08.12.2014

İstanbul :

Sayı
Our Reference: 5080

Konu
Subject : **Kükürt Emisyon Kontrol Bölgesine(SECA) Uygunluk ve ilgili yakıt değişiklikleri sorunları ve karşılaşılan güçlükler hususundaki ICS/ECSA Kılavuzu ve İncelemesi Hk.**

Sirküler No: 821 / 2014

Sayın Üyemiz,

İlgi: Uluslararası Deniz Ticaret Odası'ndan (ICS) alınan 2 Aralık 2014 tarih ve MC(14)67 sayılı yazı ve Eki ICS/ECSA Kılavuzu.

İlgi yazıda, yazı Ekindeki " Kükürt ECA (Emission Control Area – Emisyon Kontrol Alanı) Gereksinimlerine Uygunluk hakkındaki Denizcilik Endüstrisi Kılavuzunun ve İncelemenin Üye denizcilik şirketlerine ve denizcilik idaresindeki ilgili yetkililere gereğince dağıtılması istenmektedir. ICS Teknik Müdürü Jonathan Spremulli imzalı İlgi yazıda aşağıdaki bilgiler verilmektedir:

"**ICS Üyeleri, 1 Ocak 2015 tarihinden itibaren yeni kükürt limitlerinin tayin edilen Kükürt Emisyon Kontrol Alanlarında (SECA'lar) yürürlüğe gireceğini bilmektedirler.** Aşağıda belirtilen Dokümanlar, ICS Üyelerine, gemi sahiplerine, gemi işletmecilerine ve mürettebata ve aynı zamanda denizcilik idarelerine yardımcı olmak için, ECSA (European Community Shipowners Association – Avrupa Topluluğu Armatörler Birliği) tarafından da desteklenerek, rehberlik sağlamak, bilgi vermek ve dağıtılmak üzere hazırlanmıştır:

- **Kükürt ECA Gereksinimlerine Uygunluk Konusunda Denizcilik Endüstrisi için Kılavuz**

  Bu doküman gemi sahipleri, gemi işletmecileri ve gemi mürettebatı için Kükürt Emisyon Kontrol Alanlarında (SECA – Sulphur Emission Control Areas) kullanılan gemi yakıtına ait yeni kükürt limitlerine uygunluk ve kendilerini kükürt özelliklerindeki değişikliklere hazırlayabilmek için rehberlik sağlamaktadır. Bu kılavuzda HFO'dan LSF'ye geçişteki yakıt değişikliği işlemi hususunda rehberlik üzerinde odaklanılmıştır.

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İstanbul :

Sayı
Our Reference :

Konu
Subject :

- **ECA-SOx uygunluğunu etkileyen 'yakıt değişikliği' sorunları ve karşılaşılan güçlüklere ait inceleme.**

Bu Doküman, bir SECA'ya girişte yakıt değişikliği üstlenildiği zaman gemilerin karşılaştığı en önemli teknik ve işletmeyle ilgili hususlarla alakalı olarak denizcilik idareleri için bilgi sağlamakta olup, AB Kükürt Direktifi 2012/33/EC'ye uygunluğun değerlendirilmesinde bu işlemle ilgili belli sorunlar ve güçlüklerin kavranmasını kolaylaştırmaktadır.

ICS Üyelerinden, bu sirkülerin EK A ve EK B'sindeki dokümanları üyeleri olan denizcilik şirketlerine ve denizcilik idarelerindeki konuyla ilgili görevlilere mümkün olduğunca geniş şekilde dağıtmaları istenmektedir.

ICS Sekreteryası, bu değerli bilgilerin dağıtılmasını kolaylaştıran ilişikteki iki dokümanın kaleme alınmasındaki değerli katkıları için Alman Armatörler Birliğine teşekkür eder."

İlgi yazı ve iki Eki ilişikte sunulmuştur (Ek-1).

Bilgilerinizi arz ve rica ederiz.

Saygılarımızla,

Murat TUNCER
Genel Sekreter

EKLER:
Ek-1: İlgi yazı ve iki Eki.

DAĞITIM:

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2 December 2014

TO: MARINE COMMITTEE **MC(14)67**

Copy: All Full and Associate Members (for information)

ICS/ECSA GUIDANCE ON COMPLIANCE WITH SULPHUR EMISSION CONTROL AREA (SECA) REQUIREMENTS AND AN OVERVIEW OF ASSOCIATED FUEL CHANGEOVER ISSUES AND CHALLENGES

Action required: To distribute as appropriate the attached guidance and information to member shipping companies and relevant officials in your maritime administration.

Members will be aware that new sulphur limits come into effect in the designated Sulphur Emission Control Areas (SECAs) as of the 1st of January 2015. In order to assist Members, ship owners, ship operators and crews as well as maritime administrations the following documents, co-sponsored by ECSA, have been prepared and are attached for guidance, information and distribution:

- **Industry Guidance on Compliance with the Sulphur ECA Requirements**.

  This document provides guidance intended for ship owners, operators and crew to enable them to prepare for the changes in fuel characteristics and compliance with the new sulphur limits for ships fuel used in in Sulphur Emission Control Areas (SECA). The focus of this guidance is on the process of fuel switch over from HFO to LSF;

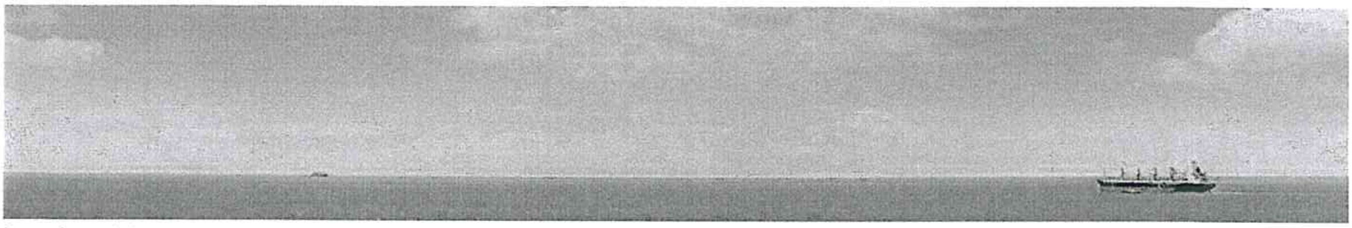
- **Overview of 'fuel changeover' issues and challenges as they affect ECA-SOx compliance**.

  This document provides an overview intended for maritime administrations concerning the key technical and operational aspects faced by ships when undertaking fuel changeover on entering a SECA together with an insight into the particular issues and challenges of that process when assessing compliance with the EU Sulphur Directive 2012/33/EC.

Members are kindly requested to distribute the documents attached as annexes A and B to this circular as widely as possible amongst their member shipping companies and to relevant officials in maritime administrations.

The Secretariat would like to thank the German Shipowners Association (VDR) for their valuable support in the drafting of the two documents attached which has facilitated the distribution of this valuable information.

Jonathan Spremulli
Technical Director



October 2014

Industry Guidance on Compliance with the Sulphur ECA Requirements

Assistance to ship owners, operators and crew

This Industry Guidance shall give assistance to ship owners, operators and crew to prepare for the changes in fuel characteristics and compliance with the new sulphur limits for ships fuel used in in Sulphur Emission Control Areas (SECA) as of January 1, 2015. The main emphasis of this paper lies on the process of switch over from HFO to LSF.

Introduction

As of January 1, 2015, 0:00h, the sulphur content of fuel oil used on board ships within SECAs shall not exceed 0.10% m/m. This is required both by the European Directive n°2012/33/EU of 21st November 2012 as well as Annex VI of the international MARPOL Convention. In most cases, compliance will require the use of Low Sulphur Fuel, LSF (MDO or MGO) by the ship or of the recently offered compliant fuels such as HDME50 with higher pour points and viscosities that require heating. Prior to entry into a SECA, it is therefore required to have fully switched over from any high sulphur fuel in use to the SECA compliant marine fuel. Alternative compliance can be achieved by using fuels with higher sulphur content if exhaust gas cleaning systems are used, the so-called scrubbers.

Current SECAs are the designated areas within 200 nautical miles offshore the coast-line of the USA and Canada, the US Caribbean ECA (waters around Puerto Rico and the U.S. Virgin Islands), as well as the Baltic Sea and North Sea/English Channel in Europe. This paper mainly concentrates on implications of the European SECAs.

Generally speaking, the western boundary of the North Sea SECA is the longitude extending from Brest (France) to Falmouth (U.K.) and further northwards from Strathy Point east of the Orkney Islands (U.K). The northern boundary of the North Sea SECA is the latitude extending from Vågsøy (Norway) to Thorshavn (Faroes). Further, the area is bound by the latitude extending from Skaw to Gothenborg (i.e. entry to the Baltic SECA).

Legal Background

With regard to sulphur oxide emissions the relevant regulation (MARPOL ANNEX VI, Regulation 14.4.3) states:

> *While ships are operating within an Emission Control Area, the sulphur content of fuel oil used on board ships shall not exceed [...] 0.10% m/m on and after 1 January 2015.*

The international MARPOL Regulations is transferred to European law by Directive 2012/33/EU regarding sulphur content of marine fuels. It regulates inter alia the sulphur content of fuels used by maritime transport in the Baltic Sea, North Sea and English Channel. It states in the relevant regulations:

- Member States shall take all necessary measures to ensure that marine fuels are not used [...] within SOx Emission Control Areas if the sulphur content of those fuels by mass exceeds [...] 0,10 % as from 1 January 2015.
  If a ship is found by a Member State not to be in compliance [...] with this Directive, the competent authority of the Member State is entitled to require the ship to:
  - ☐ present a record of the actions taken to attempt to achieve compliance; and

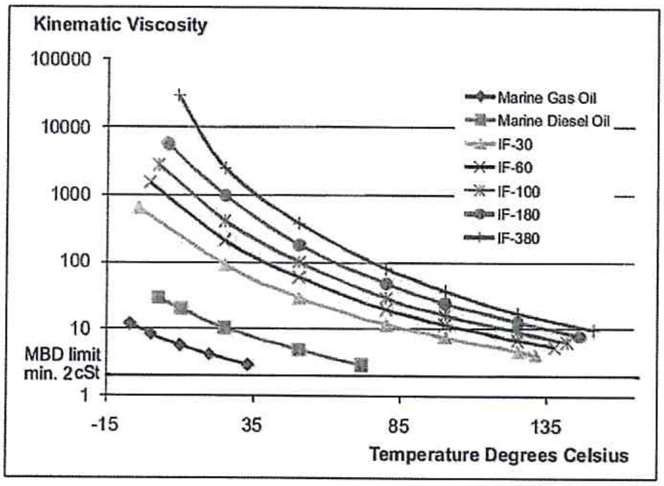


Fig.1: Viscosity of marine fuels as function of temperature (Source: MAN)

- ☐ provide evidence that it attempted to purchase marine fuel which complies with this Directive in accordance with its voyage plan [...] and [...] no such marine fuel was made available for purchase.
- ■ The ship shall not be required to deviate from its intended voyage or to delay unduly the voyage in order to achieve compliance.

Properties and compatibilities of fuels

Energy content per Volume

Between High Sulphur Fuel Oil (HFO) and distillates lies a difference in density of approximately 8%. As the fuel pumps deliver a defined volume of fuel to the engine, this may result in a reduction of available energy for combustion and a potential reduction of maximum power that is not compensated by the higher net calorific value of distillates (~ + 2%). In normal operation of a vessel this will usually not be a problem, but might have a negative impact in extreme circumstances.

Compatibility

Reports further show that modifications in the refinery processes have led to considerable changes in fuel properties. In a report by Chevron (Chevron, July 2007) it is evidenced that the stability of asphaltenes is deteriorated by the visbreaking process. They can form sediment (coagulation is influenced by time and temperature) when the aromaticity of the fuel matrix is changed by blending of HFO and MDO. The change-over procedure from HFO to MGO usually takes a longer period of time, during which there will be a mix of the two very different fuels. As a result of this mixing, the asphaltenes of the heavy fuel are likely to precipitate as heavy sludge, with filter clogging as a possible result (MAN, Primeserve, 2010).

The most obvious way to avoid this result is to check the compatibility between the fuels before bunkering, which can be done either manually with a test-kit on board, or via an independent laboratory. The latter often being too slow a process, as the ship will already have left the harbor before the laboratory returns with the test result.

The risk of an incompatibility of marine fuels is also acknowledged by the ships engine manufacturers. Amongst many, MAN verifies in a report on the operation of MAN B&W Two-stroke Engines on low-sulphur fuels that when switching from heavy fuel to a distillate fuel with low aromatic hydrocarbon content, there is a risk of incompatibility between the two products.

HDME50 is compatible with Gas Oil, however, is sensitive to mixture with low sulphur residual fuels. Above 2% of residual fuel precipitation of asphaltenes may occur. Temperature control of the fuel may be required to prevent paraffines to fall out.

Viscosity

For optimum combustion the fuel has to be distributed very evenly in the engine, which requires a certain viscosity at the injection nozzle. Fuels with high viscosities are heated up to temperatures above 100°C. At this temperature the viscosity of MDO will be below the limit of 2cSt (see Fig.1). That means when switching from HFO to MDO the temperature in the relevant fuel system has to be reduced to and kept at values not exceeding 50°C. The use of fuels like HDME50 offer the advantage to reduce the temperature control requirements.

Preparing considerations for fuel switchover

Fuel requirements

Depending on the operational profile the required amounts of HFO and LSF from January 1, 2015 onwards and the resulting tank capacities should be estimated. The considerations should include the requirements of the charterer, if applicable. If the ship operates solely within a SECA and only LSF will be used, the decision should include how to proceed with any remaining High Sulfur Fuel (HSF) on board. Depending on the decision, a disposal should be organized.

In cooperation with the charterer contact fuel suppliers, negotiate and decide on sulphur content and date of bunkering. (Remember that nearly all ships in the SECA or entering will require LSF).

If a fuel switchover before entering into the SECA is necessary a sulphur content below 0,10% is advantageous because the time for switchover and the use of LSF outside the SECA can be reduced with a low sulphur content of LSF. If a switchover will take place often, sulphur contents near 0,10% should therefore be avoided.

Storage tank arrangement

LSF should not be heated in the storage tanks to prevent unwanted reduction of viscosity (cf. Fig.1); however, for ships operating in winter in the Baltic Sea the pourpoint of LSF should

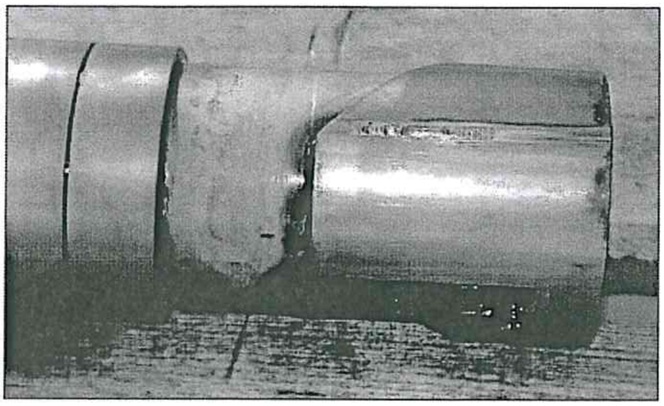


Fig. 2: Damaged plunger of injection pump

be checked. To prevent unwanted heating, HFO tanks and temperature sensitive LSF tanks should be separated.

After longer use sediments will build up in fuel tanks that could go into solution when the tank is used for LSF, resulting in contamination and potential non-compliance. Therefore tank cleaning might be necessary and should be arranged in time.

Fuel system

Separated bunkering lines could prevent unwanted contamination during bunkering operations. HFO and LSF should use separate pipes as much as possible.

The differences in temperature and viscosity could lead to leakages in the system. It is advised to timely plan countermeasures. If necessary, sealings etc. should be replaced to prevent fire risks.

To prevent contamination of LSF during switchover a special fuel pipe should transfer the fuel backflow from the machinery to the HFO tank. When switchover is completed the backflow should be returned as usual.

It is advised to clearly study the fuel circuit, including tank return of the pipes, in order to quantify the possible tank contamination (matter of volume and frequency, special care to be considered at low consumption/high return volume). Depending on result, risk of filter-clogging etc. should be analysed and corrective action/procedure implemented.

Most fuel pumps currently in use are displacement-type pumps, such as screw or gear pumps. According to manufacturers, these pumps are designed to operate with a minimum fluid viscosity of 4 cSt. An assessment should be made of all fuel pumps on board to determine whether they are able to operate with the lower viscosity and lubricating properties associated with the low sulphur marine distillate fuel and to consider the need for modification or replacement.

Considerations for ships with repeated switchover

The design and arrangement of the fuel system has an influence on the LSF used during the switchover process that hat to take place outside the SECA to comply with the requirement that the switchover has to be completed when the ship enters the SECA. For ships with only one service tank this can be an important amount of fuel. A separate service tank for LSF would reduce time and effort for switchover.

Above that the calculation of the LSF consumption outside the SECA and the required time for switchover as well as an analysis of possible improvements of the fuel system are recommended. Depending on the number of switchovers the additional operating costs could pay back the investment for an improvement of the fuel system within the restrictions existing ships inevitably have.

Proposed installations for inspection purposes

Port State Authorities may require samples of the fuel currently used for combustion. This will require taking a sample form the feed or returning line of the engines. Because of the lower fuel pressure it is recommended to install a permanent and safe sampling valve in the return line combined with temperature measurement. If a data logger permanently stores this temperature in reasonable time intervals because of the different temperature of HFO and LSF, this may serve as evidence that switchover was completed correctly and compliant fuel is used for combustion.

Diesel engines

Contact your engine manufacturer with regard to the special requirements when operating on LSF, e.g. minimum viscosity at engine inlet, lubrication oil requirements, recommendations for changes in the fuel system etc. In the following some general findings are given.

As stated above the fuel viscosity at the injection nozzle should not be below 2cSt that means the temperature should not be above 45 to 50°C. This is especially important at low loads and idling. Excess fuel not required for combustion is returned to the service tank. The material temperatures of the engines are kept around 80°C by cooling. If a high amount of fuel is recirculated a gradual temperature increase may follow with a reduction of viscosity below 2cSt and resulting combustion and starting problems. A fuel cooler in the return line could prevent this.

During switchover the temperature in all components of the fuel supply system to the engine has to be reduced from a temperature above 100°C to a value corresponding to the required viscosity. The allowable maximum temperature transient is about 2°C/min for switch-over to prevent seizure at the injection pumps (Bartmann, 2014). Due to the increase of pressure at the injection pump from 600 bar (1960ies) to 1600 bar (today) with common rail injection in the course of engine development, the wall thicknesses were increased making the pumps more vulnerable to fast temperature changes (Fig. 2).

Therefore time should be allowed to maintain the temperature gradient recommended by the engine manufacturer, e.g.

2°C/minute, in a controlled manner while switching fuel. This will in many cases be necessary in order to avoid a thermal shock to the system, e.g. seizure of fuel injection pumps, and/or other operational problems that may occur due to low viscosity and/or rapid temperature changes.

Injection pumps are designed with quite small tolerances and benefit from sulphur content in fuel to ensure lubrication. By running on MGO, these elements may seize due to lack of lubrication, with the result of potential loss of power. Worn injection pumps may have increased leakages leading to alarms and disturbances in operation. Consequently reduced maintenance intervals may be necessary.

MAN for example acknowledges these risks and underlines that low viscosity of the marine fuel used may cause seizures, starting difficulties and problems operating at low load. Statistical data shows that the majority of the supplied fuels have viscosities in the range of 2.5 – 4 cSt (at 40 degC). As parameters requiring increased focus operating on distillate fuels, MAN describes:

- Viscosity (> 2 cSt, preferably >3 cSt);
- Change-over between HFO and MDO / MGO;
- (Compatibility, thermal shocks, gassing of hot gas oil);
- And vice-versa (MDO/MGO to HFO);
- Lubricity (max. 460 mm according to ISO12156 (HFRR test));
- Correlation between low sulphur and cylinder oil BN.

MAN recommends to test the engines low viscosity limit, to install "tools" in the fuel system where possible (cooling/change over) and to focus on cylinder condition (lub oil consumption/BN).

Boilers

Boilers already operate on LSF in European Ports, so no special considerations are expected.

Recommended operating instructions

Detailed operating instructions including precise documentation of performance will prevent mistakes and failures during bunkering and switchover as well as disputes with Port State Authorities.

Bunkering

Operating instructions for bunkering should include:

- Clear identification of bunker lines for HFO and LSF
- Acceptable sulphur content (No value on Bunker Delivery Note above 0,10 is acceptable, inaccuracy of measurement is no argument!)
- Test of compatibility (if applicable)
- Place and procedure to take MARPOL sample
- Documentation of bunkering procedure
- Storage of samples
- Procedures and notifications if LSF is not available or available fuel exceed required limits

Switchover

Conduct initial and periodic crew training along operating instructions. Detailed operating instructions for switchover should include:

- Planning of switchover including calculation of time and location of start of switchover depending on:
  - ☐ Volumes in the fuel system to be flushed (tanks, pipes etc.);
  - ☐ Sulphur contents of HFO and LSF as stated on BDNs;
  - ☐ Fuel consumption at current engine power.
- Exact & detailed definition of switchover process: Sequence and time intervals of opening and closing of defined valves, starting of pumps etc.;
- Checks for possible leakages in system seals, gaskets, flanges, fittings, brackets and supports;
- Check of system pressure and temperature alarms, flow indicators, filter differential pressure transmitters;
- Fuel system inspection and maintenance schedule;
- Test of main propulsion machinery, ahead and astern, while on marine distillates.
- Ensure start air supply is sufficient and fully charged prior to maneuvering;
- How to proceed in case of bad weather and sea state conditions in the sea area for switchover that prevent switchover for safety reasons.

Documentation

Please note that Section H of Oil Record Book-Part I requires each ship to record details of every bunkering. The information to be recorded is

- Place of bunkering;
- Time of bunkering;
- Type and quantity of fuel oil and identification of the tanks were the fuel was stored.

The documentation of switchover should clearly state:

- Exact time of start and end of switchover;
- Corresponding positions of ship;
- Power of main engine(s);
- Inventories of all tanks especially at times of tank switchover.
- Interdiction of the use of LSF in a vessel without approved modifications
- Charterers must provide the vessel with fuels of the necessary sulphur content to allow the vessel to trade within the emission control zones ordered by the charterers. The charterers are also required to use bunker suppliers that operate in accordance with Regulations 14 and 18 of MARPOL Annex VI.

- The responsibility for the storage, management and use of the fuels supplied rests with the owners as does the emission control requirements of MARPOL Regulations 14 and 18.

Navigational Rights and Freedoms under UNCLOS

The sulphur content limits set out under Regulation 14.4.3 MARPOL ANNEX VI and under Art. 4a para. 1 b) EU Directive 2012/33 apply to vessels of all flags within ECAs. According to some European Member States, some EU maritime administrations are planning measurements of sulphur emissions with remote sensing technology to check compliance that a maximum sulphur content of 0.10% m/m is being emitted as from 1 January 2015. Some Member States have announced to install remote "sniffer technology", e.g. under the Great Belt Bridge.

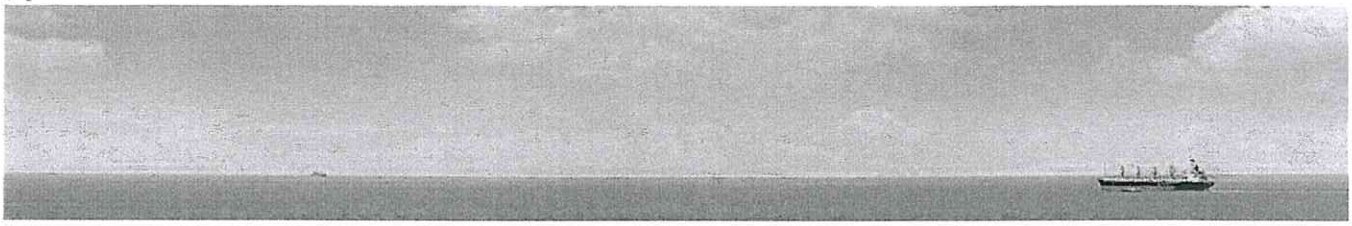
From a legal perspective, the use of such systems is allowed. In accordance with the United Nations Convention on the Law of the Sea (UNCLOS) States can check and enforce against foreign flagged vessels in their ports for non-compliance with marine environmental regulations (esp. Art. 212, 222 UNCLOS).

Only as regards vessels under flags of MARPOL ANNEX VI States, a port State may also enforce against vessels in their ports in respect of violations of the sulphur emission limits, which occurred beyond the internal waters, territorial waters or exclusive economic zone (EEZ), where the evidence so warrants (esp. Art. 211, 218 UNCLOS).

Under UNCLOS, coastal States only have restricted at-sea enforcement powers as to foreign vessels navigating in its territorial sea or its EEZ. Foreign vessels enjoy the right of innocent passage in the territorial sea (Art. 17 pp. UNCLOS) and the freedom of the high seas in the EEZ (Art. 58 para. 1, 87 para. 1 a) UNCLOS).

The coastal State may only undertake physical inspections "on the spot" of foreign vessels navigating in its territorial sea, where there are clear grounds for believing the vessel has, during its passage in the territorial sea, violated its laws and regulations adopted in accordance with UNCLOS or applicable rules and standards for the prevention, reduction and control of pollution from vessels, such as the sulphur limits under MARPOL ANNEX VI.

Inspections of foreign vessels under flags of MARPOL ANNEX VI States navigating in its EEZ or territorial sea may only be undertaken, where there are clear grounds for believing the vessel has, in its EEZ, committed a violation of the sulphur limits under MARPOL ANNEX VI, resulting in a substantial discharge causing or threatening significant pollution of the marine environment (Art. 211, 220 UNCLOS).



November 2014

ECSA
European Community Shipowners' Associations

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).