The Role of the Homogenizer in Modern Shipping

Improvement of the performance of Diesel Engines with Microniser System
Synopsis

This paper addresses the role of the homogenizer in the modern shipping industry, which has to be considered within the extensive variances of quality of the Heavy Fuel oil. In common practice we found IFO 380 fuel nowadays, followed by IFO 500 showing increased demand leading up to IFO 700 heavy fuel oil which will be the future fuel oil grades used. Prior to 1970 marine fuel quality was fairly predictable and did not seem to be a major cause for concern. It could be that today’s need for efficiency of the oil refinery plants and higher economic pressure on the fuel manufacturing processes the residual fuel quality has been altered.

Driving forces by International Convention and National Requirement have been established to trace the philosophy of an environmental clean ship “Green Ship” in all aspects, realising that in coastal areas, as well as in ports, the percentage of air pollution can be significantly high, especially SOx and NOx. Whereby CO2 is directly proportional and related to the fuel consumption, and on the marine side shows lower amounts in comparison to other modes of transport such as aeroplanes and lorry’s Ref. (8, 2, 42 and 29). To achieve better environmental control the shipping industry improves current systems in developing new equipment. Homogenisers were known to the shipping industry but perhaps not in the correct light. Different types of homogenisers are available on the market, now working with mechanical shear forces and ultrasonic waves. Due to environmental impact the Marine Environmental Protection Committee (48 session), has incorporate this issue to allow the use of the new Homogeniser/Microniser system as environmental protection devices. Ref. (22).

Considering of above mentioned factors, the focus of new homogeniser/microniser-systems in the fuel system is to be highlighted, because the microniser may help to solve the problems in using heavy fuel oil on board vessels. The only question is how?

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1 Introduction

Today the world's fleet includes approximately 55% slow speed diesel, 40% medium speed diesel and 5% other engine types. Slow speed diesels tend to produce higher NOx emissions than medium speed diesels. Ship engines are very fuel efficient, but have a relatively high output of NOx emissions. Ref.(15)

Prior to 1970 marine fuel quality was fairly predictable and did not seem to be a major cause for concern. Residual fuels were purchased for boiler and slow speed diesel engine consumption, both for marine and shore installations, where they were a viable alternative to solid fuels or gas. At that time residual fuels may found under the titles or "short" names as "Burner Fuel", "Heavy Oil", "Boiler Oil", and "Bunker C" which still exists.

Today the efficiency of the oil refinery processes is quit good and now the residual fuels are produced using different refinery processes. The prices are very expensive due to high light crude oil prices.

Therefore implementation of good fuel oil treatment is still very essential coercive in order to operate a vessel without problems.

If in the fuel system the new homogeniser/microniser-system is positioned in the right place, the microniser can help to solve some operational problems, which may occur during the use of heavy fuel oil on board of the vessels.

2 Crude oil and their products

2.1 Crude Oil

Crude oil is unprocessed oil and comes out of the earth and is a mixture between small hydrocarbon molecules and large molecules. Crude oil is an inflammable fluid which is not mixable with water. Crude oil is a fossil fuel which was made by decaying plants and animals several millions years ago. The colours change from yellow over brown to black, also vary in the viscosity and in the content of water and other solid particles. The crude comprises of hydrocarbon molecules which exist in various lengths and chemical structure. The main molecule groups are: paraffin’s, aromatic, napthenes or cycloalkanes, alkenes and alkynes. Both hydrogen and carbon contain a lot of energy. The crude oils average values for Carbon is 84 % and Hydrogen 14 %, Sulphur between 1 – 3 %, Nitrogen less then 1 %, Oxygen less then 1 %, Metals less then 1 %, also Solids less then 1 % and water less then 1%.

2.2 Refinery process

From crude oil it is possible to make different types of products like petroleum gas, Naphtha, Gasoline, Kerosene, Gas oil or Diesel oil, Luboil, Heavy gas oil and residues. Ref. (9 and18).

In 2002 the following oil products were manufactured worldwide: 26 % Gasoline, 26 % Distillates, 15 % Gas oil, 15 % Other, 13 % Fuel oil, 10 % Kerosene, 5 % Liquid petroleum gas and 5 % Naphtha. From the 13 % Fuel oil one-third was used for marine diesel engines and the other two-thirds for
power plants and other industries. Ref. (43). These percentages will change in the future to more distillates grades.

A distillation column

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>20°C</td>
<td>Crude Oil</td>
</tr>
<tr>
<td>40°C</td>
<td>Reformer</td>
</tr>
<tr>
<td>70°C</td>
<td>Alkylation Unit</td>
</tr>
<tr>
<td>120°C</td>
<td>Cracking Unit</td>
</tr>
<tr>
<td>200°C</td>
<td>Coker</td>
</tr>
<tr>
<td>300°C</td>
<td>Naphtha</td>
</tr>
<tr>
<td>600°C</td>
<td>Gasoline</td>
</tr>
<tr>
<td></td>
<td>Kerosene</td>
</tr>
<tr>
<td></td>
<td>Gas Oil or Diesel</td>
</tr>
<tr>
<td></td>
<td>Lubricating Oil</td>
</tr>
<tr>
<td></td>
<td>Heavy Gas Oil</td>
</tr>
<tr>
<td></td>
<td>Residual</td>
</tr>
</tbody>
</table>

Destillation column

An oil refinery is a combination of all of these units

### 2.3 Heavy fuel oil

The refinery process of Crude-oil produces different kinds of fuel oil products. These marine fuel oil products are the Marine-Gas-Oil (MGO), the Marine-Diesel-Oil (MDO) and finally the residual fuel Heavy Fuel Oil (HFO).

MGO is a fully distillate product like the Gas Oil for cars, but with a flash point of a minimum 60°C and not 55°C. MDO is an MGO, which is blended with a small quantity of residual fuel. Marine fuel oil is a mixture of MGO and residual fuel oil. Marine bunker oil or also called Heavy Fuel Oil contains a high proportion of residual component.

The need for more gasoline and distillates caused the refining process to maximise the light fraction yield. So after the first stage of conversion, of crude oil to distillate products (atmospheric and vacuum distillation), a secondary stage (thermal and catalytic cracking) was developed. The fuel from the atmospheric and vacuum distillation is usually more stable than fuel from the cracking process.

Cracking is a process whereby the sizes of the large hydrocarbon chains are reduced through heat or in the presence of catalysts. The results are that the amount of lighter distillates increases. The
residuals from such a process are blended with refinery gas oils to reduce the viscosity of the residues. After blending this product will be supplied on the Marine Bunker Market.

The residual fuel is the end product in the refinery process of crude oil. In this residual fuel are dispersed very large asphaltenes. Asphaltenes can be split in two types, the asphaltenes with moderate molecular weight and with high molecular weight. The asphaltenes with high molecular weight may cause some problems with diesel engines, Ref. (38). Asphaltenes are not abrasive like catalytic fines are, but they also have negative influences like causing delay of internal combustion, accelerated clogging of the filters and so on.

Asphaltenes are complex macromolecules made up of polyaromatics hydrocarbons with a large amount of non-hydrocarbons portion and from high molecular weight. The molecular formulae, for example from Kuwait residues are C218, H244, S 7.7 and O 4.4. The chemical analysis of asphaltenes show a carbon content to vary between from 79-85 %, hydrogen content from 7.4 to 8.8 % and other elements like Sulphur 0.3 to 10.3 %, Oxygen 0.3 to 4.9 %, Nitrogen 0.6 to 3.3 %, Vanadium 3-300 ppm and Nickel 1-100 ppm. The marine residual fuel oils can contain approximately 2-10% asphaltenes, Ref. (38).

The residual fuel can contain contaminants like catalytic-fines and others from the distribution system such as: coke particles, grit, clay and sand. If the agglomeration of asphaltenes occurs, then the amount of asphaltenes is the same, only the size increases due to instability. Instability can happen due to overheating of fuel tanks. It is important therefore that the fuel has a good stability reserve to avoid any increase in sludge deposits through thermal and mechanical stress.

Marine heavy fuel oils have often been seen as a convenient dumping ground for waste products such as used lubricating oils (ULO) and from time to time a concoction of waste chemicals. These waste products can have a range of adverse affects on the machinery plant from reduced separator efficiency, through the presence of used lubricating oils to crippling machinery damage.

2.4 Engine Manufacturers and fuel oil quality

The engine manufacturers make every effort to improve the combustion efficiency. Some improvement for example is the increase of the compression ratio or retarded injection. They can guarantee a sufficient combustion process only, if a fuel used is in accordance the manufacturer’s standard. The engine manufacturers specify which quality of fuel should be used and can recommend a suitable fuel treatment system.

2.5 The quality of heavy fuel oil

The quality of the residual fuel is affected by the type of crude oil, the refinery process itself and the type of blending components used. The residue is mixed with other kind of fuels to reach the requested viscosity; E.G. MGO is mixed with heavy fuel oil.

The stability of the residual fuel can be negatively affected by the blending process. Stability of fuel oil can be described as the resistance to formation of organic sludge. In other words, a fuel oil is stable, if after heating and storage, it does not produce separate solid deposits/sludge. This sludge can result in engine shut down through choked separators and blocked filters, Ref. (44).
A residual fuel must have the correct chemical composition in order to avoid that the asphaltenes agglomerating together and leading to heavy sludge deposits. Bad Fuel Oil quality can lead to operational problems like:

- Instability of the fuel and sludge formation.
- Engine damage caused by ignition delay and excessive wear
- Health aspects and safety of the crew because of a mixture of waste products
- Environmental aspects - Emissions of: Soot, Hydrocarbons, Sulphur Oxides (SOx), Nitrogen Oxides (NOX) and Slop/Sludge

Typical Characteristics of a poor quality fuel oil and the resulting problems.

- Silicon and Aluminium lead to abrasive wear (Cat-Fines)
- Ash lead to Solids Contamination of the fuel and lub oil fouling the T/C
- Carbon lead to Residue Deposits
- The CCAI say something about the Ignition Quality
- Cold properties lead to Filter clogging
- The Density affects the Centrifuging of the fuel oil and about the Economy of the fuel oil.
- Micro-organisms lead to Filter clogging
- The presence of Sodium is a clear indication that Sea water are included in the fuel oil
- Sulphur can lead to cold Corrosion inside the engine
- Total amount of Sediments lead to problems with Sludge and Filtering
- Vanadium leads to Hot Corrosion
- Viscosity affects Heating/Injection of the fuel oil
- Water leads to affecting combustion and possible fuel system component damage

The price of fuel reflects the processing and quality. The specification for marine fuels the ISO8217 standard covers the quality of fuels and the combined amount of the catalytic-fines is limited to 80mg/kg for all residual fuel grades by this ISO standard. So the problem with mechanical wear is reduced.

2.6 The fuel oil treatment

Many efforts have to be made to produce a stable and clean residual fuel during the refinery process, the transportation and the storage of the fuel.

It is essential not to mix dissimilar fuels, Ref. (44). If it is necessary to mix them it is recommended that a compatibility test between the two fuels is carried out. More often than not however, fuels can be mixed at a 50/50 proportion with no problems of incompatibility.

When in colder sea temperatures, heating coils should be used to avoid formation of wax crystals and allow ease of transfer to settling tanks (additionally heating in storage will promote settlement of water and sediments). But overheating has to be avoided.

Before burning in the engines, all bunkers must pass through the purification and filtration plant on board the vessel. Careful attention must be paid in keeping this plant at a high stage of operating conditions e.g. correct preheating, flow rates and proper fitting of centrifuge gravity.

The settling and service tanks should be checked for water by operation of drain valves on a watch basis.
2.7 Nature of residual fuel combustibility

In the first step, the fuel will be injected into the engine combustion chamber followed by evaporation and mixing of the injected fuel with the air in the cylinder. During the delay period, fuel air mixture is forming continuously. The volatile hydrocarbons evaporate from the droplet surface and together with the heat from the compressed air forms an inflammable mixture. After that the mixture ignites and burns. The heat released from the burning mixture initiates thermal decomposition of the hydrocarbons fraction in the fuel droplet. The result is now more volatiles will be released from the fuel oil droplets. In the third step, the asphaltenes and the remaining heavy fractions in the droplets decompose rapidly; absorb a large amount of heat from the flame front. They decompose to gaseous liquid and solid components. Through the high temperature and pressure the rest of the fuel oil droplets will be ruptured and the flame front increase. Finally the non-volatile components result in solidification. The carbonaceous solids burn by a slow surface reaction, so the time to burn completely is not enough during the combustion process.

2.8 Remarks to Marpol 73/78 Annex VI Regulation 18

MARPOL Annex VI came into force on 19 May 2005 after 15 members signed the annex. Today there are now 30 countries signed up to the protocol, representing over 63% of the gross tonnage of THE world wide merchant fleet

The fuel oil quality is described in Marpol Annex VI Regulation 18 (1), Ref. (22) as:

(1). fuel oil for combustion purposes delivered to and used on board ships to which this Annex applies shall meet the following requirements:

(a). except as provided in sub-paragraph (b):

(i). the fuel oil shall be blends of hydrocarbons derived from petroleum refining. This shall not preclude the incorporation of small amounts of additives intended to improve some aspects of performance;

(ii). the fuel oil shall be free from inorganic acid;

(iii). the fuel oil shall not include any added substance or chemical waste which either;

(1). jeopardizes the safety of ships or adversely affects the performance of the machinery, or

(2). is harmful to personnel, or

(3). contributes overall to additional air pollution; and
3 Sludge

3.1 Definition of Sludge

What is sludge, the answer is easy and very vague. Sludge is formed from water, asphaltenes, metals such as rust particles, catalytic fines and other dirt with some of the oil base being carried over. Ref. (25 and 40). The correct adjustment of the separators is of high importance. If the adjustment of the separator is correct, the amount of fuel in the sludge should be limited; however you could argue that an increase quantity of MDO would be required to burn the sludge in the incinerator.

3.2 Marpol Guidelines for Handling Oily Wastes on Ships

Annex I of the MARPOL 73/78 contains certain regulations and unified interpretations related to equipment for the storage, handling and disposal of oily residues and engine-room oily bilge-water. The Definitions for the purpose of these Guidelines are: Oily waste: means oil residues (sludge) and oily bilge-water. Oil residue (sludge) means:

1. Separated sludge, means sludge resulting from purification of fuel and lubricating oil.
2. Drain and leakage oil, means oil resulting from drainages and leakages in machinery spaces.
3. Exhausted oils, which means exhausted lubricating oil, hydraulic oil or other hydrocarbon-based liquid which are not suitable for use in machinery due to deterioration and contamination, Ref. (22).

3.3 Sludge on board ships

Sludge is an economical and environmental problem in the shipping industry. The overboard discharge is strictly prohibited in most areas of the world. Normally the fuel oil is separated in bunker tanks, settling tanks and service/day tanks. The bunker tanks are for the normal storage of the fuel oil. These bunker tanks need continuous preheating where residual fuel oils are stored. The preheating ensures that the heavy fuel oil is able to pump and in the case of fuels having high pour points, avoids solidification.

The settling tank and also the other tanks will accumulate sludge through sedimentation in the tank bottoms. The heavy fuel oil contains particles like the minerals and metallic particles from the original crude oil and from the refinery process. If the fuel has a limited stability reserve, the chains of the organic molecules may lead to agglomeration of the fuel oil after preheating. The agglomeration must be eliminated.

On the way from the settling tank, the fuel oil goes through the separators. The elimination of the agglomeration and the other particles like cat fines etc is difficult. So again the correct adjustment of the separator is essential to avoid that mineral and metallic particle exist in the fuel. Because if after treatment mineral and metallic particle still present in the fuel, then this can led to abrasive engine wear.

The sedimentation in the tanks builds up over some time and leads finally to more cost for the owner. The extra costs are the result of loss of capacity in the tanks, regular cleaning of the tanks, maintenance and repair cost and finally the cost for sludge disposal.

3.4 Remarks to Marpol Annex I Reg. 17 Amount of Sludge

For ships which do not carry ballast water in oil fuel tanks, the minimum sludge tank capacity (V1) should be calculated by the following formula:

\[ V1 = K1 \times C \times D \] (m3)

where: \( K1 = 0.01 \) for ships where heavy fuel oil is purified for main engine use, or \( 0.005 \) for ships using diesel oil or heavy fuel oil which does not require purification before use,
C = daily fuel oil consumption (metric tons),
D = maximum period of voyage between ports where sludge can be discharged ashore (days). In the absence of precise data a figure of 30 days should be used.

That means one percent of the fuel consumption is sludge. This 1% formula is still used by all PSC inspectors to recalculate the Oil record book, Ref. (22). Investigations from surveyors on board various types of vessels show clearly, that the amount of sludge will be more or less around 1%. For example, a container vessel with 6000 TEU, 24 knots service speed and 8 years old needs for one round trip Europ-Asia-Europ approx. 8000 metric tons of heavy fuel oil. The variation in the amount of sludge is between 64 metric tons and 85 metric tons for each voyage.

3.5 Measures for reducing Sludge

3.5.1 Reducing sludge before the combustion process

One simple way to reduce the sludge problems and also the problem of the quality of the heavy fuel oil is the use of MGO, but that is a quite expensive method. The use of the additives which are an additional insert in the fuel is also a possibility but the results must be checked with care. The permanent running of fuel oil, luboil and sludge separators is the most commonly used method. The separators must be in absolute perfect condition and 100 % perfectly adjusted.

The installation of a microniser in the fuel line before the separator led to a reduction in the amount of sludge. Different reports give a clear indication, that a reduction of sludge will be happen, Ref. (30, 23 and 10). The report of the Madeira Power station show clear, that the interval of the fire up from the separators increases from 30 minutes interval up to 150 minutes interval after the installation of a microniser (see chapter 7.2).

3.5.2 Reducing sludge after the combustion process

The use of incinerator is a method to dispose the sludge. Problems will arise if there is too much water in the sludge or too much agglomerated asphaltenes are included in the sludge and so on. To burn this kind of sludge, a high amount of gas-oil will be required.
To reduce the amount of water in the sludge, draining tanks, separation of the sludge or sludge vacuum evaporators are possibilities.
A microniser system can also be used as a treatment of the sludge with a possibility to produce a burnable Sludge-Fuel-Water- Mixture. This mixture can be burned in the incinerator without the need of gas-oil.
4 Exhaust emission from Diesel Engines

4.1 Exhaust emissions and their impact on the environment

The most important emissions from Diesel Engines are nitric oxide (NOx), sulphur dioxide (SO2), carbon monoxide (CO), carbon dioxide (CO2), oxygen (O2), hydrocarbons (HC) and other particulates (see chapter 4.2 for details). The emissions of air pollutants from ships trading around Europe were in the year 2000, 2.6 million tons of sulphur and 3.6 millions tons of nitrogen oxides (Source: Intec 2002).

Some specific Intake and Exhaust from a four stoke diesel engine in Volume percent. Ref.(1).

- Intake
  - Air = 7.5kg/kWh with 79 % N2 and 21% O2
  - Fuel = 180g/kWh with 97 HC and 3 % S
  - Luboil = 0.8 g/kWh with 97.5 HC, 1.5% Ca and 1%S

- Exhaust
  - 99.7 % Exhaust with N2, O2, CO2 and H20
  - 0.3 % waste products with NOx, SOx, HC, CO and PM

HC will be more produced on engines with heavy fuel oil as on MGO or MDO.

Every year approx. 16 Million diesel engines are manufactured. 1 % of them are super large bore diesel engines. These engines in power stations or on board ships produce a power of approx. 200 power stations with 200 MW each. Ref.(1). The reduction of the exhaust emissions onshore led to more pressure being put on the shipping industry to follow (Marpol Annex VI).

In general, it could be said, that NOx, CO and HC and emission factors were principally related to engine load and speed. The NOx formation rates are primarily a function of combustion temperature, the combustion pressure and residence time of the combustion gases in the combustion chamber. CO and HC emission generally react fast on change of the engine load. NOx emission is not directly affected by the rate of change of load. NOx is more affected by the percentage of engine power load.

4.2 Exhaust emission parts

4.2.1 Carbon Dioxide

CO2 is one of the basic products of the combustion process. For one ton of fuel the average exhaust of CO2 is 3 tons. Ref.(1). The only way to reduce the amount of CO2 is reducing the amount of fuel. If the vessel reduces 1/3 of its speed, the amount of CO2 can be reduced by approx. 50 %. Another possibility to reduce the amount CO2 is weather and ocean current routing. Bad weather conditions can be avoided or use of the ocean currents. Clean under water parts of the hull, clean propeller and new design of propellers, reduce the fuel consumption. CO2 is not toxic but has been linked to the greenhouse and a global warming effect. CO2 reduction is not included in the Marpol Annex VI.

4.2.2 Carbon Monoxide

CO is formed in the case of incomplete combustion of the organic material, because the time for the oxidation process may not be long enough. The formation of CO is dependent on the ratio from air/fuel mixture, low ratio produces a higher amount of CO. Diesel engines have a high ratio of air/fuel mixture, so during the time in the combustion chamber, the formation of toxic gases is minimal. CO reduction is at the moment not included in the Marpol Annex VI.
4.2.3 Hydrocarbons

The emission of the hydrocarbons is the result of unburned fuel through insufficient temperature in the combustion chamber. For reasons of health, the HC should show the same carcinogen impacts. The HC is in general less on a diesel engine as on an Otto-Engine. Ref.(1). The emissions of HC may also happen through bad maintenance or an incorrectly designed fuel injection system. HC reduction is at the moment not included in the Marpol Annex VI.

4.2.4 Particulates/Smoke

Other exhaust emissions are also the agglomeration of very small particles of unburned fuel (HC), partly burned luboil (HC), ash content of fuel oil and cylinder luboil and/or sulphates and water. The combustion of lub-oil leads automatically to an increase of PM. In the luboil are additives contained, which improve the lubrication capacity of the oil. These additives are not combustible. One possibility to reduce the PM is the fuel-water emulsion. In theory the use of cyclones, electrostatic filters and filter bags are also possible. One problem with the new diesel engines with high efficiency is the producing of smoke during low load operation. Particulates reduction is at the moment not included in the Marpol Annex VI.

4.2.5 Sulphur oxides

The emissions of SO2 are directly proportional to the sulphur content in the heavy fuel oil. The formation of Sulphur oxides (SOx) in exhaust gases are caused by the oxidation of the sulphur in the fuel into SO2 and SO3 during the combustion process. Further problems with sulphur are the low temperature corrosion depending on the mass of Sulphur in the residual fuel. The Sulphur attacks some of the engine parts, if the surface temperature below the dew point temperature of the exhaust gas. Ref. (3).

The only way to reduce the sulphur emissions is the reduction of the sulphur content in the fuel oil. The average sulphur content in heavy fuel oil is around 3 %. With 3% sulphur content an estimated average value 64 kg SOx will be emitted for every 1000 kg of heavy fuel oil.

A Typical heavy fuel today have a sulphur content of around 3 percent and for these fuel a lub oil with a Base Number between 60 and 70 are in use, which provide the right alkalinity to match the fuel sulphur level. The TBN of oil is the measure of the alkaline reserve, or the ability of the oil to neutralise acids from combustion. Severe depletion of the TBN results in acid corrosion and fouling within the engine. Maintaining a correct alkaline reserve is critical in preventing unnecessary corrosion of the upper piston, piston rings and top end bearing. If the value of the TBN not as required by the sulphur content of the fuel oil, then corrosion inside the engine will increase.

As a guide, the TBN of fresh oil should be at least:
10 x fuel sulphur content (%) for trunk piston engines (10mgKOH/g)
20 x fuel sulphur content (%) for cylinder oil in x-head engines (20mgKOH/g)

4.2.6 Nitrogen Oxides

The Nitric Oxide (NO) is relatively inert and only moderately toxic, but after oxidising NO becomes the more harmful gas Nitrogen dioxide NO2. Ref.(1). NOx emissions have residence times of 1 to 3 days, which may mean they are transported 400 to 1200km. Ref.(15)

Nitrogen (N2) is in the major part of the atmosphere and remains mostly inactive during the combustion period, however a small percentage will be oxidized to form various oxides of nitrogen. Nitrogen present in residual fuel itself also affects the NOx formation. If the temperature is increased in the flame front, the nitrogen is no longer inactive and starts reacting with oxygen to form nitric oxide (NO) and nitrogen dioxide (NO2). At first more NO will be produced, but later in the combustion
process it will be formed to NOx. The NOx concentration increases exponentially with the temperature. NO formation rate can increase by a factor of 10 for every 100K temperature rise. Ref. (15). The condition for NOx formation in the cylinder is: The combustion temperature is approx. 2100 Kelvin or above, O2 and N2 must be available. Ref. (26, 44 and 15).

A slow speed diesel engine, in general, tends to have more NOx formation than a high speed engine because the combustion process spans a longer time period so there is more time available for NO formation. Ref. (31, 35, 8 and 15). The critical time period for NOx creation is the start of the combustion and shortly after the peak pressure. Nearly 20 % of NOx formation will happen at that time. Ref. (33).

4.3 Measures for reducing NOx

The engine manufactures have designed numerous different designs for reducing NOx as shown below. Ref. (31 and 33).

The simplest method is unfortunately not possible. Lowering the temperature in the combustion at the time of highest combustion pressure is very effective but that may leads to an increase of fuel consumption and raises the amounts of other pollutants like Hydrocarbon and particulates. So other methods have to be used and a way should be found for less NOx, satisfactory combustion, high efficiency of the engine and amount of other pollutants.

But is must be noted, that today the engines built after 01 January 2000 must comply with Marpol Annex VI. Any changes in the engine may invalidate the engines Nox certificate and a the technical must be re-approved and the EIAPP Certificate re-issued.

4.3.1 Engine adjustments

- Delaying the time of fuel injections and the injection rate, Common Rail Control is a very effective way of reducing NOx and reducing the smoke problem and Modification of the fuel nozzle design or the number of fuel nozzles can reduce the amount of the NOx.

4.3.2 Combustion processes

- Emulsified Fuel or Fuel-Water emulsions lead to a clear reduction in NOx emissions at lower cost and no change in the design of the engine, Ref. (7). Manufacturers stated that the fuel Water injection results in a NOx reduction of 1% Ref. (32, 4, 29, 10, 43 and 1) for each percentage point of water in the fuel and the fuel consumption will be on the same level as before. The limit of the use of fuel-water emulsion is the maximum injection pressure and the maximum delivery capacity of the fuel injection pumps and pipes. Ref. (27). In other words the limit is around 20 mass per cent and correspond to 45.5 volume percent. Ref. (7). If the emulsified fuel is stowed in the storage-tanks for longer time, then the risk of microbiologic attack should be taking into consideration. Ref. (36, 52 and 10)

- Other methods are the Combustion Air Saturation System CASS, Ref. (33), Humid Air Motor HAM Ref. (13, 33), the Diesel-Water-Injection (DWI), Ref. (29), and the Exhaust Gas Recirculation System, Ref. (33 and 7).

4.3.3 Secondary methods (after engine)

One other type of system is the Selective Catalytic Reduction SCR, here the exhaust gas mixes with ammonia and so the result is single atom nitrogen passing a special catalyst with the final being the NOx is reduced to stabile nitrogen and water. Ref. (33 and 7).
5 History of Homogeniser

5.1 Fuel oil Treatment

Fuel oil, which is used in the shipping industry, must be treated before use in Diesel Engines. The ISO 8217 Standard requests quality on a lower basis for use on slow speed two stroke engines. The most commonly used method for fuel oil treatment is passing the fuel oil through a centrifugal separator and after that through a filter. Not so often in use is the method to add some chemical additives in the fuel oil. It was also tried to treat the fuel oil in a mechanical way and pump through a so called homogeniser.

5.2 Homogenisers

The content of carbon residues in heavy fuel oil is on a high level. Most of it was removed by the centrifugal separator and the attached filter elements. But some of the finer carbon particles were not removed by the separator and the filter elements and passed through to the engine. The carbon elements led to agglomeration of the asphaltenes and finally to filter clogging. The use of heavy fuel oil with 500 cst or 700 cst led to further problems with the separator.

To improve the quality of the heavy fuel oil, the idea was to develop a mechanical device in which extremely high mechanical pressure would be applied to the fine particles and specially asphaltenes and therefore reduce the size of them. With the smaller sized particles it will easier to carry out a proper fuel oil treatment with separators. Different types of homogenisers were developed and tested in the shipping industry.

At the same time the refinery process was still improved through a so called cracking process. In this process a lot of powdered aluminium/silicon based material was introduced. Some of that powder escape the refinery process and remained in the fuel oil. This powder is known as catfines. In the engine these metallic particles included in the carbon particles led to abrasive wear in the engine. Ref.(3).

5.3 Type of Homogenisers

There are different types of so called homogeniser equipment available on the market. Below you will find a list which is not a ranking list.

A simple method which is not done by homogeniser equipment, can be by introducing a small amount of additive chemicals to control water droplet size and prevent coalescence. Proper mixing and proportioning of the water, oil and the surfactant will create a stable emulsion that is ready to burn.

One version is the use of ultrasonic generators applied with fine filters. This system is designed to prevent the adhesion of asphaltenes. So the fuel should be in better condition as before treatment.

A simple system is the pump system. This system works to treat the fuel oil, but not to reduce the size of the agglomerates asphaltenes. The size of the fuel oil droplets is still unaffected so the system does not homogenise the fuel oil.

One other type is the static homogeniser system, in which the fuel goes to a multiple channel system. The size of the fuel oil droplets is not affected in a notable manner.
The dynamic homogenizer based on a rotor-stator principle. That means a rotor is running in a stator with high revolution. The gap between the stator and rotor is very small. With such equipment it is possible to reduce the size of the fuel oil droplets. Also it is possible to produce a stable fuel-water-emulsion.

Another dynamic system consists of two counter-rotating special rotors, which accelerates the fluid until the fuel bursts. This system will also shear the carbon/asphaltenes into smaller particles in order to let them pass through the purifier.

5.4 Concern against the use of Homogeniser System

5.4.1 General

Some manufactures of purifiers fear that a homogeniser system will reduce the separation efficiency of the purifier. So the manufacturers claim that they cannot give any guarantee for the correct working of the separators, and strongly advising against adoption of a Homogeniser on board ships. So finally the engines manufactures did not allow use of a homogeniser without separators and filter elements. All the reasons mentioned below, together with imperfect design and trouble during the first service time, finally gave the homogeniser a bad image (leakages in general) in the shipping industry until today. For details see also chapter 6.1.

5.4.2 What are the arguments against the use of homogenising systems?

If a homogeniser system, installed in front of a purifier, which will reduce the separation efficiency of the purifier with regards of the separation of minerals, other particles and water. The opinions are that the catfines will also be treated by the homogeniser, the size reduced and so the purifier has no chance to remove the catfines out of the fuel oil. The catfines can now pass the purifier and increase the wear inside the engines. It was also claimed the use of a homogeniser increases the consumption of fuel. Ref. (24). For details see also chapter 6.1.

Further doubts arose about fuel-water-emulsion. Ref. (24) Some doubts were regarding the limited stability of the emulsion, risks of cavitations and safely starting the engine with fuel-water-emulsion. Further it was argued that producing lub-oil-sludge and corrosion can happen, after water goes into the luboil. Also a concern against fuel-water-emulsion is the poor performance of the engines. The percentage of water is constant and cannot be changed for cold start or other operating conditions. If the engines operate under full ahead, the performance is reduced. Ref. (2). This results in a request of a load-dependent-water-control-unit from Marpol. Ref. (22). Some sources maintain such a system has great disadvantages like the complexity of an emulsion device, a special control strategy for drive off and shutting down the engine, and the need to provide enough fresh water to the homogeniser. Ref. (4). For details see also chapter 6.1.

5.5 The future of Homogenisers

In the Marine Environmental Protection Committee, 48th session, Agenda Item 12, submitted by Germany (MEPC 47/61from the 15/10/2001), is the executive summary for the future of homogeniser as follow: “This information introduces the homogenizing technology for the reduction of oil sludge formation during the fuel treatment process on board of seagoing vessels and considers also further benefits of this technology.” Ref. (23).

INTERTANKO produce the MEPC 47/6/8 with the issuing date 11/01/2002. The MEPC 47/61 resolution was later withdrawn by Germany for further consideration and an info MEPC 48/INF 13 was sent back form Germany for information. The Microniser system is still ordered from Shipowners for their vessels.
6 The next Generation of Homogenisers

6.1 The new homogeniser generation and the arguments against them

It is important to investigate to which extent the microniser system effects the purifier ability to clean the fuel. Under Ref. (30) it is write down for a fuel oil analysis from a motor vessel: “... The separation efficiency was in the region of 50 – 70 %, and no significant changes in separation efficiency between untreated and homogenised fuel could be detected...” In Ref.(19) is a comment about a fuel oil analysis carried out over for a period from two years, done by the Korean Fuel Oil Quality Test Institute:

1) Purifier are working more efficient when the HFO is pre-treated by the CD-92 fuel conditioner. This is proven by the fact, that water and sediment contents in the remaining HFO sludge are higher when the HFO has been pre-treated by the CD-92 Fuel conditioner. In the case of purifier operation only, water and sediment contents in the remaining HFO sludge are significantly lower. .... 2) The same analysis shows, that the remaining calories in the sludge are reduced by 30%. This is due the fact that the CD-92 unit reduces the size of burnable fuel and reduce the grow-up of asphaltenes. This means that by installing a CD92 fuel conditioner, the HFO keeps more calories for the combustion process. .... 4) The sludge amount / production itself was reduced by more than 50% due to the extended flushing periods of the purifier.” Analysing Attest from the laboratory “Intertek Testing Services Caleb Brett ITS” show similar results from fuel oil analysis.

The fuel consumption is not significantly affected through the use of a microniser system. Under Ref. (30) it is stated: “No significant change in the specific fuel consumption was found when operating homogenised fuel. "-No significant change in the specific fuel consumption was found when operating emulsified fuel." This result is also confirmed under Ref.(27 and 47).

The fuel-water-emulsion FWE is marked in questions from different sides. Ref. (24). Some remarks about these concerns as mentioned above under 5.4.2: mentioned under Ref. (28) are “The emulsion of water with either MDO or HFO is stable over a period of several days – without need to use additives. The engine can safely restart with emulsion without flushing within 24 hours after stop. Further experience will show if this window can be lengthened beyond 24 h.” The risk of cavitation is not relevant, because: “A closed pressurised system avoids cavitation and boiling-off in the low pressure section”. For the problem of poor performance in engine mode with the Fuel Water Emulsion FWE switched off, Ref.(28) gives the following statement: “Not relevant, because FWE is active over the complete load range from idling to full load.” To the concern against the limited NOx reduction, following statement was made: “FWE works on 15% water addition to the fuel, independent of the engine load. With simultaneously retarded injection at part load, NOx emission can almost be halved.” The problem of entry from water in the luboil or from free water in the combustion chamber does not exist, Ref.(27).

One question is further raised, what is happening if seawater contaminates the fuel oil? In this case, the microniser must be bypassed. The control of the Sodium in the fuel can be done by salinometer. The salinometer can be installed in front of the microniser system or in all settling tanks in different levels of the tank.

Negative consequences after the use of water-diesel-fuel-emulsion in the diesel engines are not until now known. Ref. (13 and 28). Engine manufacturers have used emulsified fuel in power stations since the 80ties. The results from these power stations show clearly only low cylinder wear and a total absence of problems in the fuel injection system. Ref. (47). Such equipment was also installed in the 90ties on board ships and stated: “…These prime movers were commissioned between 1995 and 1998, their service results are satisfactory, both with regards to NOx reduction and engine performance …”

and later was further stated: “... by summer 2003 the engine had logged 21000 hours operation, the system still functioned properly under all operating conditions. ...” Engine manufacturers have no fear to use homogenised fuel from a microniser system. Ref.(13, 29, 54, 46 and 47)

**6.2 Functional principle of a rotor stator Homogeniser**

The basic principle of a microniser system is rotor-stator principle. Between both is a gap clearance from 5/1000 mm and the speed from the rotor is around 3000 rpm. This design produced sheer- and friction forces on the moving surfaces from the fuel oil. Additionally ultrasonic waves, produced through the system itself, and up to a frequency from approx. 5000/7000 Hz has also influence on the fuel oil. The shear forces together with the ultrasonic waves reduce the organic particles from the fuel oil will down to 3/1000 mm. Ref.(36).

All mineral and metallic particles are not affected by the microniser and passed the microniser on the way through the separators. The cat fines and similar particles can now be separated easily from the fuel oil with the separators and fine filters. Ref. (19). The sizes of the HFO parts in an untreated fuel oil vary between 5/1000 mm up to 1/10 mm. After the treatment the size will be down to approx. 3/1000 or 3 µm.

If the size of the fuel oil particles or fuel droplets is reduced from by example 70/1000 down to 3/1000, the surface of the fuel oil droplets increases dramatically. In this case the surface area from all fuel oil droplets is around 23 times higher as before.

**6.3 Sludge reduction**

The amount of sludge is a direct function of the fuel oil stability and the fuel oil purification/separation process. After treatment by a microniser the fuel oil consists of a well balanced structure. So the separator can work more easily. The reduction in size of the agglomerated asphaltenes through the microniser is one reason why the separators works better. The size of the reduced asphaltenes is now smaller as the reference size from the separation equipment and so more fuel oil can pass the separators. The flushing interval can be extended and that results in fewer amounts of sludge and water (for flushing the separator) in the sludge. The amount of sludge can be reduced now down to 0.3 % from the total fuel oil consumption. Ref. (19). See also results from Test Run of the Madeira Power Station

**6.4 Combustion improvement**

The microniser provides the engines with a fuel, in which the fuel oil droplets size is approx. 3/1000 mm. If the microniser is fitted close to the engine, the remaining asphaltenes will be small in number and size. In the combustion process the size of the fuel oil droplets is important. The size of the fuel oil droplets will, after treatment with a microniser, be around 3/1000 mm so each fuel oil droplet ignites immediately and burns completely.

After injection of the fuel in the combustion chamber, the fuel will be heated up from the compressed air. The fuel oil droplets will ignite, but can only burn from the surface down to the nucleus. If a fuel oil droplet is too big, it can’t burn completely in the short time during the combustion process. The bigger fuel oil droplets burn on the surface and the heat initiates a thermal decomposition of the
hydrocarbons particles. So volatile components evaporate and burn also during this time in the combustion process. Other parts of the hydrocarbon are going through a thermal cracking process and result in an incomplete combustion. Finally, the increase of pressure and temperature ruptures the remaining parts of the fuel oil droplets, leads to a development of the flame front and finally to formation of soot and carbon particles.

6.5 Diesel Fuel Emulsion

6.5.1 Water introduction in internal combustion engines
The introduction of water to internal combustion engines has been well known for over a period of about 100 years. The first known use of water in the combustion process for internal cooling was in 1900 in an Otto cycle engine. The next known use of water introduction was in the year 1913 in gas engine, mid 1920 in tractor engine and 1938 in air craft engines. Just prior to and during World War II shows the use of water fuel alcohol mixture, especially for supercharging from aircraft engines. Further publications show the continuous interest in water fuel emulsion from the 1960’s until today. Ref. (51).

6.5.2 Emulsified fuel
An emulsion can be defined as a fluid, which is a mixture of normally not insoluble liquids. The definition of a permanent emulsion is described as follows: An emulsion is called permanent, if the droplets have reached sufficient size to prevent the separation of the insoluble material. An emulsion can be called stabilized or un-stabilized. The so called stabilized-emulsion uses an emulsifying agent to suspend the water in the fuel and reduce the required energy to produce the emulsion. Un-stabilized -emulsions don’t use emulsifying agents and so need higher shear forces to suspend small droplets of water in the fuel. Both solutions can produce fuel-water emulsion, which are stable over a long period. Ref. (7).

It is mentioned in some articles, that a blend of fuel and water need a load-dependent-water-control unit. This is also a requirement of Marpol. Ref. (22 and 2).

6.5.3 Fuel oil water emulsion and the combustion process
If a stable fuel-oil-water emulsion is pumped to the injection nozzle, the water is completely surrounded by the fuel oil. After injection of the fuel oil in the combustion chamber, the fuel oil will be heated up through the compressed air. The water inside the fuel oil droplets transforms from water to steam and increases in size up to 1600 times higher as it was before. During the transformation from water to steam the components of oxygen and hydrogen are released. The fuel oil droplets rupture through the increasing steam and finally the size of the fuel oil droplets is reduced to numerous smaller fuel oil droplets. These smaller fuel oil droplets ignite and burn easier than the bigger droplets.

At the moment it is not clear if an improvement of the thermodynamic process will be in place through the release of oxygen and hydrogen during the transformation from water to steam. Ref. (57 and 38).

One problem to fulfil the above mentioned combustion process is the different boiling temperature under atmospheric pressure from water (100°C), MGO (Approx.:160 °C) and MFO (above 400°C). To bring these different boiling temperatures in line, three conditions are necessary: a.) The time needed to evaporate the water in the emulsified fuel must be shorter than the time needed for the self ignition of the fuel in the emulsified fuel. b.) The heat for evaporation of the water must be less than the heat to evaporate the surface of the fuel oil droplets. c.) To reach a complete evaporation of the water droplets in the emulsified fuel, the water droplets should have a diameter of less than 4 micrometer. Ref. (57 and 51).

6.5.4  The positive effect of a fuel oil water emulsion

The improved atomisation of the fuel is one advantage of the fuel-water-emulsion. Ref. (29). The other effect of the fuel-water-emulsion is the cooling down effect of the combustion chamber temperature. This cooling effect is reached through the lowering of the maximum peak temperature during the combustion process. This will happen through the heating and evaporation of the water. The heat for heating and evaporation of the water is no longer available for heating up the combustion process and so the temperature will be not so high. Ref. (13, 31, 29, 7, 44 and 34).

Finally it can be stated, that a correctly produced fuel-water-emulsion will result in a notable change in engine performance, like reduction of NOx, reduction of exhaust temperature, reduction also of thermal stress inside the engine and a cleaner combustion. Ref. (51, 44 and 47).

Until today, engine manufacturers have not stated that negative consequences through the use of water-diesel-fuel-emulsion respective. the use of the microniser system are known. Ref. (13, 31, 54, 46 and 47)

6.6 Waste oil recycling

The sludge which is collected in tanks and the waste oil can also be treated by a microniser. The result is a stable fuel – oil – sludge mixture. This mixture can be burned in the incinerator or in the boiler. The amount of gas oil to burn sludge can be reduced nearly to zero. On the other hand there are cleaner surfaces of the heating surfaces of boiler/Incinerator.

6.7 Blending of High Sulphur fuel with Gas Oils

Marpol Annex VI require for low sulphur areas (SECA) where fuel with an maximum sulphur content from 1.5 % must be used. The idea is now to use the new generation of homogenisers also to blend high sulphur fuel with gas oil to achieve a 1.5 % sulphur content. The developments of such a equipment were still ongoing.
Type Approval Certificate

This is to certify that the undernoted product(s) has/have been tested with satisfactory results in accordance with the relevant requirements of the Lloyd's Register Type Approval System.

This certificate is issued to:

PRODUCER  S.I.T.Schiffs- & Industrie Technik GmbH
Wittenmoor 36
22525 Hamburg
Germany

PLACE OF PRODUCTION  Am Marienhof 12
22880 Wedel
Germany

DESCRIPTION  Mechanical Fuel Conditioner based on Rotor/Stator principle, homogeniser

TYPE  CD92-M Microniser; 85-M, 100-M, 130-M, 140-M, 200-M

APPLICATION  As oil fuel treatment processor on ships and offshore installations classed or intended for Classification with Lloyd's Register.
   a) Homogenisation of inhomogeneous and incombustible structures
   b) Forming non-mineral and non-metallic particles in sizes below 0.5mm
   c) Diminishing of re-agglomeration of hydro carbons (asphaltenes) leading to fuel utilization/improvement
   d) Significant reduction of sludge formation (up to 85%)
   e) Generation of a long stable water-in-diesel fuel-emulsion

RATINGS
Max capacity: 25 m³/hr
Max pressure: 16 bar
Max temperature: 150°C
Oil fuel type: heavy fuel oil IFO 180 – 380 cSt/50°C;
              marine diesel oil
Supply: 400/440V; 50/60 Hz; IPS4

Certificate No.  04/20014
Issue Date  26 February 2004
Expiry Date  25 February 2009

Sheet  1 of 2

Ramona Zettelmaier
Hamburg Plan Approval Centre
Lloyd's Register EMEA
71 Fenchurch Street, London EC3M 4BS

THE DOCUMENT IS SUBJECT TO THE PROVISIONS ON THE REVERSE
SPECIFIED STANDARDS
Lloyd's Register Rules and Regulation for the Classification of Ships, July 2003;
Manufacturer's Standard; BWB No. C-5776;

OTHER CONDITIONS
Installation and servicing to be in accordance with producers instructions and recommendations;
Installation of the CD92 microniser is not to render the fuel oil supply to the diesel engines inoperable;

“This Certificate is not valid for equipment, the design, ratings or operating parameters of which have been varied from the specimen tested. The manufacturer should notify Lloyd's Register EMEA of any modification or changes to the equipment in order to obtain a valid certificate.”

The Design Appraisal Document No. HMD 12235-04 and its supplementary Type Approval Terms and Conditions form part of this Certificate.

Certificate No. 04/20014
Issue Date 26 February 2004
Expiry Date 25 February 2009
Sheet 2 of 2

Ramona Zettelmaier
Hamburg Plan Approval Centre
Lloyd's Register EMEA

Lloyd's Register EMEA
71 Fenchurch Street, London EC3M 4BS
7.2 Results from test run of the Madeira Power Station

7.2.1 General

The visit was carried out to verify the effective working of the CD 92 microniser. It was stated by the owner of the power station that the power station couldn’t cope with excessive sludge amount in the past. That was the reason, why the owner decided to investigate in SIT microniser.

7.2.2 Description of the Power Station

The power station consist of three Gen-sets, one incinerator, one water separator (three stage overflow principle) and two fuel oil separators (Alpha Laval).

- 3 Main Engine Type: Sulzer 16 ZAV 40 S, V-Type, 16 cylinder, 400 mm bore, 560 mm stroke, 500 rpm, max output power 11520 kW, Medium pressure 24.56 bar, Fuel type IFO 380

- Generator sets consist of 3 ABB generator Type: ABB HSG 1600, Active power 11.68 MW, Apparent power 14.6 MVA, Power Factor 0.8, nominal current 766 A, nominal voltage 11kV, Protection class IP 21

7.2.3 Results of the visit

There is evidence, that the amount of sludge has been reduced. Before the installation of the CD-SR system the flushing of the F.O. separators produced approx. 1300 to 1400 kg/day sludge. After the installation the flushing interval decrease from 48 times per day down to 10 times per day and approx. 280 to 300 kg/day sludge were collected.

The amount of gas oil used in the incinerator to burn the sludge was reduced after the installation of the microniser. The total amount of gas oil in the year 2002 was 164.78 tons. From the 164 tons were 84.2 tons for the incinerator and 80.5 tons for the diesel engines. The micronisers were installed in June 2003. Until the end of November 2003 the amount of gas oil was reduced to 48.64 tons, 23.19 tons for the incinerator and 25.46 tons for the diesel engines. The monthly average from the consumed gas oil was in 2002 13.73 tons, in 2003 4.4 tons and in the range from July 2003 to November 2003 the average was down to 1 ton.
7.3 Producing Gas Oil-Water-Emulsion with the CD 92 WIDE Microniser

7.3.1 General

Purpose of the visit was to measure the efficiency of the CD92-85 WIDE to produce stable water-fuel-emulsion and to carry out analysis in the test laboratory.

7.3.2 Procedure for the test

Test equipment was the CD-92–M–85 WIDE Microniser. The amount of fuel was pumped with the water from a separate tank through a pump and then to the microniser, finally back to the tank (see picture).

The emulsion was prepared in a separate tank. In the tank were 40 litres of gas oil (from car petrol station, quality in accordance with the requested Petrol-Station-Standard). In the first test run 10 % (4 litres) of water (drinking water in accordance with Hamburger-Wasser-Werke Standard) were added to the gas oil. Normally this has to be done by the WIDE-UNIT, but for these tests it was found not practicable.

In order to have a stable emulsion a special additive (10 cl Emulsit, for the use in gas oil only) has also be added in the fuel oil. Emulsification in Gas oil (MGO) is possible only with the use of an emulsifying agent. For HFO and MDO is this emulsifying agent not necessary. Ref. (29).

The blend was then mixed with the S.I.T CD – 85 – M WIDE microniser in the next 10 minutes. The capacity of the microniser was 1715 litre per hour, so the 40 litre tank was mixed through approx. 7 times in the 10 minutes.

After ten minutes two tests samples were taken, analysed with a microscope, photographed and finally sealed and made ready for transportation to the test laboratory.
In the second, third and fourth test run, the content of water was increased in steps with 5 % water and 5 cl. Emulsit. Each test run was running about 10 minutes, before test samples were taken, analysed and sealed.

Test phase with 10 % water just after the CD92-WIDE switched on

Test phase with 10 % water just after few seconds

Third phase with 10 % water after approx 4 minutes

7.3.3 Results of the Test

During the time in the workshop of the Messrs. S.I.T, the following was summarised as follow: The gas oil and the water were mixed in the microniser to a “milk like” liquid. With 10 % water the “milk” is a

little bit shiny but with 20 % water the emulsion shows a strong white colour. The 10 % water-diesel emulsion shows under the microscope clearly, that the water droplets are surrounded by the gas oil.

The test report from the test laboratory shows very clearly, the gas-oil-water-emulsion remains stable over a period of a few weeks. After approximately six weeks only gas oil found separated. No amount of free water was detected in the laboratory.

The final result from this test is: A stable diesel-water emulsion was produced from the CD92 WIDE equipment.

**7.4 Microniser systems on board**

On board of a ship various combination of Micronisers are possible.

- One Microniser for reducing sludge, one Microniser for combustion improvements and or a Microniser for Fuel-Water Emulsion.
- Other types of Microniser could also be fitted like Sludge Reduction, Waste Oil Recycling or Blending Unit.
- Measurement equipment, designed to measure the exhaust on seagoing vessel and comply with Marpol Annex VI Continuous Measurement Method like the MARINOX SYSTEM Type Approved by Lloyd’s Register 2005 were also a possible combination.

**8 Future Development**

The current requirements of Marpol Annex I and VI are not necessarily the latest stage. So may be in the future the requirements for existing ships increased. Per example the allowed value of NOx for already certified engines will reduced. Also the allowed value of Sulphur Europe will be reduced from 2010 onwards. For all these future requirements the new generation of Homogenisers can be a valuable tool for an acceptable price. The development of Fuel Blending Unit based on the Microniser is now the latest development of this kind of equipment.
9 Conclusions

As clearly shown in this paper, to reach the “Green Ship” status on ships with diesel engines, a combination of a microniser system and separators are a useful combination. The separators, accompanied by filters, can eliminate the mineral and metallic particles like cat-fines from the heavy fuel oil. The microniser produces, through the sheering forces on moving surfaces of the heavy fuel oil, a reduction of the non-mineral and none-metallic particle size down to approx. 3µm. The fuel oil, after passing the microniser and the separator filter system, is now cleaned and well homogenised and can improve the combustion process.

There is evidence, that the use of a microniser system can reduce the amount of sludge by approx. 80 %. This happens through the reduction of the non-mineral and none-metallic particle size in the microniser and the final cleaning in the separator unit. The final amount of sludge can be further treated by a microniser system, by which a fuel-oil-water mixture will be produced and finally burned in the incinerator, without any use of gas oil for burning the sludge.

Fitted microniser systems also improve the combustion process, through the treatment of the heavy fuel oil. The size of the fuel oil droplets will be reduced from their original size up to 100 µm, down to approx. 3µm. The smaller sizes of the droplets leads to more an effective working condition of separators and also to much better ignition and combustion in the diesel engine. The engine produces less visible smoke and inside the engine is much cleaner as an engine without a microniser. Furthermore a reduction of the NOx can be reached.

There is also evidence, that through the use of Water-Fuel oil-emulsion, produced by a microniser system, reduction up to 20 – 30 % of the NOx can be reached. Water-Fuel oil-emulsion reduces the exhaust temperature and the thermal stress inside the engine.

A Type Approval certificate was issued with the sludge reduction and the production of a stable fuel-water-emulsion was signed.

10 Acknowledgement

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Appendix A

Principle drawing of a ship piping system with fitted CD 92 microniser
Jürgen Rischmann joined LR in 1998 in the Düsseldorf Office for industrial works. In 1999 he moved to the Kiel Office and worked as a new building Surveyor on a Mega Yacht. Later in 1999 he was transferred to the Hamburg-Port Office as a Surveyor and obtained his seniority in 2006. Also in Hamburg he continues his work as a new building Surveyor on the Mega Yacht. In 2001 he was Project Coordinator for a shaft repair of a twin screw Mega Yacht. Currently he works as Senior Surveyor in the Hamburg-Port Office for the classification and statutory survey on existing vessels. Further he worked as ISM and ISPS Code Lead Auditor and in addition as Lecturer for internal and external training courses.

Prior to joining Lloyd's Register he started his career as a mechanic for agricultural machines, later on he served in the German Navy as an Engineer Chief Petty Officer. After his study as technician at the Merchant Marine Training College, Cuxhaven and German Diploma Study Course Ship Operation Engineeering at the Hochschule Bremerhaven he worked on a Freelancing expertise for Klinikum Hannover aiming for the total expected amount of necessary maintenance of the seven hospitals.