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**Thanh Hai Truong**
Ho Chi Minh City University of Transport, Ho Chi Minh city, Vietnam

**Van Vang Le**
Ho Chi Minh City University of Transport, Ho Chi Minh city, Vietnam

**Thi Minh Hao Dong**
Ho Chi Minh City University of Transport, Ho Chi Minh city, Vietnam

**Correspondence**:
**Thanh Hai Truong**
Ho Chi Minh City University of Transport, Ho Chi Minh city, Vietnam

# An Overview on Low Sulfur Fuel for Marine Engines

**Thanh Hai Truong, Van Vang Le, Thi Minh Hao Dong**

**Abstract**
According to the new regulations of the International Maritime Organization (IMO), starting from January 1, 2020, large ocean shipping vessels (types of ships used to transport goods through the oceans) must use use low-sulfur fuel, only 0.5% such as MGO (marine gasoil) or ULSFO (ultra-low sulfur fuel oil) to replace heavy oil with sulfur content 3.5% (or the rest of the bunker oil) is being widely used today. This transformation aims to cut sulfur-dioxide emissions (SO2) in shipping operations. Currently, the global shipping industry accounts for 13% of global SO2 emissions every year. If not converted to clean fuels with low sulfur content, air pollution due to SO2 toxic gas from shipping vessels will increase 570,000 premature deaths worldwide in the period 2020-2025. The new IMO regulation will affect at least 60,000 ocean freight vessels and make the shipping industry cost $ 50 billion more annually. This cost burden led to warnings and noisy arguments about the quality and availability of new fuels as well as calls to delay implementation of the new IMO regulations.

**Keywords:** sulfur oxides, alternative fuels, low-sulfur fuel (LSF), marine engines

## 1. Introduction

There is a general consensus in the shipping industry that customers will incur additional fuel costs as long as shipping companies have to be clear and transparent about the costs they have to pay to operate ship. Shippers expect shipping rates to rise significantly at the beginning of next year. In the past five years, shipping rates have been break-even points for shipping lines due to excess shipping capacity, forcing shipping lines to embark on a battle to lower prices to gain market share. Many shipping companies around the world operate unprofitable during the past decade and the shipping industry's business outlook is expected to remain bleak until 2021 when the global economy slows down and US trade tensions with China and the European Union (EU) are expected to persist.As a ship owner bears the sole responsibility for ensuring that the ship installations use low sulfur marine fuels required by the regulations specified by the EC, International Maritime Organization (Annex VI to MARPOL Convention) and by national regulations of other countries [1,2]. From the viewpoint of operational safety and the ship itself, it is important that engines, pumps, boilers and boiler burners be properly adjusted for the maintenance and burning of low sulfur marine fuels. In which the modification of the installations are necessary due to the requirement to use such fuels, such installations shall have been previously approved and then subjected to the survey to demonstrate the possibility of their safe operation [1].

Regulations for prevention of air pollution from ships included in Annex VI to MARPOL 73/78 specify, among others, limits on maximum sulfur content in marine fuels. Annex VI entered into force on 19 May 2005 [3]. After three years of its application, the need for numerous amendments to the regulations for prevention of air pollution from ships. Therefore, a number of amendments to this Annex were adopted to take effect on 1 July 2010. In the new proposals, the idea of SOX Emission Control Area – SECA has been amended and extended to constitute Emission Control Area – ECA. This is due to:

− Introduction in Regulation 14 of Annex VI to MARPOL of a new noxious factor associated with emission from ships, which has not been covered by the rules so far, and with taking control of the compliance with the requirements concerning the emission of Particulate Matter – PM [4];

− Introduction in Regulation 13 of Annex VI to MARPOL provisions on special requirements concerning NOX emissions Emission Control Areas. According to the new requirements, ECA means an area where special obligatory requirements have been adopted to prevent, reduce and control air pollution with SOX, NOX, and particulate matter and their attendant adverse impacts on human health and the environment. New ECAs cover the present SOX Emission Control Areas, i.e. the Baltic Sea and the North Sea inclusive of its access routes and the English Channel [1, 4].

Emission of environmentally harmful sulfur oxides (SOX) originated from the combustion on ships is being reduced, by setting limits of the sulfur content of marine fuel oils, to comply with the requirements of Regulation 14 [1,3,5]. New limits on the sulfur content of marine fuel oils used outside the ECAs shall be reduced as follows Table 1 and Fig 1.

**Table 1:** Limits on sulfur content in marine oil fuels [1]

| Effective from | Sulphur content limits [%m/m] | |
|---|---|---|
| | SOX, ECA | Total |
| 15 May 2005 | 1.5% | 4.5% |
| 01 July 2010 | 1.0 % | |
| 01 January 2012 | | 3.5% |
| 01 January 2015 | 0.1% | |
| 01 January 2020 | | 0.5% |

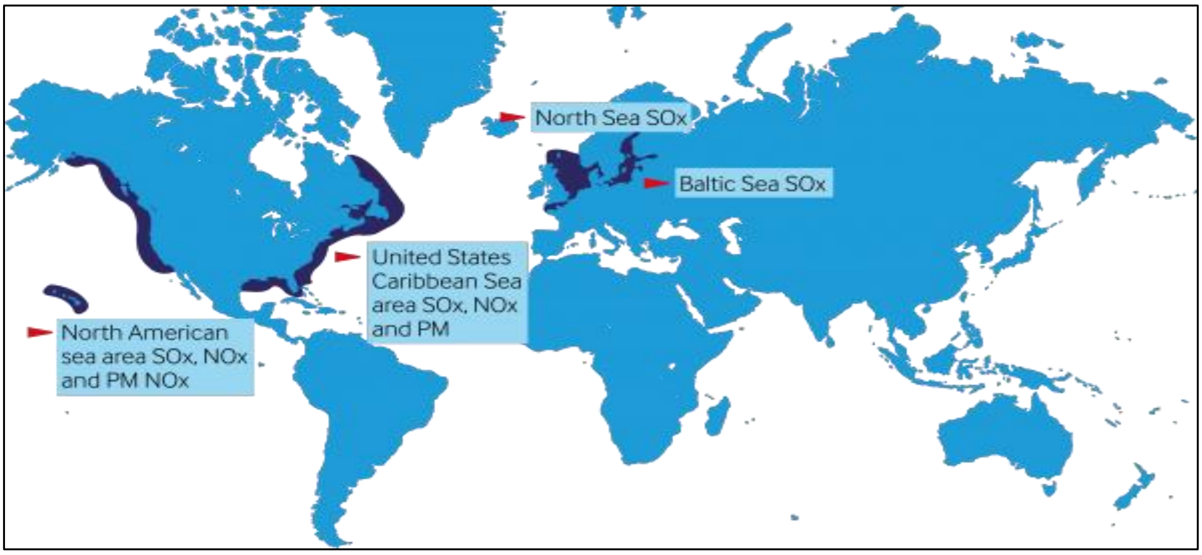


**Fig.1:** Limits of sulfur content in oil fuels according to Annex VI to MARPOL [6]

Low-sulfur fuel (LSF) that generally comply with the regulations mentioned above include Marine Gas Oil (MGO) defined as DMA grade, DMX grade or DMZ grade, and Marine Diesel Oil (MDO) defined as DMB grade in ISO 8217. It can be seen from Table 1 that, the disadvantages of LSF are:

*Low viscosity*: The viscosity of low sulfur fuel oil is extremely low compared to the viscosity of heavy fuel oil (C) and marine diesel oil (A). (Min. 1.5 cSt at 40˚C in DMA grade of ISO 8217). As a result, internal leakage in FO pump, increase in flow ability of fuel from the fuel injection nozzle, are likely to occur, and the effect of these on various equipment is a cause for concern.

*Low lubricity*: Since the lubricity of fuel oil depends on the viscosity, the lubricity of LSF is low. Consequently, abnormal wear is likely to occur in the sliding/contact parts of pumps.

*Acidity*: The sulfur content in fuel oil changes to acid salt because of combustion, but most of it becomes sulfur dioxide ($SO_2$) while a part of it gets converted to anhydrous sulfurous oxide ($SO_3$). Anhydrous sulfurous oxide reacts with water in scavenging air or water generated during combustion to form sulfuric acid ($H_2SO_4$). With the reduction in sulfur content, the amount of sulfuric acid generated also reduces. When cylinder oil with high alkali base number for heavy fuel oil (C) in diesel engines is used continuously, deposits may be formed, and abnormal wear of the cylinder liner may occur.

*Flash point*: Fire hazard increases because the flash point of low-sulfur fuel oil, such as gas oil, is low. The use of fuel oil with flash point below 60˚C is prohibited according to the SOLAS Convention (Regulation 4.2.1.1 of II-1). On the other hand, the lowest flash point of gas oil of DMX grade defined in ISO 8217 is 43˚C; the introduction by mistake of gas oil with such low flash point into ships is a cause for concern.

## 2. Methods for using ULS

The lubrication of cylinders is an important point to be borne in mind for low speed diesel main engines. Until now, it was commonplace to use high alkali base number cylinder oil for heavy fuel oil (C) (sulfur content 1.5% or more), but engine and oil manufacturers are recommending the use of low alkali base number cylinder oil for low-sulfur fuel oil (sulfur content below 1.5%). As measures for low-sulfur fuel oil, it is important to monitor the exhaust gas temperature to check abnormalities of rings/liners, and to carefully check the condition of the rings during the maintenance and inspection work. Besides, the viscosity and residual carbon in low-sulfur fuel oil in recent years are generally low. There is a high probability that clarified oil with high aromatics is used as cutter stock in the manufacturing stages of such fuel oil. Fuel oil with high aromatics tends to become ignitable, combustible, and also defective; such fuel oil generally hinders combustion because of the abnormal wear it causes in rings/liners.

Currently, the low lubricity of gas oil is the most focused and important issue related to properties of low-sulfur fuel oil. Problems associated with low lubricity include abnormal wear of plunger/barrel and oil leakage in fuel injection pump for generator engine. Generally, the lubricity of fuel oil is considered to be due to oil film formed because of viscosity and due to the lubricity of the sulfur content itself. Generally, such low viscosity is not considered during the design stage of fuel injection pump having sliding/contact parts. To prevent problems due to low lubricity beforehand, fuel oil cooler may be installed, or agents may be added to fuel oil for improvement of lubricity. The following methods may be considered as immediate measures on board the ship: Reduce engine output, Reduce cylinder cooling water temperature, Tentatively increase the cylinder oil quantity, Raise the scavenging air temperature, Advance fuel injection timing, Enhance fuel cleaning, Mix with normal fuel, Add combustion accelerating agents. To use ULS, it must be cooled in order to improve the viscosity. The cooling energy is gotten by the absorption cooler. The diagram of absorption cooler is shown in Figure 2.

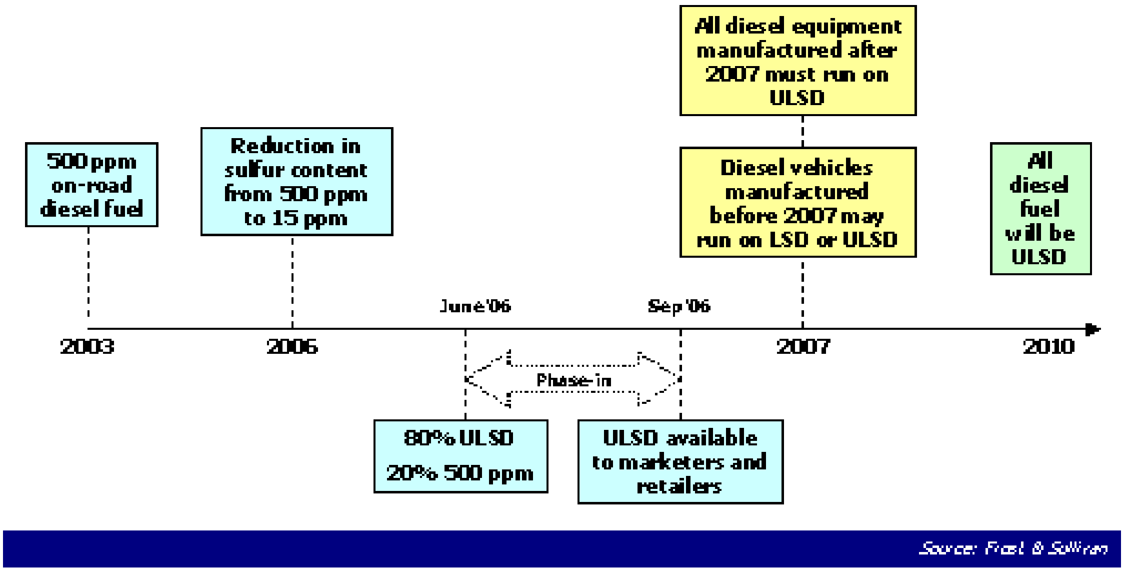


**Fig.2:** The diagram of absorption cooler

The absorption cooler is used to cool the ULS. Although achievable, it is difficult to optimize all of these factors at the same time. This complicates operation on fuels in the lowest end of the viscosity range. To build in some margin for safe and reliable operation and to maintain the required viscosity at engine inlet, installation of coolers will be necessary in those fuel systems which do not have these (Figure 3). For the very low viscosity distillates, a cooler may not be enough to cool the fuel sufficiently due to the cooling water available on-board. In such a case, installation of a 'chiller' is a possibility. This solution is not used extensively. The fuel viscosity not only affects the engine fuel pumps. Most pumps in the external system (supply pumps, circulating pumps, transfer pumps and feed pumps for the centrifuge) also need viscosities above 2 cSt to function properly [6]. We recommend contacting the actual pump maker for advice.

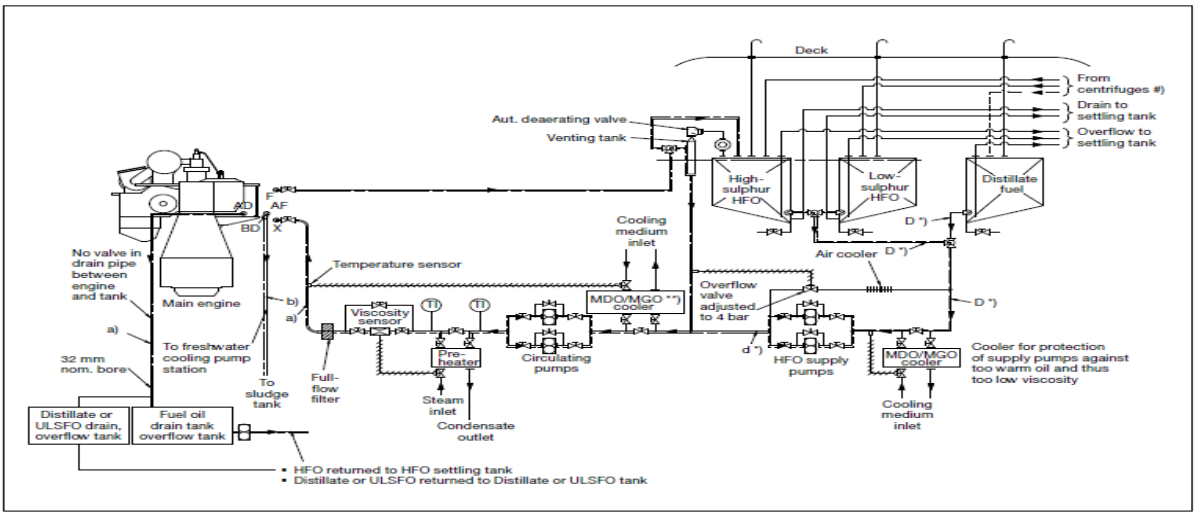


**Fig.3:** Fuel system with cooler in the circulating system

During normal operation, a small amount of fuel leaks through the main engine fuel pumps. This is clean fuel which, traditionally, is lead back to the HFO settling tank. The new SECA rules will enforce more operation time on distillates or ULS, thus it should have the drain system to update [6]:
Two overflow tanks - one tank with piping leading to the HFO settling tank and one tank with piping leading to the distillate or ULS tank;
Installing an extra line from the overflow tank - the overflow tank will have piping both to the HFO settling tank and to the distillate or ULS tank, the overflow tank has to be emptied before switching to a different fuel.

**3. Conclusions**

For use of low-sulfur fuel oil in machinery and equipment designed for marine diesel oil (A) and heavy fuel oil (C), the measures are studied by different machinery manufacturers for the various problems. However, the measures differ according to the specifications of each machinery, so it is necessary to adhere to the recommendations of manufacturers on whether low-sulfur fuel oil can be used or not, and on the modification methods. Various troubles are anticipated to occur because of the problems mentioned above when low-sulfur fuel oil is used; fortunately, however, no instances of major accident or damage have been reported until now. This is attributed to the appropriate response and measures adopted by shipbuilders and machinery manufacturers possessing the latest technologies and ship management companies and ship owners engaged in the operation of ships.

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