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Overview of ‘fuel changeover’ issues and challenges as they affect ECA-SOx compliance

Assistance to Member State Administrations

This overview of the key technical and operational aspects faced by ships when undertaking fuel changeover on entering an ECA-SOx is intended to provide competent authorities with an insight into the particular issues and challenges of that process when assessing compliance with the EU Sulphur Directive 2012/33/EC.

Introduction

From January 1st 2015 the maximum sulphur content of fuel oil used by ships within the Emission Control Areas for SOx (ECA-SOx) as given in both MARPOL Annex VI and the EU Sulphur Directive will reduce from the current 1.00% limit to 0.10 %, except where an approved alternative means (sulphur emission abatement technology) is in use. Outside the ECA-SOx the fuel oil used will remain, for now, to be usually a high viscosity residual fuel oil generally limited to 3.50% maximum sulphur - HSRFO. Whereas much of the 1.00% maximum sulphur fuel oil was, like the outside ECA-SOx fuel oil, a residual fuel oil product, this 0.10% maximum sulphur fuel will mostly be a low sulphur distillate fuel oil – LSDFO. Consequently, for ships operating both inside and outside ECA-SOx, this will represent a major change from existing practice both in terms of the different characteristics of the two types of fuel oils used and the increased sulphur differential between those fuels (Alternative 0.10% sulphur content marine fuel characteristics with storing and handling qualities of HSRFO – such as Exxon’s HDME 50 - are also just being introduced into the market adding to further handling challenges for the crew).

Although the EU Sulphur Directive already requires the in-use fuel oils not to exceed 0.10% sulphur when at berth, this only affects the auxiliary machinery and the changeover is undertaken after the ship is secured at berth. Therefore in these cases the change-over process may simply be limited to starting those engines and other machinery which are already set up on the required fuel and thereafter shutting down those that are not. The extension to using 0.10% maximum sulphur fuel within the ECA-SOx will therefore not only additionally require the main engine(s) and their associated fuel systems to be switched over but also for that changeover to be undertaken while all the systems are in operation and the ship is at sea. Furthermore, since the 0.10% maximum sulphur fuel oils are expected to be produced at very close to that limit, there will be very limited scope for admixture with those fuel oils used outside the ECA-SOx, typically around 2.5% sulphur, and still remain compliant.

1. Fuel changeover challenges

There are a number of technical and operational issues related to the use of these LSDFO type fuels in marine systems, however in terms of the changeover process itself and the demonstration of compliance the following would be identified as the major issues:

1.1. Flushing through of the fuel oil service system

The fuel service system is required to be fully flushed through before entry into the ECA-SOx so that it is only compliant fuel oil which is being used. Given the limited margin between the typical LSDFO sulphur content and the 0.10% limit, this essentially means that it is only the LSDFO which is being used at that point.

In the case of ships with only a single service tank it is generally extremely difficult to completely flush that tank of the existing HSRFO product due to the fact that, for safety reasons, the tank cannot be allowed to be totally run-down before refilling and that there will rarely be a clear or retained HSRFO /

LSDFO interface which moves down as the tank is drawn from, indeed due to 'short circuiting' within the tank it is quite possible that pockets of essentially straight HSRFO remain until eventually dispersed into the other fuel in the tank or disturbed by ship movement. Ships built after 1998 usually have two service tanks for each fuel used on board and therefore can keep the HSRFO and the LSDFO fully segregated up to the changeover valve at the start of the fuel oil service system which therefore ensures that, following changeover, only LSDFO is being fed into the system.

1.2. High fuel temperature changes

However, for all ships arranged to use residual fuel oil there is a need to supply heated (typically 100-140˚C) fuel oil to the engine's injection system and in order to assist in this, these systems incorporate a high level of spill back from that point of use to near the start of the fuel service system itself. Therefore, following the changeover from HSRFO to LSDFO, it is not simply a case of an interface of the two fuels progressing through the system – instead it will be a process of ongoing dilution of the circulated fuel oil in the system with the new (LSDFO) fuel being introduced at the rate of consumption. Consequently it can be very difficult to calculate at what point the fuel oil actually being used is just the LSDFO product, and therefore any calculation will be an estimate only.

1.3. HSRFO pick up from dead end pockets

Additionally, due to the required duplication of components in the fuel service system (pumps, heaters and filters) there will be the ever present prospect of pockets of the previously used HSRFO being retained in the dead-leg sections of pipework. These pockets, over time, will either be gradually diluted out into the LSDFO stream or falling out, possibly due to ship movement, as isolated slugs thereby acting to increase the sulphur content as actually used - either as a temporary slight general increase or as a few occasional peaks.

1.4. Cleaning action mobilising deposits

Furthermore, LSDFO will tend to have a cleaning action within the fuel service system – mobilising deposits of HSRFO and associated sludge adhering to pipe walls and system components. The amount of these depending, in part, on whether the ship enters and leaves ECA-SOx every few days or this is the first visit for a number of years. Since these deposits and sludge will inevitably be of higher sulphur content than the LSDFO itself, the effect will again be to temporarily increase slightly the sulphur content of the fuel oil as actually used.

1.5. Flushing time

The required time for this flushing process therefore not only depends on the design of the fuel system and the known factors of system capacity and consumption rate, but also on a number of potentially highly variable and uncontrollable unknowns. Consequently, while from the known factors it is possible to calculate the estimated time for the fuel service system to be fully flushed out – which may be from an hour to a number of days – there remains the ever present risk, despite the operators best endeavors, that the unknown factors could, under certain circumstances, result in the sulphur content of the fuel oil as used being temporarily somewhat higher than that of the LSDFO as loaded.

2. Managing the changeover transition

Maine diesel engine fuel oil injection systems generally use ram type pumps to provide the injection pressures required. These pumps seal solely by the tightness of fit between the plunger and the pump barrel which, by virtue of the fuel oil's viscosity, restricts flow between these components. Furthermore that tightness has to be managed across the operating temperature range – too tight and the pump will seize / too loose and the fuel oil flow will be such that the required injection pressure will not be generated - in either case the engine will not run with all the attendant consequences whether it is a main, propulsion, engine or an auxiliary, electrical power generating, engine. Therefore an essential part of the changeover process is to manage the transition of the temperature of both the fuel oil and injection system components so that the required viscosity is maintained and the thermal expansion of the components is uniform.

2.1. Viscosity differences

The typical supplied viscosity ranges of HSRFO are around 100-500 cSt at 50˚C – necessitating an injection temperature of between 100-145˚C to achieve 12-15 cSt - whereas for LSDFO supplied viscosities are around 2-8 cSt at 40˚C and are injected at ambient temperature – indeed if viscosity is too low as a result of the temperature being too high, it may be insufficient to support the plunger off the barrel wall resulting in seizures. The consequence of fuel pump seizure or excess spillage is fail to start and maneuver and or loss of power and propulsion (LOP).

2.2. Temperature change rate

Consequently, the change in fuel oil temperature requirements between HSRFO and LSDFO means that the changeover process itself is not simply a matter of swinging over a valve. It is a process where the temperature change rate must be managed to no more than 2˚C per minute to avoid differential expansion of the fuel pump plunger and barrel which could potentially result in their seizure and so stopping of the engine and LOP. During this process it is also necessary to avoid either under or over heating the mixed HSRFO and LSDFO therefore the temperature of the mixed fuels must be constantly managed as their proportion change. Although many ships use a purely manual process to control this changeover a number have instead automatic systems in which the LSDFO inlet valve to the fuel oil service system is gradually opened as the HSRFO inlet valve is correspondingly closed – the changing blend ratio of these two fuels then controls the amount of heating applied at any instant with the temperature gradient thereby being regulated as required.

2.3. Written procedure requirement for changeover

Under MARPOL Annex VI there is a requirement for each ship which undertakes a fuel changeover before entering an ECA-SOx to have a written procedure covering that process which will include the time that process takes and hence the point at which it needs to be commenced in order to be completed before the ECA-SOx boundary. Whether that overall time is set by the flushing process or the allowable temperature gradient it must be recognised that this is not, and cannot be, either an instantaneous action or one where the authority can arbitrarily set a particular duration to this changeover process.

3. Operator concerns at changeover

There are a number of technical and operational reasons why ships' crews may be reticent to undertake fuel changeover as required. Mostly these may be considered as general issues which by training and preparation would be resolved, but in certain cases there could be aspects related to specific fuels. Primarily there is the issue of familiarity with the changeover processes as outlined in Items 1 and 2 above which of course is simply a matter of preparation and training. On ships which are regularly entering ECA-SOx the crew will readily incorporate the necessary actions into their routine operating procedures whereas for other ships, which may never have previously entered an ECA-SOx, the process may initially appear quite daunting.

3.1. Loss of power and propulsion

Concern over of possible loss of either propulsion or electrical power – or even both – may be another issue. While this can occur as a result of operational problems due to a lack of familiarity with the changeover process resulting in a key valve in the system not being duly opened, it is often more a technical problem. For HSRFO the temperature of the fuel at the injectors will normally be controlled to give a viscosity of around 12-15 cSt at which condition it may still be possible to continue to operate despite relatively worn fuel pumps with overlarge clearances between the plunger and barrel. However, on changeover to LSDFO with a possible viscosity of only around 3-6 cSt at the injectors there is not the same resistance to flow through the plunger/ barrel clearance and, as experience from California shows, this results in excessive leakage flow and hence an inability to generate the required injection pressure – resulting in reduced, even no power and an inability to subsequently re-start the engine. Similar problems can be encountered with the pumps in the fuel oil service system where again clearances have become overlarge and while still capable of handling HSRFO when faced with the much lower viscosity of LSDFO cannot supply at the rate required. In these instances it is clearly a case of both maintenance, replacing worn components in a timely manner, and preparation – if an engine or service system has not previously been operated on fuel with a viscosity of the LSDFO then this needs to be duly checked under controlled conditions where any failure will not cause problems or safety concerns at a critical moment.

3.2. Overheating of LSDO

In contrast to the use of HSRFO, and other residual fuels, where the issue is often difficulty in achieving high enough temperatures at the injectors, a problem with the use of LSDFO, and other distillates, can often be to keep them sufficiently cool that they retain sufficient viscosity to still provide supporting hydrodynamic lubrication particularly to fuel injection system components. In changeover from using HSRFO to LSDFO, apart from controlling the fuel oil heater, it is also necessary to ensure than other sources of heat inflows, such as trace heating, are also duly shut down. Additionally there can be the issue of uncontrolled heat flows from, for example, the engine itself which were not a problem, even a benefit, when operating on HSRFO but which can be a real issue with the LSDFO. Again this would be seen as a matter of preparation before the event – tracing out how heating systems can be securely shut down as required and, where means of cooling, even chilling, the fuel are found necessary, these are installed and tested in readiness as required.

3.3. Fuel seepage and excess leakage

A further issue with the changeover from HSRFO to LSDFO, in addition to the cleaning effect already referred to, can be the searching nature of the latter which, together with the temperature differential between the two fuels, results in seepage from pipe flanges, joints, seams and instrument connections. This again is an issue to be resolved by maintenance and once dealt properly dealt with will not be a recurring problem.

3.4. Incompatibility

There is however the issue of incompatibility between the HSRFO and the LSDFO – the effect that on mixing the combined fuel will not be able to retain the asphaltenic material from the former in suspension and that will be instead precipitated as sludge with a tendency to heavily load the filters reducing the rate of fuel flow. However, since this possibility can be fairly accurately predicted, even by onboard tests, and will only occur at the interface between the two fuels it will be a transient problem to be dealt with by closely monitoring the situation and ensuring that filter loading does not accumulate.

3.5. Crew training

Most ships should have addressed the concerns earlier outlined through increasing the awareness of the crews through training and practice. In addition they will have applied a risk assessment which will have identified additional measures such as increased frequency of maintenance checks, reduced service life estimates and other such steps. For these ships where such preparation has been put in place it is to be expected that the fuel changeover process will be a routine operation with no particular concerns

4. Inspection

Inspection and onboard sampling guidelines are under development and to be made available in early 2015 by the EC for the purposes of providing a uniform approach across the Member States for the determination of compliance to the Sulphur Directive.

4.1. Documentation, procedures and records

Ships' crews must be aware of their responsibilities with regard to demonstrating compliance. As part of this they must be familiar with both the documentation and operational aspects of the fuel changeover process. In addition to the written fuel changeover procedures each ship has to have onboard, it is also required to keep records in respect of the completion of any fuel oil changeover prior to entering an ECA-SOx and the commencement of any fuel oil changeover after exiting an ECA-SOx. These records must include the date, time and position of the ship at completion or commencement of changeover as relevant together with the quantities of the 0.10% maximum sulphur fuel oil in each tank at that time. This record is either entered in a log book as prescribed by the ship's Administration or, where there is no such requirement, in another suitable log book. Any inability to produce these procedures and records, together with the relevant bunker delivery notes and associated MARPOL Samples, on demand at inspections or lack of awareness of the actual application of the process will be a sure trigger to a more detailed physical inspection.

As mentioned above, there is the probability that although LSDFO is being supplied into the fuel oil service system not all the HSRFO or associated deposits and sludge may have been flushed through despite allowing more than the calculated time which should be taken in account when assessing the results from fuel oil samples drawn from the fuel oil service system as part of a compliance inspection.

4.2. Ships intent to comply

Neither MARPOL Annex VI nor the EU Sulphur Directive require there to be segregated fuel oil service systems up to the point of use; a common system which handles both HSRFO and LSDFO is fully compliant. Therefore in reviewing samples drawn from those systems which are above the ECA-SOx limit value of 0.10% it is always necessary to consider whether there is a clear intent to comply or evade the requirements. Clearly if the sulphur value determined is that of the HSRFO, there has been no attempt to changeover as required. However, if that value is only marginally above that limit, together with the log records available, does it instead indicate that, despite the crew's best endeavors, for the reasons given above, the changeover was still not complete at the time of sampling. One key point in this would be "What is the sulphur content of the LSDFO being supplied into the fuel oil service system?" – given that there are no open cross connections or other means by which the fuel as being supplied should otherwise differ from the fuel oil as used. Consequently, in that case it may be seen as appropriate to also test a sample of the fuel oil being supplied into the service system and to also assess that result, taking into account as ever test reproducibility[1], before coming to a conclusion.

5. Summary of changeover risks and consequence

a) **Clogging filters – loss of propulsion (LOP)**
b) **Increased leakages –fire risk/ fail to start / LOP**
c) **Overheating of MDO – low viscosity -increased wear of fuel system components, loss of power LOP**
d) **Insufficient flush through time – noncompliance (NC)**
e) **cross contamination from residues of HSRFO possible**
f) **Poor crew awareness increases consequence of NC**

Experiences in California reported by the US Coast Guard

g) **Fuel changeover nearly doubled the number of LOPs;**
h) **This only reduced with increasing experience of vessels crew;**
i) **On average 1 LOP occurred every 3 to 5 days in Californian waters.**

With traffic density in the European ECA-SOx, especially in the English Channel, being much higher than in Californian waters, the **implications of any LOP need to be considered by Member States carefully**, being countered by an awareness campaign.

With sufficient crew awareness, training and investment in preparedness and maintenance the risks of 5(a) to 5(i) can be considerably minimized.

Other technical challenges such as reduced lubricity of LSDFO, 2-stroke cylinder oil requirements, continuous running on MDO requiring tuning and component changes, have not been dis-cussed, as considered out of scope of this document.

[1]A detailed assessment of the various issues related to this point can be found in the cross industry publication: 09 | 2014 CIMAC Guideline 'The Interpretation of Marine Fuel Oil Analysis Test Results with Particular Reference to Sulphur Content' By CIMAC WG7 'Fuels' (http://www.cimac.com).