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INTRODUCTION

It is not hard to find articles on the matters associated with the operational requirements, procedures or hazards faced by vessels obliged to burn low sulphur fuels. It is hard to find even one such article that is not prefaced by a paragraph or two of disclaimers.

What follow here are no more than observations, notes by the author on phenomena that may be encountered handling, burning and changing between the 'heavy' fuels oils still sanctioned for use at sea, and the low sulphur products that must be used in a growing number of ports and territorial water zones, in and offshore California particularly.

Present-day articles generally assume that the burning of ‘normal’ heavy oil in a marine engine is a ‘normal’ problem-free operation[1] and address the drawbacks of using a low sulphur fuel and problems transitioning from heavy to the lighter fuel.

The approach has merit and is followed here.

SUMMARY

To minimise the potential for problems:

- Know your system.
- Test all fuels for compatibility.
- Keep track of all fuels on board.
- Diligently control all changes from one fuel grade to another.
- Ensure the incoming fuel fully displaces the outgoing fuel from the system.

Be prepared to react to the following possibilities:

- Blocked filters due to precipitates from mixing fuels.
- Sticking fuel pump valves and injector needles.
- Gas-locked pumps.
- Engine manoeuvring and particularly starting problems.
- Increased fuel leakages when running on low sulphur products.
- Increased wear rates when running on low sulphur products.

OPTIONS

There are no options. The rule is, where it applies, that low sulphur fuel will be used. Reduction of sulphur emissions by cleaning (scrubbing) the exhaust or by chemical neutralization are not to be found in the regulations. Crews have no option but to get used to handling significantly different fuel grades. They best serve themselves and the vessel owners by becoming knowledgeable about the products and proficient in the various procedures. Crews must also be diligent in recording fuel transfers, consumption, and loss, for they must not only use the right fuel, they may be asked to demonstrate that they have used the right fuel.

PROPERTIES OF THE PRODUCTS

Liquid fuels are defined by the properties they exhibit; density, viscosity, flash point are commonly quoted. Besides listing properties a chemical analysis will identify contaminants together with empirical indicators of how the fuel may burn, may best be processed or how well it may mix with another specified fuel.

Lubricity, a term that frequently crops up in discussions about low sulphur fuels, is not an inherent property. Empirical tests are used to determine lubricity indices. Lubricity changes with an oil's density, viscosity, surface tension, chemical composition and purity. Sulphur is an element known to improve lubricity performance – however, clean low sulphur oil may well out perform contaminated high sulphur oil.

The differences in the properties of petroleum products from light gasoline to pitches and waxes are proportionate to the size of the dominant molecules in the grade. Small molecules dominate in light gasoline. They are more mobile and less interlinked. (Short molecules = more molecules per unit volume or weight = more spaces between molecules). This equates to low viscosities, low boiling points and to lower densities.

The longer molecules in heavier products require more energy to slide one over the other (liquid shear) which means higher viscosities. They also need more energy to separate from the liquid surface (gassify) which means higher boiling points and, put simply, the reduced number of larger molecules in any given volume equates to tighter packing of the elemental material and thus to higher densities.

All petroleum fuel oils are generally miscible but there are fuel mixtures that may cause waxes or some other undesirable sludge to form. Given samples of two fuels that will be mixed, a modern laboratory will be able to advise the user if the mixing process is likely to give rise to problems.

STORING AND TRACKING

If economic factors were not a concern ship owners could burn clean low sulphur fuels all the time and the plant and prime movers would be designed to accommodate the chosen fuel. However heavy fuel v low sulphur fuel price differences are substantial and it is currently cost effective to construct separate tanks for the various fuel grades and to duplicate significant sections of the pipework systems handling them.

Mixing takes place when fuel, heavy fuel with heavy fuel or low sulphur fuel with low sulphur fuel, is bunkered into partially filled tanks and the properties of the resulting mix can only be predicted imperfectly. Better therefore to only bunker into empty[2] tanks.

With all but the steadiest of liner trades it is unlikely that the Chief Engineer will know which batch of heavy fuel will be in use when the vessel is next obliged to switch to low sulphur fuel. However, if samples[3] of all fuels are retained at least until the associated fuel supply is exhausted, together with of course the fuel oil analysis results, it may be possible to predict – and avoid – mixing related problems both between and across grades.

MIXING AT CHANGE OVER

At some stage along the fuel system for a finite time the heavy fuel and low sulphur fuel will have to comingle. Currently comingling generally takes place in the pipes leading to the fuel pumps through to the injectors. The mixing may take hours.

The starting mix is 100% heavy fuel, 0% low sulphur fuel and the end point 100% low sulphur fuel, 0% heavy fuel. The duration of the process is governed by the need to maintain the viscosity of the changing mixture within tight limits.

The viscosity of the changing mixture is maintained by controlling the mixture temperature. For a heavy fuel the 'right' viscosity may occur at temperatures exceeding 130°C: for the low sulphur fuel even the ambient engine room temperature may be undesirably high in some cases.

If the low sulphur fuel is introduced too quickly the heat remaining in the fuel system components, pipes, pumps, filter bodies and injectors, may raise the temperature to a point were gasification occurs; fractions of the fuel mix boil.

Gas-locking of the pumps may occur together with cavitation damage as vapour bubbles form and collapse. Fuel pump valves may tip and stick due to the turbulent flow of the liquid - vapour mixture.

The much reduced viscosity of an overly hot fuel mix seriously affects the lubricating ability of the oil; essentially the oil is too thin to keep rubbing surfaces apart and metal to metal contact occurs. Finally, the overly thin oil mix has the propensity to leak through any weaknesses in the oil-tightness of the fuel system.

Conversely if the low sulphur fuel is introduced too slowly (or the temperature is reduced too quickly) the oil at the injectors will not atomize well and combustion will be affected. Poor atomization and cool fuel will affect the smooth running of the engine: potentially more seriously it affects the efficient manoeuvring of the engine and starting operations especially could be compromised.

In a different way the ability of overly thick oil to lubricate will be impacted. Put simply the thick oil mix may not penetrate sufficiently into the fine clearances between injector needle and injector body and between fuel pump barrels and plungers.

MIXING AFTER CHANGE OVER

At the end of the changeover to low sulphur fuel there should be no further mixing until the process is reversed when the vessel leaves the restricted area.

However, if any mixing does take place the vessel will be in violation and may face delays due to investigations: and penalties if the investigators determine that a violation has occurred.

Contamination of a low sulphur fuel may occur after a fuel change over if the system pipework is not flushed through effectively. This could occur if the change over was effected with the engine running at a relatively slow speed with correspondingly low fuel oil velocity in the system pipework.

Higher fuel velocities subsequently, say during a full astern manoeuvre (with typical additional whole hull vibrations), in the restricted area may lead to scouring of residual heavy fuel form pipe walls and crevices. Contamination can also occur if duplex filters have to be changed over and flushing of the standby chamber was not accomplished during the fuel change over. Contamination has the propensity to occur similarly with automatic filters.

To flush all chambers of an automatic system may not be practical and consideration should be given to switching off and bypassing any auto-filter systems once the changeover to low sulphur fuel has been completed.

Post changeover contamination from the sources mentioned above is not likely to directly affect the operation of the engines but could lead (and is believed to have led) to the detection of excessive sulphur content in a supposedly low sulphur fuel and consequently at least an administrative burden.

Uncomfortable as it may be the temptation for saving a few dollars and preserve the reserve of low sulphur fuel needs to be confronted. Any crew member who cracks open valves to bleed heavy fuel into the low sulphur fuel stream after change over is guilty of a criminal act. The potential loss to the vessel Operators far outweighs the small ‘savings’ that may accrue and the perpetrators may find themselves facing jail time.

BURNING LOW SULPHUR FUEL

Even after the prime movers are being fed with low sulphur fuel only problems can still arise and the engineers must remain diligent. In fact it is the potential problems at this stage that capture most attention for, in all probability, the vessel at this time will be in closed waters and will be manoeuvring.

Though the change over may have been effected completely and efficiently the low sulphur fuel temperature (actually viscosity) still needs to be monitored continuously and carefully. The low sulphur fuel serves as a coolant in the pumps, pipes and passageways through which it passes.

When the engine stops the fuel flow stops and temperature of the oil in the pipes will be raised by the heat in the engine. This can lead to, and all too frequently does, starting difficulties. The leakage of the hot thin oil at the fuel pumps reduces the pump efficiency and desirable atomization pressures are not achieved.

Excessive leakage between the injector needle and body will also depress the pressure at the actual nozzle. Further, the hot oil may gassify during the pump suction stroke and form a compressible cushion which again may depress the atomization pressure.

The effect of poor lubricity is increased wear of rubbing surfaces and over time fuel system components in a low sulphur fuel burning engine will show higher wear than those operating in a higher sulphur content fuel given that both fuels have similar density, surface tension and viscosity characteristics.

The condition of the fuel pumps may be assessed in service by reference to the engine performance and the fuel rack positions. As the wear increases the rack position has to be increased to compensate.

Through careful record keeping it should be possible to detect developing wear an implement remedial measures before the problem becomes acute.

J. Arthur Waddington

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[1] Author's note: This was not always the case; there was much discussion when motor vessel Owners changed from diesel grades to 'boiler' fuel grades in the 1950s and 60s.
[2] Tanks wherein the contents are only the unpumpables.
[3] This must be in addition to any MARPOL samples retained on board. Retention of samples at the testing laboratory could prove advantageous.