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Fuel oil bunkering mechanism and ways ahead in strategic enforcement

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Fuel Oil Bunkering Mechanism and Ways Ahead in Strategic Enforcement

By

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Declaration

I certify that all the material in this dissertation that is not my work has been identified and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my personal views and are not necessarily endorsed by the University.

Signature: 

Date: 17th September 2021

Supervised by: **Dr Alessandro Schonborn**

Assistant Professor

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Abstract

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The shipping business relies on the bunkering industry for supplying fuel oil that ships consume. The safe operation of vessels also depends on the quality of the fuel oil supplied since bad quality fuel oil can cause various problems, such as frequent clogging of filters, fuel pump damage, excessive wear of cylinder liners, fuel valve damages and malfunctioning, exhaust valve seat damages, turbocharger fouling any many others which could lead to breakdown and even stoppages of the vessel. The cost of bunkers is the most expensive running cost. The International Maritime Organization (IMO) has implemented the 0.5% maximum sulphur limit on marine fuels and this has further raised challenges for shipping companies. Shipping companies desire that the quantity of fuel oil received during bunkering is not less and that the quality is as per the specifications in the order.

However, the bunker market has some dishonest suppliers and barge operators who, driven by the associated immediate financial benefits, manage to supply lesser quantity and/or poor quality of bunker fuel oil. This creates problems for bunker buyers worldwide, additional costs for the buyer, unwarranted mistrust, and disputes amongst the owners, charterers, and other parties involved are some of them.

This dissertation is a study of marine fuel oil bunkering mechanism and offers potential and feasible solutions and strategies which, if implemented, could reduce the menace of supplying lesser quantity and/or poor quality of bunker fuel oil. A bunker buyer's preventive measures to minimize the possibility of receiving short delivery and poor quality bunker have also been identified.

The qualitative research method was used to evaluate these issues. Primary data has been collected using a questionnaire. The respondents selected were from different areas of the shipping operation, having extensive knowledge of bunkering and all other related issues. The secondary data was gathered from peer-reviewed journals, articles, and books.

The study concludes that the bunker market needs to be more transparent to prevent this menace. Also, if a bunker licensing mechanism is adopted and enforced, things are likely to improve drastically.

KEYWORDS: Fuel Oil, Bunkering, Quality, Quantity, Regulation, Licensing, Enforcement

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List of Abbreviations

BIMCO	Baltic and International Maritime Council
IMO	International Maritime Organisation
ISO	International Organization for Standardization
ASTM	The American Society for Testing and Materials
CCAI	Calculated carbon aromaticity index
CII	Calculated ignition index
DNV	Det Norske Veritas
SECA	Sulphur Emission Control Area
ECA	Emission Control Area
BDN	Bunker Delivery Note
H&M	Hull and Machinery
STS	Ship-to-ship transfer
BDR	Bunker Delivery Receipt
COQ	Certificate of Quality
BS	Bunker Supplier
PS	Product Supplier
QMS	Quality Management System
MSDS	Material Safety Data Sheets
SOLAS	The International Convention for the Safety of Life at Sea
MARPOL	International Convention for the Prevention of Pollution from Ships
SOPEP	Shipboard Oil Pollution Emergency Plan
HSE	Health, Safety and Environmental Standards
WMU	World Maritime University

Chapter 1.0. Introduction

1.1. Background

The maritime industry is indispensable for the world. A significant portion of the world trade is carried by ships. Initially, sails were used on ships to harness wind energy for commercial shipping. Steamships became popular in commercial shipping from the start of the nineteenth century to the later part of the twentieth century and gradually displaced the sail ships. Motor ships gained dominance in the second half of the twentieth century. The diesel engine was invented in 1892, and subsequently, the ships with four-stroke marine diesel engines became functional twenty years later. As ships grew bigger and faster, two-stroke designs took a significant lead by 1930. Between World Wars I and II, marine diesel engine propelled ships accounted for nearly 25% of the total tonnage (Chevron, 2012).

Consequently, further innovations on diesel engines made the use of residual fuels possible in diesel engines. Later cylinder lubricating oils with high alkalinity were developed to offset the effects of the acids produced during the combustion of residual fuel oil with high sulphur. The rate of wear reduced and became close to those observed with distillate fuel. Ships powered by residual fuel oil started becoming popular, and by the late 1960s, motor ships had left behind the steamships in commercial shipping. Motor ships constituted 98 per cent of the world fleet at the turn of the twenty-first century (Chevron, 2012).

Heavy Fuel Oil (HFO) is obtained from the leftovers or the heavier fractions of the refining process of petroleum. HFO is also known as residual fuel since it primarily consists of residual products of petroleum refining. Distillate fuel oils are made from the lighter fractions and are obtained by cooling the vapours generated during the distillation of crude oil. They are therefore the cleaner products of petroleum and include diesel oil and gas oil. Residual fuel oils are rich in asphaltenes and consist of complex mixtures of aliphatic and aromatic hydrocarbons, with a small amount of sulfur, nitrogen, and oxygen compounds. They may be combined with distillate fuel to improve some properties for operational and/or environmental performance. These residual fuels are predominantly used on ships for propulsion, heating and power generation due to their relatively low cost and are commonly referred to as bunker fuel oil (Bracken et al., 2011).

Bunkering of ships is a mechanism wherein fuel oil is supplied to merchant vessels for use on board in the main engine for propulsion, the auxiliary engine for power generation, auxiliary boilers, etc. Fuel is supplied to vessels through fixed pipelines from terminals or by road trucks or motor vehicle barges (BIMCO, 2018).

1.2. Problem Statement

Ships trade globally. In the case of long voyages, the capacity of bunker tanks on board may not be sufficient, and hence bunkers have to be purchased at intermediate ports. Although there are numerous bunker ports worldwide, few ports account for a significant fuel oil supply. Singapore, China, the US, UAE, Netherlands, South Korea are the major bunker fuel oil supplying ports. Some bunker suppliers follow unethical practices and provide reduced quantity and/or contaminated fuel to the ships. Receiving a reduced amount of bunker causes financial losses to the purchaser. Contaminated fuel can lead to many severe problems like blocking fuel filters, damage to fuel injectors and fuel pumps, fouling of turbocharger and many others. Even the possibility of blackout and consequent grounding cannot be ruled out (Fisher & Lux, 2004).

With the introduction of 0.5% sulphur cap from 1st January 2020, concerns in regard to the quality of the bunker have increased. Many vessels are not fitted with exhaust gas scrubbers, so there has been an increase in demand for fuel oil having low sulphur content, and accordingly rates have increased. The compositions and properties of fuel oil with low sulphur content available in the market may vary significantly since different types of fuel blends are used. Non-distillate low sulphur fuel can have high levels of catalytic fines (cat fines) due to the refining processes and consequent blending with cutter stocks to lessen sulphur content. Cat fines are highly abrasive and increase the wear rate of engine components. Stability of fuel oil is associated with the risk of asphaltene contents precipitating out and blocking filters. This could cause blackout, loss of propulsive power and may even lead to collision and grounding. For blended low sulphur fuel oil stability becomes a major concern (International Chamber of Shipping, 2019).

Bunker quality issues may lead to many legal claims among the various parties involved in shipping. Bunker quality disputes regularly exist between the ship owners and the time charterers. The effect of IMO sulphur cap regulations is likely to increase the number of these disputes. In cases of engine damage due to bad quality bunker, there could be a growth in the claims from bunker buyers against the bunker traders and suppliers. Also, claims by the vessel owners under the Hull and Machinery insurance policies would increase (Birch & Wallace, 2020).

The problem to be addressed by this dissertation is "fuel oil bunkers received on board at times are short of the stipulated quantity and/or not as per the prescribed quality standards which leads to unwarranted losses and disputes amongst the various parties involved".

1.3. Aim and Objective

To ensure that the operational problems and legal disputes relating to fuel oil bunker supply quantity and quality are avoided, ship operators and shipboard personnel need to be fully aware of the problems that could arise during the bunkering of marine fuel oil. Steps must be taken to ensure that the ships receive the stipulated quantity of fuel oil onboard as per the given specifications. A thorough understanding of the problems that may be encountered related to fuel oil quality and quantity may help address some of the fuel oil bunkering problems at the source itself.

The aim of this research is to prevent or reduce the supply of reduced quantity and/or lower quality of bunker fuel oil to vessels by proposing some reforms.

The objectives are:

- To identify all the measures by which bunker suppliers manage to deliver a lesser quantity of bunker.
- To identify reasons for delivery of a bunker of inferior quality.
- To identify the best practices for fuel oil bunkering and suggest some changes in regulations to reduce quantity and quality issues.

1.4. Research Question

Following are the questions which would be probed during this research:

Question 1: How issues relating to quantity arise during bunkering?

Question 2: How issues relating to quality arise during bunkering?

Question 3: What could be the best practices for bunkering fuel oil on board to reduce quality and quantity issues?

1.5. Methodology

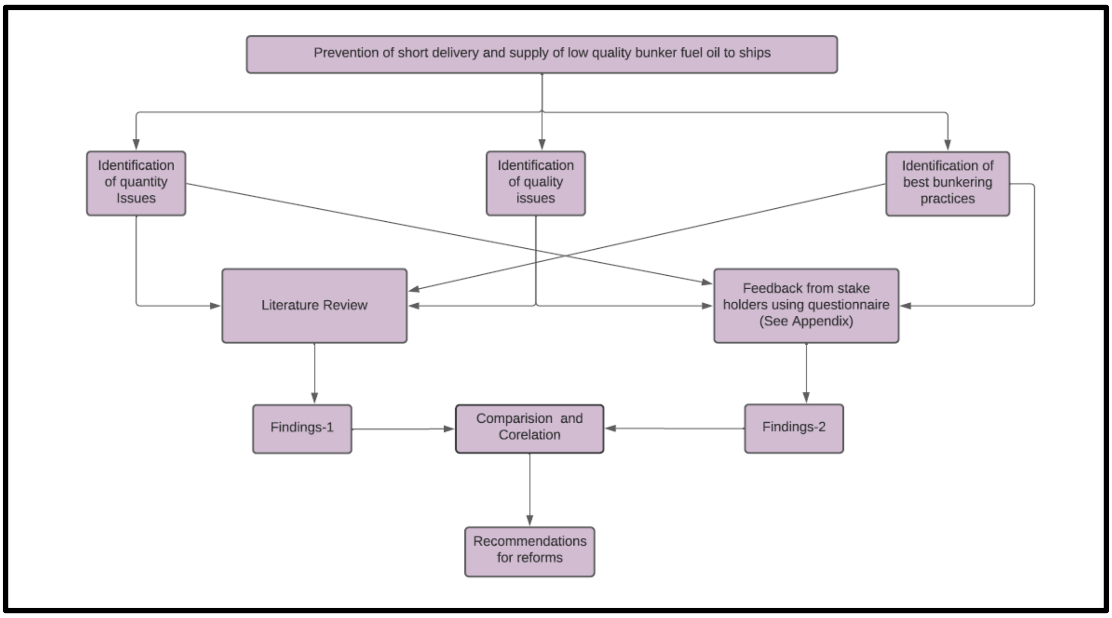

Figure 1: *Research Method* (Conceptualised by author)

The schematic diagram of the methodology used has been illustrated in Fig-1. The qualitative method was considered the most suitable method to investigate the issue since the idea was to obtain an overall view of the problem and not to compare the participant's answers. This method provides multiple ways to collect information and understand the concerns. In addition, some descriptive statistics have been used to elucidate the points better.

The first step was to collect secondary information about bunkering issues from peer-reviewed journals, scientific publications, articles, books and websites. The researcher then conducted informal discussions with Marine Chief Engineers and Marine Technical Superintendents to form an overall opinion about fuel oil bunkering issues.

All the identified ways adopted by bunker suppliers for short-deliver and reasons for the supply of inferior quality fuel oil to vessels were then compiled, which are listed below:

- Deliberate increase of Fuel Oil Volume by mixing air
- Deliberate Short Delivery by using some tricks
- Fraud in Documentation
- Involvement of Ship Personnel
- Issues in the Supply Chain

To better understand the bunker-related issues and collect primary data, the researcher decided to gather information at the ground level through survey research. Survey research is the process of collecting information from competent individuals (Ponto, 2015). The participants should be experts in the subject and must also be ready to share their experiences. A survey requires formulating questions, gathering and analyzing the data collected (Miles & Gilbert, 2005).

A semi-structured questionnaire was designed on the issues identified and the possible remedies. The questionnaire comprised thirty questions, twenty-one were multiple-choice, and nine were open-ended (see appendix). The questionnaire consisted of questions on personal identification, followed by questions on quality and quantity related issues encountered during bunkering. The researcher also sought suggestions on improving the bunkering process pertaining to procedures, technical aspects, training, policies, etc. The questionnaire had been approved for viability by the research supervisor and had the World Maritime University (WMU) ethics committee's approval. The semi-structured questionnaire enables the comparison of similarities and differences in the participant's answers. The open-ended questions allow the participants to freely elaborate their point of view on all the issues and possible solutions.

Based on technical knowledge and experience, the participants were chosen from various Shipping Companies. Marine Chief Engineers and Shore-based personnel of Shipping Companies who best understand bunkering issues were requested to respond to these questionnaires. The idea was to get feedback from different points of view. The questionnaire was distributed to the Chief Engineers who work on board ships and are directly responsible for the bunkering operations and the Technical Managers of ships who are mainly based in the shipping company's office and supervise vessels from an engineering aspect and are responsible for all technical and operational related issues.

Google form was used to carry out the survey. This was considered the most appropriate as it allowed the consent form and questionnaire to be sent out to the participants by email, thereby making the process of sending the questionnaire to the participants and collecting their responses less cumbersome. In addition, Google form also requires less time for the participants to answer.

The researcher then analyzed the information received from the survey together with those obtained from books and articles. Solutions that could reduce the menace of supplying lesser quantity and/or inferior quality of bunker fuel oil to ships were then formulated.

1.6. Limitations

This research requires analysing the bunkering process at various ports. However, in the prevailing Covid -19 scenario, the researcher had no access to the participants, ships and ports. The researcher had to depend solely on literature review and information received through the questionnaires. The researcher could not witness the actual illustration of the on-ground scene. Information received from shipping companies, bunker suppliers, and authorities have been presented in a general manner to avoid conflict of interest. The limited available time has also been a constraint for the research.

1.7. Organisation

This dissertation is divided into six chapters.

Chapter one gives a brief insight into this study.

Chapter two describes the origin of fuel oil, the various refining processes, the quality parameters, the off-spec fuel, fuel oil contaminants, and quality and quantity management.

Chapter three deals with the details of the bunkering procedure on ships, fuel oil sampling and its analysis. Some of the methods adopted by bunker barges to deliver less quantity have also been discussed in this chapter.

Chapter four considers the various regulatory and legal frameworks regarding the bunker fuel oil for ships like the Solas and Marpol regulations, the International Organization for Standardization (ISO) standards.

Chapter five looks at the findings, analysis and interpretation of the data collected through the questionnaires.

Chapter six provides some preventive measures against bunker disputes, proposals to reform the bunkering mechanism, a brief conclusion and scope for future research.

Chapter 2.0. Management of Quality and Quantity

2.1 Quality of Marine Fuel Oil

Marine Fuel oils are complex hydrocarbon mixtures consisting of alkanes, alkenes, cycloalkanes and aromatic hydrocarbons along with low nitrogen, sulphur, and oxygen concentrations. They are made from crude oil using various refining processes. Depending on the source of crude oil, the refining process, the additives used, and some other factors, the compositions of various fuel oils may vary. The hydrocarbon compositions, boiling point, additives used distinguish the various fuel oils from one another.

Fuel oil used onboard may originate from different regions of the world. Historically fuel oil used onboard ships had no significant problems; however, the evolution of a new refining process using complex catalytic cracking fuel oil grades with different properties have originated. This has led to occasional variations in the fuel oil specifications.

The quality of fuel oil consumed affects the performance of the ship's equipment. The fuel oil of good quality will enhance the vessel's performance and contribute to environmental protection.

The D396 standard of the American Society for Testing and Materials (ASTM) has classified fuels in six categories. Categories 1 and 2 are distillate fuels, categories 5 and 6 are residual fuels, and category 4 represents blended fuel made of distillate and residual fuels. Marine fuels used onboard are generally fuel oil no.6, commonly known as Heavy Fuel Oil (Laffon, 2014).

2.1.1 Origin of Fuel

Fuel oil is obtained from crude oil by refining. Crude oil comprises a series of hydrocarbons having varied boiling points and molecular weights. They are found in different parts of the world and have different properties. Table -1 shows the common crude oils along with some of their properties.

Table 1*: Some Analyses of Typical Crude Oils*

Country	Venezuela	UK	Nigeria	Iran	Indonesia
Type of Crude oil	Boscan	Brent	Brassriver	Iran Heavy	Ardjuna
Density @ 15 °C	0.9987	0.8336	0.8204	0.8703	0.8414
Sulphur %	5.5	0.26	0.09	1.65	0.11
Viscosity	90,000sus @ 100°F	3.72cSt @40°C	32.9sus @100°F	9.81cSt @100°F	3.74cSt @100°C
Vanadium ppm	1200	1.6		88	
Pour Point	+10	-3	+2	-21	+24

Table Note: From "An analysis of the practical technical and legal Issues" (Fisher & Lux, 2004)

Boscan crude obtained from Venezuela is heavier, has fewer lightweight components and a higher amount of asphaltic material. The viscosity is high due to high contaminants, including vanadium, sulphur, nickel and other metals. These crudes require blending with lighter components .

Brent crude obtained from the UK is light and has a low pour point. Lower levels of sulphur and metals are present. The residue of this crude oil is much less viscous than Boscan crude.

Brass River crude obtained from Nigerian has similar properties to the Brent crude. However, this crude oil has a lower sulphur content.

Iranian crude oil has high sulphur, nickel and vanadium content and a very low pour point, The residue from this crude has many contaminants.

Ardjuna crude obtained from Indonesia has the highest pour point. The residue of this crude contains very little sulphur, vanadium and nickel.

2.1.2 Quality Parameters

Fuel oil must maintain the stipulated quality standards to prevent detrimental effects on the main propulsion engine and other auxiliary machinery. Fuel oils are extracted from crude oil in refineries using various complex processes, and there are chances that fuel may not be of the required quality.

Ships emit pollutants that impact health and climatic changes. Fine particulate matter, sulphur oxides (SOx), and nitrogen oxides (NOx) that ships emit can cause premature mortality and morbidity. SOx emissions from ships could lead to formation of sulphate (SO_4) which causes harm to human health and is also a cause for acidification of the terrestrial and marine environments.

The principal quality parameters of fuel oil are:

- Density- Density is a measure of mass per unit volume. The ship's fuel treatment equipment limits the density of fuel oil which can be used onboard. Centrifuges onboard operating with a water seal cannot efficiently remove water from fuel with a density higher than 991 kg/m^3 (Bracken et al., 2011).
- Viscosity- This is determined by a fluid's resistance to flow. Viscosity varies with temperature, and as fuel oil is heated, it becomes less viscous and flows more easily.Since viscosity depends on temperature, it is specified at a standard temperature. These temperatures are 40°C for distillate fuel oils and 50°C for residual fuel oils (Bracken et al., 2011).
- Flash Point- This is the minimum temperature at which enough vapours are given off, which would ignite when a flam is inserted. The flashpoint of fuel being used has a bearing on shipboard safety (Bracken et al., 2011).
- Pour Point-This is the minimum temperature at which the fuel oil can flow. On-board ship fuel oils are required to be heated to achieve adequate pumping viscosity (Bracken et al., 2011).
- Carbon Residues-This gives information regarding the formation of carbon deposits at high temperatures in the combustion spaces. The carbon residue of

fuel is only an indicator since the carbon deposits will also depend on other factors like ignition quality, engine maintenance, engine settings and power outputs (Bracken et al., 2011).

- Ash- These may be naturally occurring elements or metals present in the crude oil or added during the refining process or other contaminations and include sand, rust, scale, and dirt (Bracken et al., 2011).
- Water- The presence of water, particularly seawater in fuel oil, can cause serious problems. A chemical reaction may take place between the sodium in the seawater and vanadium present in the oil, leading to high-temperature corrosion. Water can be removed by settling the fuel oil in the settling tanks, heating in the settling tanks for better separation and using purifiers. Water levels up to 0.5% v/v in residual fuels are acceptable as per ISO standards (Bracken et al., 2011).
- Sulphur- The amount of sulphur depends on the origin of crude oil and the amount of blending with low-sulphur components. This is one of the most problematic constituents in marine fuel oil. Sulphur in fuel oil forms sulphur oxides (SO_X) on combustion, and this can dissolve in water and produce sulphuric acid. Sulphuric acid being corrosive can damage engine components and also the environment through acidic rains. Cylinder lubricating oils are alkaline and prevent acid attacks on the liners and the combustion spaces. Acid corrosion of the exhaust gas uptakes is reduced by maintaining the exhaust temperatures below the recommended levels (Bracken et al., 2011).
- Vanadium and Sodium-Vanadium and sodium occur naturally in crude oil. The presence of vanadium in fuel oil becomes a significant issue when high levels of sodium are also present. Vanadium and sodium oxidised during combustion to form a sticky, semi-liquid salt, which could deposit on high-temperature surfaces leading to high-temperature corrosion. This causes damage to the exhaust valves and turbochargers.This problems can be reduced by the use of materials like stellite and nimonic steels, modified engine designs, temperature

control, good maintenance and improved operational conditions (Bracken et al., 2011).

- Aluminium and Silicon-Aluminium and silicon can occur in traces naturally in crude oils. They may also come as contamination with alumino-silicates which are used as catalysts in the crude oil refining process. These catalytic fines (cat-fines) are extremely hard and damage engine components like fuel valves, fuel pumps, cylinder liners and piston rings. Effective shipboard fuel oils treatments methods like settling, purification and filtration can reduce cat-fines to acceptable levels (Bracken et al., 2011).
- Sediments-The amount of sediments in fuel oil is a measurement of the fuel oils cleanliness and stability. Fuel oils with total sediment of greater than 0.1% are likely to give rise to fuel-handling issues like frequent clogging of fine filters and operational issues with purifiers (Bracken et al., 2011).
- Compatibility- Two or more fuels can be termed compatible if on commingling these fuels there is no material separation. The asphaltenes present would not precipitate when fuels are mixed if they are compatible. Issues relating to incompatible fuel oils can lead to major sludge formation. Incompatible fuel oils are a significant cause of bunker disputes (Bracken et al., 2011).
- Stability- Stability refers to the quality of fuel oil to remain unchanged and not to produce sludge during normal storage conditions. Unstable fuel oil can lead to sludge formation, which may choke filters, block fuel lines and cause deposits in tanks and centrifuges (Bracken et al., 2011).
- Ignition Quality-This refers to the ability of fuel oil to ignite and is the time taken between injection in the combustion space and the beginning of ignition. This is generally calculated from the calculated carbon aromaticity index (CCAI) and the calculated ignition index (CII). Generally, CCAI values are in the range of 800–870 for residual marine fuels. The ignition and combustion of residual fuel are significantly affected by the pressure and temperature in the combustion chamber. Slow-speed engines are more resistant to the ignition

quality of fuel oil as they provide more time for ignition and combustion (Bracken et al., 2011).

Table No – 2 shows some important fuel properties, its implications and whether it is affected by separation.

Table 2*: Important Fuel Oil Parameters*

Fuel property	Implication	Affected by separation
Density	Bunker price and separator adjustment	Not affected
Viscosity	Injection temperature and required heating/cooling	Not affected
Water	Corrosion and deposits in tank	Strongly
Micro carbon residue	Deposits in engine	Not affected
Sulphur	Emissions, lubrication and base number (BN)	Not affected
Sediments	Separator (and filter) load	Strongly
Ash content	Engine wear	Moderately
Vanadium	High temperature corrosion in engine	Not affected
Sodium	Deposits and corrosion in engine from NaCl	Strongly
Aluminium + Silicon	Abrasive wear from cat fines	Strong to moderate
CCAI	Engine ignition quality	Not affected
Pour point	Filter clogging	Not affected
Flash point	SOLAS and classification societies rules generally require temperatures at a minimum of 60°C	Not affected

Table Note: From "The Alfa Laval Adaptive Fuel Line BlueBook"(Alfa Laval, 2018)

2.1.3 Shore-based Refining

Crude oils are natural resources found in different regions of the world. They are complex organic compounds of carbon and hydrogen. Marine fuel oils are made from crude oils in refineries. Depending upon the proportion of hydrogen and carbon and the structure of the molecular chain in the hydrocarbon, crude oils can be classified as Paraffinic crude, Naphthenic crude or Aromatic crude.

- Paraffinic crude oils have significant paraffinic components and low bitumen content. They usually yield more distillate products than naphthenic and aromatic crudes. They primarily contain straight and branched chain hydrocarbon structures and have high pour-points.
- Naphthenic crude oils have a cyclic atomic structure and a low pour-point.

- Aromatic or Asphaltic crude oils are of benzene ring structures and are remarkably stable. The residues obtained from these crudes are used in the construction and road-building industries.

The refining of crude oil produces many valuable products, including gases, various distillate products and residual marine fuel oil. Residual marine fuel oils are obtained from those products of the crude oil refining process which remain after distillation.

Atmospheric Distillation

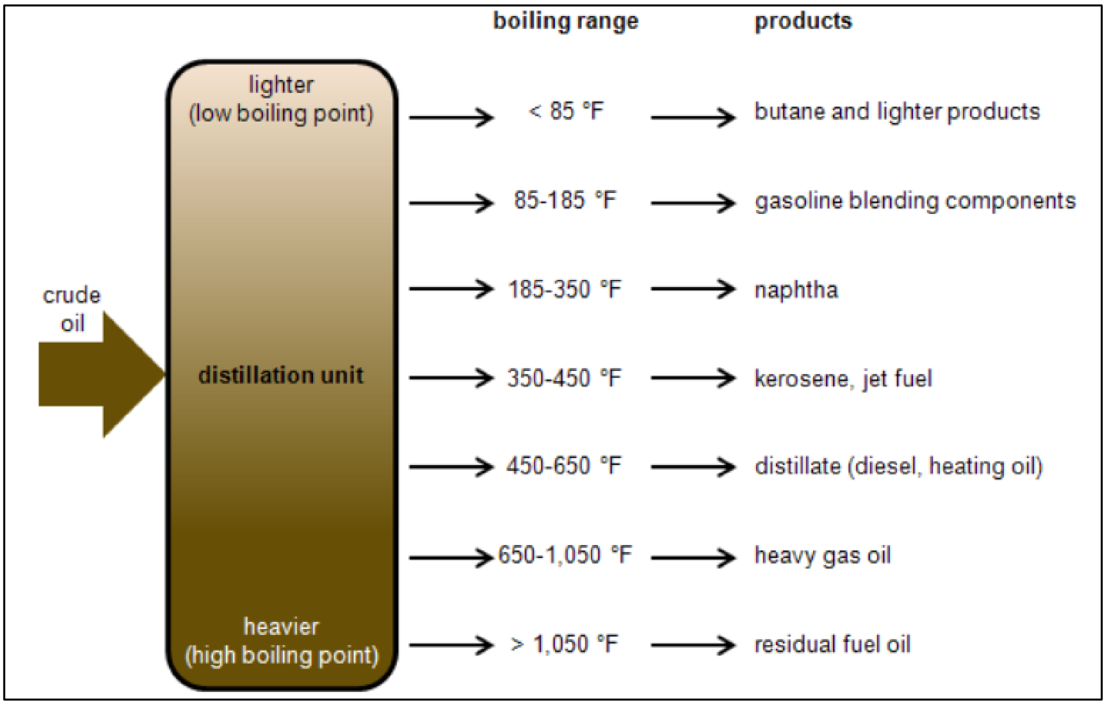

Figure 2: *Crude oil distillation unit and products* (U.S. Energy Information Administration, 2012)

Atmospheric distillation is the traditional method of refining crude oil and is shown in Figure 2. Crude oil is separated into different fractions by gradually heating to about 350°C. The lighter products boil off and are cooled down, collected and condensed back. Condensation occurs in the fractionating column, and the products obtained range from gases from the upper end to residues at the lower end. The various products obtained are petroleum gases (propane and butane), jet fuel, petrol, naphtha, kerosene, vaporising oil, gasoil, diesel oil, heavy diesel oil and residues.

Vacuum Distillation

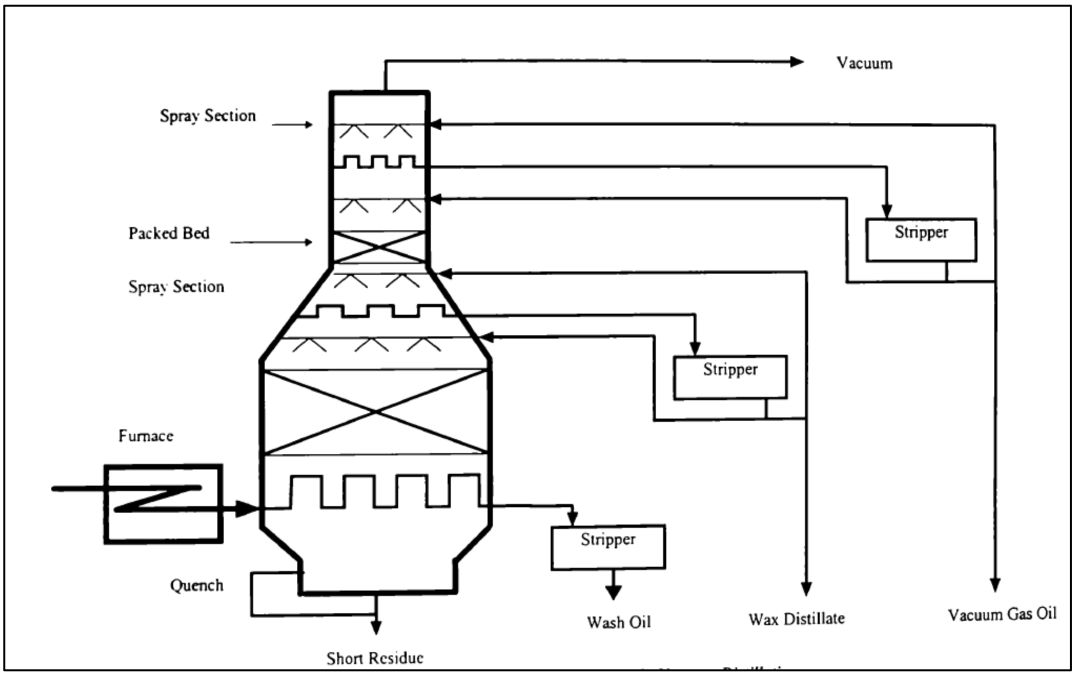

Figure 3: *High Vacuum Distillation* (Fisher & Lux, 2004)

In order to get the maximum amount of distillate product from the crude, the residues from atmospheric distillation are further refined at reduced pressures and high temperatures. This is known as vacuum distillation and is shown in Figure 3.

Secondary Refining

Due to the fuel crisis of the 1970s and 1980s and the increase in demand for distilled products, refineries started secondary refining or cracking. This process follows the atmospheric and vacuum distillation and is carried out by the substantial increase in heating (thermal cracking) or by the use of catalysts (catalytic cracking).

Thermal cracking

In thermal cracking, the pressures is raised to 70 bar and the temperatures up to 750°C. The large hydrocarbon molecules crack further, break into smaller fractions, and hence more products are recovered from the crude oil using this process.The heavy residues from vacuum distillation are thermally cracked to reduce their viscosity, known as vis-breaking. This reduces the amount of cutter stock required to reduce viscosity. Figure 4 shows a vis breaking process.

Vis Breaking

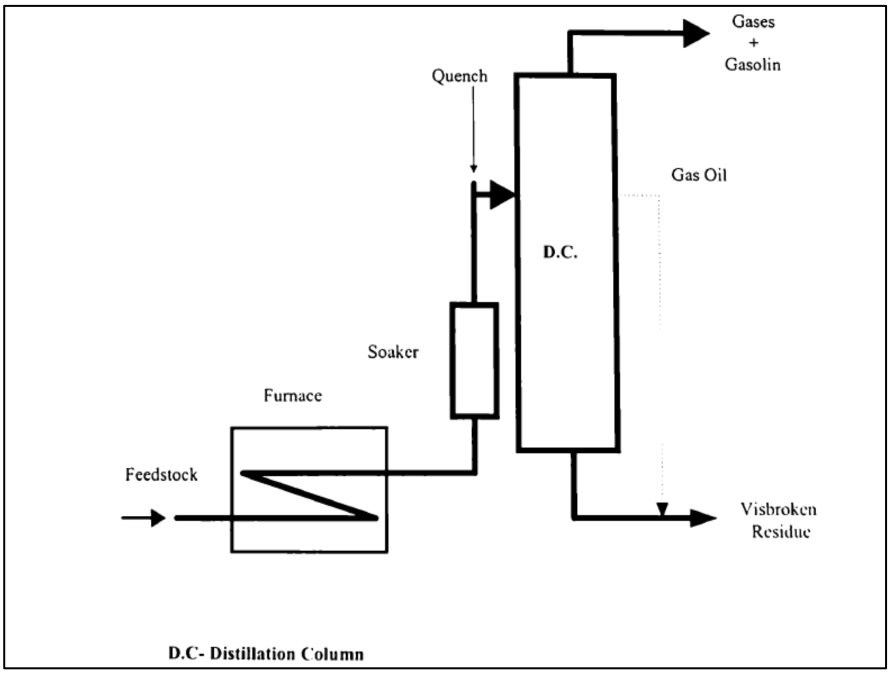

Figure 4*: Shell Soaker vis breaking process* (Fisher & Lux, 2004)

Catalytic cracking

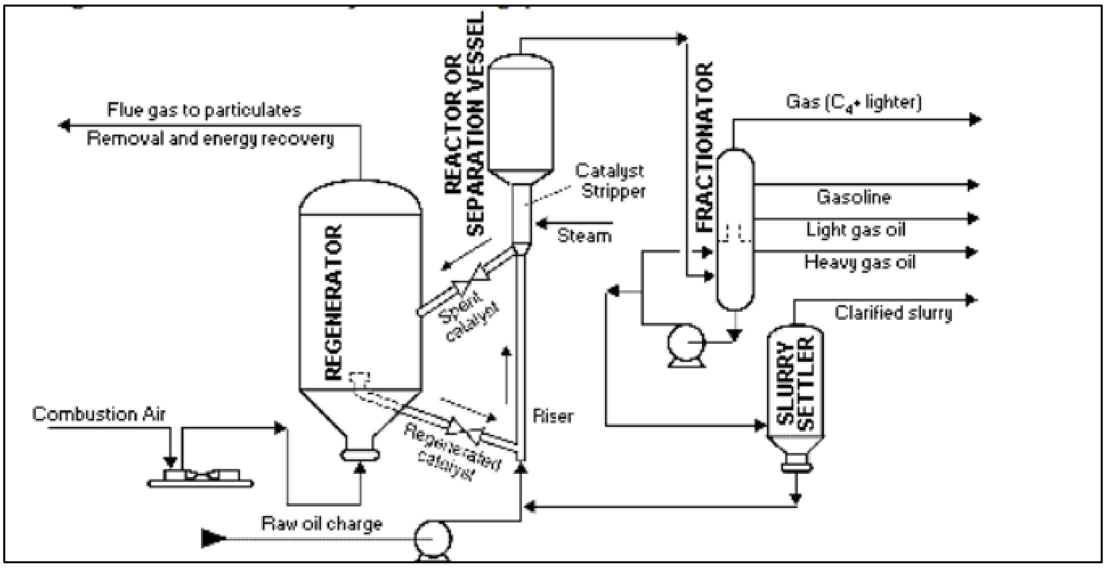

Figure 5*: Fluid catalytic cracking* (U.S. Energy Information Administration, 2012)

Catalytic cracking is another process of breaking large hydrocarbons into smaller fractions to recover more products from crude oil. Catalytic cracking is carried out at high temperatures by the use of catalysts for cracking. The catalysts are very hard and abrasive materials, generally aluminium and silicon. They remain unchanged in the process, and since they are expensive, the refineries try to recover them for subsequent use. Catalytic cracking yields poorer quality residues and from these marine fuel oils are produced. Also, the catalysts which may remain could cause significant damage to the engine components. Figure 5 shows the catalytic cracking process.

Blending

The majority of marine fuel oils are diluted with distillates or cutter stock to achieve the required specifications for use onboard ships. Cracking and blending affects the quality and characteristics of marine fuel oils and lead to an increase in fuel density, more significant stability issues, increase in sediment, the problems related to catalytic fines and poor ignition quality.

2.1.4 Trends in Fuel Quality

Heavy fuel oil has been used as marine fuels since 1960. The quality of fuel oil is dependent mainly on the crude oil's origin and the subsequent refining and blending procedure. The quality records of fuel oil show a rapid decline in quality with an increase in density and carbon residues of fuel oil in the late 1970s and early 1980s. The oil crisis in 1973 and 1979 had led to the deployment of more sophisticated refining processes like secondary refining and fluidized catalytic cracking (FCC). These innovations had made it possible to extract the lighter petroleum products further leading to deterioration in the quality of residual marine fuel. The general trends observed are fuels becoming more aromatic thereby having a negative impact on ignition and combustion, increase in the density of fuels world-wide, increase in cat fines in fuel due to introduction of new cat crackers and increasing in chemical contamination of fuel like polymers and corrosive chemicals (Odland, 2005).

Extensive damages to the engines had been reported, and the engine manufacturer had to come out with recommendations on the fuel oil to be used in their engines. With further increase in quality issues, Det Norske Veritas (DNV) introduced a fuel quality testing program in 1981.

The density specified by engine manufacturers decides the suitability of fuel for marine diesel engines. Density becomes an essential parameter for fuel purification on board. The oil must be of a density that is adequately different from water since purifiers use centrifugal force. Viscosity is also an important deciding factor for the use of marine fuel. Various grades of marine fuel oil based on their density are used on board like IFO 380 and IFO 180 having viscosity of 380 and 180 centistokes respectively.

The British standards were used since 1982. Subsequently, ISO 8217 standards were established, and quality standards were set for marine fuel oil. However, ISO has not limited the sulphur content. Significant work has been done in setting the standards for marine fuels worldwide since 1978. ISO 8217 (Marine Fuel Species) standards came in 1987, and since then amendments are incorporated in every new edition to meet more stringent environmental requirements. ISO 8217:2010 has been remarkably amended, and it now defines seven classes of distillate fuel oils (including one for emergency diesel engines) and six classes for residual fuel oils. RMA 10 grade has been introduced and RMG and RMK grades have been enlarged to include different grades of viscosity. RMF and RMH groups have been eliminated, and sulphur limits have been removed from residual fuel limits. ISO 8217:2012 was published in 2012 as a response to issues about H_2S content measurement. Presently ISO 8217:2017 standards are available. Table No - 3 and Table No - 4 shows the ISO 8217 -2017 quality standards for marine distillate fuel oil and marine residual fuel oil.

Table 3: *Marine Distillate Fuel Oil ISO 8217-2017 Standards*

Characteristic		Unit	Limit	Category ISO-F-							Test method(s) and references
				DMX	DMA	DFA	DMZ	DFZ	DMB	DFB	
Kinematic viscosity at 40 °C		mm^2/s [a]	Max	5,500	6,000		6,000		11,00		ISO 3104
			Min	1,400	2,000		3,000		2,000		
Density at 15 °C		kg/m^3	Max	–	890,0		890,0		900,0		ISO 3675 or ISO 12185; see 6.1
Cetane index		–	Min	45	40		40		35		ISO 4264
Sulfur [b]		mass %	Max	1,00	1,00		1,00		1,50		ISO 8754 or ISO 14596, ASTM D4294; see 6.3
Flash point		°C	Min	43,0	60,0		60,0		60,0		ISO 2719; see 6.4
Hydrogen sulfide		mg/kg	Max	2,00	2,00		2,00		2,00		IP 570; see 6.5
Acid number		mg KOH/g	Max	0,5	0,5		0,5		0,5		ASTM D664; see 6.6
Total sediment by hot filtration		mass %	Max	–	–		–		0,10 [c]		ISO 10307-1; see 6.8
Oxidation stability		g/m^3	Max	25	25		25		25 [d]		ISO 12205
Fatty acid methyl ester (FAME) [e]		volume %	Max	–	–	7,0	–	7,0	–	7,0	ASTM D7963 or IP 579; see 6.10
Carbon residue – Micro method on the 10 % volume distillation residue		mass %	Max	0,30	0,30		0,30		–		ISO 10370
Carbon residue – Micro method		mass %	Max	–	–		–		0,30		ISO 10370
Cloud point [f]	winter	°C	Max	–16	report		report		–		ISO 3015; see 6.11
	summer	°C	Max	–16	–		–		–		
Cold filter plugging point [f]	winter	°C	Max	–	report		report		–		IP 309 or IP 612; see 6.11
	summer	°C	Max	–	–		–		–		
Pour point (upper) [f]	winter	°C	Max	–	– 6		– 6		0		ISO 3016; see 6.11
	summer	°C	Max	–	0		0		6		
Appearance				Clear and Bright [g]					[c]		see 6.12
Water		volume %	Max	–	–		–		0,30 [c]		ISO 3733
Ash		mass %	Max	0,010	0,010		0,010		0,010		ISO 6245
Lubricity, corrected wear scar diameter (WSD) at 60 °C [h]		µm	Max	520	520		520		520 [d]		ISO 12156-1

Table Note: From “Petroleum products - Fuels (class F) - Specifications of marine fuels” (ISO, 2017)

Table 4: *Marine Residual Fuel Oil ISO 8217-2017 Standards*

Limit	Parameter	RMA 10	RMB 30	RMD 80	RME 180	RMG				RMK		
						180	380	500	700	380	500	700
Max.	Viscosity at 50°C (mm²/s)	10.00	30.00	80.00	180.0	180.0	380.0	500.0	700.0	380.0	500.0	700.0
Max.	Density at 15°C (kg/m³)	920.0	960.0	975.0	991.0	991.0				1010.0		
Max.	Micro Carbon Residue (% m/m)	2.50	10.00	14.00	15.00	18.00				20.00		
Max.	Aluminium + Silicon (mg/kg)	25	40		50	60						
Max.	Sodium (mg/kg)	50	100		50	100						
Max.	Ash (% m/m)	0.040	0.070			0.100				0.150		
Max.	Vanadium (mg/kg)	50	150			350				450		
Max.	CCAI	850	860			870						
Max.	Water (% V/V)	0.30	0.50									
Max.	Pour point (upper) in Summer (°C)	6		30								
Max.	Pour point (upper) in Winter (°C)	0		30								
Min.	Flash point (°C)	60.0										
Max.	Sulphur (% m/m)	To comply with statutory requirements as defined by purchaser										
Max.	Total Sediment, aged (% m/m)	0.10										
Max.	Acid Number (mgKOH/g)	2.5										
	Used lubricating oils (ULO): Calcium and Zinc; or Calcium and Phosphorus (mg/kg)	The fuel shall be free from ULO, and shall be considered to contain ULO when either one of the following conditions is met: Calcium > 30 and zinc > 15; or Calcium > 30 and phosphorus > 15.										
Max.	Hydrogen sulphide (mg/kg)	2.00										

Table Note: From "Petroleum products - Fuels (class F) - Specifications of marine fuels" (ISO, 2017)

Due to the wide use of low-quality fuel oil and the international concerns on its implications like health issues, ozone depletion, global warming, acid rains and others the IMO made decisive efforts for the use of cleaner fuels on board. MARPOL Convention has set regulations for reducing marine pollution by ships. Annex-VI sets limitations on emissions of oxides of sulphur and nitrogen.

Sulphur is available in heavy fuel oil and converts to sulphur oxides when the fuel is burnt. The emission of sulphur oxides poses a severe threat as sulphur dioxides cause acid rain. In 2008, IMO amended MARPOL Annex VI aiming towards a step by step cutting in the amount of sulphur content of marine fuels. From 1st January 2012 the sulphur ceiling has been reduced to 3.50% from 4.50% and further down to 0.50% with effect from 1st January 2020. In Sulphur Emission Control Areas (SECAs) from 1st July 2010, the sulphur ceiling was reduced to 1.00% from 1.50% and from 1st January 2015 the limit has been further lowered to 0.10%. The reduction in sulphur content has been shown in Table - 5.

Table 5: *Phases of sulphur limits enforced globally*

IMO GLOBAL		SECA/ECA	
Date	Sulfur %	Date	Sulfur %
Initial limits	4.50%	Initial limits	1.50%
1 Jan 2012	3.50%	1 Jul 2010	1.0%
1 Jan 2020	0.50%	1 Jan 2015	0.10%

Table Note: From “Global Sulfur Cap-2020”(ABS, 2017)

ISO has recently specified fuel oil quality standards ISO/PAS 23263:2019, which relate to the entire variety of marine fuels in the wake of the enactment of maximum sulphur content of 0.50 mass percent. It establishes general requirements for all fuels containing less than 0.50 mass percent sulphur and certifies the application of ISO 8217 to these fuels. Additionally, it discusses technical deliberations that may pertain to specific fuel oil based on their following characteristics (ISO, 2019):

- Kinematic viscosity;
- Cold flow properties;
- Stability;
- Ignition characteristics;
- Catalyst fines

2.1.5 Temptation to bring down Quality

With the technological advancements in the refining process, superior petroleum products like gasoline, gas oil, jet fuel are extracted more effectively from crude oil, and this influences the constitution of the end residual component from which Intermediate Fuel Oil for ships are made. Almost every parameter has increased, and the outcome is that bunker fuels with higher density, cat fines, carbon residue, sulphur and others have to be used onboard. The primary consumption of residual fuel takes place in the marine market. There is also an excess availability of residual fuel, which tends to reduce prices and the margins for bunker fuel oil suppliers. In addition, competition amongst sellers of quality products is predominant. Suppliers who have difficulty in selling a quality product at a fair price in a competitive market and who do not care for their reputation or brand image driven by the associated immediate financial benefits reduce the quality of bunker fuel oil to increase their profit margins.

2.1.6 Off-specification Fuel Oil

The fuel that fails to satisfy the quality requirements set by a contract or regulation is considered off-spec. Fuel can be off-specification in any of the stipulated quality limitations. Engine manufacturers stipulate the grade of fuel oil that must be used in the engine. Off-spec fuels do not mean fuel of a grade different than the one stipulated by the engine manufacturer. Failure to meet the specified parameters of the grade requested will term the fuel as off-spec.

The use of off-spec bunkers can cause significant damage to the engine and disruption in the vessels' ability to trade. Around 60-70% damages of the main propulsion engine occur due to fuel-related issues. Additionally, problems may be encountered in recovering the costs incurred due to the use of off-spec fuel from the insurers due to limitations in the insurance cover.

ISO 8217:2017 has specified the quality standards for distillate fuels and marine residual fuel. Before bunkering ships, personnel must ensure that fuel being supplied

meets the quality standards and statutory regulations.

2.1.7 Marine Fuel Oil Contaminants

The amount of contaminants in fuel oil is relatively small compared to its volume; however, even small amounts of some contaminants give rise to significant concerns and may cause many operational and legal issues. Contaminants may lead to fouling and seizure of fuel pump, fouling of turbochargers, clogging of filters and a host of fuel system related issues. In some case, these may even lead to engine failures and loss of propulsive power which may lead to even collisions or groundings.The most common fuel oil contaminants are:

- Aluminium: The presence of Aluminum in fuel oil can lead to the formation of aluminium oxides. Aluminium oxides are very hard particles and can cause substantial damages to engine components (Lindholm, 2018).
- Iron- The presence of iron is common in fuel oil. It is less damaging than Aluminum. However, its presence becomes a concern since it can combine with carbon leading to the formation of persistent soot, which is an air pollutant (Lindholm, 2018).
- Silicon- Silicon is generally present as an oxide in fuel oil. It is very hard and can cause substantial damages to the engine components (Lindholm, 2018).
- Sulfur- Sulfur is present in crude oil and finds its way into the fuel oil. Sulphur forms Sulphur oxides (SO_X) on combustion, and this can dissolve in water and produce sulphuric acid. Sulphuric acid being corrosive, can damage engine components and also the environment through acidic rains (Lindholm, 2018).
- Vanadium- Vanadium can be present in fuel oil in small quantities, leading to abrasive wear and engine damage (Lindholm, 2018).
- Water-Water emulsifies and lowers the energy density of fuel oil. The presence of water in the fuel may also lead to microbial growth (Lindholm, 2018).
- Microbes- Anaerobic bacteria can develop in stored fuel oil under warm conditions if water is present. These bacteria can thrive on hydrocarbons even in the absence of oxygen (Lindholm, 2018).
- Polymers- Marine fuel oil is made from the leftovers of the crude oil refining process and may contain polymers which are long chain hydrocarbons. The presence of polymers adversely affects the combustion quality of the fuel (Lindholm, 2018).
- Low Flashpoint Oils- Oils having low flashpoint are added to reduce the viscosity of fuel oil and improve their pour point. The presence of low

flashpoint oils reduces the fuel oil quality and may lead to gasification in the fuel system (Lindholm, 2018).

- Paraffin- Paraffin are long-chain polymers, and their presence in fuel oil adversely affects the combustion characteristics of fuel oil (Lindholm, 2018).
- Asphalt- Asphalt remains after all other products have been extracted from crude oil and may include silicon dioxide. The presence of asphalt in fuel oil leads to separation and combustion problems (Lindholm, 2018).

The presence of contaminants in fuel oil can cause damage to fuel treatment equipment, fuel oil burners and injectors, fuel valves, pistons, turbine blades.

2.2 Issues: Quantity and Quality

A bunker supplier is expected to deliver a specified quantity and quality of bunker fuel oil as per the order at the designated place. Vessels expect to receive fuel as per the order placed both in terms of quality and quantity. The orders for bunker fuel oil are placed, taking into consideration the fuel requirements for the intended voyage. The quality of fuel ordered is in line with the engine manufacturer's recommendations and as per the specifications stipulated in the statutory regulations.

It is anticipated that there is no quantity or quality discrepancy during the purchase of bunker fuel oil. The quantity stemmed must be as specified in the Bunker Delivery Note (BDN). As an additional safeguard against short-deliveries, a prudent bunker purchaser engages a third-party bunker surveyor for bunkering. The quality must be as specified in the order. Bunker samples are landed ashore and tested in shore-based laboratories to ascertain their quality.

The bunker market generally has some dishonest suppliers, and barge operators driven by financial gains manage to provide short delivery and/or bunkers of inferior quality. The consequences of these increase the ship owners' financial burden and jeopardize their business reputation and credibility.

2.2.1 Quantity Concerns

Shipping is a fast-paced industry that is rapidly growing with the introduction of new and more advanced vessels. The average price of bunker fuel has been increasing over the years. Figure - 6 represents the price of 380 centistoke bunker fuel oil from May 2020 to May 2021.

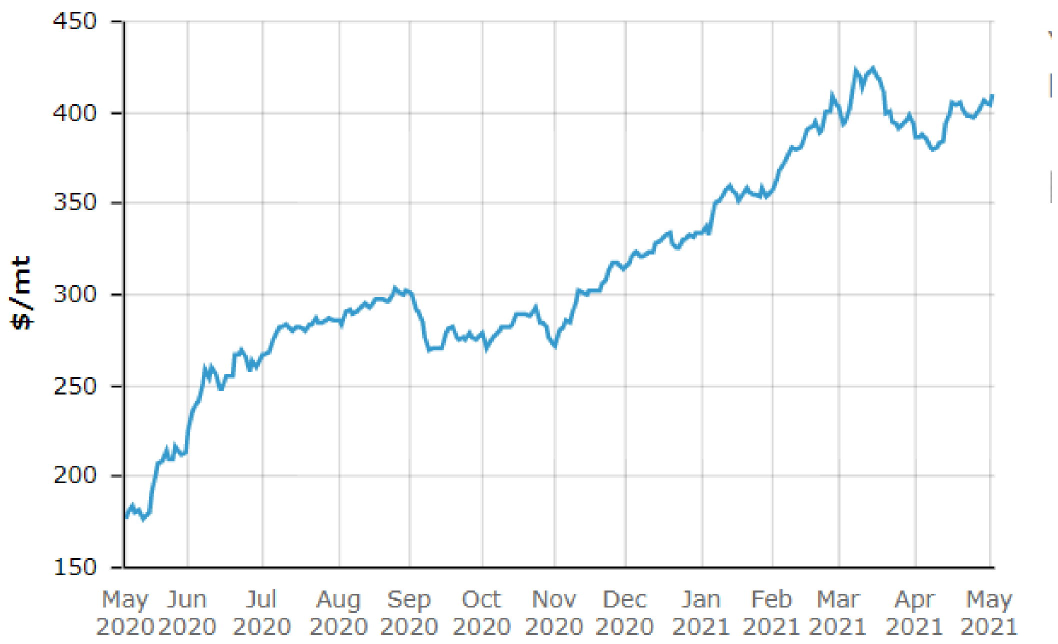

Figure 6: 380 centistoke (cst) bunker fuel Price (Bunker World, 2021)

With the growth in shipping, the bunker market has also expanded. However, new bunkering techniques have failed to evolve and keep pace with the growth. Marine fuels are sold in terms of mass. Since it is difficult to weigh large quantities of fuel, the quantity calculation is done by measuring the fuel volume and multiplying with the density. Volume is still measured manually by sounding the fuel oil tanks using a measuring tape attached to a heavy bob. The measurement is taken from the top tank to the oil surface (ullage) or from the oil surface to the tank bottom tank. The tank undulations may lead to error in the measured value; also, the measuring equipment can be tampered thereby giving an incorrect value (Cockett, 1997).

Bunker suppliers adopt many techniques to deliver less quantity of bunker fuel or to deceive and give the impression that the total contracted amount has been duly delivered to the ship.

Singapore was infamous for the "Cappuccino bunkers". On completion of bunkering, the supplier would blow compressed air or nitrogen through the line to remove the remaining oil in the bunker hose. The justification would be to avoid the possibility of oil leaking and causing pollution during the disconnection of the bunker hose. The air or nitrogen pumped entrails in the viscous bunker and increases the volume substantially for a short time, and less quantity of bunker is delivered on board.

Fuel cost accounts for around 50% to 60% of the total ship's operating cost (Stratiotis, 2018). Short delivery of the bunker will lead to payment for fuel that has not been received.

2.2.2 Quality Concerns

The quality of marine fuel has deteriorated over the years and reveals the following general trends:

1. Fuels are becoming more aromatic, and this has a detrimental effect on their ignition and combustion properties.
2. The average density of fuel is increasing globally.
3. Cat fines are being detected in a more significant number in fuels due to the introduction of new cat crackers.
4. The number of cases involving fuel contaminated with chemicals like polymers and corrosives is increasing.

The consequences of using low-quality fuel could be severe and may lead to many operational issues and damages to the vessel's machinery. Fuels contaminated with waste chemical products can cause harm to the ship's equipment and its crew. Water in fuel oil is likely to form emulsions and cause fuel treatment issues on board. Fuel oil of density that exceeds the acceptable value would cause issues with the onboard fuel oil purification system.

The implementation of the sulphur cap of 0.50 % may cause a significant impact on fuel quality with an increase in demand for good quality fuel. However, to reduce sulphur content, the mixing of oil components of different origins would increase, leading to variations in low sulphur fuel compositions and properties. In non-distillate fuels with low sulphur content, due to the refining procedure and blending with cutter stock, the level of catalytic fines would be high. The stability of blended low sulphur fuel is a significant concern as the possibility of asphaltene content precipitating out of solution depends on stability.

Ships must receive good quality bunker fuel oil to minimize operational issues and economic losses. Bunker quality complaints could also lead to many legal claims like claims against bunker traders , claims against Time Charterers, claims under Hull and Machinery (H&M) insurers in cases of engine damage, etc.

Chapter 3.0 Bunkering on Ships

3.1 Bunkering Procedure

Bunkering refers to the supply of bunker fuel oil to ships and includes loading and distributing the fuel in the various fuel oil storage tanks on board. Bunkering is likely to take place offshore, at anchorage or jetty. Depending on the port and the accessibility of the vessel, bunkers can be delivered by bunker barges, pipelines or road tankers. Bunkering is a critical activity, and any lapses could lead to pollution, fines or even imprisonment. Ship-to-ship transfer (STS) is the most prevalent method for supplying bunker fuel oil.

The bunker barge is filled at the quay and comes alongside the vessel to deliver the bunker. Ship staff make the necessary preparations before bunkering operation. The fuel remaining onboard is determined, and owners and charterers informed of the quantity intended to be bunkered in anticipation of the expected voyage. The tanks in which bunkers are planned to be received are made empty to avoid mixing the different bunkers (Fisher & Lux, 2004).

Before commencement of transfer, the chief engineer completes the pre-delivery documentation and formalities. All the save-all tanks are plugged, and all the deck scuppers closed. After all the pre-loading checks are completed, the ship is ready for bunkering. The transfer hose is connected to the ship's manifold from the barge. The transfer lines are correctly set to receive oil in the desired tank by operating the corresponding valves.

The ship then requests the barge to begin the transfer. The barge begins pumping fuel oil at the agreed starting rate, which is intentionally kept significantly less for safety reasons. Fuel is usually transferred at around 40°C, to decrease viscosity and make it easier to pump the oil. The manifold and the associated pipelines are constantly monitored up to the designated tanks. The air vent of the filling tank is monitored since the tank getting filled will expel air through its vent pipe. Monitoring is also done by feeling the pipelines which would be warmer and by taking the tanks sounding or ullage. After ascertaining that there is no system leakage and that the fuel is going to the designated tank, the barge is advised to increase the pumping rate. During the entire bunkering process, the ship personnel constantly monitor the manifold, the loading rates, integrity of the pipeline, and tank ullages.

The deck duty officer ensures that the moorings are properly maintained throughout the bunkering process and that signals mandated by regulations are displayed to indicate that the vessel is undergoing bunkering operation.

Monitoring becomes crucial during the topping off a tank. The filling valve of the subsequent tank intended to be loaded slightly opened, and oil gets delivered simultaneously to two tanks. As an additional precaution, the barge is also requested to reduce the pumping rate during topping off. Tanks are normally not filled beyond 98% by volume. On approaching 98% by volume, the filling valve to the tank is fully closed, and the valve to the next filling tank is fully opened. The flow rate is then again increased. Valves should never be closed against pumping pressure as this could damage the hose, pipeline and lead to a fuel oil spill.

Before disconnecting the transfer hose on completion of bunkering, fuel calculations are carried out as any agreed shortages could be delivered.

3.1.1 Calculation of Quantity

To determine the quantity of fuel oil received, gauging the tanks of the bunker barge or the receiving vessel or both are generally carried out to calculate the fuel volume. Flow meter readings could also be used for volume calculations if fitted.

Before bunkering, the tanks of the barge and the receiving vessels are measured by gauging or sounding the tanks. Gauging is done using a sounding tape with a brass bob at the end. A tank can be gauged either by measuring the distance from the tank top to the surface of the oil (ullage) or from the surface of the oil down to the bottom of the tank (sounding). Volume varies with temperature, so the volume is corrected to a standard temperature of 15°C after measuring the tank temperatures. List and trim of the vessel are taken into account, and the volume of oil in each tank is calculated using the ullage or sounding tables. By measuring and calculating corrected volumes before and after transfer on the barge and the ship, it is possible to determine the volume transferred.

For barge: volume transferred = volume before transfer – volume at completion

For ship: volume received = volume at completion – volume before transfer

The fuel oil density (in kg/m³) at 15°C is assumed to be what is reflected in the BDN. The quantity is determined by multiplying the volume of oil received by the density.

The accuracy of quantity calculation depends on the several key factors which include (Bracken et al., 2011):

- Accuracy of the vessels list and trim.
- Accurate soundings or ullaging of tanks.
- Correct temperature determination.
- Accuracy in the necessary corrections and calculations.
- Accuracy of the correction tables for list and trim.
- Reliability of the correction tables for volume.
- Reliability of the correction tables for temperature.
- Reliability of density as quoted by the supplier.

3.1.2 Bunker Delivery Note

Bunker Delivery Note (BDN) has emerged from Bunker Delivery Receipt (BDR) which was used to track the quantity of product delivered to customers and serves as a proof of receipt (Exxonmobil, n.d.). As per regulation 18 of MARPOL annex VI, BDN of all fuel oil taken on board must be available (IMO, 2020a). MARPOL Annex VI requires specific information in a BDN as stipulated in appendix V of this annex. The inclusion of the sulphur content had been mandated by resolution 176(58) of MEPC (IMO, 2008).

The BDN must be kept for three years readily available for inspection from the delivery of bunker. Port State Control officers can inspect BDN to ensure that the fuel complies with regulations.

It is also mandatory by regulations that a sealed representative sample of bunker fuel duly signed by the bunker supplier is retained for each of the bunker delivery notes. The bunker delivery note is signed and stamped by the master of the barge and the chief engineer of the receiving vessel.

Since the laboratory determined density of the fuel oil is not known during bunkering, the BDN is filled by the figures for volume received. Also, the Chief Engineer signs all the documentation mentioning “for volume at observed temperature only.”

If bunkering occurs in a country which has not ratified the MARPOL Convention, the bunker supplier may not issue a BDN. The ship would still need papers for port state control inspections at other places. In such a situation, the master should inform the port state authorities at the bunkering port and the flag state of the ship and keep a copy of such notification for use at subsequent port state control inspections.

3.1.3 Letter of Protest

Before the commencement of bunkering, the Master requests the charterers, port agents and bunker suppliers to witness the representative bunker sampling. If the charterers agent and/or the bunker supplier’s representative refuse to attend the sampling, it would be prudent for the Master to issue a letter of protest.

Also, if a dispute arises regarding the bunker quantity received on board, the Master of the receiving vessel should promptly issue a letter of protest. The letter of protest must include:

- Date and time of loading bunker.
- Receiving vessel name.
- Shortfall in volume.
- Grade of oil bunkered.

- Percentage of the shortage.
- Bunker suppliers name.
- Name of the bunker barge.
- Reference number of the BDN.

The letter of protest must be signed and stamped by the chief engineer and given to the bunker barge representative. The letter of protest must also be signed and stamped by the master of the bunker barge.

The Master must forward a copy of the letter of protest to:

- The shipowner
- The charterer
- Laboratory carrying out fuel analysis.
- Bunker supplier
- Bunker broker.

Generally, bunker contracts have a short time limit for registering protest, so it is essential that any protest is registered promptly. The only information about quality at this stage would be as provided by the bunker supplier. The onboard fuel oil testing equipment, if available, would be used to ascertain quality until the reports of the fuel oil sample sent ashore for analysis are received

3.2 Sampling of Bunker and Analysis

Bunker quality disputes rely heavily on the analysis reports of the representative samples taken during bunkering. Fuel oils are generally not homogeneous, so it is challenging to get a truly representative sample, especially when loading large quantities of the bunker. Also, fuel oils delivered on ships are generally blended, and suppliers could carry out blending during the transfer of fuel oil to the ship. This process is called in-line blending and is likely to cause different bunker tanks to be filled with fuels of varying viscosities unless high grade controlled blending devices are used. As such, it would be prudent for the fuel oil purchaser to specify that the supplier must blend the fuel oil before delivery.

Every effort must be made to collect a truly representative sample during bunkering. IMO Resolution MEPC.96(47) has laid down guidelines on fuel oil sampling during bunkering (IMO, 2002). The continuous drip sampling method taken throughout the whole period of bunkering is used for bunker fuel oil sampling globally and this method is in line with internationally recognized standards.

3.2.1 Sampling Procedure

The bunker sampling point and the sampling equipment used during bunkering are agreed upon between the ships representative, barge or shore representative and the independent bunker surveyor (if appointed) before the start of bunkering. These people are expected to witness the sample being collected in the receiving container and then being transferred to individual sample bottles.

As per regulation 18 of MARPOL annex VI, each BDN is required to have a representative fuel oil sample. The MARPOL sample is taken at the receiving vessel's manifold. Usually, ship owners also take their commercial samples at the vessel's manifold, the custody transfer point.

The continuous drip method of sampling at the receiving vessel's manifold provides the best representative sample. An automatic or manual continuous drip method of sampling is generally adopted. Adequate volume of the representative sample should be collected to suffice for both commercial and statutory MARPOL sample requirements.

On completion of bunkering, the sample in the receiving container is thoroughly mixed and poured into at least four sample bottles. The sample bottles should be labelled and sealed. The seal numbers of the sample bottles should be different. Labels on the sample bottles are required to contain the following information:

- Receiving vessel name and IMO number.
- Port of bunkering.
- Bunker suppliers name.
- Name of the bunker barge.

- Date of commencement of delivery.
- Sampling method used.
- Grade of fuel oil.
- Location of sampling point.
- Name and signature of the bunker supplier.
- Name and signature of the receiver.
- Seal numbers of various sample bottles.

One sample bottle is handed over to the supplier; one is retained on board, one of these is the MARPOL sample which is also retained on board, and one sample bottle is sent for shore-based laboratory analysis. All samples should be carefully stored as they could provide evidence in case of bunker quality disputes. In case of a quality dispute, the sample retained on board can be tested as the MARPOL sample bottle is not allowed to be used for this.

If a sample bottle is received from the bunker supplier that the ship staff has not witnessed, it should be accepted with the comment 'for receipt only, source unknown'.

3.2.2 Fuel Analysis on Ship

Most of the ships have fuel oil testing kits. These are sophisticated but easy to use electronic test equipment and give reasonably accurate results. Shipboard personnel can use these kits to determine the following:

- Density
- Viscosity
- Water content
- Compatibility or stability
- Compatibility issues with fuel oil already present

Shipboard engineers generally use the onboard fuel oil test kits to get early indications of fuel oil quality.

3.2.3 Fuel Analysis on Shore

In case of bunker quality disputes, the analysis result obtained from an independent laboratory becomes essential. There are many recognized laboratories globally that carry out detailed fuel oil analysis. All the parameters identified in ISO 8217 standards are tested in the shore-based analysis. The complete characteristics of the bunker fuel is known after the analysis and hence it is possible to avoid the associated problems if any by effective treatment of the fuel oil or by de-bunkering.

If the laboratory analysis reveals that a specific parameter is likely to cause problems, the ship-owner must be informed and the engine manufacturer consulted for advice. Ship-owners can seek advice from independent bunker specialists and technical consultants. Some fuel oil testing laboratories also provide detailed technical advice and guidance on pre-heating requirements, the setting up of centrifuges and potential fuel oil handling and combustion problems.

3.3 Issues Leading to Bunker Disputes

The various issues which give rise to quantity and quality disputes consequent upon bunkering have been identified and discussed in the following sections.

3.3.1 Failure to Measure Barge Tanks

In some instances, the shipboard personnel, due to inclement weather and safety considerations, cannot go on the barge to measure the barge's tanks, which would encourage short delivery (Malmros, 2013).

3.3.2 Measuring only Nominated Tanks

If a barge has to deliver a bunker to more than one ship, it will fill several of its tanks. Therefore, the barge crew may not sound those tanks that are not nominated for a particular receiving vessel. In such a case, bunkers from the nominated tanks may be transferred to another tank during the bunkering process. The decrease in volume of the nominated tanks would be entered in the BDN, and the vessel would have received a reduced quantity of bunker (Malmros, 2013).

3.3.3 Tampered Measuring Tape

In some cases, the measuring tapes are tampering, which gives the impression that there is more in the barge tank, which is likely to impact the delivered amount significantly (Malmros, 2013).

3.3.4 Pre-Signing of BDN

A nonchalant Chief Engineer may at times be duped into signing the BDN before the commencement of the bunkering. Several documents are required to be signed before the commencement of bunkering. The deceitful supplier could deliberately put BDN among these documents, and the Chief Engineer could accidentally sign it even before the commencement of delivery. In case the BDR is signed, the receiving vessel cannot protest even if they receive a lesser bunker quantity since the BDN has been signed for the correct quantity (Malmros, 2013).

3.3.5 Deliberate increase of Fuel Oil Volume

The fuel volume is increased by mixing air with the fuel oil, commonly referred to as the Cappuccino effect. The mixing of air could be done either during the actual transfer process or before bunkering using pumps or the compressed air equipment used for blowing through the pipelines. The density of the fuel oil gets reduced by the mixing of air. Since the actual density of the fuel oil is ascertained later from the shore-based laboratory analysis, calculations for quantity on the completion of bunkering is carried out as per the density specified in the BDN. The Cappuccino effect can be identified by looking into the tanks. The oil surface should be black and shiny, but the surface would be bubbly and disrupted if the oil is aerated. Also, if air is mixed into the bunker while sounding the tanks, the oil on the measuring tape would not be smooth (Malmros, 2013).

3.3.6 Deliberate Short Delivery

By transferring the oil from the nominated tank to some other tank or void spaces during bunkering or by retaining the line fuel oil, deliberate delivery of a lesser amount of bunker fuel oil could be done (Malmros, 2013). Again, the availability and use of updated equipment and proper education of crew members of the receiving vessel could help eliminate these issues.

3.3.7 Density and Temperature

The bunker quantity is calculated by measuring the delivered volume and multiplying it with the density. Volume varies with temperature, and any error in measuring temperatures and applying the temperature correction would lead to the delivered mass being lower (Malmros, 2013).

3.3.8 Role of Ship Personnel

It is common for the vessel to have some undeclared bunker. Therefore, the ship's personnel may agree to receive an equivalent amount of reduced bunker from the bunker barge in lieu of some cash and sign the BDN for the stipulated quantity (Malmros, 2013).

3.3.9 Issues in the Supply Chain

In the bunker oil supply and distribution chain, sampling and analysis are not done at each point during the custody transfer of the bunker fuel oil. This also applies to bunker fuel oil loaded from oil storage terminals and bunker fuel oil received from other bunker tankers. These may lead to issues relating to quality and difficulties in fixing liabilities amongst the parties involved in the supply chain.

Chapter 4.0 Regulations and Guidelines

4.1 SOLAS 1974

SOLAS, 1974 stipulates regulation for the flash point of fuel permitted to be used on ships and the Material Safety Data Sheets (MSDS) provisions.

The lowest temperature that can ignite an air and fuel mixture above the fuel surface is the flashpoint of the fuel oil. More specifically, the lowest temperature that can ignite vapours from a test section and cause the flame to spread throughout the liquid surface under the specified test conditions on applying an ignition source is called the flashpoint.

For the determination of flashpoint, different test methods are available. The most significant is the open cup and the close cup methods. The difference between methods applied in flashpoint measurement is considerable, and the flashpoint value measured is representative only for a specific test type. The Pensky-Martens closed cup method is applied for marine fuels (ISO, 2002).

MSDS is a document containing detailed information on a controlled commodity related to the following:

- Physical data
- Fire and explosion hazards
- Effects on health on exposure to the product
- Hazards related to handling, storage and use
- Measure to reduce risk of exposure
- Emergency measures

4.1.1 Flashpoint Requirements

SOLAS Ch-II-2 Reg. 4.2.1 stipulates that no fuel oil having a flash point lower than 60°C is permitted, except for an emergency generator where fuel oil with a flashpoint up to 43°C is permitted (IMO, 2020b).

4.1.2 Provisions for MSDS

SOLAS Chapter VI Regulation 5.1 stipulates the requirement for MSDS to be provided on board ships before fuel oil bunkering (IMO, 2020b).

4.2 MARPOL 1973/78

4.2.1 Annex – I

During bunkering, there is a possibility of an oil spill if adequate preventive measures are not implemented. Spillage and leakages while bunkering is a prime source of oil pollution. Spills occur due to negligence by those supplying bunkers or those on board the vessel receiving them. Regulation 37 of MARPOL Annex - I requires that for combating oil spill, all oil tankers of 150 gross tonnes or more and all other ships of 400 gross tonnes or more must have a shipboard oil pollution emergency plan (SOPEP) that is authorized by the Administration (IMO, 2020a). The SOPEP details the course of action required to report in case of an oil pollution incident and is based on the IMO guidelines. The vessels must keep onboard materials for combating oil spills like oil spill dispersant, booms, sawdust, portable weldon pumps etc.

4.2.2 Annex – VI

4.2.2.1 Regulation - 14

This regulation stipulates the following requirements (IMO, 2020a):

- From 1st January 2020, the sulphur content of fuel used on ships should not go beyond 0.50% m/m.
- The average sulphur content of residual fuel oil consumed on ships worldwide shall be monitored as per the IMO guidelines.

- When inside an Emission Control Area (ECA), the sulphur content of fuel oil being consumed on ships should not go beyond 0.10% m/m on and after 1st January 2015.
- The content of sulphur in fuel shall be documented by its supplier in the BDN provided.
- Ships burning other fuel oils to comply with the regulation of ECA should have a documented procedure for the change-over of fuel oil.

4.2.2.2 Regulation – 18

Regulation - 18.3 stipulates that bunker oil used on ships must be a blend of hydrocarbons obtained by petroleum refining and must be free of inorganic acids. The oil should not have any substance or chemical waste added that would endanger the ship's safety or affect the machinery negatively. The fuel oil should not be harmful to ships personnel or contribute to further pollution of air. The fuel oil should not exceed the applicable sulphur limit or cause engines to exceed the applicable NOx emission limit (IMO, 2020a).

Regulation -18.5 stipulates that the specifications of fuel oil delivered to ships should be documented through a BDN, containing at least the stipulated information specified in Annex – VI (IMO, 2020a).

Regulation - 18.6 stipulates that the BDN must be retained on ships for inspection for at least three years from the fuel oil delivery date (IMO, 2020a).

Regulation -18.9 requires the member states to ensure that their designated authorities have a register of local bunker suppliers. The local vendor of fuel oil must provide BDN and representative fuel oil samples to certify that the fuel oil delivered is as per all the MARPOL Annex - VI requirements. In addition, the local suppliers of fuel oil must retain the copy of BDN for inspection and verification for a minimum of three years. The member state is also required to take appropriate actions against any local fuel oil supplier who has delivered fuel oil not complying with the information stated on the BDN (IMO, 2020a).

4.3 International Organisation for Standardization (ISO)

ISO is a worldwide alliance of standards bodies from different nations and prepares international standards. Each member with interest in any subject for which ISO has formed a technical committee is entitled to have a representation in that particular committee. In addition, various international organizations, governmental agencies and non-governmental bodies liaise with the ISO and are involved with its work.

4.3.1 ISO 8217:2017

ISO 8217 Standards came in 1987 to meet the requirements of marine fuel oil supplied for ships worldwide. New environmental legislations are changing the nature of marine fuels from traditional oil products of crude oil processing to the possible inclusion of oil products derived from alternative sources. Amendments are incorporated in every new edition to meet more stringent environmental requirements.

ISO 8217:2017 has considered the diverse nature of fuels and has specified seven varieties of distillate fuels and six varieties of residual fuels. In line with the provisions of the SOLAS Convention, ISO 8217:2017 specifies minimum flash-point limitations (ISO, 2017).

MARPOL Annex-VI stipulates that the fuel should not exceed a specified maximum sulphur content or should use an approved equivalent alternative means. ISO 8217:2017 specifies fuel standards for marine diesel engines and boilers preceding on board treatment (ISO, 2017).

4.3.2 ISO 13739:2020

Bunkering is a complex and hazardous operation and requires extreme caution to mitigate the risk of fire or oil spill. ISO 13739 was developed for the maritime industry and sets out procedures and requirements meeting the health, safety and environmental (HSE) standards for uniform and expeditious transfer of bunkers fuel oil to ships using bunker tankers, road tankers or shore pipelines (ISO, 2020). Bunkering operation comprises of the following:

- Pre-Bunkering: This is the process of preparing a vessel to take bunker fuel oil, and includes making ready the bunkering equipment, bunker oil tanks, etc.
- Bunkering: Carrying out the bunkering operation as per the established procedures and storing the fuel oil in the bunker oil tanks as per the bunker plan.
- Post Bunkering: Completing the bunkering operation safely and ascertaining that the correct quantity and quality of fuel oil has been received on board.
- Documentation: Confirmation of quantity received, issuance of BDN, and verification that fuel received meets MARPOL Annex -VI specifications.

ISO 13739:2020 standards are applicable for pre-bunkering, bunkering and post-bunkering checks and documentation.

4.3.2 ISO 4259:2020

In bunkering fuel oil, quality disputes may emerge when the sample analysis result of the customer indicates an off-spec fuel, and the supplier҆s certification shows that the fuel oil is on specification. Generally, the suppliers and the customer's analysis results would not come from the same laboratory.

ISO 8217 specifies that in case of a dispute regarding test results, the processes specified in ISO 4259 should be used. ISO 4259 states that each test result is merely a representation of the "true value." The true value of a test result is the average of countless individual test results obtained from a countless number of laboratories.

A test done several times in the same laboratory, on the same sample, under identical conditions, would not typically give precisely the same result for each test because the test method itself always has variability quantified as "repeatability (r)." When two separate laboratories analyse the same sample by identical method, it is known as "reproductivity (R)." Repeatability and reproducibility characterize a test method's precision, and these are published. All fuel characteristics are examined using a test method whose accuracy is thus established.

No solitary test can quantify actual value with 100% certainty. However, every testing method has an established accuracy that can be used to ascertain how much away from the actual value any test result could be anticipated when considering the variability of the test method.

ISO 4259 sets the statistical basis for using test precision to determine how much results variability could be expected from test method variables alone versus when a test result does not meet a specification. It shows that for a single test result to be considered not meeting the specification, it should exceed (0.59 x Reproducibility) the limit.

Test reproducibility (R) is used to define the precision range for the disputed fuel characteristic. In addition, by defining acceptability limits, ISO 4259 helps prevent unnecessary disputes over variations simply due to testing variability (ExxonMobil, n.d.).

Chapter 5.0 Data Collection, Analysis and Evaluation

5.1 Data Collection

The methodology has been discussed in chapter-1 under section 1.5. Although the researcher managed to get a good number of respondents, few challenges were encountered in the data collection process. Many Chief Engineers believed that participating in the survey was likely to affect their future employment opportunities adversely. Some company Technical Managers were apprehensive about the information passing into the wrong hands. Consequently, these people refrained from responding. Given the COVID-19 pandemic restrictions, the researcher couldn't visit any vessel or office, so the researcher had made all efforts through telephone and email. The data collection had been stopped at data saturation. The survey process commenced in May and was completed in June.

5.2 Data Analysis

Data analysis reduces the information to make sense of the data collected (Bryman, 2016). This study has benefitted from the experience of many Chief Engineers and Technical Managers of shipping companies. Altogether 52 people participated in the survey. Out of these, 29 were Chief Engineers, and 23 were Technical Managers. The survey had representation from 29 shipping companies.

The researcher had read the participants' response, analysed the data collected, and drew conclusions based on the information gathered through the survey. The researcher was convinced that the answers were valid and provided a good representation of the bunkering scenario.

The researcher is an ex-seafarer, so the researcher's bias could have influenced the outcome since an element of inclination and preconception was likely. Additionally, bias can occur due to small sample size (Smith & Noble, 2014). Therefore, the researcher made the number of participants as large as possible.

Confidentiality had been maintained throughout the study. Respondents and Shipping Companies names have not been reflected in this study, and the data had been anonymised. To maintain the anonymousness of the participants in terms of name, occupation and company, they have been referred to as respondents number 1 to 52.

5.2.1 Analysis of Quantity Concerns

The survey participants, in general, agreed that the issue of delivering a reduced quantity of bunker is a rampant phenomenon. The bunker barge resorts to various tricks to reduce the quantity of bunker oil delivered to vessels.

As evident from Fig-7, 90.4% of survey participants experienced air mixing in the bunker oil to increase its volume. One of the respondents said that,

"Once the bunkering operation is completed, C/E must wait for at least 1 hour before signing the BDN. After one hour soundings of the ships fuel tanks must be taken again to ascertain that the oil level has not dropped"(Respondent-28).

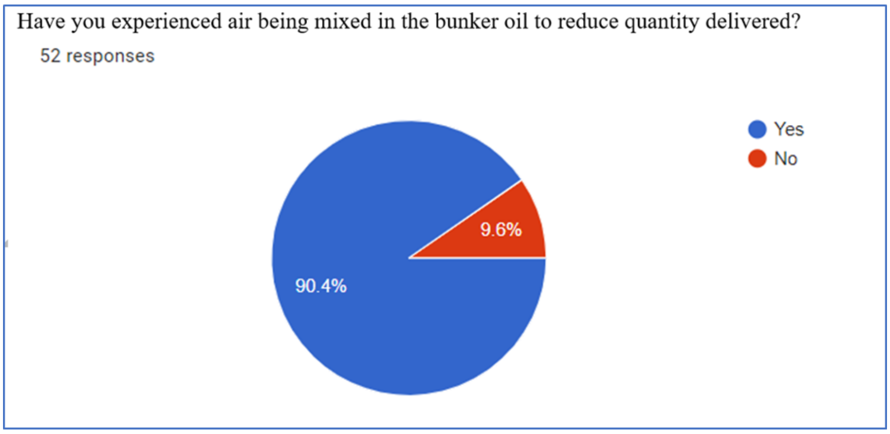

Figure 7: Opinion of respondents on mixing of air in bunker oil

However, this may not be possible as the vessel has to adhere to a strict schedule due to commercial considerations. This view has been echoed by one of the respondents who mentioned that, *"While taking a bunker at anchorage /enroute time is short and the onus lies on ship to complete and move on"(Respondent-12).*

One of the respondents suggested,

"Not to allow the air blow of bunker hose"(Respondent-37).

Using a tampered measuring tape by the barge personnel to demonstrate the barge tank sounding was experienced by 38.5% of the respondents. Getting the BDN signed by the Chief Engineer before bunkering by deceit was experienced by 28.8% of the respondents. These have been shown in Fig-8 and Fig-9. Thus, these two methods adopted by the bunker suppliers to deliver less quantity of bunker are not as rampant as mixing air in the bunker.

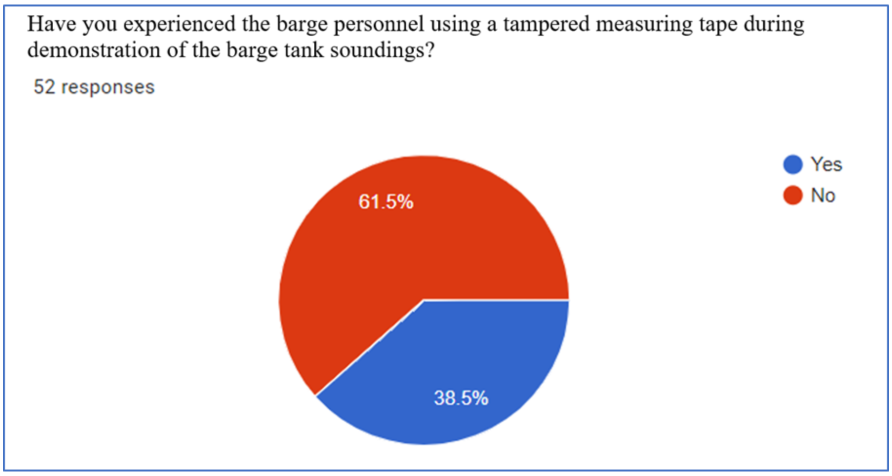

Figure 8: Respondents on the use of tampered measuring tape

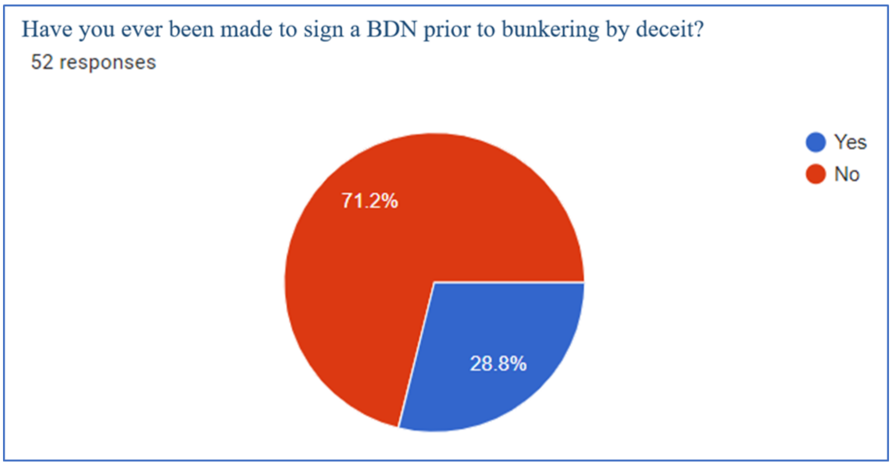

Figure 9: Respondents on signing of BDN by deceit

As represented in Fig-10, 69.2% of the respondents have faced a situation where the barge tanks were not measured jointly before bunkering, possibly due to the absence of safe access to the barge, lack of awareness, etc. One of the respondents holds the view that,

"Ship staff is reluctant to go on board barge and measure their tanks accurately"(Respondent-40)

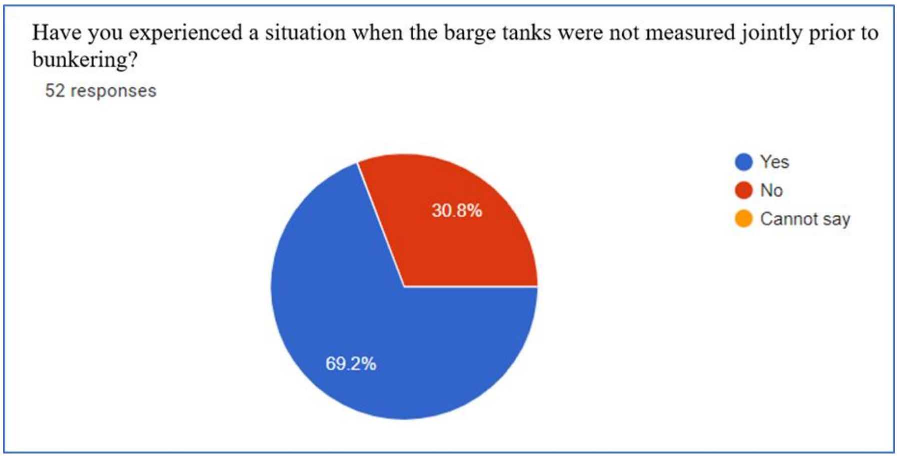

Figure 10: Opinion of respondents on not measuring the tanks jointly

Also, as shown in Fig-11, 75% of the respondents had faced situations where they could witness only the nominated bunker barge tanks. This could be due to a lack of awareness of the ship staff and/or the astuteness of the barge personnel. Both these situations would be advantageous to the supplier, and they would be tempted to supply a lesser quantity of bunker to the vessel.

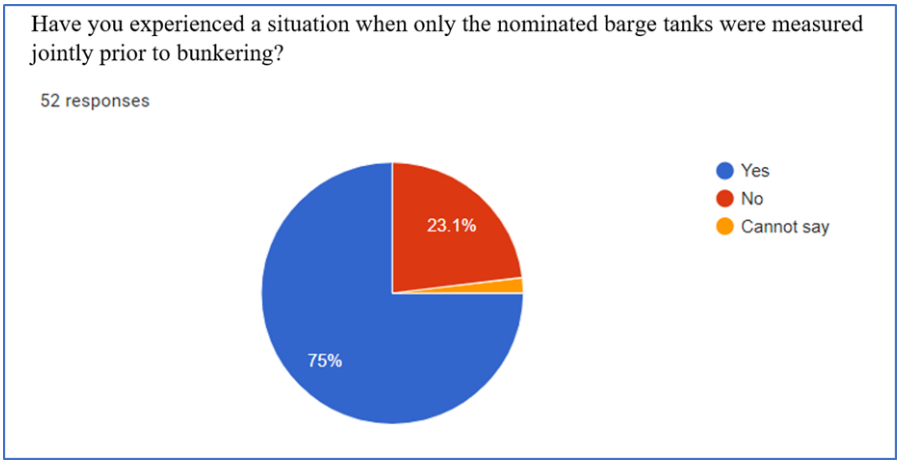

Figure 11: Opinion of the respondents on measuring only nominated tanks

The deployment of an independent bunker supplier appears to be a rare phenomenon, as is evident from Fig-12. However, 69.2% of the respondents agreed that the engagement of a bunker supplier would reduce the possibility of bunker quantity disputes, as evident from Fig-13.

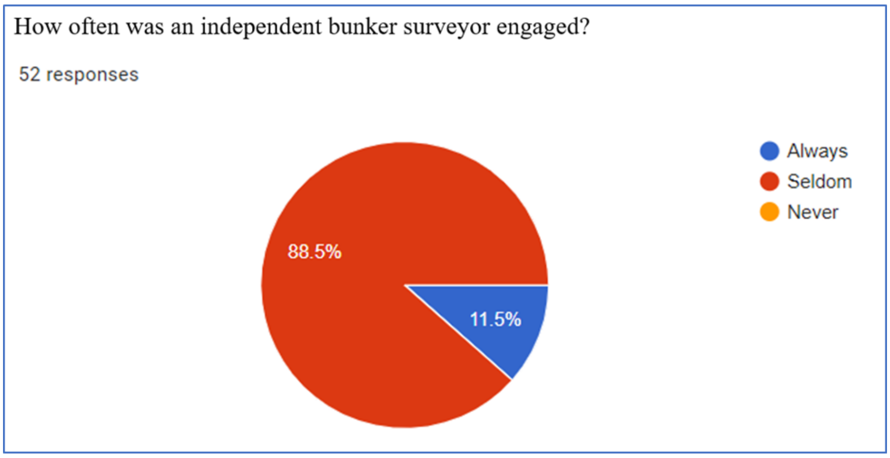

Figure 12: Opinion of respondents on deployment of bunker surveyor

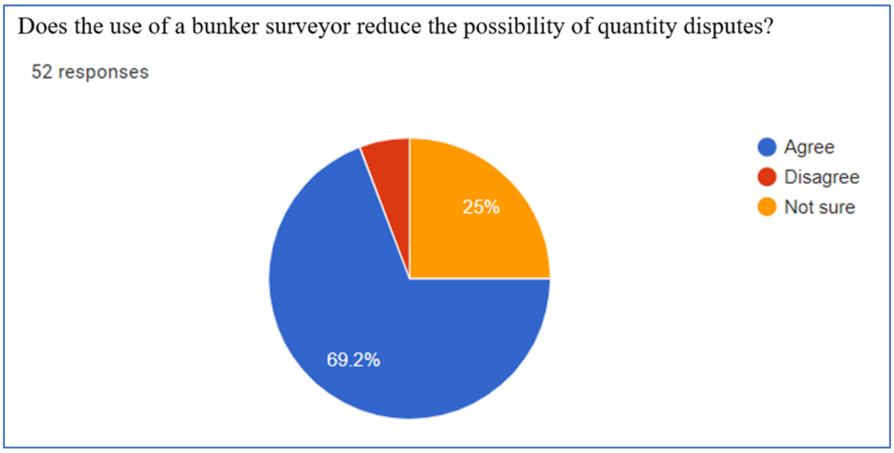

Figure 13: Opinion on reduction of quantity issues by engaging bunker surveyor

One of the respondents had the following statement to offer,

"Presence of an independent Bunker Surveyor gives immense moral support to sailing staff and the inspiration to report cases of mal-practise without fear of any fallout/persecution"(Respondent-48).

However, counter-arguments have been provided by some of the respondents as,

"If Bunker surveyor or Barge personnel come to know that the ship's CE is having extra bunkers in hand then they will supply reduced quantity"(Respondent-9). "Bunker surveyors make deals with bunker barges and supply less bunker to vessels by taking the wrong sounding of barges"(Respondent-37).

"Measures on bunker surveyors are required so that they are not in hand and gloves with the supplier/ barge personnel"(Respondent-17).

"Companies shall stop appointing bunker surveyors as they are 100 percent corrupted"(Respondent-14).

The use of a Mass flow meter was found to be sporadic, as evident from Fig-14. However, 88.5% of the respondents believe that Mass flow meters would help reduce quantity disputes arising during bunkering, as is evident from Fig-15.

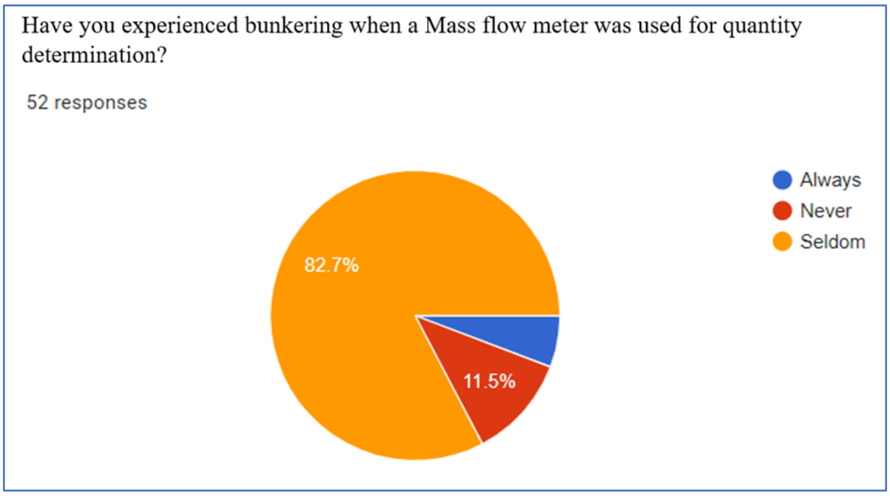

Figure 14: Opinion of respondents on use of mass flow meter

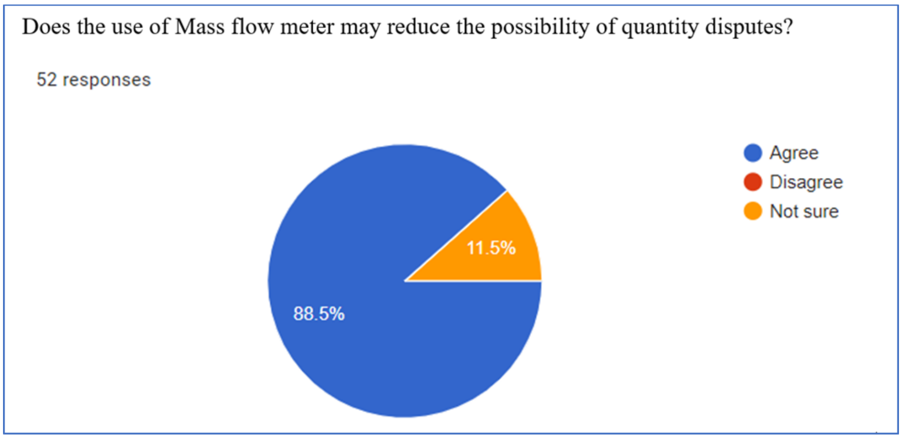

Figure 15: Respondents on use of mass flow meter to reduce quantity disputes

As evident from Fig-16, 65.4% of the respondents had not undergone any bunker oil supply and management training. Since a majority of the ship staff do not attend any bunker oil supply and management training, they are more likely to be deceived by the bunker suppliers.

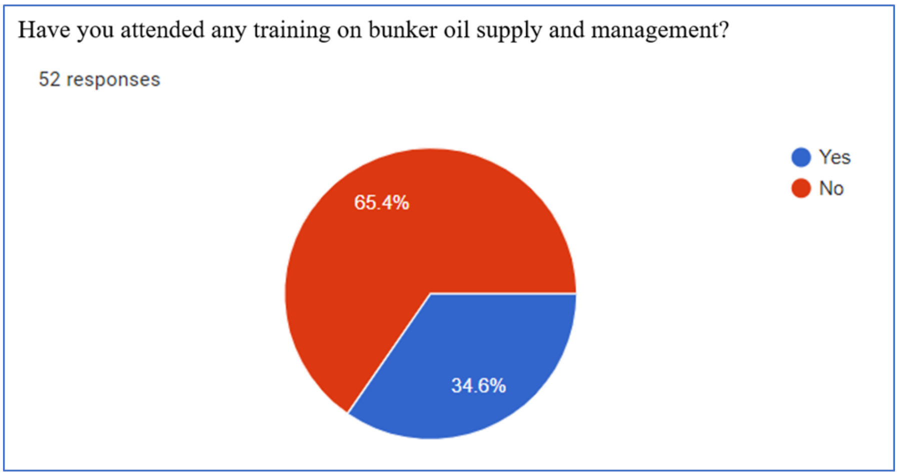

Figure 16: Training of ship staff in bunker oil supply and management

5.2.2 Analysis of Quality Concerns

The survey participants also agreed that quality issues in bunkering are a matter of concern. The reason for inferior bunker quality as stated by one of the respondents is,

"Mixing of water or sludge by the bunker barge personnel to pilfer good quality bunker fuel oil, basically to make illegal money"(Respondent-1).

Another respondent has the opinion that poor bunker quality is due to,

"Mixing of bunker oil from various sources in the barge tanks, insufficient cleaning of bunker barge tanks, and mixing of sludge by bunker barge personnel. If a bunker is received directly from the shore tanks then quality issues are very rare"(Respondent-27).

75% of the respondents had faced situations where the fuel oil analysis report indicated the fuel oil being off-spec. Aluminium and Silicon over the stipulated limit accounted for the fuel being off-spec, as reported by 27.5% of the respondents. These have been shown in Fig-17 and Fig-18.

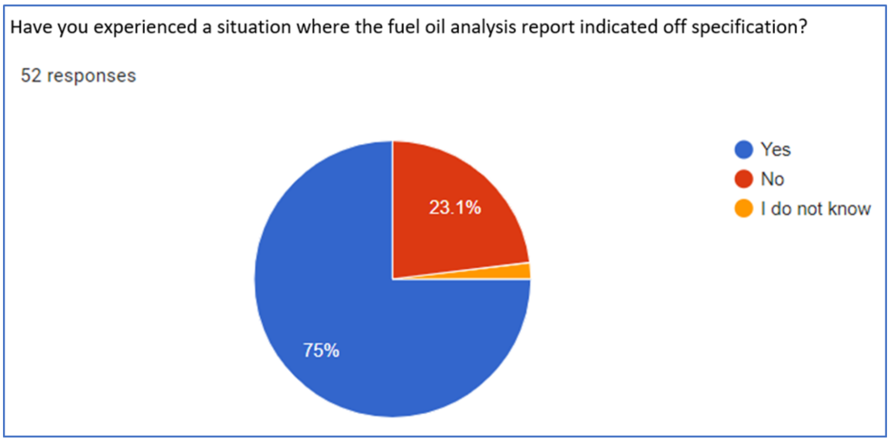

Figure 17: Respondents on fuel oil analysis report indicating off-spec fuel

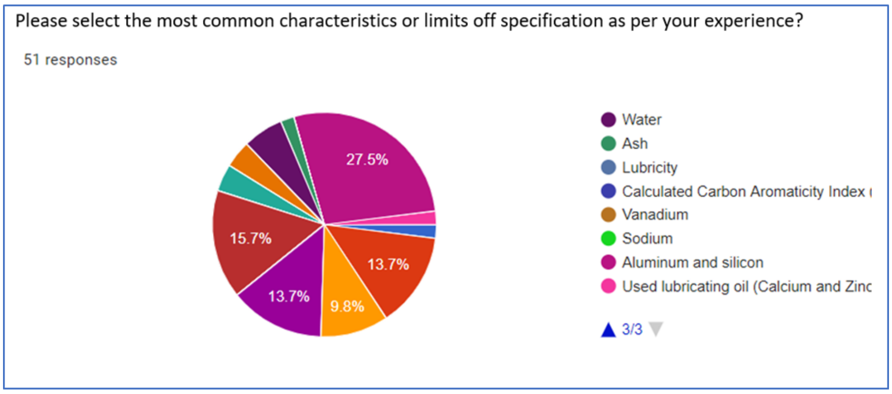

Figure 18: Opinion of respondents on most common characteristics that are off specification

As shown in Fig-19, 19.2% of the respondents had come across cases when the flashpoint of the fuel oil received was below 60°C, thereby posing a fire hazard on board.

One of the respondents holds the opinion that,

"In response to the new IMO regulation of 0.5% Sulphur, refineries have switched to new types of blended fuels that contain high levels of aromatic compounds, or Asphaltenes, leading to stability issues when combined with low Asphaltene blends" (Respondent-28).

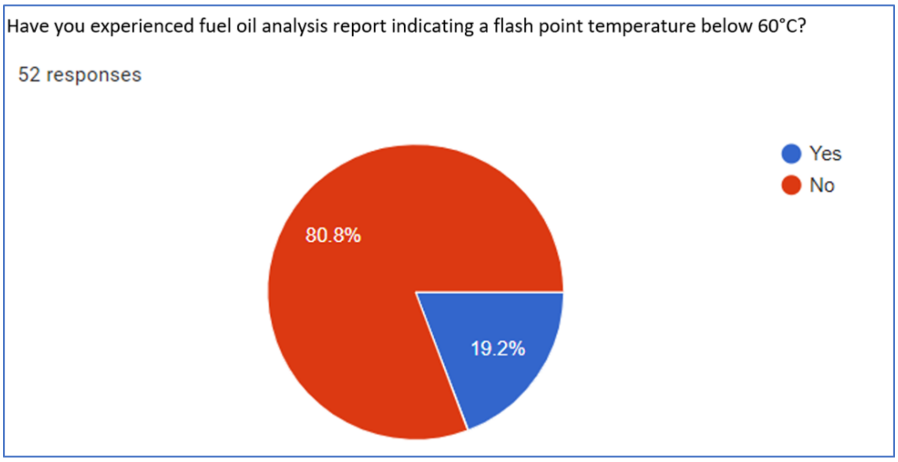

Figure 19: Opinion of respondents on flash point being less than 60°C

96.2% of respondents had experienced excess sludge generation from the purifiers due to inferior quality bunkers, 92.3% of respondents had experienced clogging of fuel pipes, separators and suction filters and 73.1% of participants had come across poor ignition and incomplete combustion-related problems, as shown in Fig-20, Fig-21 and Fig-22.

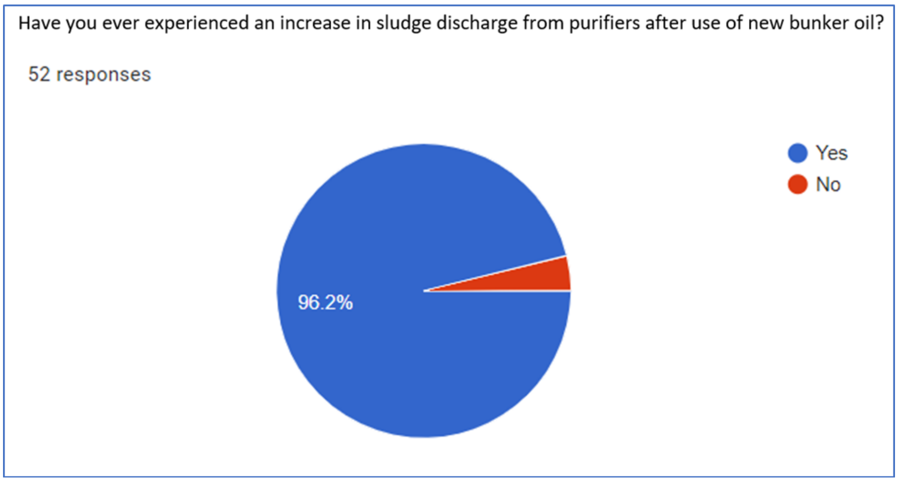

Figure 20: Opinion of respondents on increase in sludge generation on use of new bunker oil

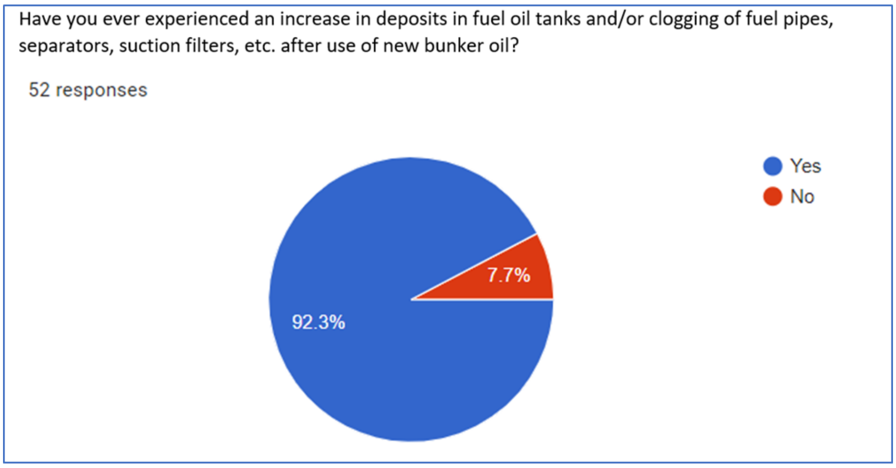

Figure 21: Opinion of respondents on increase in tank deposits and clogging of fuel pipes, separators , suction filter after use of new bunker oil

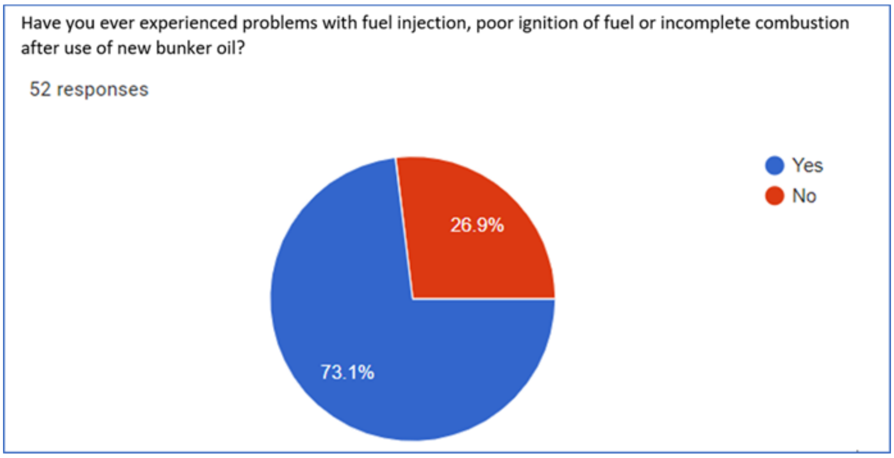

Figure 22: Response on injection and combustion problems with new bunker oil

Another respondent has succinctly pointed out that,

"Bunker supply agreement between ship owner and suppliers is totally one sided favouring bunker supplier and there is a lack of control of national government on bunker supplier"(Respondent-35).

However, only 38.5% of the respondents had encountered fuel pump seizures and blackouts due to bad quality bunker fuel oil as shown in Fig-23 and Fig-24.

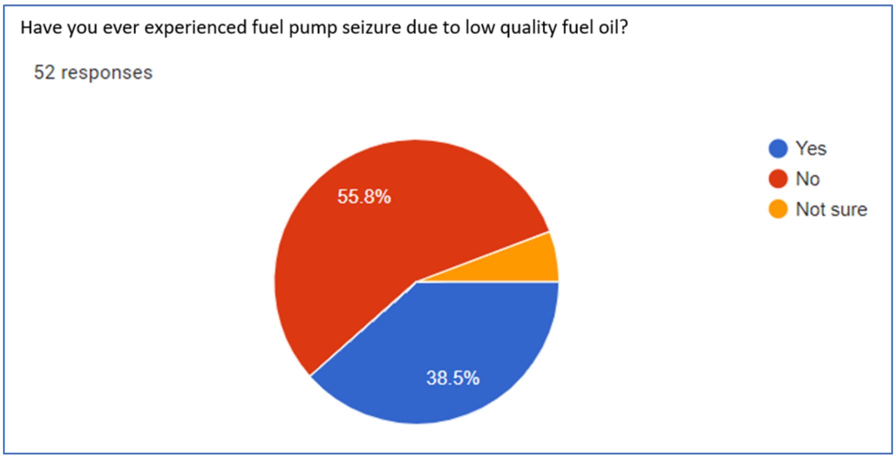

Figure 23: Opinion of respondents on fuel pump seizure due to low quality fuel

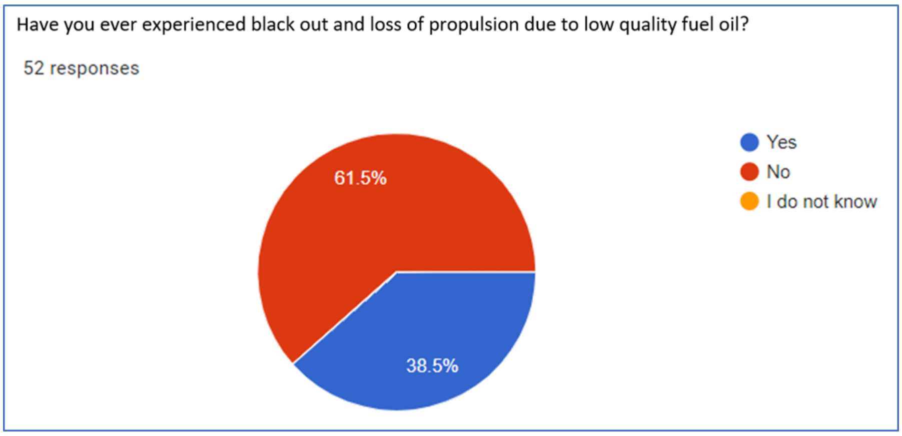

Figure 24: Respondents on black outs due to low quality bunker fuel oil

Another major contributing factor for the supply of poor quality bunker as per one of the respondents is,

"Lack of adequate Quality control and inspection regime by local administration on the Bunker supplier chain side"(Respondent-47).

38.5% of the respondents had come across bad quality bunker fuel oil which eventually had to be de-bunkered, as shown in Fig-25

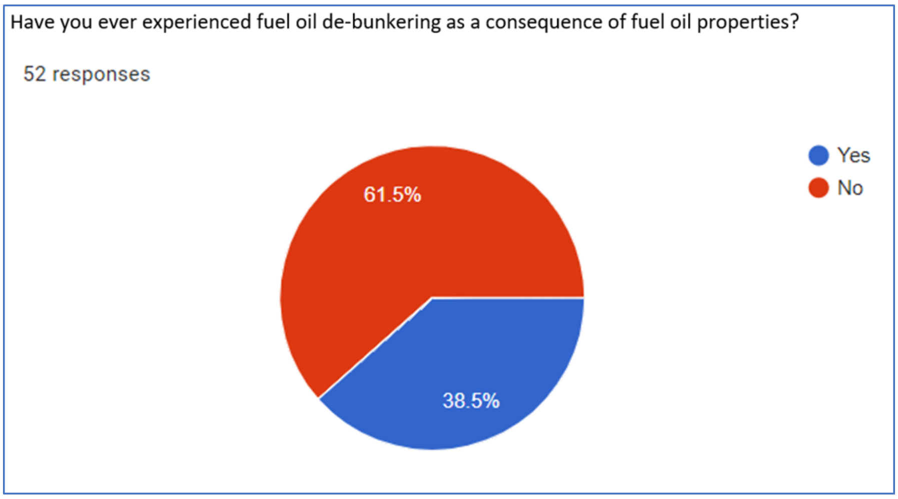

Figure 25: Opinion of respondents on fuel oil de-bunkering

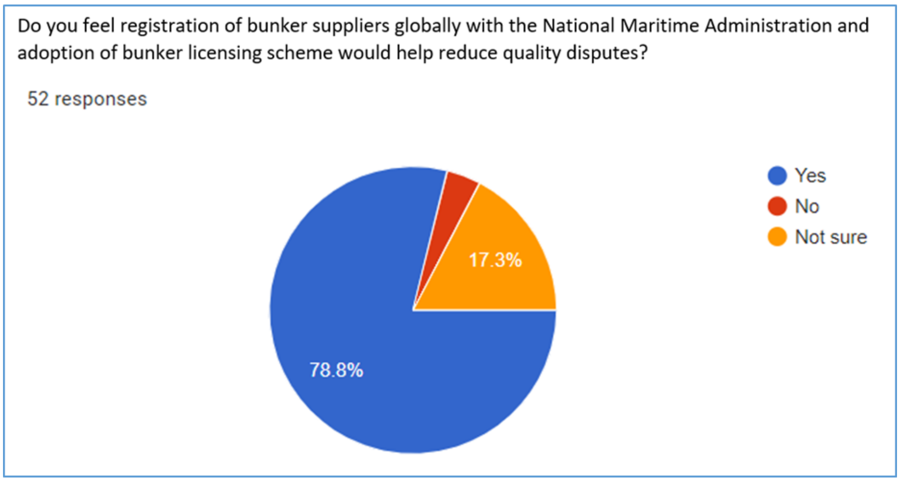

Figure 26: Respondents on bunker licensing scheme to reduce quality disputes

78.8% of the respondents believe that the registration of bunker suppliers globally with the national maritime administration and adoption of the bunker licencing scheme would help reduce quality disputes, as shown in Fig-26.

It is evident from this chapter that adequate reforms in the bunkering mechanism are an impending need. Accordingly, IMO and member states need to work together and devise a water-tight regulatory intervention to reduce the menace of supplying reduced quantity and inferior quality of bunker fuel oil to ships.

Chapter 6.0 Recommendations and Conclusions

6.1 Preventive Measures against Bunker Disputes

The various issues which give rise to quantity and quality disputes consequent upon bunkering have been discussed in chapter-3 under section 3.3. Some measures which, if resorted to, could help reduce bunker disputes have been listed in Table No - 6 and are discussed in the following sections.

Table 6: *Preventive measures and issues addressed*

Preventive Measures against Bunker Disputes	**Fig.No relating to issues likely to be addressed**
Engagement of Bunker Surveyor	7,8,9,10,11
Engagement of Bunker Trader	7,8,9,10,11
Use of Coriolis Mass Flow Meter	7,8,10,11
Addressing Issues in The Supply Chain	17,19,20,21,22,23,24,25
Bunker Survey and Bunker ROB Audits	20,21
Bunker Licensing Scheme	7,8,9,10,11,17,19,20,21,22,23,24, 25

Table Note: Conceptualized by Author

6.1.1 Engagement of Bunker Surveyor

A Bunker surveyor is an unaffiliated third party entity that the bunker purchaser may hire to oversee the bunkering operation. The surveyor confirms the bunker onboard the receiving vessel and the bunker barge both before and after the bunkering operation. In addition, he takes a bunker sample and analyzes its water content. He is experienced in identifying the ‘cappuccino’ effect and other means adopted by the bunker barge to withhold the bunker and control the bunker's quantity and quality.

Engaging a bunker surveyor is a popular way to minimize the risks during bunkering (Cockett, 1997).

6.1.2 Engagement of Bunker Trader

The bunker buyer can benefit by using a bunker trader since the trader can inquire from every supplier in the port where bunkers are required and get the best deal. Generally, bunker traders operate in many ports. Therefore, it is relatively more manageable for the buyer to associate with a particular trader and get the bunker supplied through him rather than deal with the various suppliers in different ports. Also, if a problem occurs, the buyer has to deal only with the trader who would deal with the supplier. Through a trader, it is possible to get better terms and conditions for purchase than that which could have been obtained directly from the supplier (Malmros, 2013).

6.1.3 Use of Coriolis Mass Flow Meter

The mass flow meter could be fitted on the bunker barge, on the receiving ship or both. However, very few ships or bunker barges have the mass flow meter installed because of its high installation cost and other related issues, for example the need for regular calibration. Nevertheless, the meter can solve all density and temperature associated issues, and the reading can reflect the shortage. The Coriolis mass flow meter uses the acceleration force of the flowing liquid to measure the bunker delivered. The meter can operate with both singular and double phase flow. The singular-phase flow is when only the oil passes through the meter, and the double-phase flow is when the oil containing air passes through the meter. As a result, the fluid flow, density and temperature are accurately measured, and the quantity calculation can be correctly done. Also, the measurement of the air volume in the bunker increases the accuracy of the calculation (Malmros, 2013).

6.1.4 Addressing Issues in The Supply Chain

At every point in the bunker supply change where a change in custody occurs, sampling should be carried out mandatorily to enable better tracking of the bunker quality along the supply chain. Also, bunker suppliers must be required to obtain a Certificate of Quality (COQ) from an accredited testing laboratory for the purchased oil cargo certifying that the fuel oil conforms to MARPOL Annex VI and ISO 8217 requirements before supplying the fuels to any vessel.

6.1.5 Bunker Survey and Bunker ROB Audits

Unannounced bunker surveys and bunker audits should be carried out to stop the practice of keeping undeclared bunker fuel oil on ships. The ship staff could trade this undeclared fuel oil with the bunker barge master for cash and accept an equivalent amount of lesser bunker. These surveys and audits would also ensure that all the laid down shipboard procedures for bunkering are being correctly followed and documented and that accurate records are maintained, which would be crucial to support the vessel's position in a dispute.

6.2 Proposed Reforms - The Bunker Licensing Scheme

Ships carry out bunkering in many ports of the world. Different ports have different practices, and there is no uniformity among the ports as any international regulations do not mandate it. To have consistent practice worldwide and ensure the bunkers supplied on board have quality as per ISO standards and ensure that buyers receive the correct quantity of fuel, there is a need for some uniform international mechanism for bunkering. The Licensing of bunker suppliers and introducing a mandatory Bunker Code by IMO is a pragmatic way to address the bunkering issues.

6.2.1 Ways Ahead – IMO Guidelines

MARPOL is an International convention aimed at reducing pollution from ships (IMO, 2020a). Regulation 18 of MARPOL Annex VI pertains to fuel oil quality. Regulation 18.3 specifies that fuel oil consumed on ships must not have any added substance or chemical waste that could jeopardize ship safety or impair machinery performance. Regulation 18.9 of the MARPOL Annex VI stipulates that the parties should maintain a register for local fuel oil suppliers and require these fuel oil suppliers to provide ships with BDN and representative fuel oil samples and take action against bunker suppliers if they deliver fuel oil that does not correspond to what is stated on the BDN. This regulation also requires the Maritime Administration of member states to establish mechanisms for action against bunker suppliers who supply bunker that is not complying with the Convention's requirements (IMO, 2020a).

Regulations 14.4 and 14.1 of MARPOL Annex VI specifies limits on the sulphur content of fuel oil consumed on ships, within and outside SECA areas (IMO, 2020a).

IMO MEPC Circ. 1/875 stipulates guidelines on best practices for fuel oil purchasers and users for assuring the quality of fuel oil used on board ships (IMO, 2018).

MEPC.1/884 stipulates guidance on best practices for Member state/Coastal state to ensure MARPOL Annex - VI compliance (IMO, 2019).

The IMO MSC 100 session has recommended that the Bunker license mechanism be established by each member state and recommended that MEPC consider an amendment to MARPOL.

The purpose of this scheme is to ensure that the quality of bunker fuel is maintained. While the member state ensures compliance with MARPOL Annex VI regulations, buyers will benefit by receiving the total quantity of quality fuel oil.

6.2.2 Bunker Licencing Mechanism

With increased awareness of environmental protection, ship bunkering has evolved into a highly focused shipboard operation, especially concerning quality assurance and regulatory compliance. The bunker licencing mechanism would ensure better quantity and quality assurance and compliance with all the regulations.

6.2.2.1 Registration with National Authority

Any organisation intending to supply bunkers should be required to register with the national authority and get a registration number. The details of the bunker suppliers should be available in the online system for quick verification of credentials. The registered bunker suppliers should issue bunker delivery notes only in the online mode to facilitate national authority monitoring the bunker supplies (DGS, 2014).

6.2.2.2 Requirements For Bunker Suppliers

Bunker suppliers produce or purchase, own, store, and sell bunkers. They may utilize pipelines, trucks, and/or barges to distribute bunkers and blend various products for meeting specifications. They may have or may charter a distribution network or contract with a third party for delivery services. They are responsible for issuing the Bunker Delivery Note and the fuel oil samples.

The Bunker Supplier (BS) should be a company registered under the respective country's laws and is responsible for bunker delivery to the ship via barge, road tanker, or directly from the shore.

Apart from bunker suppliers, there are product suppliers, who may be oil manufacturing companies. A Product Supplier (PS) is a registered company that supplies bunker/product to a Bunker Supplier. The company shall provide the Bunker Supplier with a declaration attesting the fuel's quality, which must meet the ISO 8217 quality standards in force. The Product Supplier may also assume the responsibilities and obligations of the Bunker Supplier. In such cases, the Product Supplier would be required to comply with all applicable national licensing requirements and have a valid Bunker Supplier Registration Certificate (DGS, 2014).

To be considered for issuing the Bunker Supplier Registration Certificate, the Company must:

1. Establish and continuously improve the effectiveness of a Quality Management System (QMS) based on ISO 9001: 2008 standards, as amended.
2. Establish and maintain documented systems, including but not limited to supplier selection and periodic evaluation of products supplied, to ensure that purchased products comply with applicable regulations of MARPOL - Annex VI and the ISO 8217 standards.
3. Ensure effective systems for the bunker's 'custody control' from receipt to delivery, including transportation systems. Outsourced processes must be

documented in the quality management system, and the supplier must maintain complete control over them.

4. Establish a procedure for identifying, storing, retrieving, retaining, and disposing of records and other evidence generated in connection with bunker delivery.
5. Ensure that safety and environmental protection is established.

6.2.2.3 Periodic Verification Requirements

The licence should be valid for five years conditional upon satisfactory annual verification to ensure that the bunker supplier fulfils the requirements of the bunker licence system.

6.2.2.4 Issuance of BDN

Every registered Bunker supplier should be required to indicate the validity of their bunker supplier licence certificate and certificate number on the BDN. They should be required to maintain a copy of each BDN for three years and produce it before the competent authority during inspection and verification.

The BDN should certify that the delivered bunker complies with the requirements of MARPOL 73/78 - Annex VI, regulations 14 & 18 and must include at least the details as specified in the sample BDN (see Appendix).

The bunker supplier must also provide the vessel with the Material Safety Data Sheet (MSDS), as required under SOLAS 74 and details of the Physicochemical characteristics of the product and other information as per IMO Resolution MSC.286 (IMO, 2009).

6.2.2.5 Sampling

The bunker supplier must ensure that for every bunker supplied; samples are collected, sealed and given to the vessel along with the BDN as stipulated in Regulation 18.8 of MARPOL Annex VI (IMO, 2020a).

The IMO recommendations on sampling, particularly concerning sampling equipment, containers, seals, labels etc., as detailed in MEPC.182(59), must be followed (IMO, 2009a). The samples that are taken during bunkering should be representative of the entire bunker oil supply. The sampling process, the taking of samples in bottles and the sealing of sample bottles must be witnessed by both the buyers and the seller's representatives. All the samples must be numbered and the numbers specified in BDN.

6.2.2.6 Maintenance of Fuel Oil Quality

The bunker supplier should be solely responsible for ensuring that fuel oil quality is maintained. Therefore, they must ensure that fuel supplied meets the MARPOL Annex- VI fuel oil quality requirements and should provide a laboratory analysis report to support this claim. The specifications in the laboratory analysis report should be on the bunker delivery note.

6.2.2.7 Bunkering Operation

Bunkering operation must be carried out as per established procedures and taking guidance of ISO 13739 standards. A mass flow meter is essential to ensure that quantity is ascertained apart from quality assurance.

The following procedures are required to be incorporated:

1. Pre Bunkering Checklist
2. During Bunkering Checklist
3. Post Bunkering Checklist
4. Documentation Checklist

6.2.2.8 Licence Certification Process

Every new applicant seeking registration as a bunker supplier must apply to the designated national authority. An interim bunker registration certificate valid for six months should be issued conditional upon fulfilling the stipulated conditions. During this period, the supplier should be required to demonstrate capabilities to deliver fuel to the vessel safely. After this, a full-term bunker registration certificate valid for five years must be issued.

6.2.2.9 Suspension of Bunker Licence

Bunker license should be liable for suspension on account of for the following reasons:

1. The licensee does not deliver bunker for a period exceeding one year or
2. The licensee does not meet the requirements and conditions laid down in the licence or
3. The licensee violates the relevant applicable regulations.

6.3 Conclusions

The bunkering process involves many externalities. As a result, it is difficult to have a single guaranteed way to safeguard a vessel from quantity and quality disputes.

The deployment of a bunker surveyor is the simplest way to overlook the quantity delivered. An unaffiliated third party representative ensures the correctness of the amount stemmed on board. However, there could be problems finding an honest bunker surveyor since unethical activity exists amongst surveyors too and would also increase the bunkering expenses.

The bunker trader simplifies the buying process and facilitates in case of any dispute. The trader is associated closely with various suppliers and has an in-depth knowledge of the bunker market, thereby enabling better pricing and terms and conditions. If the trader fails to resolve the issue, the bunker purchaser must approach the administration for redressal. However, an additional cost is incurred for using the services of a bunker trader.

A mass flow meter would be expensive to install and maintain on a bunker barge. Also, it would require frequent calibration. However, from a bunker buyer's perspective, the mass flow meter would be prone to easy tampering like any other measuring device.

The member states need to have firm control over the bunker market and bunker suppliers with a strict inspection and regulatory regime. In addition, the bunker buyers should have a mechanism to report any issues arising during bunkering with the bunker supplier, bunker surveyor or bunker trader to the regulatory authority. Also, introducing a feedback mechanism and rating system for the bunker suppliers by the bunker purchasers would prove highly beneficial. The online display of the ratings and feedback would prove to be an eye-opener for the bunker buyers and deter the bunker suppliers from indulging in malpractices.

The introduction of the mandatory bunker code by the IMO and the mandatory implementation of the bunker licensing system by the member states would go a long way in improving the bunkering mechanism.

A right combination of awareness, transparency, legislation, equipment and trained ship staff is likely to make the bunker market fully transparent, fair and devoid of any malpractice.

6.4 Scope for Future Research

Possible future research could be on the effects of bunker quantity and quality issues and their disputes on the different stakeholders involved in the operation of a vessel (ship owners, ship charterers, Technical managers, ship agents, ship staff, consignees and consignors).

Bunker fuel oils are paid for in mass. However, since a Coriolis mass flow meter is seldom used, they are measured in volume first and converted to mass. Therefore, researching how to measure bunker fuel oil directly in mass on delivery other than using a Coriolis mass flow meter would prove beneficial. In addition, it would be a remedy for most of the tricks adopted by the bunker barge personnel for the short delivery of fuel oil.

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Appendix – A: Questionnaire

Questionnaire

Section-1

Personal Details

Name:

Rank:

Name of Ship or Company:

E-mail Id:

Section-2

Quantity Issues

1. Have you experienced air being mixed in the bunker oil to reduce quantity delivered:
   - Yes
   - No
2. Have you experienced the barge personnel using a tampered measuring tape during demonstration of the barge tank soundings:
   - Yes
   - No
3. Have you ever been made to sign a BDN prior to bunkering by deceit:
   - Yes
   - No
4. Have you experienced a situation when the barge tanks were not measured jointly prior to bunkering:
   - Yes
   - No
   - Cannot say
5. Have you experienced a situation when only the nominated barge tanks were measured jointly prior to bunkering:
   - Yes
   - No
   - Cannot say

6. How often was an independent bunker surveyor engaged:
   - Always
   - Seldom
   - Never
7. The use of a bunker surveyor reduces the possibility of quantity disputes:
   - Agree
   - Disagree
   - Not sure
8. Have you experienced bunkering when a Mass flow meter was used for quantity determination:
   - Always
   - Never
   - Seldom
9. The use of Mass flow meter may reduce the possibility of quantity disputes:
   - Agree
   - Disagree
   - Not sure
10. Have you attended any training on bunker oil supply and management:
   - Yes
   - No
11. Please describe if at any occassion you were not satisfied with the representative sample given by the supplier:

12. Please describe what in your opinion is the most common method adopted for supplying reduced quantity of bunker:

13. Please describe any other bunker quantity related issues that you may have come accross:

14. Please suggests measures on how to solve the problems of short delivery during bunkering:

15. Please describe your opinion on registration of bunker suppliers globally with the National Maritime Administration and adoption of bunker licensing scheme to reduce bunker quantity disputes:

Section-3

Quality Issues

16. Please specify the standards for the bunker fuel oil specification being used:
   - ISO 8217: 2005
   - ISO 8217: 2010
   - ISO 8217: 2012
   - ISO 8217: 2017

17. Have you experienced a situation where the fuel oil analysis report indicated off specification:
   - Yes
   - No
   - I don't know

18. Please select the most common characteristics or limits off specification as per your experience:
   - Deleterious materials
   - Viscosity
   - Density
   - Cetane index
   - Sulphur
   - Flash point
   - Hydrogen sulphide
   - Acid number
   - Total sediment
   - Oxidation stability
   - Fatty acid methyl ester (FAME)
   - Carbon residues
   - Cloud point
   - Cold filter plugging point

- Pour point
- Appearance
- Water
- Ash
- Lubricity
- Calculated Carbon Aromaticity Index (CCAI)
- Vanadium
- Sodium
- Aluminium and silicon
- Used lubricating oil (Calcium and Zinc / Calcium and Phosphorus)

19. Have you experienced fuel oil analysis report indicating a flash point temperature below 60°C:
   - Yes
   - No
20. Have you ever experienced an increase in deposits in fuel oil tanks and/or clogging of fuel pipes, seperators, suction filters, etc after use of new bunker oil:
   - Yes
   - No
21. Have you ever experienced an increase in sludge discharge from purifiers after use of new bunker oil:
   - Yes
   - No
22. Have you ever experienced problems with fuel injection, poor ignition of fuel or incomplete combustion after use of new bunker oil:
   - Yes
   - No
23. Have you ever experienced fuel pump seizure due to low quality fuel oil:
   - Yes
   - No
   - No
24. Have you ever experienced black out and loss of propulsion due to low quality fuel oil:
   - Yes
   - No
   - I don't know
25. Have you ever experienced fuel oil de-bunkering as a consequence of fuel oil properties:

- Yes
- No

26. Do you feel registration of bunker suppliers globally with the National Maritime Administration and adoption of bunker licensing scheme would help reduce quality disputes:
    - Yes
    - No
    - Not sure

27. Please describe any other bunker quality related issues that you may have come accross:

28. In your opinion what are the reasons for delivery of low quality bunker fuel:

29. Please suggests measures on how to solve the problem of inferior quality of bunker fuel oil being delivered:

30. Your suggestions on how to improve the fuel oil bunkering system so that the issue of quantity or quality are reduced:

Appendix – B: WMU Research Protocol

WORLD MARITIME UNIVERSITY

WMU Research Ethics Committee Protocol

Name of principal researcher:	Sudhir Kumar Shrivastava
Name(s) of any co-researcher(s):	N/A
If applicable, for which degree is each researcher registered?	M.Sc in Maritime Affairs – Maritime Safety & Environmental Administration
Name of supervisor, if any:	Dr Alessandro Schonborn
Title of project:	Fuel oil bunkering mechanism and way ahead in strategic enforcement
Is the research funded externally?	No
If so, by which agency?	N/A
Where will the research be carried out?	World Maritime University
How will the participants be recruited?	Marine Chief Engineers & Technical Superintendents
How many participants will take part?	30
Will they be paid?	No
If so, please supply details:	N/A
How will the research data be collected (by interview, by questionnaires, etc.)?	By Questionnaire
How will the research data be stored?	On the google drive linked to World Maritime University email address of the researcher
How and when will the research data be disposed of?	Data shall be deleted on completion of study by Nov-2021
Is a risk assessment necessary? If so, please attach	N/A

Signature(s) of Researcher(s): Sudhir   Date: 23/05/2021

Signature of Supervisor: Alessandro Schönborn   Digitally signed by Alessandro Schönborn DN: cn=Alessandro Schönborn, o=World Maritime University, ou=Maritime Energy Management, email=as@wmu.se, c=SE Date: 2021.05.24 20:47:02 +02'00'   Date:

Please attach:

- A copy of the research proposal
- A copy of any risk assessment
- A copy of the consent form to be given to participants
- A copy of the information sheet to be given to participants
- A copy of any item used to recruit participants

Appendix – C: Approval from WMU Ethics Committee

WMU WORLD MARITIME UNIVERSITY

SHRIVASTAVA, Sudhir Kumar <w2005558@wmu.se>

REC DECISION # REC-21-14(M)

1 message

Email, PhD <PhD@wmu.se> Thu, May 27, 2021 at 11:09 AM
To: "SHRIVASTAVA, Sudhir Kumar" <w2005558@wmu.se>
Cc: Alessandro Schönborn <as@wmu.se>

Dear Sudhir,

This is to let you know that the members of the WMU Research Ethics Committee (REC) have approved the research related documents that you submitted to this office on 24 May 2021 concerning your research study involving human participation.
You are now free to start your data collection work in consultation with your supervisor.

Kind regards/Med vänlig hälsning/Με εκτίμηση/Ystävällisesti/祝好/Amicalement/Atentos saludos/Atenciosamente/ Saygılarımla/Сувaжeниeм/ Mit besten Grüßen/Distinti saluti/Serdeczne pozdrowienia/Venlig hilsen/Met vriendelijke groet/敬具/ سپاس

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REC Secretary
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Appendix – D: Information to be included in the BDN

1 Name and IMO Number of receiving ship
2 Port
3 Date of commencement of delivery
4 Name, address, and telephone number of marine fuel oil supplier
5 Product name(s)
6 Quantity in metric tons
7 Density at 15^{0}C (kg/m^{3}) footnote
8 Sulphur content (%m/m)footnote
9 A declaration signed and certified by the fuel oil supplier's representative that the fuel oil supplied is in conformity with regulation 18.3 of this Annex and that the sulphur content of the fuel oil supplied does not exceed:
□ the limit value given by regulation 14.1 of this Annex;
□ the limit value given by regulation 14.4 of this Annex; or
□ the purchaser's specified limit value of _____ (% m/m), as completed by the fuel oil supplier's representative and on the basis of the purchaser's notification that the fuel oil is intended to be used:
.1 in combination with an equivalent means of compliance in accordance with regulation 4 of this Annex; or
.2 is subject to a relevant exemption for a ship to conduct trials for sulphur oxides emission reduction and control technology research in accordance with regulation 3.2 of this Annex.
The declaration shall be completed by the fuel oil supplier's representative by marking the applicable box(es) with a cross (x).