Contamination of Fuel Oil

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More than 40 years ago engine manufacturers modified fuel treatment plants and designed vessels in such a manner that heavier distillate could be used. The economic recession, which started around 1970, forced vessel’s operators to seek alternatives to diesel oil (today referred to as MDO or Marine Diesel Oil) which was at that time predominantly used for diesel engines. During a ten-year period the price for crude oil increased from approximately USD 1.80 per US barrel to about USD 35 per barrel in 1981. Although oil prices plunged in the mid 80’s the price mechanism had then already affected the designers and the goal was to make use of far heavier fuel products than MDO.

The initial approach of the engine owners/designers was slow; largely due to the fact that on- board fuel treatment plants could not handle high viscosity oil, which required substantial heating. Also, in the beginning, fuel tanks were designed with heating coils only situated around the suction pipe, which restricted the use of oil to products with fairly low viscosity. Whilst vessel owners and engine manufacturers were trying to develop engines capable of burning cheaper fuel products, the rising living standard, especially in the industrialised countries, caused refiners to change course and concentrate on production of gasoline. They wanted to get a higher yield of light distillates, and succeeded in doing so by introducing sophisticated cracking methods. The result was that the refiners had to start in the high viscosity end and, by blending with lighter products, produce an Intermediate Fuel Oil (IFO) that was possible to use as a diesel fuel. Unfortunately this left the owners with a much worse product compared to when diesel was diluted with heavier residuals. Today it is fair to say that many refiners do not even make use of diesel when blending fuels, especially in the United States and other countries where the gasoline production is substantial. Thus it is to be expected that IFO purchased from sources in these countries contain more solids and other products, which may affect the safe operation of engines.

Problems with cracking of crude oils

The advanced methods for cracking leave residues, which are rich on solids and may be aromatic. These residues have high viscosity and density and must be blended in order to meet the specifications. Unfortunately they may also contain remains of catalysts or catalytic fines, which usually are based on aluminium and silicates. If introduced in an engine they will cause abrasive wear and can quickly destroy fuel pumps, injectors, and cause substantial damage to cylinder liners and piston rings.

Blending of Heavy Fuel Oils to achieve IFO

As noted earlier, diesel oil is rarely used in Intermediate Fuel Oils, at least not in the highly industrialised countries. Instead, so called FCC (Fluid Catalytic Cracking) slurry oils are widely used as blend components for residual fuels, mainly due to their excellent solubility characteristics and the fact that they make compatible fuel blends. However, they are very aromatic and with that comes poor ignition quality (high CCAI) and the possibility of introduction of catalytic fines in the IFO.

Heavy Fuel Oils are less expensive and not the primary target in the refining process. As a matter of fact most refiners try to produce as little HFO as possible. Thus the blending with slurry oils serves another purpose or gives the producer the possibility to reduce the production of HFO. It is also an excellent way to get rid of a residue, which as a matter of fact is referred to as toxic waste by EPA (United States Environmental Protection Agency).

CCAI value

The ignition properties of oil must be acceptable. If not, the thermal efficiency of the diesel engine will be reduced and severe damage caused to the engines. The Calculated Carbon Aromaticity Index (CCAI) is a calculated value, which gives good guidance about the fuel oil ignition quality. The theory behind the equation for calculation of CCAI is that there is a relationship between ignition quality, viscosity and density. Slurry oils have high density but reasonably low viscosity. When Heavy Fuel Oils are blended with slurry the end product, the IFO, will also have high density and low viscosity. The calculated CCAI index, which follows a reversed scale, gives an indication of the influence of this slurry on the ignition properties. The higher the CCAI index, the worse is the ignition quality.

Much can be learnt from the above. The engine manufacturers do of course take interest in the calculations and issue guidelines about what the delivered engines can burn and what the limitations of ignition quality (CCAI) is. The reader of marine engine manuals will note that various manufacturers have different opinions. The following statements are based on experience from studies of problems, related to high CCAI index.

1. Medium speed engines are more sensitive than large bore engines.
2. When auxiliary engines are operated on the same IFO as the main engine (large bore), the auxiliary engines are more prone to suffering damage.
3. Older engines are more sensitive than the newer ones.

There are simple explanations for the above. The piston in a large bore engine is moving slower than one in the medium speed engine or the auxiliary engine. Thus the effect of delayed ignition will be less harmful in these engines since larger areas of the cylinders have not been exposed. It is also known that the higher the compression temperature is, the lesser is the ignition delay. Thus new engines with much improved thermal efficiency may prove much more tolerant to fuel oils with high CCAI index.
There is another important lesson to be learnt. The less slurry you have in the fuel, the better it burns. Thus, if blending with slurry is suspected, 380 cSt oil is preferable to grades with less viscosity. The writer would think that most chief engineers would jump with joy if the bunker receipt showed 180 cSt rather than 380 cSt. They may quickly change their mind when the report of analysis from the laboratory tells them that the oil delivered has a very high CCAI index. Remember that we are blending from high to low viscosity!

The purchaser should also learn from the above! To ask for IFO with “a maximum viscosity of 380 cSt” is not necessarily a wise choice. It is much safer to ask for an IFO with a viscosity in the range 300-380 cSt. A maximum viscosity of 380 cSt oil is preferable to grades with less viscosity.

It is well known that today’s advanced cracking methods produce fuel containing contaminants. Finally, the scope of the typical analysis is limited, such that it can fail to pick up contaminants, which deliberately or by mistake have been introduced into the fuel.

**Fuel Oil Testing**

The importance of analysing fuel oils cannot be overstated and in addition vessel owners/charterers have access to statistics showing the quality of oil from bunker stations all over the world. The standards for marine fuel oil is set by the International Standard Organization, who in publication ISO 8217:1996 (E) have stated the limits for various parameters and contaminants found in fuel oils.

While the writer strongly recommends that vessel owners/operators subscribe to the services provided by such laboratories, he also recognises the weaknesses in the system. One weakness is that the analysis result is usually not available to the owner until after the oil has been put into use. The logistics of taking fuel oil samples and sending them to a testing laboratory does not allow for immediate results and it is reasonable to expect that it will take more than a week before the owners know what they received in the tanks. Some operators can avoid this problem by taking bunkers early on during a coastal voyage rather than in the last port. Other owners are encouraged not to use the last bunkered fuel until the result of analysis is known. Another weakness is the guidelines provided by ISO. They do not contain any recommendations regarding the ignition properties, nor do they clearly define what is to be looked upon as contaminants. Finally, the scope of the typical analysis is limited, such that it can fail to pick up contaminants, which deliberately or by mistake have been introduced into the fuel.

**Are the current ISO standards adequate to verify fuel quality?**

No! It is well known that today’s advanced cracking methods produce fuel of inferior quality to that available in the past. It is likely that the future quality of fuel will deteriorate further. It is thus essential that vessel operators be given much better information concerning the fuel oil intended to be delivered for consumption. Screening of fuel oil under current ISO guidelines may not detect unknown or unexpected contaminants which, accidentally or deliberately, have been added. Some contaminants may not affect the combustion process however cause serious damage to the engines. The following two characteristics will cause excessive wear of machinery parts, such as fuel pumps and injectors:

- High acidity levels, causing corrosive wear.
- Poor lubricity, causing excessive wear.

Different chemical wastes, such as acids or esters, added to the fuel can create such problems.

**Is it possible to determine if contamination has taken place?**

The presence of acids may be determined by screening for TAN (Total Acid Number). This screening, if added to the testing procedure guidelines, will give valuable indications of the presence of acid, however, this is a quantitative test that will not identify which type of acid is present. Other types of harmful contaminants could be present which can only be detected using more advanced screening techniques.

It is now possible to “fingerprint” fuel oils. Fourier Transform Infrared Spectroscopy (FTIR) is commonly used to identify unknown compounds in mixtures. The method is based upon measurement of absorption of light. The wavelength of light is unique for each chemical bond and the latter may be identified from a “library” of stored spectra. By comparing a “fingerprint” from a sample with that of a known typical fuel it can be determined if contamination has occurred and what chemicals may have been added. The method is computerised, fast, exact and available to ship operators.

**Recommended Precautionary Measures**

In addition to the measures recommended and related to sampling of fuels and subsequent analysis, the following precautions are recommended:

- The fuel quality service used should be asked to test for total acid number (TAN) levels.
- When purchasing bunkers, consider inserting additional language in the purchase order and contract providing that the total acid number (TAN) should not exceed 3.0. Some major oil refineries use this as their own “in-house” limit.
- To the extent possible, avoid commingling bunkers in the vessel’s tanks. Commingling fuel creates the possibility of incompatibility and excessive sludge.
- Instruct ship’s crews to be on the alert for uncharacteristic odours from samples taken during bunkering and air venting from the bunker tanks.
- Wherever possible, do not use the fresh IFO until the results of a laboratory analysis have confirmed its acceptability.
- If problems with the high-pressure fuel pumps are encountered when using freshly bunkered oil, switch (if possible) to IFO from tanks containing previously consumed oil or diesel oil and seek technical advice immediately.
- When in doubt, or if problems are encountered, contact the Club or their local representative.
- Should damages be known or suspected due to poor quality or off-specification fuel, ensure that the relevant parties, particularly the bunker supplier, are placed on notice immediately and invited to participate in joint sampling and survey of damages.

**The future**

Fuel oils will not become better. In order to safeguard for breakdowns it will probably be necessary to require that the suppliers of fuel oil already at the time of sale submit adequate and true information of how the IFO will be blended. It is also reasonable to demand that fuels and blending products are “fingerprinted”. This should be organised in a manner that allows for traceability of the products! In the writer’s opinion the standards of ISO 9000 could well be applied also to sales and purchase of fuel.

Where appropriate, the supplier shall establish and maintain documented procedures for identifying the product by suitable means from receipt and during all stages of production, delivery and installation.