as the Calculated Carbon Aromaticity Index (CCAI) are resorted to as an aid, which are derived from determinable fuel properties. We have found this to be an appropriate method of roughly assessing the ignition quality of the heavy fuel oil used.

A test instrument utilising a constant-volume combustion technology (FIA fuel ignition analyser) has been developed and is currently being evaluated at a number of testing laboratories. The ignition quality of a fuel is determined as an ignition delay in the instrument that is converted to an instrument-related cetan number (FIA-CN or ECN). It has been observed that fuels with a low FIA cetan number or ECN could, in some cases, lead to operational problems.

As the fluid constituent in the heavy fuel oil is the determining factor for its ignition quality and the viscous constituent is decisive for the combustion quality, it is the responsibility of the bunkering company to supply a heavy fuel oil grade of quality matched to the Diesel engine. Please refer to Figure 2.

General

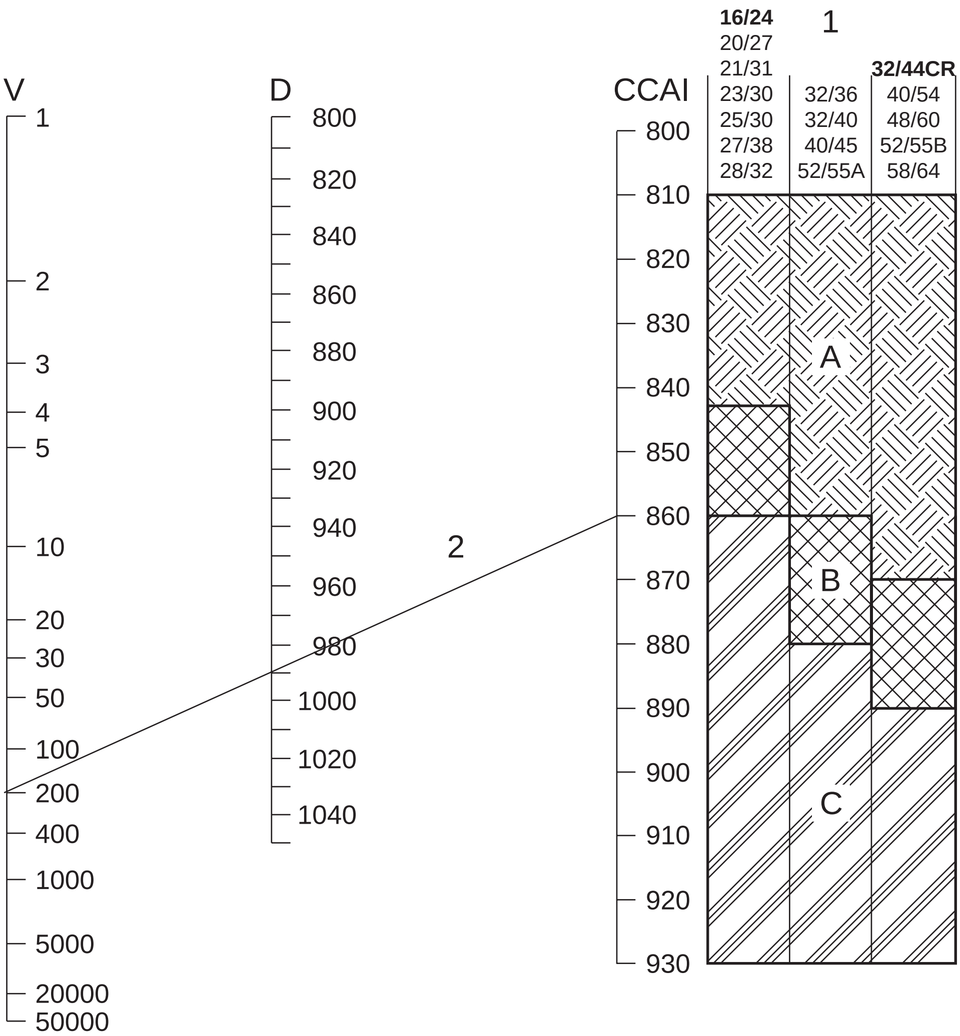


Figure 2 *Nomogram for the determination of CCAI - assignment of CCAI ranges to engine types*

V	Viscosity mm²/s (cSt) at 50° C
D	Density [kg/m³] at 15° C
CCAI	Calculated Carbon Aromaticity Index
A	Normal operating conditions
B	Difficulties may be encountered
C	Problems encountered may increase up to engine damage after a short time of operation
1	Engine type
2	The combining straight line across density and viscosity of a heavy fuel oil results in CCAI.

CCAI can also be calculated with the aid of the following formula:
CCAI = D - 141 log log (V+0.85) - 81

Sulphuric acid corrosion

The engine should be operated at the cooling water temperatures specified in the operating manual for the respective load. If the temperature of the component surface exposed to the acidic combustion gases is below the acid dew point, acid corrosion can no longer be sufficiently prevented even by an alcaline lubricating oil.

If the lube oil quality and engine cooling meet the respective requirements, the BN values (see “Quality of lube oil (SAE40) for heavy fuel oil operation (HFO)”) will be adequate, depending on the sulphur concentration in the heavy fuel oil.

Compatibility

The supplier has to guarantee that the heavy fuel oil remains homogenous and stable even after the usual period of storage. If different bunker oils are mixed, separation may occur which results in sludge formation in the fuel system, large quantities of sludge in the separator, clogging of filters, insufficient atomisation and high–residue combustion.

In such cases, one refers to incompatibility or instability. The heavy fuel oil storage tanks should therefore be emptied as far as possible prior to rebunkering in order to preclude incompatibility.

Blending heavy fuel oil

If, for instance, heavy fuel for the main engine and gas oil (MGO) are blended to achieve the heavy fuel oil quality or viscosity specified for the auxiliary engines, it is essential that the constituents are compatible (refer to “Compatibility above).

Additives to heavy fuel oils

MAN Diesel engines can be economically operated without additives. It is up to the customer to decide whether or not the use of an additive would be advantageous. The additive supplier must warrant that the product use will have no harmful effects on engine operation.

The use of fuel additives during the guarantee period is rejected as a matter of principle.

Additives currently in use for Diesel engines are listed in Table 4, together with their supposed effect on engine operation.

Pre-combustion	• Dispersants/stabilisers • Emulsion breakers • Biocides
Combustion	• Combustion catalysts (fuel economy, emissions)
Post-combustion	• Ash modifier (hot corrosion) • Carbon remover (exhaust system)

Table 4 *Additives to heavy fuels - Classification/ effects*

Low sulphur HFO

From an engine manufacturer‘s point of view there is no lower limit for the sulphur content of HFO. We have not experienced any trouble with the currently available low sulphur HFO, that are related to the sulphur content or specific to low sulphur HFO. This may change in the future if new methods are applied for the production of low sulphur HFO (desulphurization, uncommon blending components). MAN Diesel will monitor developments and inform our customers if necessary.

If the engine is not operated permanently on low sulphur HFO, then the lubricating oil should be selected according to the highest sulphur content of the fuels in operation.

Safety/environmental protection

Wrong handling of operating media may cause harm to health, safety and environment. Respective instructions of the manufacturer have to be followed.

General

Examinations

Sampling

To be able to check as to whether the specification indicated and/or the stipulated delivery conditions have been complied with, we recommend a minimum of one sample of each bunker fuel to be retained, at least during the guarantee period for the engine. In order to ensure that the sample is representative for the oil bunkered, a sample should be drawn from the transfer pipe at the start, at half the time and at the end of the bunkering period. “Sample Tec”, supplied by Messrs Mar-Tec, Hamburg is an appropriate testing kit for taking samples continuously during the bunkering.

Analyse samples

The samples received from the bunkering company are frequently not identical with the heavy fuel oil bunkered. It is also appropriate to verify the heavy fuel oil properties stated in the bunker documents, such as density, viscosity. If these values should deviate from those of the heavy fuel oil bunkered, one runs the risk that the heavy fuel oil separator and the preheating temperature are not set correctly for the given injection viscosity. The criteria for an economic engine operation with regard to heavy fuel oil and lubricating oil may be determined with the help of the MAN Diesel Fuel and Lube Analysis Set.

Our department for fuels and lube oils (Augsburg Works, Department GQC) will be glad to furnish further information if required.

Analysis of fuel oils are carried out by our chemical laboratory for customers. For examination a sample of approx. 0.5 litre is required.

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