The Bunkering Industry and its Effect on Shipping Tanker Operations

by

Angelos Boutsikas

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Signature of Author:__________________________
Department of Ocean Engineering
September 2, 2003

Certified by:__________________________
Henry S. Marcus
Professor of Marine Systems
Thesis Supervisor

Accepted by:__________________________
Michael S. Triantafyllou
Professor of Ocean Engineering
Chairman, Departmental Committee on Graduate Studies

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ABSTRACT

The bunkering industry provides the shipping industry with the fuel oil that the vessels consume. The quality of the fuel oil provided will ensure the safe operation of vessels. Shipping companies under their fuel oil management programme confirm that the quality and quantity of fuel oil provided are as requested. To be certain of the quality and quantity loaded, correctly performed bunkering procedures need to be integrated in the fuel oil management programme. The data collected through them will prove more than useful when a dispute arises either in terms of fuel oil quality or the loaded quantity.

Ship emissions to air are a concern of IMO and recently the European Union, as the shipping industry contrary to land-based industries is not yet subject to any regulations to reduce emissions. Sulphur oxides are targeted as they depend on the sulphur content of the fuel oil. Identical limits are set by both the IMO and the EU, but IMO's regulations are yet to be ratified and EU will not accept any vessels travelling within its waters to burn high-sulphur fuel oil from 2010 onwards. Till then, those involved in the matter might have to consider implementing an emissions trading scheme, as in the land-based industries, as a more viable option to capping sulphur content.

Every shipowner is aware of the fact that the single most costly and highly volatile running cost paid is the cost of bunkers. The options available to him/her are hedging instruments such as futures and OTC products. When used effectively along with freight futures, although not yet commonly available, shipping companies may reduce their risk exposure and enhance their profits.

When purchasing fuel oil from a number of ports, cost savings may be augmented by a carefully improvised bunkering planning, as well as negotiating the price of fuel oil purchased based on its density, aluminium content, viscosity, water content and net specific energy.

Thesis Supervisor: Henry S. Marcus
Title: Professor of Marine Systems

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

Fuel oil is of great importance to the shipping industry. The prime movers of the merchant vessels will consume fossil fuel, until the day it will cease to exist. Bunkers make up the largest part of a ship's running costs, and always have done. It is estimated that their cost comprises a percentage of 50-60% of the total running costs, i.e. dialy running costs and voyage costs.

Marine fuel oil consists largely of a residue that remains from crude oil distillation after stripping off all components of lower boiling ranges. It consists of a great variety of long chain hydrocarbons in a boiling range predominantly well above that of gas oil. As crude oil varies widely in composition and quality, so does the residue. In particular, there are crude oils of high and low viscosity, high and low sulphur content, etc. This results in varying yields of residues suitable for producing marine fuel oil. Furthermore,, a refiner for economic reasons is interested to extract as many high value fractions from the crude oil. "A modern refinery of sophisticated design is operated to affect precisely this. Little or even no residue at all is left today. The consequence is that these residues contain most components and contaminants of the crude oil undesired in the high value products in a high concentration. Inevitably, therefore, the last 30 years of 'upgrading' refineries have resulted in a corresponding downgrading of residues and in consequence marine fuel oil quality." [Ref. 6, 1997]

2 QUALITY AND QUANTITY MANAGEMENT

2.1 QUALITY OF MARINE FUEL OILS

The quality of a fuel has an effect on:

- The combustion process
  - The exhaust valves
  - The inlet valves and pumps
  - The turbochargers and exhaust gas system
- The handling of the fuel
  - The fuel treatment process

2.1.1 QUALITY PARAMETERS

- Density (kg/m^3)
- Viscosity (cSt)
- Pour Point and Cloud Point (^{o}C)
- Flash Point (^{o}C)
- Carbon Residue (% m/m)
- Asphaltenes (mg/kg)
- Ash Content (% m/m) – Al/Si (mg/kg) – Vanadium (mg/kg)
- Water and Sea Water (% v/v)
- Sulphur (% m/m)

- Compatibility and Stability
- Ignition Quality

Information on each of the above quality parameters is not mentioned in the thesis, since it is not the purpose of this project to establish basic knowledge on fuels. It is important to know though in what way will each of these affect the onboard usage of the fuel. This is diagrammatically illustrated in the following figure.

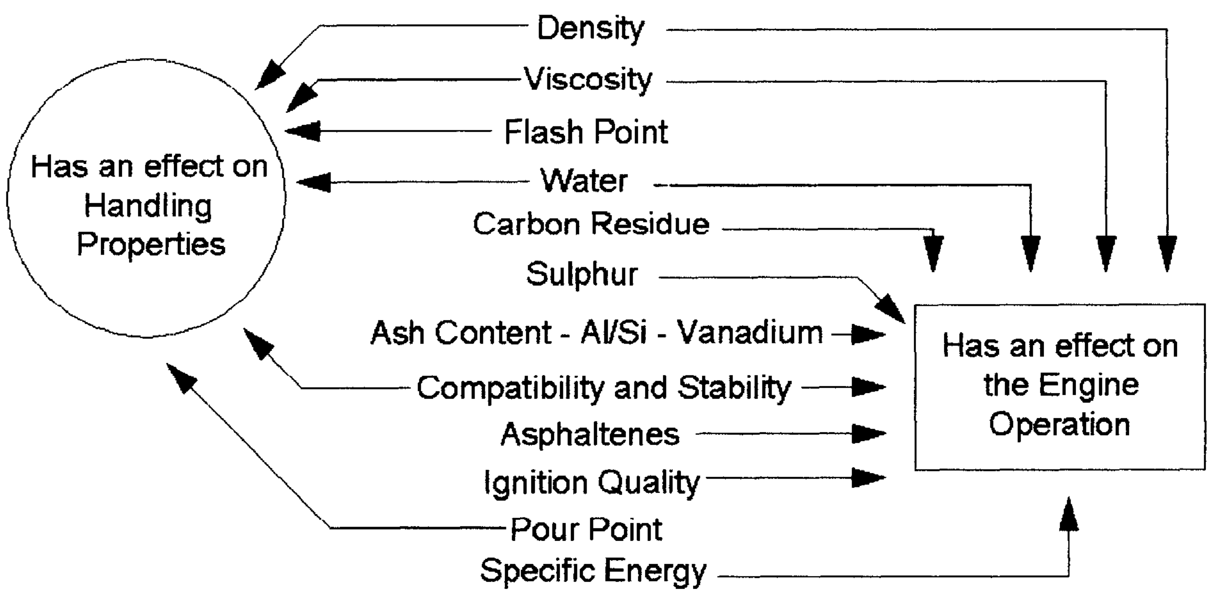

Figure 2.1: The fuel oil quality parameters and their effect on the Handling Properties and Engine Operation. [Ref. 17, 1993]

2.1.2 FUEL QUALITY TRENDS

Examination of quality records shows rapid increases in the global average density and carbon residue in the late 1970s and early 1980s, indicative of the increasing absorption of residue conversion process and other secondary refining technology. Figure 2.2 illustrates the rapid change in average density about that period, and the subsequent much slower increase. Figure 2.3 presents more recent data on average carbon residue trends, which confirms that the rate of change of fuel quality has slowed considerably. What we are seeing today is not the rapid change which caused the justified concern in the 1970s, but a more gradual shift. A slowly increasing proportion of today's fuels are approaching the critical specification maxima, but there is no pressure from the supply perspective for these maxima to be relaxed to provide continued availability of fuel.

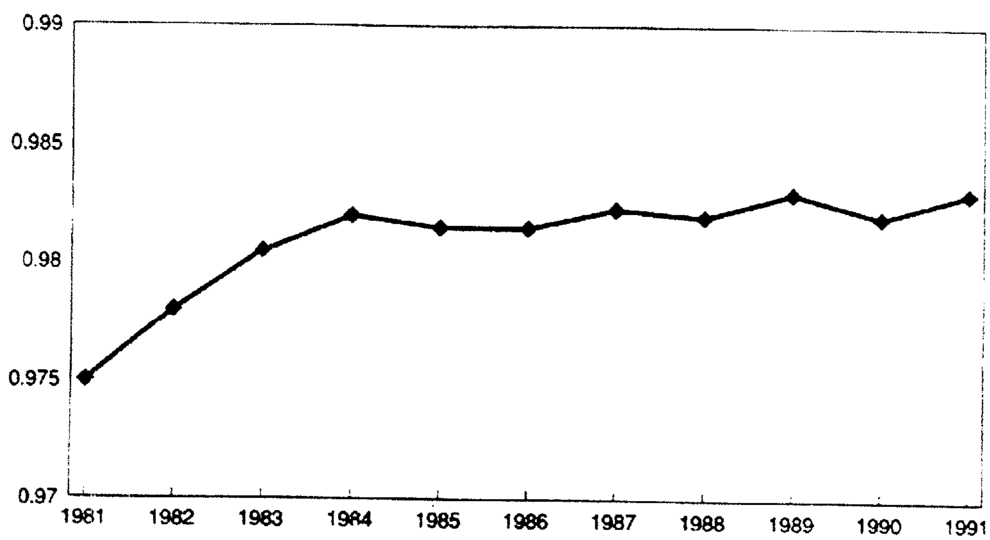

Figure 2.2: Average density of all fuels worldwide in the 250-400 cSt viscosity band, for the period 1981 to 1991. [Ref. 13, 1998]

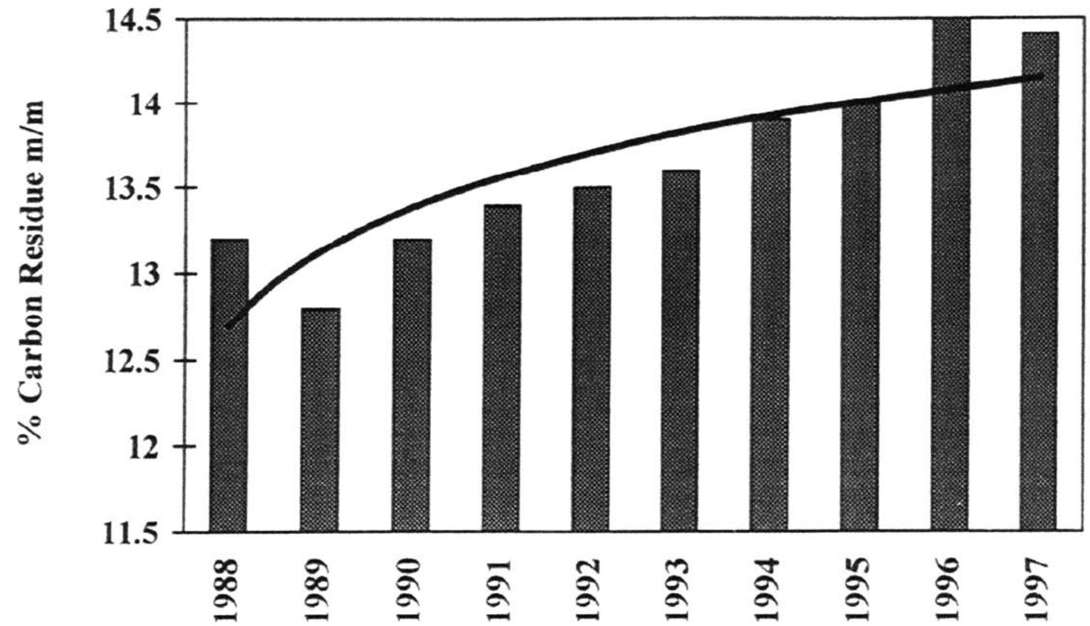

Figure 2.3: Average carbon residue values for IFO bunkers supplied during the period 1988-1997. [Ref. 13, 1998]

There are probably two reasons for the slowdown. In recent years, there has been little need or little opportunity for investment in new residue conversion processes in refineries. Where there has been major investment, it has sometimes been in a new generation of residue conversion processes which produce little or no fuel oil. It is anticipated that the same trends will continue in the future. Where refiners do need to invest in residue conversion processes, the chosen processes are likely to be those which minimise fuel oil production, since projections show a declining market for fuel oil in the future. "There will be a continuing decline in the amount of straight-run residue which goes into the bunker fuel oil pool, both because some of the older straight-run refineries will close, and because straight-run residue will have a higher value as a feedstock for secondary refining rather than as a fuel oil component. The overall effect will be a continuation of the current slow drift of average fuel quality towards the specification maximum, and is likely to be accompanied by a continued tightening of fuel oil availability." [Ref. 13, 1998]

2.1.3 TEMPTATIONS TO REDUCE QUALITY

Global oil demand growth is projected to have slowed to an average of 1.3% per year for the period 1997 to 2000, reflecting the loss of incremental Asian oil demand and three consecutive milder-than-usual winters in the Northern Hemisphere. Post 2000, with the resumption of Asian oil demand growth, world oil demand growth is expected to rise again to annual average levels of around 2%. The world residual bunker fuel demand (excluding marine gas oil) has increased from 105 million metric tonnes in 1990 to almost 120 million in 1998. The global bunker fuel demand is expected to increase only slightly between 1999 and 2005 with an annual growth rate of 0.3%. In Europe, the Pacific, the Middle East and the Far East, the supply/demand balance for bunkers will move towards an oversupply. Furthermore, in many parts of the world the marine market may become the main market for residual fuel oil. In particular, the power generation "dash for gas" will progressively release low quality components into the bunker market, fuel oil previously designated for power generation. In the longer term this may also be an effect of reduced need for residual fuels to be imported to the US. [Ref. 8, October 2000]

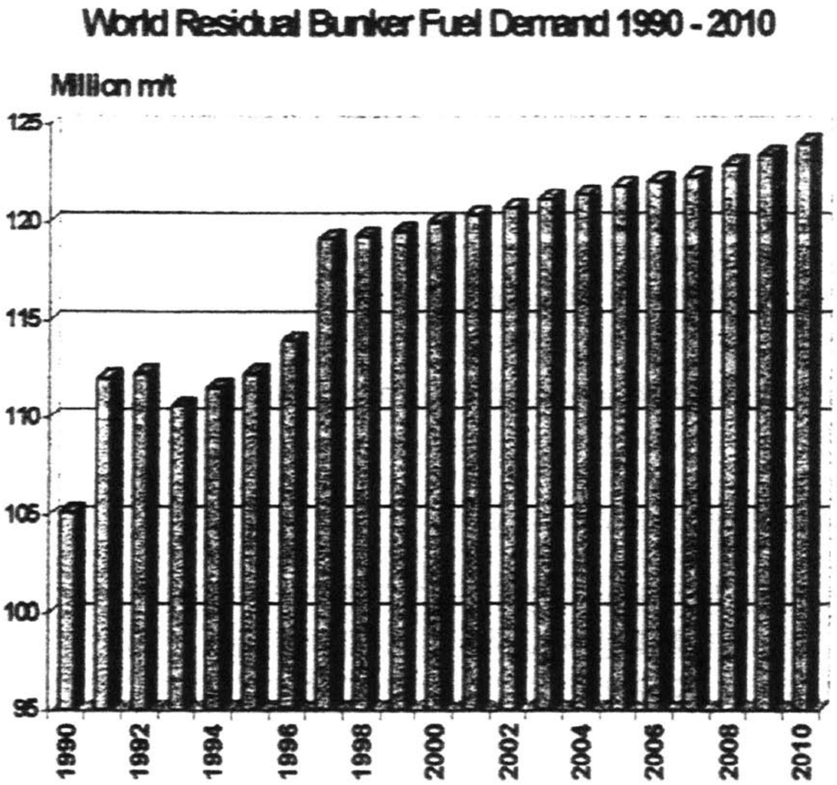

Figure 2.4: World Residual Bunker Fuel Demand 1990-2010. [Ref. 8, October 2000]

The over supply of residual fuel in terms of heavier components tend to drive prices, and therefore margins for suppliers, down. In addition to price, competition amongst sellers on the quality of product is unlikely to disappear. Indeed in such an environment, a few temptations may arise for those suppliers who do not need to protect their brand, or those who find it difficult to sell high quality product at a reasonable price. Despite the existence of internationally recognised supply specifications, fierce competition between suppliers may mean that the gap between high and low quality product supplies may well widen in the future. [Ref. 8, October 2000]

2.1.4 OFF SPEC FUELS

A fuel can be off spec in any of the quality parameters. It is true that today's engines will run with several grades of residual fuel oil. By off spec fuels, one does not mean the case of a fuel being of a different grade than the one proposed by the engine manufacturer to be used. Not meeting the required specification of the grade ordered will characterise a fuel as being off spec.

"There are opinions stating that 70% of all marine engine problems are fuel related." [Ref. 19, 1995] "Fact is that at reputable suppliers more than 99% of all deliveries investigated are on spec, a few are minor overshoots, and one in 1000 only is definitely unfit for use." [Ref. 6, 1997]

Engine builders have been trying to develop reliable engines, and in the case of SULZER RTA-engines, fuel oil of 810 cSt viscosity is the 'Bunker limit' which indicates minimum quality of heavy fuel oil to feed. When we look into the statistics of DNV fuel oil analysis, however, there are so many varieties of the most commonly used 380 cSt fuel and corresponding fuel oils available in the market.

"Bunker quality makes the news only when people think they have had a bad lot of fuel. But bunker quality is not just about how fuel meets specifications. Almost all of the very few disputes which arise over bunkers stem not from the fuel itself, but from misunderstandings which have occurred somewhere in the whole chain of bunker purchasing and supply. It is extremely rare to get a load of fuel which cannot be burnt. It is less rare to find people involved in the purchase and supply of bunkers who unintentionally turn minor technical problems into major disputes through a lack of understanding." [Ref. 20, June 2000] "Whatever the case, one strike (bunkering) is enough to destroy a marine engine in service." [Ref. 10, October 2000]

2.1.5 FUEL OIL CONTAMINANTS

Except from the case of a fuel being out of spec, a fuel oil might contain chemical waste. This might be in the form of used lubricants, polypropylene, organic acids, cleaning chemicals and hydrogen sulphide.

"IMO strives to ban chemical waste from inclusion into marine fuel oil. Reputable suppliers will support this concept. However, agreement on a clear and unambiguous definition of what constitutes 'chemical waste' is needed, and its presence and concentration should be monitored and recorded. IMO, and in consequence ISO, have to develop a policy on above, considering fully environmental, technical and economic aspects." [Ref. 6, 1997]

In particular, concerning the waste lube oil addition, some say that if properly managed, it is an environmentally effective way of disposing of a difficult waste product of the domestic motoring habit. Others say that, no matter how small the operational risk, the addition of waste lube was in contravention of the international fuel quality standard ISO 8217, specifically clause 4.1 which states:

"The fuels shall be blends of hydrocarbons derived from petroleum refining. This shall not preclude the incorporation of small amounts of additives intended to improve some aspect of performance. The fuels shall be free of inorganic acid.

NOTE 3 The fuel should not include any substance which

1. jeopardises the safety of ships or adversely affects the performance of the machinery

2. is harmful to personnel; or

3. contributes overall to additional air pollution." [Ref. 35, 1996]

One oil major picked up the baton and undertook research (together with a leading manufacturer of fuel treatment plant) to identify the risks to ship systems and to quantify the same. The result of that research was published in 2000. "The summary concluded that the industry norm of up to five per cent waste lube oil could lead to a considerable reduction in fuel treatment efficiency. Even small percentages showed some deterioration and that the researchers felt that the amount of any added waste lube oil should be strictly controlled in the next revision of ISO 8217." [Ref. 4, March 2002]

The new ISO standard will cover waste automotive lube oil but every few months another contaminant in fuel oil is identified with the potential to do damage to machinery or crew, as mentioned before polypropylene, organic acids, cleaning chemicals and hydrogen sulphide. Adding parameters to the specification to control every eventuality should be controlled as the time and cost of testing will become uneconomic, but that does not mean that sellers should not seriously consider the oil's fitness for purpose. "At the moment all of them exclude this specifically in their sales terms and claim it is the buyer's responsibility to select exactly what his ship needs. I think this is somewhat disingenuous as we all know that 90 per cent of marine heavy fuel is going to be used in a slow speed diesel engine and that the seller should declare that this is the basis of the product, leaving the buyers, to advise if they need a superior product for their particular engine or if they can accept a lower standard, say for a steamship. Some may say that the supplier's attitude of caveat emptor is as inappropriate to modern business as the shipyard's guarantee of one year on the ship." [Ref. 4, March 2002]

2.2 QUALITY AND QUANTITY MANAGEMENT

A supplier has to deliver an agreed quantity of a specified quality at the contracted time and place. Murphy's Law says: "When things can go wrong, they will do". [Ref. 16, 1985] "In consequence contracts, documents, procedures, notes, etc. must contain instructions that do not allow "things to go wrong" i.e. other than agreed. It is, furthermore, fact of life that specifications without adequate controls will not be followed consequently." [Ref. 6, 1997]

2.2.1 QUANTITY

"Marine fuels are sold on a mass basis with few exemptions: Gas oil in small quantities is supplied in litres to inland waterway and fishery vessels as well as leisure craft. In view of the problem to weigh large quantities of fuel the way adopted nearly always is to measure the volume and convert to mass by multiplying with the density". [Ref. 6, 1997]

With the recent increases in bunker prices the question of the quantity of received bunkers has reappeared creating the problems of alleged short deliveries of this costly material. Some methods and techniques, which are used by the bunker suppliers to avoid full delivery, or at least make the vessel believe that it has reached its full contracted amount, appear to range from at best most devious to the outright scandalous. "Last year DNVPS have issued their Bunker Alerts warning their customers of the devious use of compressed air or nitrogen that was used by certain bunker barges in Singapore for the apparent clearing of pipelines upon completion of delivery of bunkers to a vessel. Although on face value such a technique may be valid from a pollution prevention perspective to avoid the potential of any residue leaks from the bunker hose when disconnecting from the receiving vessel, clearly, such barges carrying out this technique do not have drip trays of adequate capacity or have systems in place to drain the delivery hose back to the bunker barge upon completion of bunkering. This being the apparent or potential reason, one must ask the question as to whether the barge is seaworthy for the function or service it is performing within the confined waters off Singapore and the potential pollution problems to be associated with a bunker spill. Notwithstanding the foregoing, the consequences for the measurement of the delivered bunker quantity onboard the receiving vessel could be large. By entraining air or nitrogen within a viscous bunker the resulting observed volume will be artificially increased over a short period of time until the entrapped gases evolve from the liquid bunker. Furthermore the use of nitrogen can cause an artificial drop in the viscosity of the bunker over a short period thereby impacting the apparent quality of the material received." [Ref. 34, February 2001]

Having said that, without the purpose being that of giving a bad name to the port of Singapore, the author would like to mention that from January 2002 the Maritime and Port Authority of Singapore (MPA) have amended their Bunkering CP 60 procedures with regard to the location of bunker sampling. The new bunkering procedure requires that bunker samples for the delivery of bunkers to ships will take place at the 'point of custody', which is at the vessel's main bunker receiving manifold. Although the above bunker sampling procedure is accredited by all three fuel analytical services (DNVPS, FOBAS and ABS), it is not common practice for many ports and operators. As it is seen, Singapore being a major port has only recently implemented it. Furthermore, sampling at the point of custody helps to resolve bunker disputes, concerning quality. [see Chapter 3]

2.2.2 QUALITY

"It is frequently claimed that the quality of marine fuels in general is deteriorating since years. This statement is endorsed by referring to a few spectacular engine damages in which inferior fuel quality was found to be the culprit. This is a regrettable imprecision of language: Either the fuel was out of spec. Hence it was inferior. Or it was on spec. In case this spec (like ISO 8217) was mutually agreed, the fuel was as contracted and not inferior." [Ref. 6, 1997]

"If there is no doubt or dispute about which sample represents the bunkers supplied, and if the quality of that sample is then assessed by a mutually agreed laboratory, a rapid assessment in the majority of cases can be made. Either the fuel is within specification, or it is not. However, the absence of an agreed sample of the fuel will make speedy dispute resolution after the event much more difficult. Even when an agreed analysis shows that the fuel is outside specification, it can still often be used. Guidance on using out of spec fuels can be obtained from the major fuel testing organisations, such as DNV and FOBAS." [Ref. 20, June 2000]

3 BUNKERING

3.1 BUNKER LOADING PROCEDURES

"The term bunker loading signifies the whole procedure that starts with the contact with the suppliers for a price quotation and ends after the delivery of the fuel oil." [Ref. 17, 1993] "Although a marine standard for fuel oil transfer procedures has not received universal acceptance, several attempts have been prepared which have gained local acceptance, including the Singapore bunker procedure (SBP) and the American Society for Testing and Materials (ASTM) bunkering protocol of 1993. There is however an ISO technical report (ISO 13739) entitled 'Methods for Specifying Practical Procedures for the Transfer of Bunker Fuel to Ships 1998'." [Ref. 1, 2000]

Prior to bunkering, the crew involved in the procedure should be aware of how to handle safely marine fuel oils. The bunker loading procedure consists of the following steps:

- Pre-arrival checks and procedures
- Agreement between ship and barge/shore
- Loading procedure

3.1.1 QUANTITY DETERMINATION

There are several methods by which the chief engineer can calculate the volume of oil transferred during the bunker transfer operation depending on the equipment available. These include:

- Measurement of bunker barge tanks and calculation of oil volumes transferred (dependent on safety implications and ease of access to the bunker barge)
- Measurement of shore based tanks and calculation of the oil volumes transferred
- Measurement of the receiving ship's tanks and calculation of the oil volumes transferred
- Fuel oil flow meter readings and calculations

[Ref. 1, 2000]

Although these methods may appear to be a mathematically accurate way to determine the quantities of fuel oil transferred, the accuracy is dependent on several key factors including:

- Accurate determination of angles of list and trim soundings, ullages, temperatures and volumes
- The ability of the chief engineer to make the necessary calculations and corrections
- The accuracy and availability of list and trim correction tables
- The accuracy and availability of volume correction tables
- The accuracy and availability of temperature correction tables.

[Ref. 1, 2000]

3.1.2 BUNKER DELIVERY RECEIPT (BDR)

Prior to commencing taking bunkers, a written statement on the BDR must be received from the suppliers indicating at least viscosity, density, water content, flash point and fuel delivery temperature for volumetric quantity calculations. If this statement is not forthcoming by the supplier, the chief engineer should advise the company and charterers' agent immediately and issue a 'Letter of Protest'. Any statement at this stage is not proof of bunker quality delivered on board at the manifold but the supplier's indication of fuel parameters supplied from the refinery/storage tanks.

Before signing the BDR, it should be stamped with the vessel's 'NO LIEN' stamps. A copy of the bunker receipt should be retained on board and a copy sent to the head office. The BDR should be signed with the following statement 'Signed for volume at observed temperature only. Determination of quality will be made upon receipt of fuel analysis results'. A copy of the BDR should also be enclosed, with the fuel sample sent to DNV Petroleum Services. For chartered vessels, the chief engineer should sign the bunker delivery receipt 'Received on behalf of Charterers Messrs…'.

3.1.3 LETTERS OF PROTEST

Prior to the bunkering procedure, the master of a vessel issues a request to the charterers' port agents and bunker supplier to attend the representative bunkers sampling. In the event of failing to attend the sampling, the master should issue a letter of protest [see Appendices 1 and 2]. It is important that, in the event of a bunker quantity dispute arising, the master of the receiving ship issues a notice of protest (NOP) as quickly as possible. The letter of protest should be signed by the master and/or the chief engineer; it should be directed to the barge master or shore representative and copied to the following interested parties:

- Shipowner/manager
- Charterer (if time charter bunkers)
- Fuel analysis organisation/laboratory
- Fuel supplier
- Bunker broker

The letter of protest, an example of which is given in Appendix 3, should also be signed, if possible by the barge master/shore representative and properly stamped with the ship and barge official stamps.

Quality has not been mentioned yet, since the only information given on quality is, as aforementioned, by the bunker supplier. Once the fuel is on board, the onboard fuel testing equipment (if any) will detect any deficiencies until the sample sent to the fuel analytical service is tested.

3.2 BUNKER SAMPLING AND ANALYSIS

"The process of bunker sampling and fuel analysis is one of the most important aspects of the fuel or bunker loading operation. Certainly, it provides the most important piece of single evidence in any bunker quality dispute. Indeed, it is probably true to say that most bunker quality disputes, will at some stage rely upon the analysis of a 'representative' sample taken at the time of loading fuel oil bunkers." [Ref. 1, 2000] This is essentially, at the moment, the goal for the fuel analytical services.

3.2.1 CUSTODY TRANSFER SAMPLING

A mutually-accepted sampling location is the key to obtaining a single and representative sample of the delivered bunkers. Such a sample can help resolve fuel quality disputes speedily and efficiently.

There are many possible reasons why a sample may not be representative, some of which are outlined below:

- A sample taken in 30 seconds from a bunkering that can take up to twenty-four hours is unlikely to epitomise the quality of the total fuel supplied
- A single sample taken at either the start, middle or end of bunkering will most probably bear scant resemblance to the actual nature of the fuel supplied as a whole
- Although ISO 8217 defines the required properties of the fuel at the place of the custody transfer, the location of this custody transfer is often debated, i.e. the barge's or the receiving vessel's manifold. That this is an important issue is reflected by the action of the Maritime and Port Authority of Singapore (MPA), which in July 2001 amended its bunkering code of practice with effects from January 2002 to switch to the custody transfer point from the former to the latter
- Barge blending, i.e. circulation within the barge's tanks, may be used to achieve the grade required; although effective if done correctly, fuel of differing 'quality'

can be loaded over distinctly separate periods of the bunker transfer, as a uniform mixture can take time to be established. The taking of a continuous drip sampler, however, can often contain the correct proportions of the fuel blend components and therefore show nothing amiss

[Ref. 26, February 2002]

DNV Petroleum Services' (DNVPS) official position on this issue is that there should be only one location for taking an umpire sample. This is at the point of custody transfer. The sample taken should be a representative sample taken by continuous drip method throughout the whole period of the bunkering and this should be the only sample used as the umpire sample in case of a dispute.

"A bunker fuel contract is no different from a typical commercial transaction in international trade and should be based on the interpretation of the commercial terms as defined in the International Chamber of Commerce (ICC) INCO terms 1990. Many bunker contracts are based on FOB terms. In accordance with INCO terms 1990, Quote: 'FOB means that the seller fulfils his obligation to delivery when the goods have passed over the ship's rail at the named port of shipment. This means that the buyer has to bear all the costs and risks of loss or of damage to the goods from that point'." [Ref. 27]

In the context of bunker delivery, transfer of custody means that the risk of loss or damage to the bunkers is passed from the fuel supplier to the ship. It does not involve a change of title to the good. Indeed, if the bunkers have not been paid for by the ship operator, the legal title will still be with the supplier even though the custody is now in the hands of the buyer.

Custody transfer has nothing to do with sampling at the bunker's barge manifold or the ship's bunker manifold. The position of custody transfer depends on the terms of the contract and will result in only one unique location where an umpire sample will be taken.

3.2.2 SHIPBOARD FUEL ANALYSIS

Many ships carry fuel test kits for onboard fuel testing and these can, when used correctly, be reasonably accurate. Certainly, these kits, one being the FUELAB ocean fleets fuel and lubricating oil test kit can give an early indication of potential problems and may be used to perform tests on the following.

- Density
- Pour Point
- Viscosity Measurement
- Water Content
- Salt Water Determination
- Compatibility/Stability Rating
- Catalytic Fine Detection
- Sludge/Wax Determination
- Microbe (for distillate fuel)

If the supplied fuel does not conform to the requested quality specifications, then the master will issue a letter of protest and note any deficiencies [see Appendix 4].

3.2.3 SHORE-BASED LABORATORY FUEL ANALYSIS

"Recognised fuel analysis laboratories can provide accurate test results quickly and give the ship information and guidance on pre-heating requirements, the set up of centrifuges, and an early indication of potential fuel handling and fuel combustion problems. The major laboratories associated with the classification societies, such as DNVPS and Lloyd's FOBAS, also offer detailed technical advice and additional guidance at relatively short notice. They can also provide critical information by fax by way of bunker alerts." [Ref. 1, 2000]

A fuel analysis report shows the typical data of the fuel and assesses conformance with the limits of the individual properties listed in ISO 8217 for the grade. In case of deficiencies advice is given on what to do with the fuel, whether it is fit for use under specific precautions. Also, the specific energy content of the fuel and the CCAI are calculated and reported. "Because ships normally need a few days to consume the remainder of the previous bunkering, results on the sample are usually at hand before the new batch is due for consumption. This gives the ship operator a chance to consult his technical department and the supplier for advice how to proceed in case the fuel is found out of spec." [Ref. 6, 1997]

3.3 LOSS PREVENTION AND COLLECTING EVIDENCE

Quantity disputes are a problem which buyers can tackle. Things to watch out are:

- Correctness of calibration tables.

- Ensure that actual measurements are done by the crew from the receiving vessel, and that they report the measurements to the head office.
- Note the temperature at the time of measuring and make sure it matches what is on the delivery receipt.

Quality disputes are unfortunately unavoidable, and dealing with this issue, goes much along the same lines as the quantity dispute. Preventive medicine is the most important feature. What is then the prescription?

- Be selective in choosing a supplier.
- Always test the fuel.
- Do not use the new fuel before test result is available.
- Avoid mix of new fuel with old fuel in the same tank(s).
- Ensure that the samples taken are as representative as possible and that they are properly labelled (They are the sole evidence of the fuel the vessel has received).

3.3.1 ROUTINE EVIDENCE COLLECTION

It is critical that all activities during the bunker operation are properly recorded. To enable the shipowner to document each step of the bunkering operation, those onboard the ship should record and retain

- Details of which tanks have been loaded and in what order they were loaded
- Details of fuel oil already onboard the ship, its location and specification
- Bunker calculations, including temperature coefficients and tank volume calculations
- Bunker loading plans and daily work plans

- Minutes of inter-departmental management meetings particularly regarding crew requirements, cargo operations and stability implications
- Deck and engine room oil record books duly completed in accordance with MARPOL international regulations
- Engine room log books
- Deck log books
- Engine room work books and record books
- Scrap or rough log books
- Bunker delivery receipts and details of previously loaded bunkers
- Shipboard bunker history - records of previous bunker loading operations
- Copies of any notice of protest which may have been issued during this or the previous bunker loading
- At least one sample of the bunkers taken at the most recent previous bunker operation and any other bunkers remaining onboard (ROB)
- List of personnel involved in the bunkering operation
- List of personnel present during routine sampling
- Laboratory fuel analysis reports of previous bunkering samples
- Shipboard fuel analysis reports. [Ref. 1, 2000]

3.3.2 NON-ROUTINE EVIDENCE COLLECTION

Where it is suspected that sub-standard bunkers have been supplied to the ship, the ship operator should immediately take steps to ensure that accurate records are kept detailing which tanks have been supplied with the suspect fuel oil and arrangements should be made to obtain the following evidence from the ship

- Evidence from the ship's bunker capacity
- Ship's general arrangement plan
- Ship's fuel oil pre-heating system drawings
- Ship's fuel oil pipeline diagrams
- Tank calibration tanks
- Relevant extracts from engine manuals and shipboard procedure manuals relating to treatment of fuel oil. [Ref. 1, 2000]

3.3.3 EVIDENCE IN THE EVENT OF BURNING SUSPECT/PROBLEMATIC FUEL OIL

In case of main or auxiliary engine damage which is considered to be fuel related it is essential that detailed written accounts of the incident are made. Additional fuel samples taken from the fuel system should be correctly labelled with dates, times, locations and signed by the chief engineer. Any engine components which have been removed from service due to damage are to be retained on board and correctly labelled for future reference. Photographs of damaged or defective parts taken with a camera which records date and time would be useful. It is advised that charterers and fuel suppliers are advised immediately of any potential claim with respect to fuel quality. If the laboratory fuel oil analysis shows the fuel to be out of specification, charterers and fuel suppliers should be immediately advised.

3.4 CLAIMS MANAGEMENT

3.4.1 DISPUTES AND CLAIMS

The purpose of developing and using fuel management policies and procedures is to reduce risk. The aim should be to minimise commercial loss. By following good procedures, an owner or charterer should be in a position to quickly identify a problem and take appropriate action to mitigate the situation. If a fuel buyer, shipowner or manager wishes to pursue a claim for shortage or poor quality, it is essential that good reliable evidence is provided. If the procedures outlined above are followed, such evidence will be available and dispute resolution should be greatly facilitated. It is suggested that if quality or quantity problems are experienced, attempts should be made to resolve the problem by discussions between all the parties involved. All those concerned should have an interest in minimising cost associated with the problem. If this fails, mediation is recommended before high costs of arbitration and court proceedings are incurred.

3.4.2 DECISION TO DEBUNKER

If a fuel is 'out of specification' it does not necessarily mean that the fuel is 'unsuitable for use'. We often have situations when the density or viscosity is exceeded from that ordered by the charterer, shipowner or whomsoever is purchasing the fuel. When specifications are contravened, technical advice is normally offered and heeded by most prudent operators. If the out of specification product can be handled effectively by taking corrective actions to the handling of the fuel through the purification system and other engine room equipment, and, can be used without incident, then the issue becomes one of cost differential rather than the belligerent response of 'DEBUNKER, IT CONTRAVENES THE ISO SPEC ORDERED'. Common sense thus prevails. Normally under these conditions, the fuel purchaser requests the fuel supplier reduce the original cost of the product to reflect the actual quality supplied. Under these scenarios no legal issues ensue and the matter is normally considered dealt with. [Ref. 5, June 2000]

"On the other hand, there are also other 'off specification' fuel oils that are both outside of the specification AND outside of the ability of the pre-treatment plant and the main engine and generators to contend with, without severe mechanical damage or handling difficulties AND outside of the realm of the engineering staff onboard the vessel to handle. Many prudent shipping companies, when confronted with these problems, will debunker the fuel oil irrespective of whether they will eventually suffer financial loss due to the inability to demonstrate that the fuel at the time of supply was compliant or non compliant with specifications. The legal problems ensuing when these type of actions occur, can be simplified by taking prudent actions to support any eventual legal claim." [Ref. 5, June 2000]

"Where it is unclear whether or not the ship can use the bunkers supplied, the shipowner should evaluate carefully the risks of doing so. The shipowner should consider whether, in light of the information to hand, it could be considered reasonable to go to the time and expense of debunkering the fuel or to attempt to use the fuel (because the risk of damage or difficulty using the fuel is small). Factors that should be considered when making this evaluation include

- Whether there is a risk of damage and/or excessive wear to the ship's machinery
- Whether the ship's performance might be inhibited
- Whether the ship can heat the fuel to obtain the correct injection viscosity."

[Ref. 1, 2000]

3.5 UNANNOUNCED BUNKER AUDITS AND ACCREDITATION SCHEME FOR BUNKER SUPPLIERS

In view of a) owners' and ship's crew duty to ensure a safe, efficient and environmentally friendly bunkering operation as per international law and industry practice, as well as to have in place fuel management processes conforming to ISM, ISO requirements, b) the very high prices of bunkers making this cost the largest single item of voyage expenses and c) the errors or omissions observed and or likely to be made in the gauging of vessel's and barge bunker tanks, which have a direct effect on quantity discrepancy and associated losses/disputes, a number of shipping companies have decided to implement unannounced bunker audits effective immediately.

Foregoing regulatory regimes establish limits related to fuel oil burning with a view to avoiding unreasonable wastage of resources (over-consumption) and to reduce the impact of emissions: CO_2 and Particles, SO_x, NO_x and furthermore, apart from safety and pollution prevention procedures connected with bunker handling and transfer operations, they define the requirements to be met by bunker suppliers.

A fundamental principle of quality management of the ISO rules is that of continual improvement by means, among other tools, of audits and corrective/preventive action to identify opportunities to improve the effectiveness of the management system. In this context companies wish to establish measurable quality objectives at functional levels, monitor vessels' performance and take actions to make improvements.

As previously stated, the success of any bunker quality or quantity dispute will depend upon the quality of evidence collected in support of the claim. The collection of evidences, when in fact integrated into shipboard procedures related to ISM, ISO requirements, need not be onerous. In other words by ensuring that the shipboard procedures, requiring all aspects of the bunkering operation to be properly documented and accurate records to be maintained, are satisfied can at the same time serve and strengthen a vessel's position in the event of a claim.

It is worth mentioning here that ever since steam replaced sail, it has been the practice of many engineers to keep some reserve bunkers on board. Chief Engineers must now be absolutely honest about every last drop of bunkers onboard, be meticulous in detailing the inter-tank transfers of bunkers, the pumping of any oily residues into sludge tank, accurate measurement and determination of bunkers lifted - taking into consideration all factors affecting the accuracy of calculations, i.e. soundings, ullages, density, temperatures, volumes, trim and list correction, availability of volume correction and temperature correction tables, detection of presence and assessment of water etc.

The ship's bunker records and bunker surveys at each port and specifically prior to and after bunkering operations have now become very important to satisfy the requirements of quality management system in general and of proper vessel's bunker management system in particular, as well as to be used as a defence to bunker quantity disputes and when it comes to tankers to rebut oil cargo shortage claims.

It is finally recognised that the vast majority of bunker transfers (supply) are undertaken by reputable operators and physical suppliers, but owners and their sea staff must be alert, particularly now when prices of bunkers are high, to the fact that there are some disreputable operators which are familiar with many tricks and deceptions and are prepared to use them on any unsuspecting receivers.

By following correct shipboard procedures and by implementing unannounced remaining onboard bunker (ROB) audits simultaneously with regular bunker survey, if such bunker survey is being conducted, companies look forward to address the principles of quality management system and avoid any irregularities of quality and any quantity discrepancy incidents/claims.

Looking from the bunker suppliers' point of view, the Maritime and Port Authority of Singapore (MPA) have recently announced the implementation of an accreditation scheme for bunker suppliers. This of course is welcomed by the industry as a whole, as Singapore is the largest bunkering port in the world, which resulted in a number of quality and quantity disputes in the past. "As announced at the Singapore International Bunkering Conference (SIBCON 2002) in September 2002, together with the Singapore Shipping Association (SSA), MPA has developed an accreditation scheme for bunker suppliers. MPA will implement the accreditation scheme from 1st June 2003. All bunker suppliers will be given up to two years to attain accreditation qualifications. The annual renewal of the bunkering licence will be subject to the suppliers achieving the accreditation qualifications. The objective of the accreditation is to recognise good bunker suppliers and deter malpractice in the industry, through the following accreditation qualifications: a) minimum paid-up capital, b) Quality Management for Bunker Supply Chain (QMBS) and c) Key Performance Indicators (KPI)." [Ref. 33, May 2003]

4 EU SHIP EMISSIONS TO AIR

4.1 THE NEED TO REDUCE ATMOSPHERIC EMISSIONS IN EUROPE

The ecosystems of Northwest Europe have long been subject to high levels of acid deposition as a result of sulphur emissions. With industry reducing harmful emissions over the past 10 years and with further clean up plans already in place, it was inevitable that the shipping industry would be brought into focus as an emissions source.

"Various studies on sulphur pollution show that in 1990 sulphur emissions from ships contributed around 4% to the total in Europe. Today that figure represents around 12% and it is predicted could be as much as 18% by 2010. Put into real terms the total SO_x emissions from international shipping in the North Sea was calculated to be 439,000 tonnes per annum in 1990." [Ref. 22, June 2000]

"The European air mass is a complex dynamic meteorological system influenced by both maritime and land mass effects. 'European waters' regarded as relevant in this respect are depicted in the map below [see Figure 4.1]. These are divided into the following sea areas: the Baltic (1), the North and Irish Sea (2), the Mediterranean (3) and the N E Atlantic (4), in accordance with MARPOL definitions, with the exception of the N E Atlantic, which has a more arbitrary definition. The North Sea area defined here is an expansion to that proposed in IMO doc. MP/CONF.3/16 (July 1997), for a North Sea SO_x Emission Control Area (SECA)." [Ref. 2, August 2000]

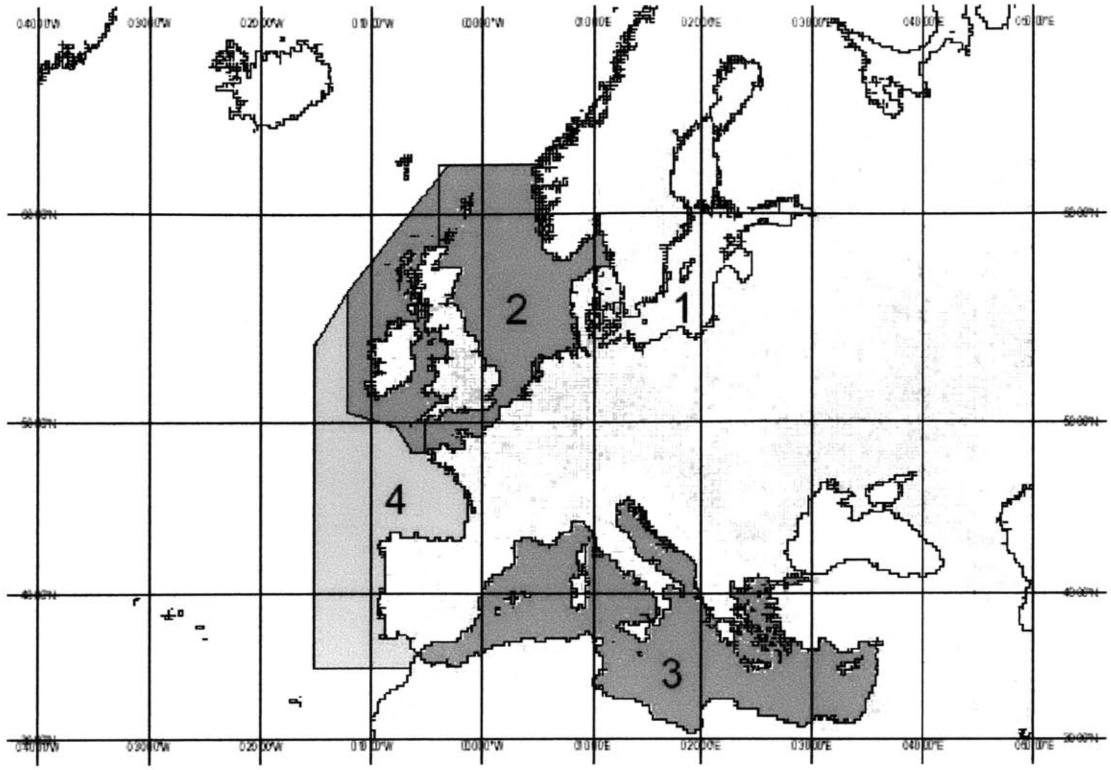

Figure 4.1: The European waters. [Ref. 2, August 2000]

EU Member States have already achieved a great deal to reduce land-based emissions of these pollutants, for example through the recent directives 2001/80 on Large Combustion Plants and 2001/81 on National Emissions Ceilings (NEC). Until recently [see Paragraph 4.2], seagoing ships were exempted from existing EU air quality legislation, including the NEC directive, and marine heavy fuel oils have not been subject to EU environmental legislation. The result is that ships' contribution to EU emissions is rising. Preliminary projections suggest it is quite possible that by 2010, ship emissions of sulphur dioxide could have reached three quarters of land emissions. For nitrogen oxides, the figure is probably nearer 60%. This scenario is illustrated in figure 4.2 below.

"The European Commission has recently let a new study contract to quantify ship emissions more precisely, based on year 2000 ship movements, and including in-port emissions for the first time." [Ref. 29, January 2001]

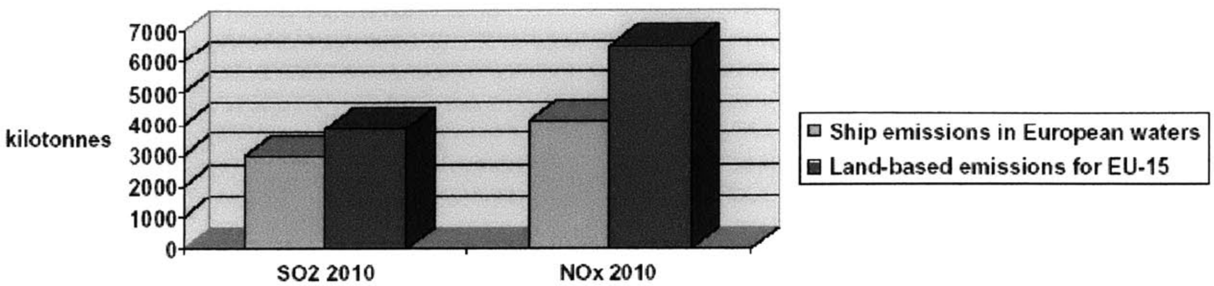

Figure 4.2: Ship and land-based emissions in 2010. [Ref. 29, January 2001]

The reason SO_x is the focus of these discussions is that it is dependent upon the quality of the fuel oil and in particular its sulphur content. This is illustrated in the following table.

Table 4.1: The pollutants and their source. [Ref. 3, March 2000]

Emission particle	Legislated by IMO	Source
SO_x	√	Function of fuel oil sulphur content.
CO_2	X	Function of combustion.
CO	X	Function of the air excess ratio, combustion temperature and air/fuel mixture.
HC	X	Very engine dependent but a function of the amount of fuel and lube oil left unburned during combustion.
Smoke/Particulates	X	Originates from unburned fuel, ash content in fuel and lube oil.
NO_x	√	Function of peak combustion temperatures, oxygen content and residence time.

"Furthermore, SO_2 emissions from ships contribute to acid deposition and particulate formation. SO_2 is a particular priority because ship emissions of SO_2 have been found to be much higher per tonne kilometre than other transport modes [see Figure 4.3]. High SO_2 emissions are a direct result of the high sulphur content of marine heavy fuel oil. The only way to reduce emissions is to lower the sulphur content of the fuel or to install exhaust scrubbing equipment onboard ships." [Ref. 29, January 2001]

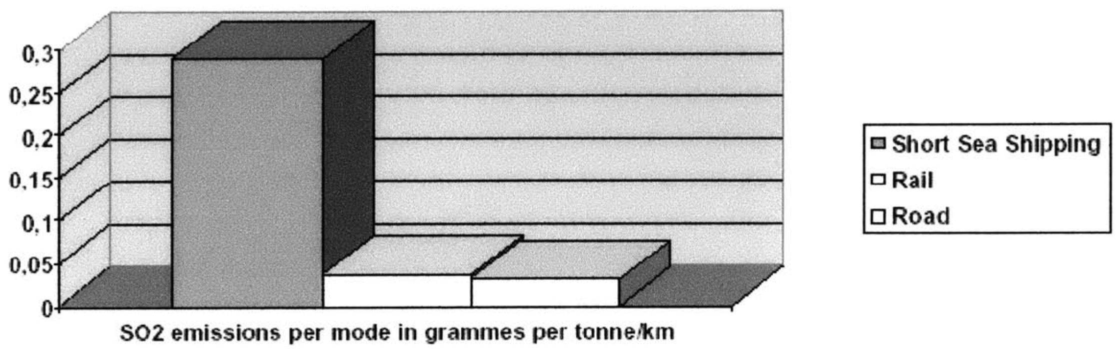

Figure 4.3: SO_2 emissions per mode. [Ref. 29, January 2001]

4.2 IMO AND THE EUROPEAN COMMISSION

MARPOL 73/78 Annex VI on air pollution from ships was adopted by a Diplomatic Conference hosted by the International Maritime Organisation in 1997 and is valid for international and territorial waters. The Annex VI implies a maximum worldwide sulphur content of 4.5 %m/m in fuels and a maximum permitted SO_x emission level in the Baltic Sea, the North Sea and the English Channel. Fuel sulphur content for these areas must not exceed 1.5 %m/m, except if the vessel is equipped with an approved 'exhaust gas cleaning system or any other technological method' to meet the maximum SOx emission level. The Annex enters into force internationally one year after it has been ratified by at least 15 countries representing 50% of the gross tonnage of the world's merchant shipping. Current signatories to MARPOL Annex VI are Norway, Singapore, Sweden, Liberia, the Marshall Islands, the Bahamas, Denmark and Bangladesh; representing 26.27% of the world's merchant tonnage. The remaining EU countries represent approximately 10% of the world tonnage and candidate countries a further 10% (notably Malta at 5% and Cyprus at 4%). As long as the entry into force mechanism remains 15 countries and 50% world tonnage, entry into force will depend upon ratification by the major open registers such as Panama (with 17% world tonnage). "The Bahamas' recent ratification is encouraging in this respect" [Ref. 29, January 2001], but even if, for example, Panama were to ratify, a further 6 states would be required to meet the 15 country criterion. The relevant regulations referred to are Regulations 14 and 18 and these regulations must be read together to gain the full meaning and intention of the rules as presented [see Appendix 5].

The EU Directive 1999/32/EC entered into force in May 1999 and EU member states were requested to implement the Directive into their legislation no later than 1 July 2000. As part of this Directive, Marine Gas Oil/Distillate Fuels (covering all 'DM' distillates according to Table 1 of ISO 8217:1996) must not have a sulphur content of more than 0.20 %m/m from 01 July 2000 onwards. The above EU Council Directive implies that marine gas oil/distillate fuels having a sulphur content exceeding the 0.20 %m/m limit are not allowed in the EU territorial waters (i.e. 12 mile zone). The use of low sulphur marine gas oil/distillate fuels is not applicable to vessels entering the EU from a destination outside the EU. Regardless of the vessel's destination from an EU port, low sulphur fuel is required within the EU (12 mile) territorial waters. The important issue here is that the buying party of the fuel has the responsibility of ordering the correct grades. Note that Belgium has not only restricted the use of high Sulphur gas oil fuel, but also has forbidden the sale of this fuel grade. Further reduction of sulphur content for marine gas oil/distillate fuels to 0.10 % m/m has been set and targeted to take effect on 01 January 2008.

On 22nd November 2002, the EU has amended Directive 1999/32/EC to include the heavy fuel oil grades. More importantly, after much discussion, it has been decided that the set limits will be in line with those set by IMO. Thus the proposal aims to "introduce a 1.5% sulphur limit for marine fuels used by all seagoing vessels in the North Sea, English Channel and Baltic Sea, in line with MARPOL Annex VI sulphur limits, in order to reduce the effect of ship emissions on acidification in Northern Europe and on air quality." [Ref. 28, November 2002] "Member States shall take all necessary steps to ensure that from 31 December 2010, marine fuels are not used in the areas of their territorial seas and exclusive economic zones outside SOx Emission Control Areas if the sulphur content of those fuels exceeds 1.5% by mass. This shall apply to all vessels of all flags, including vessels whose journey began outside the Community." [Ref. 28, November 2002]

4.3 OPTIONS FOR REDUCING SHIP ATMOSPHERIC EMISSIONS

As previously discussed [see Paragraph 4.1], the two possible ways of reducing the SO_x emissions would be to lower the sulphur content of the fuel or to install exhaust scrubbing equipment onboard ships.

In the report from the Brussels meeting on air pollution held on the 18th January 2002, when asked: "Do you believe the Commission should support the use of flue gas desulphurisation (scrubbing) equipment as an alternative to lower sulphur fuels? What, if any measures, could the Community promote in this respect?" The following answer was given.

INTERTANKO/INTERCARGO explained why this should not be pursued. Legislation should ensure international legislation to deliver to ships what is considered environmental friendly and generally readily available. Scrubbers would only move the sulphur (solid) deposition into the marine ocean environment - thus no positive gain to the general environmental picture. Summing up - Annex VI needs to be implemented and the standards set.

4.3.1 LOW SULPHUR FUEL OIL AVAILABILITY

Given the proposal to limit sulphur content to 1.5 %m/m it is necessary to address the production and supply problems associated with such a proposal.

"ISO 8217 gives a maximum limit for most of the fuel oil grades of 5.0% m/m, but in reality no more than a fraction of one percent of the marine oil fuels as currently supplied exceeds the 4.5% m/m value." [Ref. 23, October 1999] "More typically these grades of fuels would contain approximately 2.7% sulphur." [Ref. 7, September 2001]

"ABS Oil Testing Sevices data shows the global cap of 4.5% to affect a small percentage (1 to 2%) of the residual fuel oil used by ships. Whereas, the 1.5% cap set for the SECAs would represent a 15% of the residual fuel oil availability." [Ref. 5, June 2000] ABS took some of their historical fuel testing data and divided the samples into viscosity categories on fuel oils that had 1.5% sulphur or less in them. "There is a significant portion of these fuels that are in the heavy fuel categories. "The shipowner then may not need to necessarily burn diesel fuel to comply with the lower levels of sulphur required by the SECAs and thus the financial impact of so doing can be lessened." [Ref. 5, June 2000] Having said that, one should keep in mind this is a portion of the 15% of the fuel tested by ABS, which is not necessarily located at the SECAs. "Less than 4% of today's bunker fuel deliveries fall below the 1.5% limit. Low-sulphur fuel oil is available, but most of this is today consumed in the inland markets. If shipping requires such fuel, it will need to compete with inland users for the relatively small amounts available." [Ref. 12, 1999]

Given the amount and type of sulphur required to be removed from the residue fuel oils, namely approximately 1.2%, to meet the proposed sulphur capping requirements, the capital/investment cost of infrastructure required, the cost of manufacture of the 'treatment' gas (possibly a hydrogen enriched stream as explained above) and the alternative uses available for this gas, and the expected price that the market would be willing to pay for such a residue fuel oil, then it is to be considered that a refinery would not find it cost effective to supply such a material and use the residues from primary refining to manufacture alternative products which could attract premium value (alternative use of scarce resources). As an example, such an alternative process to use the residual feed stock could be by Coking to manufacture, amongst other hydrocarbon products, LNG for polymer production or domestic fuel supply. [Ref. 7, September 2001]

Clearly a limited supply of residual fuels could be manufactured by use of the residues from sweet crude oils (those crude oil containing limited or low sulphur content) where the treatment process to remove sulphur would not be so demanding. However, supplies of such crude oils are limited and they do dictate a premium value that would drive up the price of the final residue fuel oil. Current estimates suggest that the price increase for the production of lower sulphur fuels to meet a 1.5% sulphur cap could be as much as $80 per tonne.

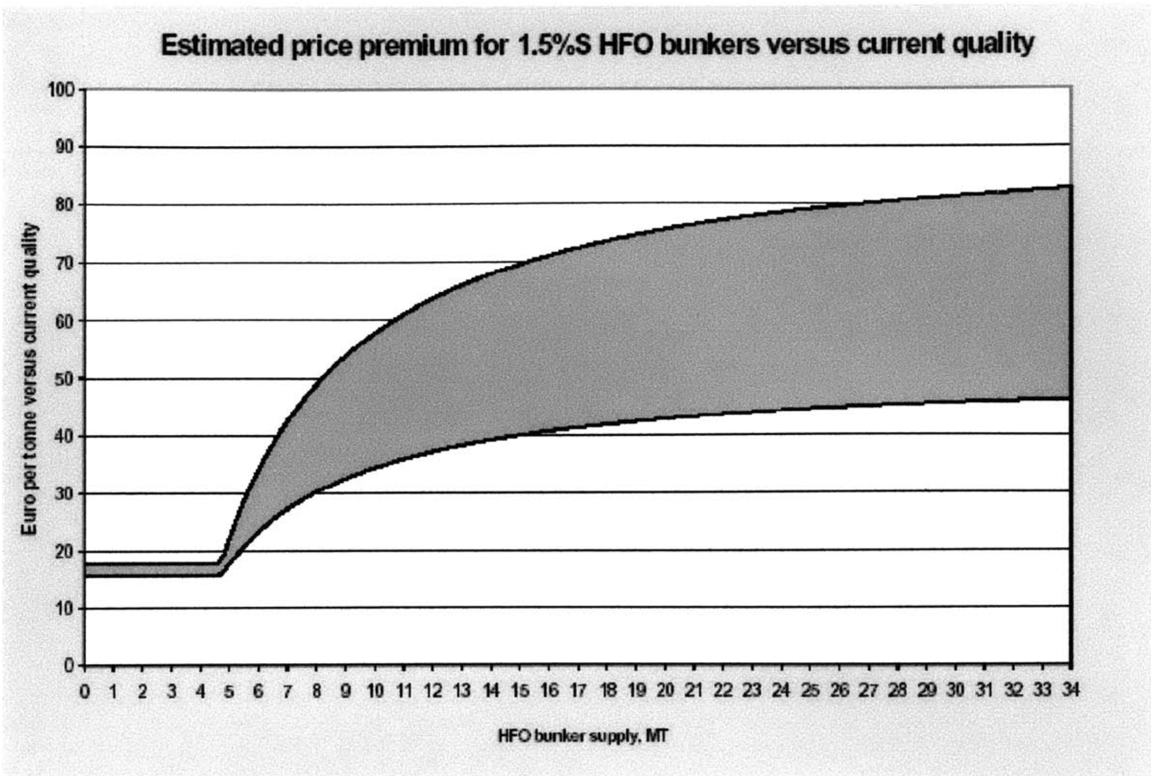

Figure 4.4: Cost curve showing the price premium for EU refiners to provide 1.5% sulphur marine fuel, against a current average content of 2.9%. [Ref. 25, April 2002]

Related to availability is the question regarding the method of controlling the sulphur limit. It would appear cost effective and more easily enforceable if requirements, or at least control, were applied at the point of delivery. Rather than a total ban on marketing of "normal" sulphur oil in the EU, this might only oblige the bunker suppliers to deliver oil of specified sulphur content when required. "The registration of suppliers is to be undertaken by the 'appropriate authority' of each country and is to ensure that the supplier's duties under the Annex regulations are met. In terms of fuel composition, the requirements of ISO 8217 are largely followed." [Ref. 24, Spring 2003] A total ban also covering oil which might be sold for use outside the SECA or other requirement area could have serious and unwanted repercussions on the European and global bunker market and consequently for the shipping sector.

To conclude, therefore, it is believed that both the current Directive will lead to market shortage or alternatively a significant increase in value for purchase such that it would have a major impact upon the extent and cost of Maritime trading within European waters.

4.3.2 OPERATIONAL PROBLEMS FOR VESSELS

Vessels are designed and constructed with a limited number of dedicated fuel oil tanks that are of sufficient size and capacity to meet the expected trading demands of the vessel and the rate of consumption of the diverse fuels required by the vessel. As an aside, but being part of the general fuel oil logistical problems for a vessel, it should be stated that there is currently international debate requiring these tanks to be protectively located such that in the event of rupture to the vessel's hull the content of these tanks would not create pollution.

With the future introduction of the MARPOL Annex VI regulations a secondary set of specifications would have to be considered by voyage planners, namely, is the vessel entering a SO_x Control Zone and if so, for how long and what bunker tonnage is required to transit this zone. In addition to this logistical problem and depending upon the length of time for the transit, the vessel may have to change the content of its sole cylinder lube oil tank, such that it becomes compatible with the lower sulphur content fuel being burnt. [Ref. 7, September 2001]

Thus, with the introduction of these regulations a bunker tank capacity problem may arise together with the possible requirement for the installation of a secondary cylinder lube oil tank, so that there is a smooth transition between the use of fuel types.

The MARPOL Regulation requires that the changeover to the lower sulphur fuel will be undertaken with sufficient time before entry in the control area such that all the fuel system is adequately flushed of all fuel residues that exceed the 1.5% maximum limit. The date, time and position of the completion of the fuel change-over, together with the volume of the lower sulphur fuel onboard, has to be recorded in the logbook as prescribed by the Flag State. Clearly, the practicalities of flushing both the settling and daily/service tanks will take some time (days) before entry into the control area could be contemplated under the regulations.

"The above mentioned problems may deter owners from placing their vessels in a European trading pattern which, in turn, could impact or disrupt the balance of the EU economy until adequate recompense/incentive for the capital (installation of required bunker infrastructure onboard) and operational (increased prices for the purchase of the lower sulphur bunkers) investment is available." [Ref. 7, September 2001]

The documentary evidence that the vessel will have to maintain to supply evidence of concurring with the diverse requirements and regulations could be large. The International specifications for bunkers are not compliant with the EU requirements and therefore additional and special bunker receipts would be required.

The bunker receipts requirement applies to all fuel oils supplied for use onboard the receiving ship. As a minimum, the supplier and supplied parties are to be clearly identified, the product type and quantity are to be stated and the actual density and sulphur content values, as determined by the relevant ISO test methods, are to be given. Furthermore, the supplier is to declare that the fuel as supplied to the ship is in accordance with the requirements of Regulations 14 and 18. These bunker receipts are to be retained onboard for a minimum of three years from the date of delivery and are to be available for inspection by the relevant authorities as required. These bunker receipts will be the primary means by which a ship will demonstrate compliance with the relevant sections of Regulations 14 and 18. However, to underpin the fuel quality statements given on the receipt, it is to be accompanied by a ship retained fuel sample drawn in accordance with IMO's Marine Environmental Protection Committee (MEPC) criteria. [Ref. 23, Spring 2003]

"In any case, procedures will need to be developed to ensure compliance with the requirements of Annex VI and staff will need to be trained in its application. This applies to both shipowners and suppliers. The implications are far reaching and if ratified, as anticipated, it is time for shipping to prepare for a whole new bunkering regime." [Ref. 14, May 2003]

5. FLUCTUATING BUNKER PRICES AND DAILY FREIGHT RATES

As stated at the very beginning of the thesis, 50-60% of the total running costs of a commercial vessel is accrued to the cost of bunkers. This is an average approximate percentage estimated by shipping companies. It would be interesting to see how daily revenues of a tanker are affected by the fluctuating bunker prices.

To begin with, indicative key routes and rates of the tanker industry are selected. In particular, the a) VLCC 250,000 deadweight Arabian Gulf – Japan, b) Suezmax 130,000 deadweight West Africa – USA East Coast, c) Aframax 90,000 deadweight North Sea – Europe, d) Clean product carrier 30,000 deadweight Caribbean – USA East Coast and e) Clean product carrier 33,000 deadweight Europe – USA East Coast routes are to be considered.

Due to lack of data on bunker prices for any date prior to 31st August 2001, the author will look into the freight rates from the 31st August 2001 till the 30th May 2003. The recession period till the end of 2002 might have been strongly affected by bunker prices, and may have been damaging to shipping companies, had bunker prices been fairly high.

Bunker prices for the ports of interest are projected graphically in figures 5.1 and 5.2. The daily freight rates for the same period of both the crude and the product tanker spot market are shown in figures 5.3 and 5.4.

To assess how much of the daily freight rate is used to finance the burning of fuel oil the following assumptions need to be made so that the graphs produced from now onwards are significant. Firstly, at an optimal speed of 14 knots the daily fuel oil consumption at sea for each vessel is as follows: a) VLCC, 73 metric tonnes per day; b) Suezmax, 55 metric tonnes per day; c) Aframax, 45 metric tonnes per day and d) Clean Product, 30 metric tonnes per day. The bunkering ports for each route are: a) Fujairah for VLCCs; b) Las Palmas/Tenerife for Suezmaxes; c) Rotterdam for Aframaxes; d) Aruba for the Clean Product, Caribbean to the USA East Coast and e) Rotterdam for the Clean Product, Europe to the USA East Coast. Finally, it is assumed that on the day that a vessel is chartered, it will receive its fuel from the loading port and will consume this for the rest of the voyage. For example, if a Suezmax is to be loaded from West Africa to unload at the US East Coast, it will load its bunkers from Las Palmas/Tenerife at the current day price. Thus, at a given freight rate, the bunkering cost is deducted for that same date [see Figures 5.5 & 5.6]. This of course would be the effective freight rate less the bunkers cost per sea day per se, rather than the bunkers component of voyage costs per day, that is including port days. Moreover, this is not a realistic view of what ship operators do. In practice, shipping companies have developed models, in the form of an optimum bunkering plan, to minimise bunkering cost [see Chapter 7].

Let us now see what percentage of the daily freight rate is composed of the bunkers cost. On average the bunkering cost is about 40% of the daily freight rate, thus according to the statement that 50-60% of the running cost is accrued to bunkers, up to 80% of the daily freight rate is used to finance the total running costs [see Figures 5.7 and 5.8]. Had the bunker prices increased by $80 per tonne, as stated in Paragraph 4.3.1, in order to meet the low sulphur fuel oil demand, the bunkering cost would on average have made up around 65% of the daily freight rate [see Figures 5.9 and 5.10].

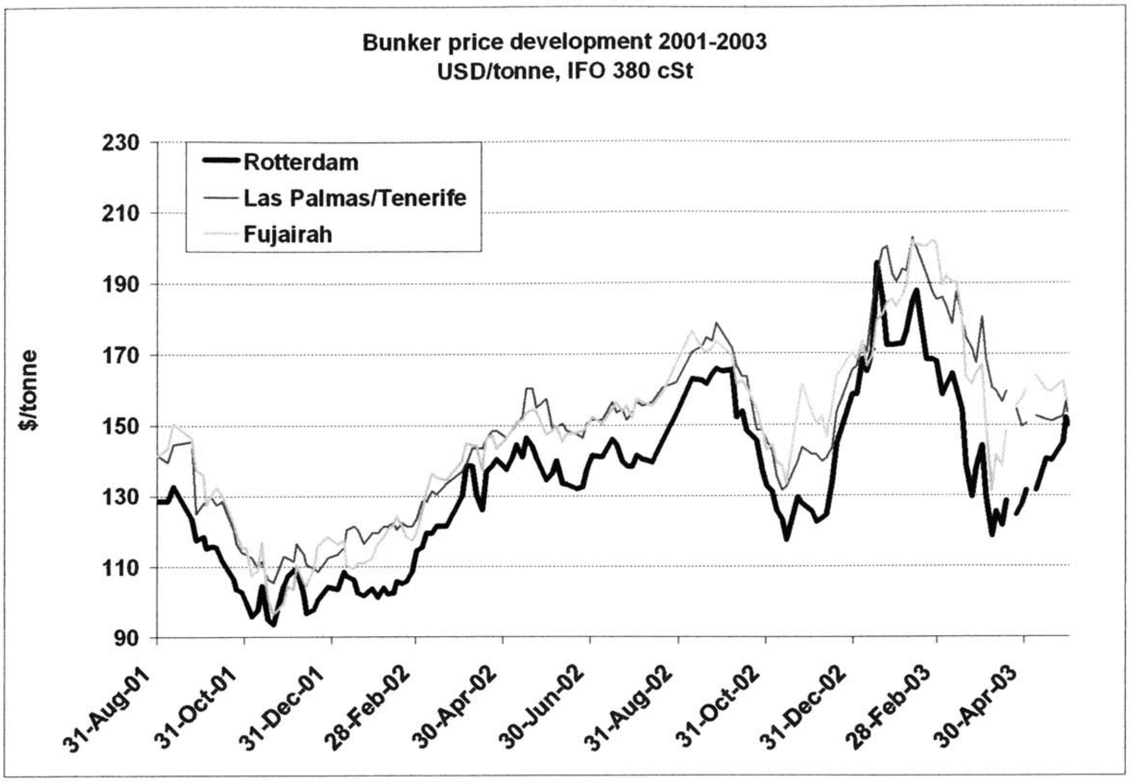

Figure 5.1: Rotterdam, Las Palmas, Fujairah Bunker Price Development 2001-2003.

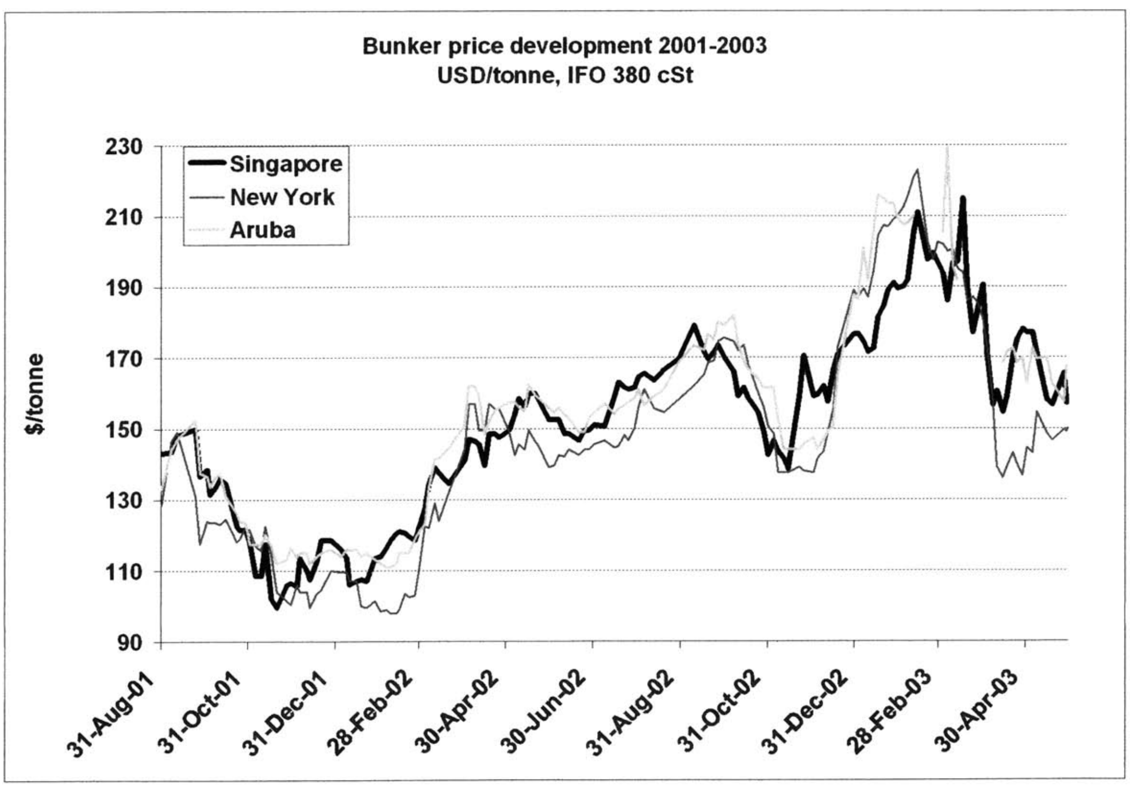

Figure 5.2: Singapore, New York, Aruba Bunker Price Development 2001-2003.

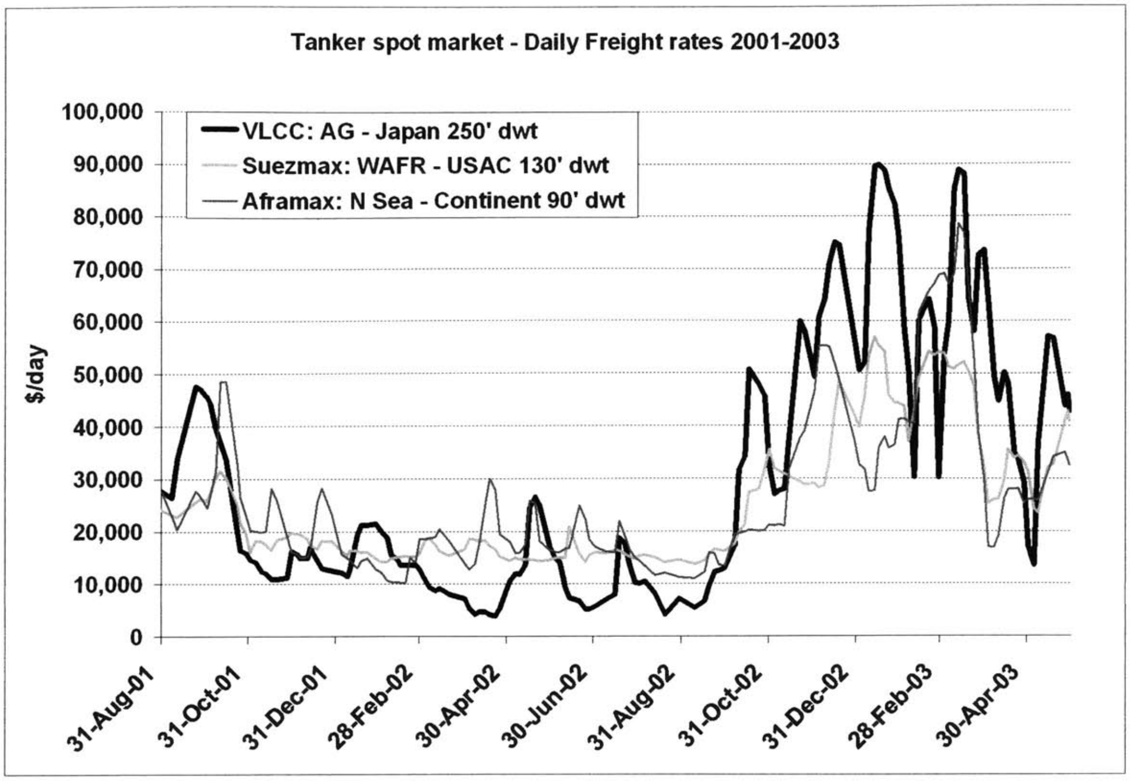

Figure 5.3: Tanker Spot Market – Daily Freight Rates 2001-2003.

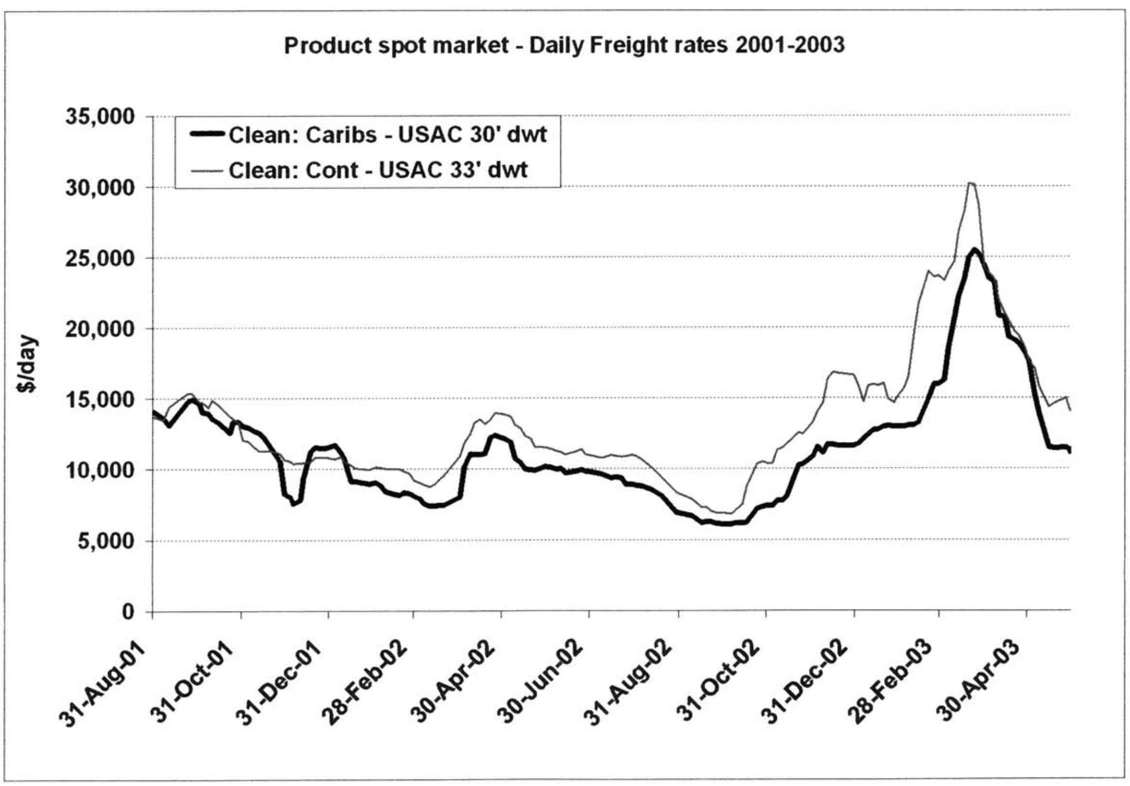

Figure 5.4: Product Spot Market – Daily Freight Rates 2001-2003.

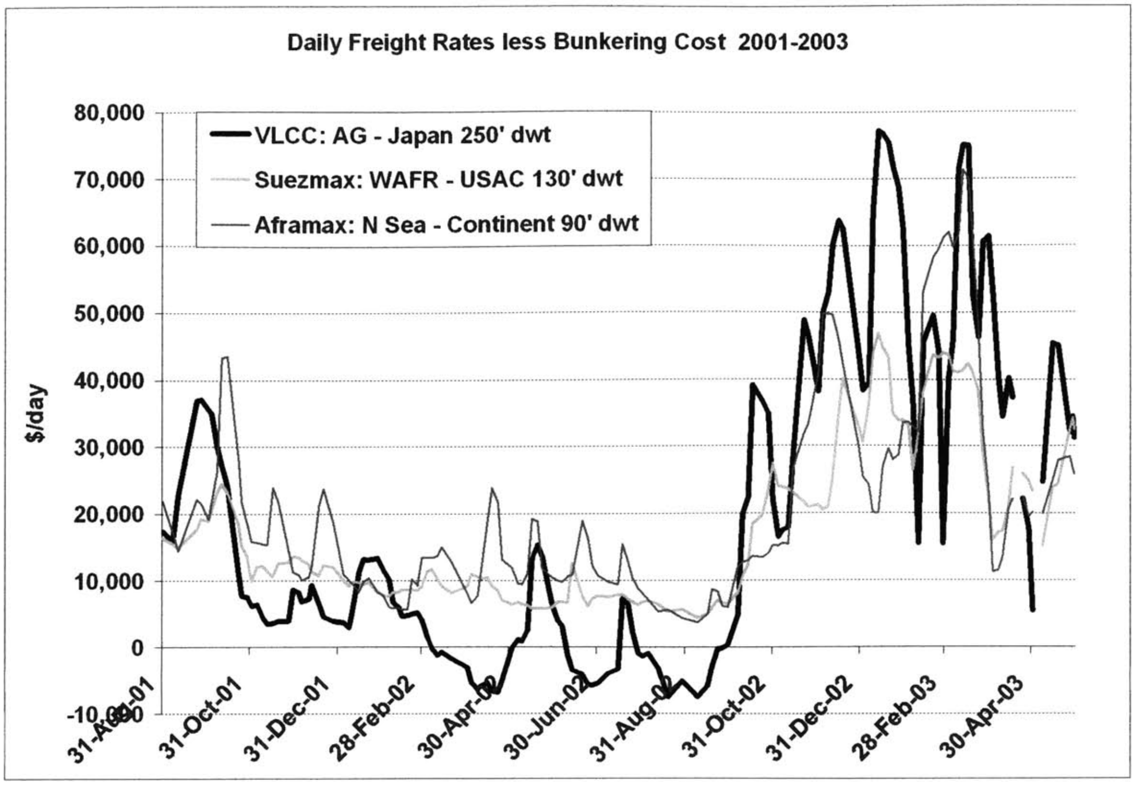

Figure 5.5: Tankers: Daily Freight Rates less Bunkering Cost 2001-2003.

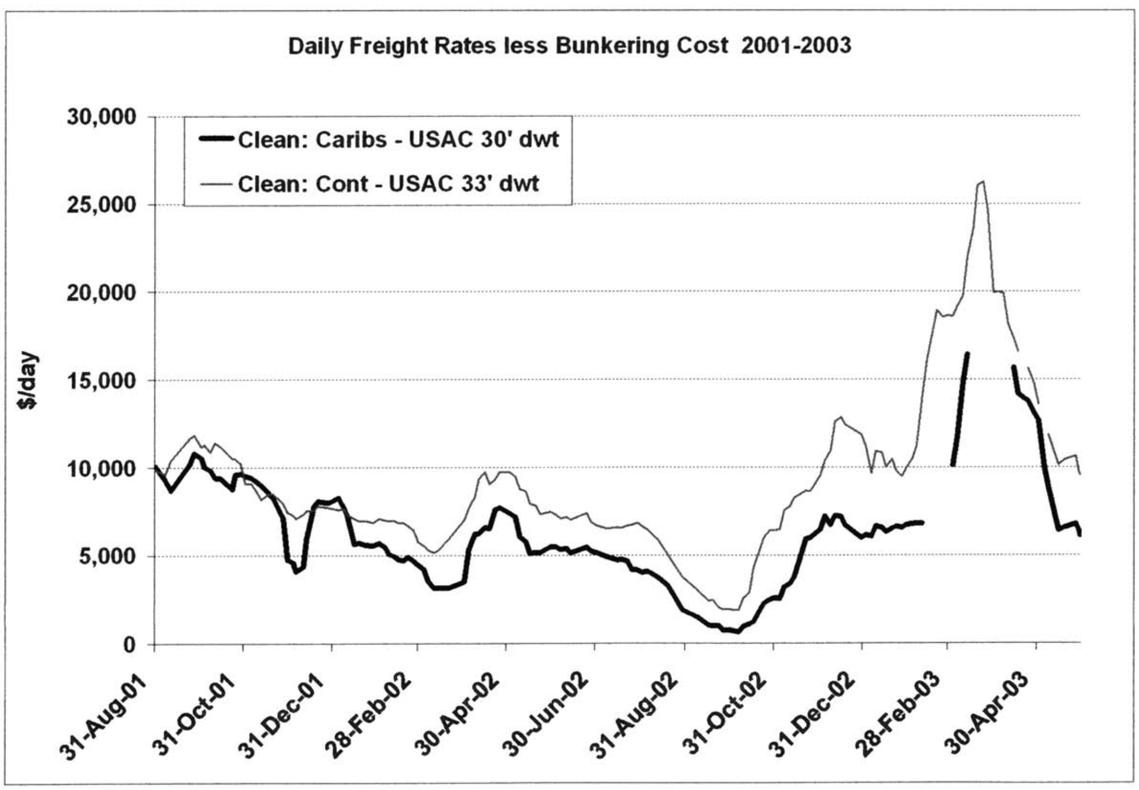

Figure 5.6: Products: Daily Freight Rates less Bunkering Cost 2001-2003.

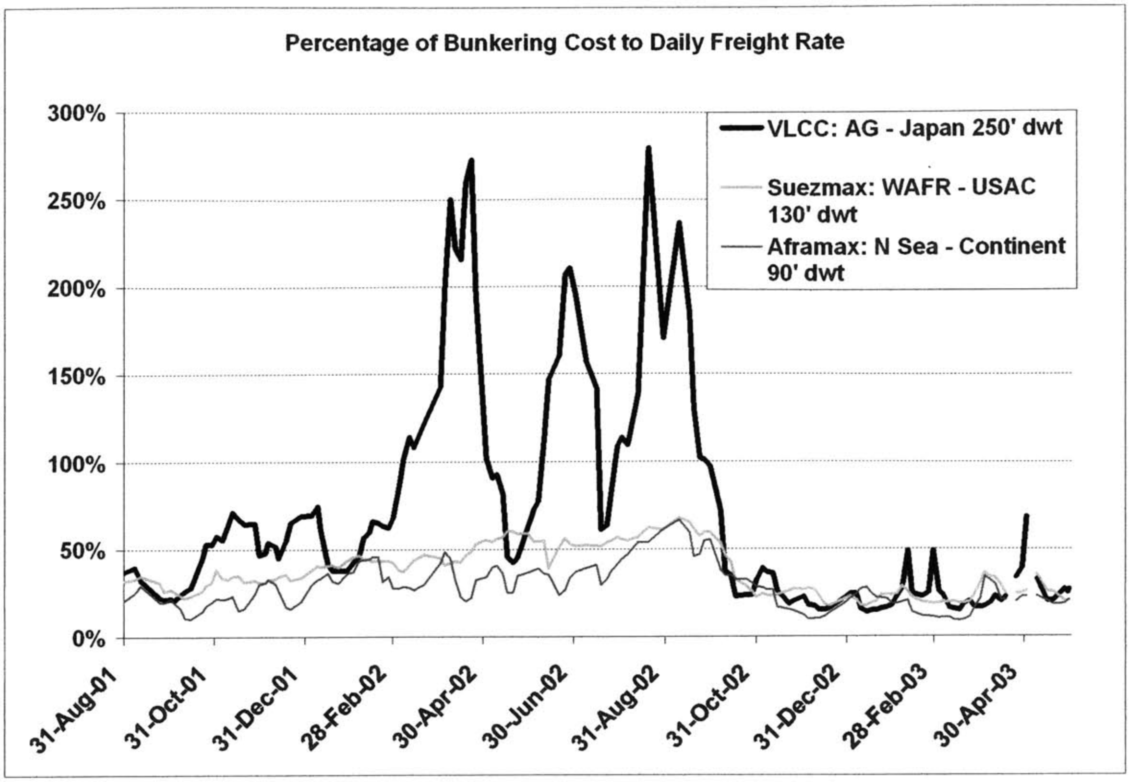

Figure 5.7: Tankers: Percentage of Bunkering Cost to Daily Freight Rate 2001-2003.

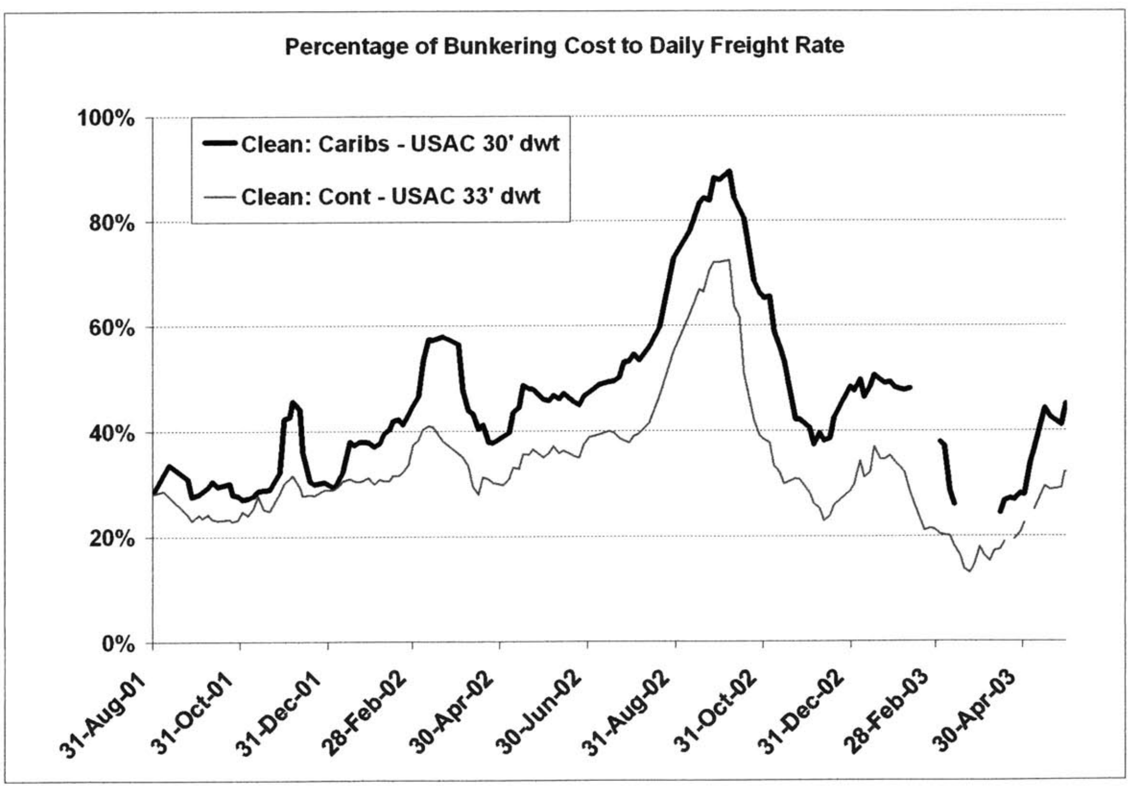

Figure 5.8: Products: Percentage of Bunkering Cost to Daily Freight Rate 2001-2003.

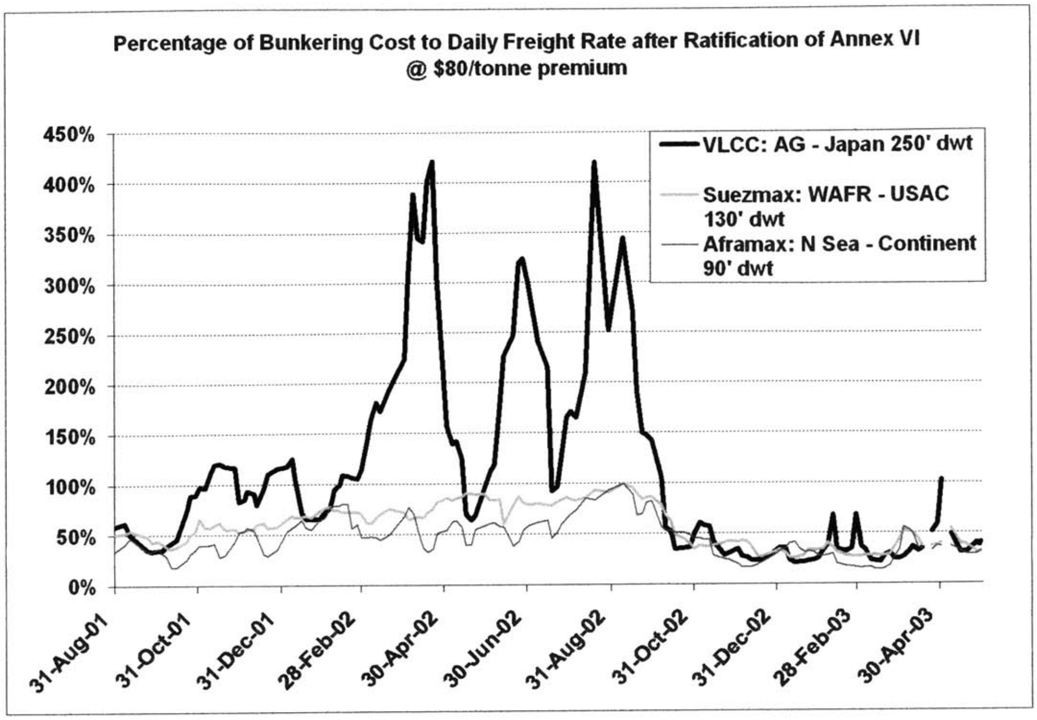

Figure 5.9: Tankers: Percentage of Bunkering Cost to Daily Freight Rate after Ratification of Annex VI @ $80/tonne premium.

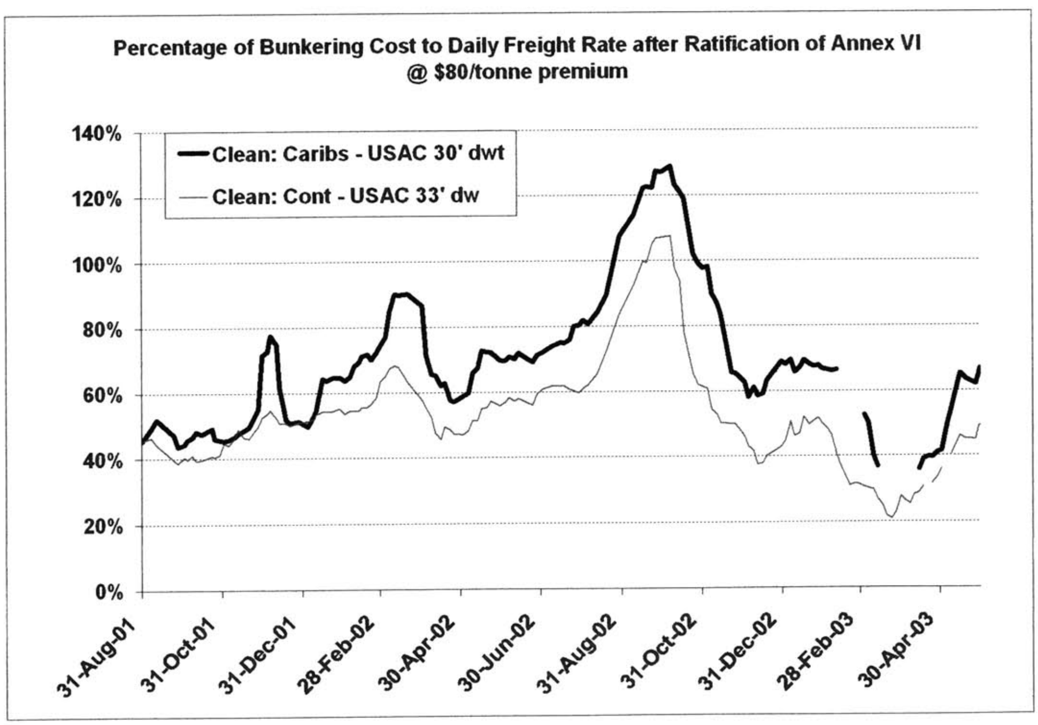

Figure 5.10: Products: Percentage of Bunkering Cost to Daily Freight Rate after Ratification of Annex VI @ $80/tonne premium.

6 BUNKER PRICE RISK MANAGEMENT

6.1 THE WORLD BUNKER MARKET

Marine fuel oil prices follow the basic forces of the market, based on the balance of supply and demand. Costs of raw material (crude oil), production, transport and storage have, of course, some influence. There is, however, little use to bring such into a formula because the aforementioned parameters can easily be overruled by market forces.

It is usually uneconomic to buy and process crude oil with the aim to produce marine fuel oil. Due to the fact that fuel oil prices are persistently below those of crude oil [see figure 6.1], it is in the economic interest of every refiner to squeeze out as many high value products, and to dispose of the residue as good as market forces allow.

In consequence, actual marine fuel oil prices are depending on crude oil prices, transport costs, the local or regional supply and demand situation, political and fiscal impacts, and -last but not least- the global economy: In boom times, more ships sail faster, and more marine fuel oil is burnt in consequence.

Generally speaking, at the time being fuel oil on a global basis is not short and will not be so in the foreseeable future. Power generation on shore has alternatives (nuclear, coal and gas) and will change to these when profitable; thus the shipping world can rely on this. Although marine bunkers are bought and sold in almost every port in the world, the world bunker market can be broadly divided into three major regional markets in which the bulk of physical bunkering activities take place. These markets are Singapore, Rotterdam and Houston. However, supply and demand patterns are shifting on a long term basis. The ARA (Amsterdam, Rotterdam and Antwerp) region has lost its role as the No.1 bunker place to Singapore almost 15 years ago and during recent years Fujairah lost its chance to fight for the pole position. The US Gulf and West Coast had a boom in the 80s, but at the moment they serve mostly as regional markets. Closure of refineries or fiscal and environmental restrictions may eliminate a bunkering place.

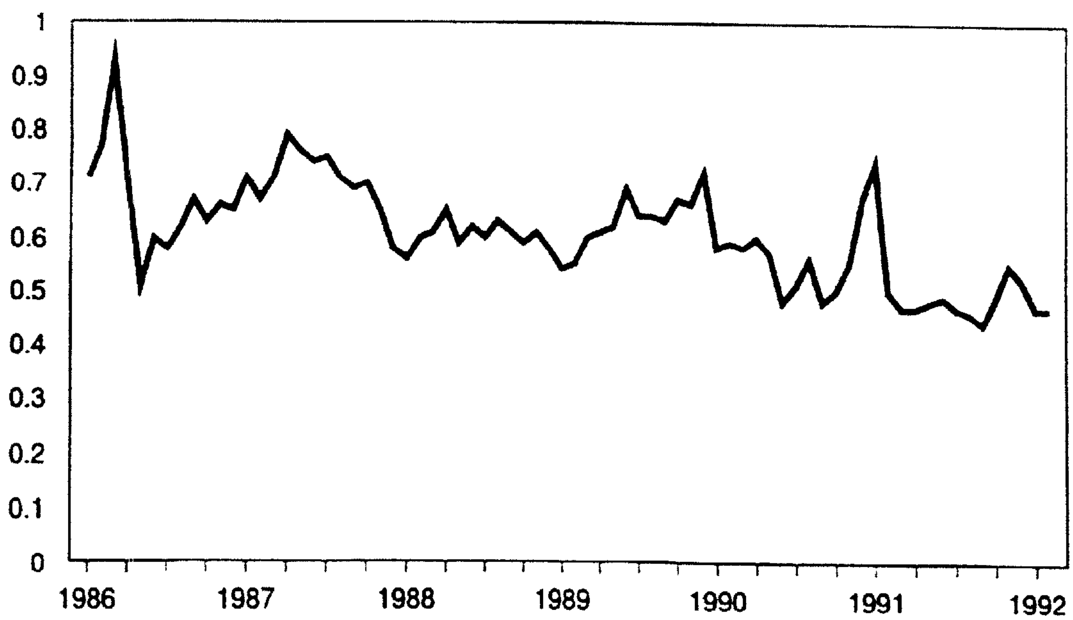

Figure 6.1: Ratio of Heavy Fuel Oil/Crude Oil Prices during recent Years. [Ref. 6, 1997]

Two observations can be made when looking at historical bunker prices [see Figure 5.1 and 5.2]. First, it can be seen that although bunker prices move together in the long run, there are short term deviations between prices. As previously mentioned, the long run co-movements of bunker prices can be attributed to the fact that bunker prices are closely related to the world oil prices. "The short run deviations between prices in different ports are mainly due to the regional supply and demand imbalances." [Ref. 15, 2002] Second, there are large fluctuations and high volatility in bunker prices, as they are linked to world oil prices, therefore shocks and large swings in the world oil market can directly affect the world bunker market. Furthermore, daily price movements can be quite hectic due to local demand and availability imbalances, but this may also be a result of expectations. In the case of an expected price increase, everybody strives to close a deal early on, otherwise, when prices are expected to drop, everybody waits till the last minute.

6.2 HEDGING BUNKER PRICE RISK

In general, risk may be defined as a circumstance, action, situation or event (CASE) with the ability or potential to impact the key dependencies that support the core processes of the organisation. Figure 6.2 illustrates the context within which risks arise; the relationship between the mission, corporate objectives, stakeholder expectations and core processes. "Risks can be divided into three types or categories of risk. These three types of risk are related and (sometimes) inter-dependent. They are:

1. Hazard risks;
2. Control risks; and
3. Opportunity risks." [Ref. 9, 2002]

Hazard risks are the CASE that can only inhibit achievement of the corporate mission. Typically these are insurable type risks or perils and will include fire, storm, flood, injury etc. The discipline of risk management has strong origins in the management and control of hazard risks. Control risks are the CASE that cause doubt about the ability of the organisation to achieve the mission. Internal financial control protocols are a good example of a response to a control risk. If the protocols are removed, then there is no way of being certain what will happen. Opportunity risks are the CASE that are often deliberately accepted by the organisation. These risks are pursued by the organisation in order to enhance the achievement of the mission, although they can sometimes inhibit the achievement of the mission, if the outcome is adverse. This is the most important type of risk for the future success of any organisation.

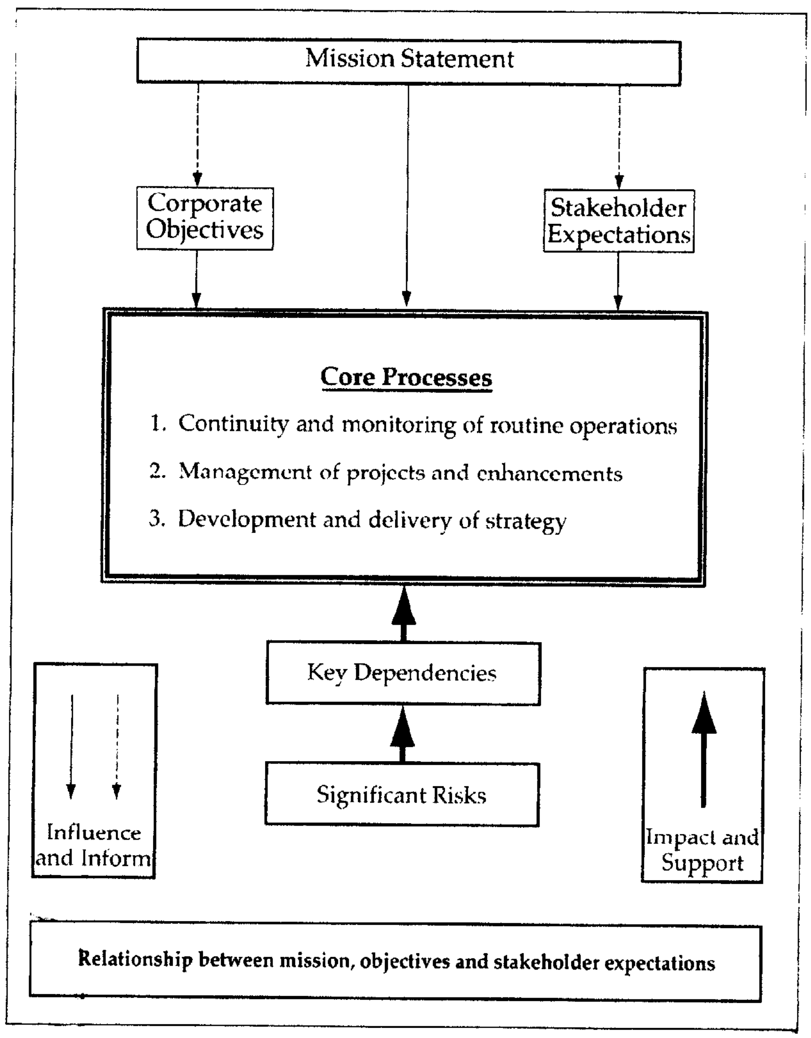

Figure 6.2: Risks in Context. [Ref. 9, 2002]

Note that a risk can be one type in certain circumstances but another type when those circumstances change. Risks change from one type to another within the organisation dependent on circumstances. In certain circumstances, an opportunity risk may become a control risk or even a hazard risk.

There are three styles of risk management based on the type of risk under consideration. A particular risk could be a hazard risk, control risk or opportunity risk in different organisations, or in the same organisation at different times. To gain maximum benefit from a risk, the organisation should, where possible, seek to shift the risk towards opportunity status. There is no single style of risk management or approach to risk management that offers all the answers. Clearly, the various styles that can be adopted should operate as complementary approaches within an organisation. The integrative approach to risk management accepts that the organisation must tolerate certain hazard risks and must have an appetite for opportunity risks. Risk management tools and techniques should be brought to bear whereby the range of possible outcomes is shifted as follows:

- hazard management limits the negativity of the outcome
- control management reduces the range of outcomes
- opportunity management makes outcomes more positive [Ref. 9, 2002]

In view of the aforementioned, a shipping company faces the challenge to properly manage the intrinsic risk of fluctuating bunker prices as suited at any given point in time. Ideally, one should seek to shift the risk towards opportunity status, but today's shipping world perceives bunker price risk management as a hazard management tool or in some cases as a control management instrument.

Bunker price risk management is an issue that needs to be debated across the whole business – it is not solely a purchasing matter. In determining price exposures it is necessary to look at how revenues are set. A shipping company's finance group may want to provide predictable returns, thus it is in the company's interest to safeguard its margin assumptions by off-laying exposures to variable bunkers cost as soon as a contract is won. When making budget assumptions, a company may have bunker price escalators in its contracts or an extra 'what if' factor is built in. Known bunker costs could turn bunker price management to a company's commercial advantage, by allowing it to be more aggressive in bidding for contracts. Moreover, a company could gain a marketing advantage by offering its customers price stability.

Despite the benefits of hedging, only a limited number of shipping and bunker companies hedge, even fewer hedge their entire price exposure. At present the convention is to hedge between 40% and 60% of their exposure over the current financial year plus one. The main reason these companies hedge a fraction of their risk is that they want to benefit should the market move in their favour. They are worried of being left at a disadvantage to their competitors. A lack of knowledge about derivatives means that many companies are unaware of the tools available to them, or the potential of the derivatives. The derivative market continues to develop. In the past, the swaps market in particular lacked competition and liquidity. This has subsequently improved - particularly for longer dated products. Spreads have narrowed, although there are inconsistencies and inefficiencies for some of the more unusual products, and less active regions.

6.3 HEDGING BUNKER PRICE FLUCTUATIONS USING FUTURES CONTRACTS

Fuel oil futures contract were traded in the Singapore Exchange during the period 1988 to 1992. However, trading was eventually stopped due to the low trading volume. The International Petroleum Exchange (IPE) also launched a bunker futures contract in January 1999. This also proved unsuccessful and the contract was withdrawn after six months.

In the absence of bunker futures contracts, and because of the close correlation between bunker prices and petroleum and petroleum derivatives prices, futures contracts on the latter commodities are alternative candidates for bunker price risk management. Hedging against bunker price fluctuations using futures contracts involves a cross-hedge against an existing crude or petroleum futures product. [Ref. 15, 2002]

6.4 HEDGING BUNKER PRICES USING OTC PRODUCTS

Hedging bunker price fluctuations using futures contracts however means that some degree of basis risk is usually borne by the user, as the contract does not cover his full market exposure. In order to eliminate this basis risk between products and offer greater flexibility, an active "Over The Counter" (OTC) market has developed. The vast majority of bunker hedging is conducted in the OTC market in the form of swaps and options (private agreements between counterparties). Hedging instruments in the OTC market can be tailored to suit the specific needs of the client in terms of price reference, quantity and duration. The number of companies managing their exposure to movements in the price of fuel oil has grown dramatically over the past few years with many sectors of industry taking an interest in active hedging, from refiners and cement companies to shipowners.

6.4.1 HEDGING BUNKER PRICES USING FORWARD CONTRACTS

A forward bunker contract is defined as an agreement between a seller and a buyer to exchange a specified quantity of bunker of certain quality, at an agreed price, at certain delivery location and time in the future. Forward contracts are usually paper contracts in the sense that settlement is made on the difference between the contracted price and the price for bunker at the delivery point, although physical deliveries are also possible.

6.4.2 HEDGING BUNKER PRICES USING BUNKER SWAP CONTRACTS

Swaps are the backbone of the energy derivatives market. Their popularity is due mainly to their simplicity. The structure of a basic or 'plain vanilla' energy swap differs little from those in any other derivative market. A simple oil swap is an agreement whereby a floating price is exchanged for a fixed price over a specified period for a defined volume of oil. It is a financial arrangement, which involves no transfer of physical oil. The difference between the floating price and fixed price is settled in cash for specific periods - usually monthly, but sometimes quarterly , six monthly or annually. The contractual obligations are settled in cash. The net result, when combined with transactions in the physical market, is that the shipowner pays the price he 'fixed' and the bunker supplier receives the price at which he fixed, for the quantity of bunkers hedged.

Similar to the Swap contract, the Extendable swap is designed to fix the fuel oil costs at a predefined level. However, in return for giving the bunker supplier the option to extend the contract for another term at the same price, the shipowner is being offered a significant discount from the standard swap.

In the Differential swap, the market player takes a position on the price difference between two separate commodities. This mechanism is frequently used when hedging one commodity on the futures market of another. Using, for example, the Gas oil contract on the IPE to hedge exposure in bunkers. There is a high degree of correlation between the price of gas oil and bunkers, and such a hedge would cover the basis risk. A differential swap would then cover variants in the price of the two commodities. This type of arrangement allows the user to take advantage of the liquidity of the listed futures market and the specific risk cover of a swaps contract. This kind of arrangement reduces the risk exposure of the market player. Whereas a standard swap is based on the differential between fixed and floating prices, a Differential swap is based on the difference between a fixed differential for two products, and the actual or floating differential over time.

The Participation swap is designed to allow the shipowner to 'participate' in bunker price protection much like a swap, while reducing the downside risk. The participation of the swap provider is generally denoted in percentage. A 40%

participation swap will mean that the swap provider gives the shipowner 40% of the total benefit available by the downward movement of oil prices.

The Double up swap is another tool aimed at getting better terms and conditions for the shipowner / bunker supplier. It involves the shipowner / bunker supplier selling a swaption to the swap provider. Swaption is basically an option on a swap. In other words, the swap provider buys an option to double the swap volume of oil before the pricing period starts. The advantage to the shipowner / bunker supplier is that they can achieve a swap price which is better than the prevailing market price. This is because the premium earned by the shipowner on selling a swaption to the swap provider subsidises the swap price.

6.4.3 HEDGING BUNKER PRICES USING OPTIONS

"Although option contracts had been used extensively for risk management in energy markets since the early 1980s, it was not until the 1990s that options were first used as a means of hedging bunker fuel risk in shipping. Nowadays, several financial institutions and commodity trading houses offer numerous types of options on bunker fuel to shipowners and shipping companies". [Ref. 15, 2002]

The Cap price agreement, also known as an Asian Option, protects the shipowner from escalating prices, yet allows him/her to take advantage of price declines as well. An index price is agreed upon by which the bunker cost in the marketplace is represented. Whenever this index price moves above the agreed cap level, the bunker supplier pays the shipowner the accrued difference in price. Much like a rebate, these payments from the bunker supplier offset the higher bunker cost in the marketplace, thereby limiting or 'capping' the shipowner's total bunker cost. When the index price is below the cap, no payments or rebates are due from the supplier. A premium is being paid to the bunker supplier to reflect this protection against rising prices. This premium varies according to the contract length, cap price level and market conditions and can be paid at the start or be spread over the life of the contract. In a similar but opposite manner, the bunker supplier uses the Floor agreement to hedge himself against low bunker prices.

The Collar is designed to keep the bunker costs within an agreed range, effectively putting a 'collar' around a shipowner's bunker price risk. An important feature of a collar is that it requires no premium payment. With the collar, rather than paying the bunker supplier a premium, the shipowner agrees to a minimum price, or floor. Perhaps the most attractive feature of this structure is that it the only time a shipowner effectively pays for this protection is when he/she can best afford it – when prices are very low. An index price is agreed upon which the bunker cost in the marketplace is represented. A cap and a floor price are selected to compose the collar, in between which the shipowner bears the marketplace bunker price. Above the agreed cap level, the bunker supplier pays the shipowner the difference and below the agreed floor, the shipowner pays the bunker supplier the difference.

6.5 PHYSICALLY HEDGING BUNKER PRICES

Wet Risk Management involves contracts for physically delivered bunkers with a Risk Management-structured price. In this case, the shipowner agrees to purchase specific volumes of fuel from a specific bunker supplier in the future. Price protection for that volume of bunkers is then guaranteed through the selected price structure. Unlike the aforementioned paper risk management structures, which derive their price protection through cash exchanges, most wet risk management structures involve no offsetting cash payments, because the price a shipowner pays for fuel is the protected price.

The Fixed price structure provides the shipowner with a known bunkers price for the duration of the contract. The price he/she pays remains fixed, regardless of how bunker prices change in the marketplace during that period and no premium payment is required. The Extendable Fixed price offers a significant price discount (versus the standard fixed price) in return for giving the bunker supplier the option to extend the agreement for another term.

Lastly, the Capped price can be a very attractive form of price protection for a shipowner who is in a highly competitive industry. This is similar to the Cap swap, as the bunker supplier's ex wharf price to the ship owner is equal to an agreed price index plus the 'cap premium'. Much like an insurance premium, you pay the cap premium in return for protection against rising prices. As long as the index price is below the agreed cap, the shipowner pays the index plus the increment; if the index exceeds the cap, he/she pays no more than the cap price plus the increment.

6.6 HEDGING MARINE PRICE RISK

A tanker owner does not only face bunker price risk, freight rate risk is similarly important, against which an owner may want to hedge him/herself. Especially during depressed markets, an owner may find him/herself being in a particularly tough situation. The good news is that, in the long term, the oil market is correlated to the bunkers market. The bad news is that the good times tend to last shorter than the bad ones and thus the time operating at cost or even below tends to last longer. The major factors affecting freight rates are:

a) Seasonal variations in commodity demand and production.

b) Supply of tonnage and forward shipbuilding order book.

c) Changes in the price of bunker fuel for ships.

d) War and acts of aggression may affect the level of confidence in world economic conditions and cause shortages of raw materials and finished products. Disruptions in patterns of supply and demand can cause increases or decreases in the costs of transportation.

e) Strikes and other disruptions in the supply of labour or services will affect the volume of cargo that can be handled and produce a temporary aberration in shipping markets.

f) Severe weather conditions can cause reduction in the supply of material and in the amount of cargo that a ship can carry.

g) Congestion in certain load/discharging areas due to concentrated commodity demand.

h) Changes in the cost of port expenses and in major canal transits.

i) Changes in international currency rates – the US dollar is the dominant currency for freight and changes in its relative value to other major currencies will affect the cost of running ships and operating them in international trades.

Freight has been considered a service rather than a commodity for a variety of reasons. The two most common reasons are environmental concerns, which is a political minefield in most companies and the vetting process that determines which ships are acceptable or unacceptable for service. The insinuation is that no two ships are alike and thus do not meet the definition of a commodity. Environmental concerns are obviously important, and fortunately technology and environment directives are easing some of these concerns, but more importantly having freight treated as a commodity will not affect its environmental importance. In fact, it may highlight environmental issues further as they continue to gain more visibility. The argument of vetting is overstated since vessel particulars generally known as 'Q-88' data, regarding size, single or double hull, age, vessel dimensions, and equipment can be classified relatively easily into distinct categories replicating a standard commodity. [Ref. 21, 2002]

Although, dry bulk derivatives have been available since 1985 through trade in Baltic International Freight Futures Exchange (BIFFEX) futures on the London International Financial Futures Exchange, with settlement made against the Baltic Freight Index (BFI), no similar exchange-traded contract is yet available for the oil tanker market. "However, an increasing number of OTC derivatives have become available. Among these, there is a growing market in forward freight agreements (FFAs). A FFA is an OTC agreement between two principals which sets a freight rate for a specified volume of cargo and vessel type on certain routes, at a date in the future. The FFA is a paper instrument, usually negotiated through a broker." [Ref. 18, September/October 2001] The existence of viable settlement mechanisms, such as the Worldscale published by the Baltic Exchange, has greatly facilitated the development of FFAs. The exchange's body of data is called the Baltic International Tanker Route Assessment (Bitra) and often forms the basis of settlement in the freight swaps mentioned.

> Turning to financial futures, ship brokers Simpson, Spence and Young (SSY) are currently working on developing a futures contract to be cleared through the Baltic Exchange and perhaps other futures exchanges in the future. Both the NYMEX and IPE have studied adding freight futures to their lists of futures products. The use of commodity futures contracts is well documented and simply allows buyers and sellers to lock in a price in the future for a certain commodity at a specific location. Freight futures in conjunction with swaps and options make risk management viable in the shipping industry.
>
> This is not a question of if but when these changes will occur. The middlemen of the industry will continue to keep the status quo and derail any attempt to change the current business relationships since they are the ultimate losers of this change process. [Ref. 21, 2002]

To sum up, not only are tanker freight rates correlated to bunker prices, but they are also dependent upon them. Thus, when bunker hedging instruments are used effectively along with freight futures, shipping companies may reduce their risk exposure and enhance their profits via more competitive management.

7 BUNKERING PLANNING AND FUEL PURCHASING

7.1 BUNKERING PLANNING

The problem, a shipping company faces any time a vessel takes a voyage including a number of bunkering ports with different prices, is how to minimise the bunkering cost. Thus, an optimum bunkering plan needs to be found to satisfy the cost minimisation objective.

The following simple optimisation model is frequently used to undertake the task. Let us suppose that we have

foc: Vessel's Fuel Oil Capacity

n: nodes with corresponding for every i to n

p_i price,

rob_i remaining on board when vessel arrives at point i,

rob_{di} remaining on board when vessel depart from point i,

q_i the requested fuel oil quantity and

c_i the required quantity from point i-1 to i.

Then the total cost is the sum of the cost of fuel oil purchased during the voyage and subtracting the cost of fuel oil used that was purchased on previous voyages. In other words, once a vessel consumes in whole the fuel oil, which remained on board when commencing its voyage, it will bear the cost of the fuel oil purchased during the voyage.

$$Cost = \sum_{i=1}^{n}(p_i \times q_i) - (p_0 \times rob_{d0})$$

Thus, the goal is to find each q_i in order to minimise cost with the following constraints.

For $i = 1$ to n, $rob_i > 0$
For $i = 0$ to n, $rob_{di} < foc$
For $i = 1$ to n, $rob_i = rob_{di-1} - c_i$

An example could be:

Table 7.1: Example of Bunkering Planning.

FOC = 200	n = 4				
When		$c_1 = 90$	$c_2 = 90$	$c_3 = 85$	$c_4 = 95$
Then	$q_0 = 47.8$	$q_1 = 53$	$q_2 = 132$	$q_3 = 53$	
	$rob_0 = 80$	$rob_1 = 37.7$	$rob_2 = 0.65$	$rob_3 = 48.1$	$rob_4 = 6$
	$rob_{d0} = 128$	$rob_{d1} = 90.7$	$rob_{d2} = 133$	$rob_{d3} = 101$	

In paragraph 7.4, data based calculations will be performed for a VLCC, a Suezmax, an Aframax and a Product tanker, along with fuel purchasing that will be discussed in paragraphs 7.2 and 7.3.

7.2 FUEL PURCHASING

Density is an important parameter when purchasing a fuel, as it plays a vital role in the handling process of a fuel. It is dependent upon the ratio of the carbon atoms that form aromatic bonds. Density and viscosity help one to calculate the CCAI (Calculated Carbon Aromaticity Index), which has an effect on combustion. Density is an excellent index of the ratio of hydrogen to carbon in a fuel. In general, without doubt the smaller the density in a fuel the better. This is illustrated in the following figure, since a fuel that is less dense, offers more energy.

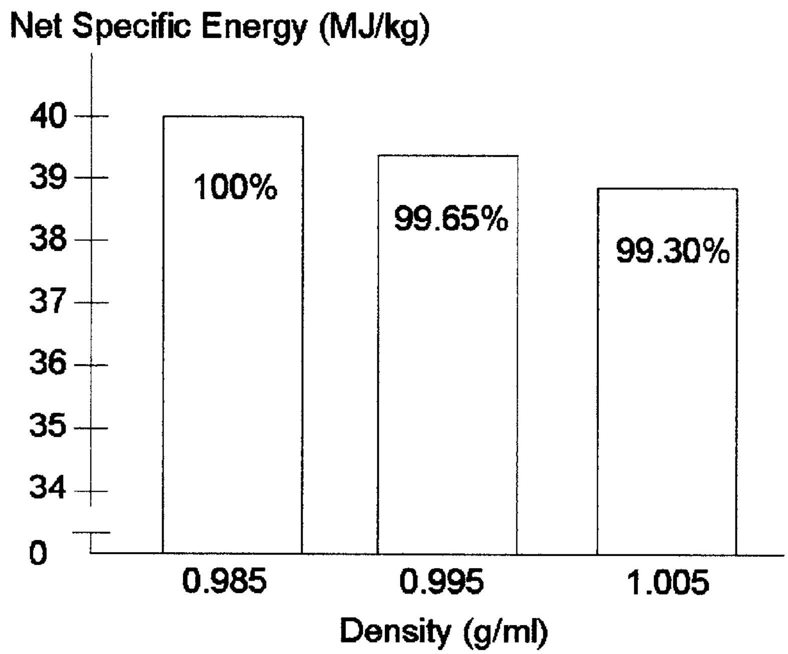

Figure 7.1: Relationship between Density and Net Specific Energy. [Ref. 17, 1993]

7.3 FIVE PARAMETERS FOR COMPARING QUALITY

"It is particularly peculiar the fact that the people in shipping companies purchasing fuel, rarely ask for information on the net specific energy (calorific value) of the fuel to be purchased, from the suppliers. Usually the price per metric tonne and the specification of the fuel is asked for." [Ref. 17, 1993]

Though, in order to create an Effective Fuel Management Programme, other parameters should be examined at the same time.

- Density (g/ml)
- Viscosity (cSt)
- Water content % (v/v)

- Aluminium (mg/kg)
- Net Specific Energy (MJ/kg)

For example, in a port, three suppliers offer an IFO 180 cSt, with the following characteristics, which are the specifications of the products typically on offer.

Table 7.2: Example of quality comparison. [Ref. 17, 1993]

Product: IFO 180 cSt, 50 °C						
Quantity: 1000 mt						
Supplier	Quotation ($)	Density (g/ml)	Viscosity (cSt)	Water (%v/v)	Al (mg/kg)	NSE (MJ/kg)
A	$100.00	0.985	180	0.3	10	41.00
B	$95.50	0.975	170	0.8	5	40.46
C	$95.50	0.988	180	0.5	15	40.10

Density/Aluminium

Concerning density, the 0.975 value is favourable, since the fuel is easily treated. It is highly likely that supplier's B fuel is a product of the blending of straight run fuel with a product of cracking. This is indicated by the existence of 5 ppm aluminium. As a matter of course, the less the aluminium the better. As aforementioned [see Chapter 2], bunkers are delivered in volume, but paid by weight. One must always check, that the density on the Delivery Ticket, is the true density of the fuel. The tolerable international limit is 0.005 g/ml, or $0.5 /mt and in a quantity of 1000mt, this is a difference of $500.

Viscosity

If the viscosity is greater than 200 cSt, this is unacceptable (the tolerance should not be greater than 7.4%).

Water Content

It is illogical to pay for water at the price of fuel, consequently, the smaller the water content, the better.

Supplier A:

1,000mt × 0.3% = 3mt × $100/mt = $300 = $0.30/mt

Supplier B:

1,000mt × 0.8% = 8mt × $100/mt = $800 = $0.80/mt

Supplier C:

1,000mt × 0.5% = 5mt × $100/mt = $500 = $0.50/mt

There is a difference between suppliers A and B of $800 - $300 = $500 or $0.50/mt.

Net Specific Energy

DATA

Quantity : 1,000 mt

Price : Supplier A = $100/mt

Net Specific Energy : Supplier A = 41.00 MJ/kg

Supplier B = 40.46 MJ/kg

ENERGY MJ Supplier A: 1,000,000 kg × 41.00 MJ/kg = 41,000,000 MJ

Supplier B: 1,000,000 kg × 40.46 MJ/kg = 40,460,000 MJ

DIFFERENCE (A-B) Δ MJ = 540,000 MJ

COST / MJ Bunker Price: $100/mt = $100/1,000kg = $0.1/kg

$$\frac{\$0.1/kg}{41.00MJ/kg} = \frac{\$0.1}{41.00MJ} = \$0.0024/MJ$$

VALUE Δ MJ 540,000 MJ × $0.0024/MJ = $1,296.0

SAVING $$\frac{\$1{,}296.0}{1{,}000mt} = \$1.3/mt$$

According to the values of density and aluminium, the offer of supplier B seems better. The following should be taken into account though:

Supplier A

Price:	$100/mt
Water:	-$0.50
Net Specific Energy:	-$1.30
	$98.20/mt

Supplier A is therefore selected.

7.4 BUNKERING PLANNING AND FUEL PURCHASING

As stated in paragraph 7.1, the four most common tanker sizes will be considered each for a number of voyages. After completion of a voyage, the operator of the shipping company, who is in charge of the vessel operations, completes the 'Voyage Details' document, on which the visited ports are filled in, as well as the loaded bunkers and those remaining on board. Using the bunkering cost optimisation model [see paragraph 7.1], the actual bunkering obtained from the Voyage Details, will be compared to the optimum bunkering plan. Moreover, based on fuel purchasing analysis [see paragraphs 7.2 and 7.3], the author will examine whether further cost reduction may be achieved.

7.4.1 VLCC VOYAGE 1

To begin with, a VLCC tanker has a fuel oil consumption of a) 73 mt/day of IFO 380 when laden at a speed of 14 knots, b) 69 mt/day of IFO 380 when ballasted at a speed of 15 knots and c) 3 mt/hour of IFO 380 when manoeuvring or at port loading/discharging cargo. Furthermore, the vessel's fuel oil capacity is 5,025 mt. The Voyage Details for a particular voyage are tabulated below.

Table 7.3: VLCC Voyage Details (7/24/01 – 9/3/01).

PORT OF	ARRIVED	SAILED	REASON
Bataan	-	7/24/01 0200	Discharging
Singapore	7/27/01 1700	7/28/01 0600	Bunkering
Ras Isa	8/9/01 0200	8/10/01 0900	Loading
Ras Tanura	8/15/01 2300	8/17/01 1200	Loading
Fujairah	8/18/01 2000	8/19/01 1400	Bunkering
Durban	8/31/01 2100	9/3/01 1300	Discharging

BUNKERS	MT	USD
ROB COM. VOY.	2,317.5	124.75
RCVD AT: Singapore	495	135.5
RCVD AT: Fujairah	3,080.799	135.16
TOTAL	5,893.299	
ROB COMP. VOY.	3,196	
CONSUMED	2,697.299	
COST	$ 483,473.29	

Using the bunkering cost minimisation model described in paragraph 7.1, table 7.4 is obtained. The key difference to what has previously been described is that when calculating cost, the cost of the used bunkers received from previous voyages is not subtracted from the current voyage's bunkering cost. This is done in order to appreciate the cost reduction size attributed to correctly performed fuel purchasing.

Table 7.4: Bunkering Cost Minimisation (7/24/01 – 9/3/01).

	Bataan	Singapore	Ras Isa	Ras Tanura	Fujairah	Durban
Ci		248.4	759	408.8	94.9	897.9
Qi		0			3,575.8	
ROBi		2,069.1	1,291.2	827.6	665.8	3,314.9
ROBdi	2,317.5	2,050.2	1,236.4	760.7	4,212.8	3,196
COST	$ 483,304.99					

Moving on to the fuel purchasing analysis, a few major suppliers of the two bunkering ports of Singapore and Fujairah are to be compared based on the fuel purchasing approach. Since a price from each individual supplier could not be obtained, it is assumed that for each port, all suppliers sell at the same price. All information is up-to-date with the DNV Fuel Quality Statistics, issued on the corresponding period. Thus, for this voyage fuel quality statistics are true as of June 2001. In order to perform the study, the values of quantity used are the ones the shipping company purchased, which does not alter the final result in any way, as it is obtained in US dollars per metric tonne.

Table 7.5: Singapore quality comparison (380 cSt). [Ref. 30, June 2001]

Product: IFO 380 cSt, 50 °C							
Quantity: 495 mt							
Supplier	Price ($)	Density (g/ml)	Viscosity (cSt)	Water (%v/v)	Al (mg/kg)	NSE (MJ/kg)	Sulphur (%m/m)
BP	135.5	0.986	356	0.3	15	40.03	3.44
EXXONMOBIL	135.5	0.982	346	0.1	1	40.11	3.67
FAMM	135.5	0.984	341	0.3	10	40.09	3.34
SHELL	135.5	0.986	353	0.0	2	40.15	3.45

<u>Density/Aluminium</u>

ExxonMobil offers the fuel with the lowest density and aluminium content.

Viscosity

All four fuels are within the tolerable limits, i.e. the tolerance of 7.4% (408 cSt for IFO 380 fuels).

Water Content

BP: 495mt × 0.3% = 1.485mt

1.485mt × $135.5/mt = $201.22 = $0.41/mt

EXXONMOBIL: 495mt × 0.1% = 0.495mt

0.495mt × $135.5/mt = $67.07 = $0.14/mt

FAMM: 495mt × 0.3% = 1.485mt

1.485mt × $135.5/mt = $201.22 = $0.41/mt

SHELL: $0.00/mt

Net Specific Energy

Of the four suppliers, ExxonMobil offers a superior fuel, but not in terms of water content and Net Specific Energy; Shell may provide a 'better value for money' fuel.

Energy MJ EXXONMOBIL: 495,000 kg × 40.11MJ/kg = 19,854,450 MJ

SHELL: 495,000 kg × 40.15MJ/kg = 19,874,250 MJ

Difference (SHELL - EXXONMOBIL) Δ MJ = 19,800 MJ

Cost / MJ Bunker Price: $135.5/mt = $135.5/1,000kg = $0.14/kg

$$\frac{\$0.14 / kg}{40.15 MJ / kg} = \frac{\$0.14}{40.15 MJ} = \$0.00337 / MJ$$

Value Δ MJ 19,800 MJ × $0.00337/MJ = $66.82

Saving $$\frac{\$66.82}{495 mt} = \$0.13 / mt$$

SHELL

Price: $135.5/mt

Water: -$0.14

Net Specific Energy: -$0.13

$135.23/mt

Shell is therefore selected and the shipping company may negotiate to purchase fuel from ExxonMobil at $135.23 rather than $135.5, as Shell comparatively offers this price advantage. Or even at a lower price from BP, which offers fuel oil with the highest water content and the lowest Net Specific Energy. Compared to Shell's fuel oil, based on the same calculations, BP's fuel oil may be purchased at a price of $134.69.

For the port of Fujairah similar calculations are performed.

Table 7.6: Fujairah quality comparison (380 cSt). [Ref. 30, June 2001]

Product: IFO 380 cSt, 50 °C							
Quantity: 3,080.799 mt							
Supplier	Price ($)	Density (g/ml)	Viscosity (cSt)	Water (%v/v)	Al (mg/kg)	NSE (MJ/kg)	Sulphur (%m/m)
EXXON	135.16	0.967	355	0.1	3	40.51	2.97
FAMM	135.16	0.978	368	0.2	0	40.19	3.44
TEXACO	135.16	0.978	386	0.2	2	40.15	3.58

Density/Aluminium

Exxon offers the fuel with the lowest density and has low aluminium content.

Viscosity

All four fuels are within the tolerable limits, i.e. the tolerance of 7.4% (408 cSt for IFO 380 fuels).

Water Content

EXXON: 3,080.799 × 0.1% = 3.081mt

3.081mt × \$135.16/mt = \$416.40 = \$0.14/mt

FAMM: 3,080.799 × 0.2% = 6.162mt

6.162mt × \$135.16/mt = \$832.80 = \$0.27/mt

TEXACO: 3,080.799 × 0.2% = 6.162mt

6.162mt × \$135.16/mt = \$832.80 = \$0.27/mt

Net Specific Energy

Of the four suppliers, Exxon offers a superior fuel, with the lowest water content and highest Net Specific Energy. Let us see how Texaco's fuel, which is inferior to Exxon's fuel, compares to the former.

Energy MJ EXXON: 3,080,799 kg × 40.51MJ/kg = 124,803,167.5 MJ

TEXACO: 3,080,799 kg × 40.15MJ/kg = 123,694,080 MJ

Difference (EXXON - TEXACO) Δ MJ = 1,109,087.5 MJ

Cost / MJ Bunker Price: \$135.16/mt = \$135.5/1,000kg = \$0.14/kg

$$\frac{\$0.14/kg}{40.51MJ/kg} = \frac{\$0.14}{40.51MJ} = \$0.00334/MJ$$

Value Δ MJ 1,109,087.5 MJ × \$0.00334/MJ = \$3,700.43

Saving $$\frac{\$3,700.43}{3,080.799mt} = \$1.20/mt$$

EXXON

Price:	$135.16/mt
Water:	-$0.13
Net Specific Energy:	-$1.20
	$133.83/mt

Therefore, if fuel oil were to be purchased from Texaco, the price could be negotiated to as low as $133.83. Returning to the bunkering cost minimisation problem, in table 7.7 and 7.8, as shown below, the bunkering cost is found for a low fuel oil price at Singapore only and a low fuel oil price at both Singapore and Fujairah, respectively. It is interesting to observe that in the first case, the bunkering quantity in Singapore has substantially increased, since the fuel oil price has fallen below that of Fujairah. The overall bunkering cost reduction compared to the actual voyage bunkering cost is $483,473.29 - $478,549.18 = $4,924.11. Moreover, since the vessel will not call at Singapore for bunkering, an amount of about $5,000 is saved that would have to be paid, otherwise.

Table 7.7: Bunkering Cost Minimisation (lower Singapore price).

	Bataan	**Singapore**	**Ras Isa**	**Ras Tanura**	**Fujairah**	**Durban**
Ci		248.4	759	408.8	94.9	897.9
Qi		2,974.7598			601.0	
ROBi		2,069.1	4,266.0	3,802.3	3,640.6	3,314.9
ROBdi	2,317.5	5,025.0	4,211.1	3,735.5	4,212.8	3,196
COST	$ 481,906.86					

Table 7.8: Bunkering Cost Minimisation (lower Singapore and Fujairah price).

	Bataan	Singapore	Ras Isa	Ras Tanura	Fujairah	Durban
Ci		248.4	759	408.8	94.9	897.9
Qi		0			3,575.8	
ROBi		2,069.1	1,291.2	827.6	665.8	3,314.9
ROBdi	2,317.5	2,050.2	1,236.4	760.7	4,212.8	3,196
COST	$ 478,549.18					

From this point onwards, the tables shown in the main body of this chapter are the actual voyage details and the final bunkering cost minimisation table, accompanied by the appropriate commenting. All the rest, along with the calculations, may be found in Appendices 6, 7, 8 and 9 for the reader who wishes to study them in detail.

7.4.2 VLCC VOYAGE 2

Table 7.9: VLCC Voyage Details (3/24/01 – 5/13/01).

PORT OF	ARRIVED	SAILED	REASON
Ulsan	-	3/24/01 0001	Discharging
Singapore	3/30/01 2100	3/31/01 1200	Bunkering
Ras Isa	4/10/01 2400	4/15/01 1000	Loading
Fujairah	4/19/01 2230	4/22/01 0400	Loading & Bunkering
Ulsan	5/9/01 1900	5/13/01 1300	Discharing

BUNKERS	MT	USD
ROB COM. VOY.	1,465/1,000	118/140
RCVD AT: Singapore	1,999.7	132.75
RCVD AT: Fujairah	583.572	137
TOTAL	5,048.272	
ROB COMP. VOY.	2,060	
CONSUMED	2,988.272	
COST	$ 345,409.54	

Table 7.10: Bunkering Cost Minimisation (lower Singapore and Fujairah price).

	Ulsan	Singapore	Ras Isa	Fujairah	Ulsan
Ci		469.2	690	292	1,241
Qi		2,583.3		0	
ROBi		1,995.8	3,859.1	3,505.1	2,199
ROBdi	2,465	4,549.1	3,797.1	3,440	2,060
COST	$ 341,121.07				

In this voyage lowering the fuel oil prices at Singapore and Fujairah from $132.75 to $132.05 and $137 to $136.09 [see Appendix 6] respectively, resulted in gaining a profit of $4,288.47. In contrast to the previous voyage though, Fujairah is a loading port and thus payment of disbursements may not be avoided, but bunkering, according to the bunkering cost minimisation, may be avoided.

7.4.3 VLCC VOYAGE 3

Table 7.11: VLCC Voyage Details (12/8/00 – 1/14/01).

PORT OF	ARRIVED	SAILED	REASON
Durban	-	12/8/00 1400	Discharging
Qeshm Island	12/19/00 0800	12/19/00 1700	Bunkering
Off Dubai	12/19/00 2200	12/20/00 2100	Bunkering
Jebel Dhanna	12/21/00 0800	12/24/00 0400	Loading
Kharg Island	12/25/00 1400	12/27/00 1900	Loading
Tabangao	1/12/01 1400	1/14/01 1600	Discharging

BUNKERS	MT	USD
ROB COM. VOY.	1,462/993	175.75/156.5
RCVD AT: Qeshm Isl.	1,500.04	148.5
RCVD AT: Dubai	790.09	125.5
TOTAL	4,745.13	
ROB COMP. VOY.	2,441	
CONSUMED	2,304.13	
COST	$ 321,912.24	

Table 7.12: Bunkering Cost Minimisation (lower Qeshm Island and Dubai price).

	Durban	Qeshm Island	Off Dubai	Jebel Dhanna	Kharg Island	Tabangao
Ci		741.75	14.49	31.60	103.44	1,152.82
Qi		1,500.04	790.09			
ROBi		1,713.25	3,180.80	3,923.29	3,734.50	2,526.33
ROBdi	2,455	3,195.29	3,954.89	3,837.94	3,679.15	2,441
COST	$ 318,254.91					

In this voyage lowering the fuel oil prices at Qeshm Island and Dubai from $148.5 to $147.8 and $125.5 to $122.2 [see Appendix 6], respectively, resulted in gaining a profit of $3,657.33. One may observe that during this voyage bunkering cost minimisation is a result of negotiating for purchasing fuel oil from the suppliers at a lower price, as bunkering quantities remained unchanged.

7.4.4 SUEZMAX VOYAGE 1

The fuel oil consumption, for the Suezmax tanker, is as follows: a) 14 knots laden: 58 mt/day, b) 15 knots in ballast: 52 mt/day, c) discharging: 60 mt/day, d) loading: 20 mt/day, e) at anchor idle: 6 mt/day and f) at port: 6 mt/day.

Table 7.13: Suezmax Voyage Details (2/22/03 – 3/21/03).

PORT OF	ARRIVED	SAILED	REASON
Savona	-	2/22/03 1200	Discharging
Messina	2/23/03 2100	2/23/03 2130	In Transit
Piraeus	2/25/03 0818	2/25/03 2100	Bunkering
Dardanelles	2/26/03 1000	3/1/03 1150	In Transit
Bosporus	3/1/03 2400	3/5/03 1348	In Transit
Novorossiysk	3/6/03 1918	3/10/03 0500	Loading
Bosporus	3/11/03 1018	3/13/03 1200	In Transit
Dardanelles	3/13/03 1742	3/16/03 1120	In Transit &

			Bunkering
Fos	3/20/03 1012	3/21/03 2248	Discharging

BUNKERS	**MT**	**USD**
ROB COM. VOY.	1,192	173
RCVD AT: Piraeus	1,099.237	177
RCVD AT: Dardanelles	1,525	169
TOTAL	3,816.237	
ROB COMP. VOY.	2,949.437	
CONSUMED	866.8	
COST	$ 452,289.95	

Table 7.14: Bunkering Cost Minimisation (lower Dardanelles price).

	Savona	**Messina**	**Piraeus**	**Dardanelles**	**Bosporus**
Ci		71.5	75.92	28.08	26
Qi			0		
ROBi		1120.5	1044.3	1013.3	950.7
ROBdi	1192	1120.3	1041.3	976.7	938.7
	Novorossiysk	**Bosporus**	**Dardanelles**	**Fos**	
Ci	65	72.5	14.5	232	
Qi			2624.2		
ROBi	873.7	740.0	713.5	3009.4	
ROBdi	812.45	727.95	3241.4	2949.437	
COST	$ 443,496.05				

During this voyage, bunkering at Piraeus had not been necessary and purchasing fuel oil from the Dardanelles lowered the cost by $8,793.90.

7.4.5 SUEZMAX VOYAGE 2

The previous voyage of the vessel ended at Wilhelmshaven discharging blend oil and the vessel's current voyage started at Wilhelmshaven loading straight run fuel oil.

Table 7.15: Suezmax Voyage Details (5/21/02 – 6/14/02).

PORT OF	ARRIVED	SAILED	REASON
Wilhelmshaven	-	5/21/02 1100	Discharging
Wilhelmshaven	5/21/02 1100	5/23/02 0130	Loading
Le Havre	5/24/02 0900	5/27/02 1500	Loading & Bunkering
Corpus Christi	6/11/02 1430	6/14/02 1800	Discharging & Bunkering

BUNKERS	MT	USD
ROB COM. VOY.	1,251	143
RCVD AT: Le Havre	1,498.1	151.5
RCVD AT: Corpus Christi	403.46	156
TOTAL	3,152.56	
ROB COMP. VOY.	1,877	
CONSUMED	1,275.56	
COST	$ 289,901.91	

Table 7.16: Bunkering Cost Minimisation (lower Le Havre and Corpus Christi price).

	Wilhelmshaven	Le Havre	Corpus Christi
Ci		77.72	870
Qi		1,901.52	0
ROBi	1,251	1,141.28	2,072.0
ROBdi	1,219	2,942.0	1,877
	$ 287,357.70		

In this voyage lowering the fuel oil prices at Le Havre and Corpus Christi from $151.50 to $151.12 and $156 to $155.08 [see Appendix 7], respectively, resulted in gaining a profit of $2,544.21.

7.4.6 SUEZMAX VOYAGE 3

Table 7.17: Suezmax Voyage Details (5/25/01 – 6/20/01).

PORT OF	ARRIVED	SAILED	REASON
LOOP	-	5/25/01 1900	Discharging
Cayo Arcas	5/27/01 1300	6/1/01 2000	Loading

Freeport (Bahamas)	6/4/01 1000	6/4/01 1900	Bunkering
Bilbao	6/17/01 0830	6/18/01 1630	Discharging
Corunna	6/19/01 1130	6/20/01 1900	Discharging

BUNKERS	MT	USD
ROB COM. VOY.	764	127
RCVD AT: Freeport	799	125.45
RCVD AT: Corunna	600.4	128.5
TOTAL	2,163.4	
ROB COMP. VOY.	963	
CONSUMED	1,200.4	
COST	$ 177,385.95	

Table 7.18: Bunkering Cost Minimisation (lower Corunna price).

	LOOP	Cayo Arcas	Freeport	Bilbao	Corunna
Ci		93.6	145	732.25	46.4
Qi			1,399.4		0.0
ROBi		670.4	427.2	1,092.1	1,033.1
ROBdi	764	572.2	1,824	1,079.5	963
COST	$ 175,554.73				

Even though the fuel oil price at Corunna was lowered from $128.5 to $127.83 [see Appendix 7], the bunkering cost minimisation suggested that bunkering could have been avoided at Corunna, thus making a profit of $1,831.22 by bunkering at Freeport.

7.4.7 AFRAMAX VOYAGE 1

The fuel oil consumption, for the Aframax tanker, is as follows: a) 14 knots laden: 43 mt/day, b) 15 knots in ballast: 38 mt/day, c) discharging: 60 mt/day, d) loading: 18 mt/day, e) at anchor idle: 6 mt/day and f) at port: 6 mt/day. It should be noted that the vessel considered burns lower viscosity fuel oil, the IFO 180 class and thus bunkering is more expensive by about $2 - $10/mt. This does not have a direct effect on the research, as the author explores what the cost savings are and not the cost in total. Moreover, the reader should not be surprised by higher NSE values, as lower density fuel offers higher a NSE [see Figure 7.1]. In general, lower viscosity fuels are less dense than higher viscosity fuels.

Table 7.19: Aframax Voyage Details (2/20/03 – 3/30/03).

PORT OF	ARRIVED	SAILED	REASON
Lawe-Lawe	-	2/20/03 0230	Discharging
Singapore	2/24/03 0530	2/24/03 2030	Bunkering
Suez	3/11/03 2100	3/12/03 2030	In Transit
Dardanelles	3/14/03 2400	3/20/03 1100	In Transit
Bosporus	3/20/03 2130	3/21/03 0800	In Transit
Odessa	3/22/03 1100	3/27/03 1000	Loading
Bourgas	3/28/03 0900	3/30/03 1900	Discharging

BUNKERS	MT	USD
ROB COM. VOY.	831.7	178.5
RCVD AT: Singapore	1,004.5	209
RCVD AT: Suez	1,200.067	177
TOTAL	3,036.267	
ROB COMP. VOY.	1,500	
CONSUMED	1,536.267	
COST	$ 422,352.36	

Table 7.20: Bunkering Cost Minimisation (lower Singapore and Suez price).

	Lawe-Lawe	Singapore	Suez	Dardanelles	Bosporus	Odessa	Bourgas
Ci		208	936	104	20.8	52	58
Qi		316.05	1,888.517				
ROBi		623.7	0.0	1,749.5	1,693.7	1,624.2	1,512
ROBdi	831.7	936.0	1,853.5	1,714.5	1,676.2	1,570.217	1,500
COST	$ 399,969.31						

During this voyage much of the cost savings were a result of the bunkering cost minimisation, as fuel oil is purchased to suffice the voyage to Suez. A prudent operator though would not compromise the redundant operation of the vessel for any cost savings and thus would stock up as much fuel oil as believed to be needed. Nonetheless, the cost savings for this voyage are $22,383.05.

7.4.8 AFRAMAX VOYAGE 2

Table 7.21: Aframax Voyage Details (11/25/02 – 1/22/03).

PORT OF	ARRIVED	SAILED	REASON
Texas City	-	11/25/02 2300	Discharging
Southwest Pass	11/26/02 2300	11/26/02 2320	In Transit
Convent	11/27/02 1830	11/29/02 0930	Loading
Norco	11/29/02 0930	12/1/02 1600	Loading
St. Eustatius	12/8/02 1130	12/9/02 1300	Loading
Singapore	1/18/03 1100	1/22/03 0300	Discharging

BUNKERS	MT	USD
ROB COM. VOY.	464.83/700/609.97	149/143/150.33
RCVD AT: St. Eustatius	1,349.783	154.7
RCVD AT: Singapore	2,189.736	178.5
TOTAL	5,314.319	
ROB COMP. VOY.	2,266.4	
CONSUMED	3,047.919	
COST	$ 599,679.31	

Table 7.22: Bunkering Cost Minimisation (lower St. Eustatius and Singapore price).

	Texas City	Southwest Pass	Convent	Norco	St. Eustatius	Singapore
Ci		52	39	0	394.4	2,320
Qi					2,432.3752	1,107.1438
ROBi		1,722.8	1,663.8	1,614.8	1,160.2	1,233.0
ROBdi	1,774.8	1,702.8	1,614.8	1,554.6	3,553.0	2,266.4
COST	$ 573,813.97					

Similarly to the previous voyage, during this voyage much of the cost savings were a result of the bunkering cost minimisation, as fuel oil is purchased in abundance from St. Eustatius at a lower price than Singapore. This, of course, can be done up to the fuel oil capacity that the vessel's fuel oil tanks offer and the remaining fuel is purchased at Singapore. Nevertheless, the cost savings for this voyage are $25,865.34.

7.4.9 AFRAMAX VOYAGE 3

Table 7.23: Aframax Voyage Details (12/4/00 - 1/10/01).

PORT OF	ARRIVED	SAILED	REASON
Lavera	-	12/4/00 1730	Discharging
Skikda	12/5/00 1945	12/16/00 0600	Loading
Algeciras	12/18/00 0830	12/19/00 0600	Bunkering
New York	1/4/01 1900	1/10/01 0730	Discharging & Bunkering

BUNKERS	MT	USD
ROB COM. VOY.	104.8/550	171.5/174
RCVD AT: Algeciras	1,500	168
RCVD AT: New York	1,209.13	173.9
TOTAL	3,363.93	
ROB COMP. VOY.	1,290	
CONSUMED	2,073.93	
COST	$ 462,267.71	

Table 7.24: Bunkering Cost Minimisation (lower Algeciras and New York price).

	Lavera	Skikda	Algeciras	New York
Ci		60.5	128.1	1,006.5
Qi			2,709.13	0
ROBi		594.3	96.3	1,706.5
ROBdi	654.8	224.4	2,713.0	1,290
COST	$ 450,528.32			

Despite the reduction in price at New York, all of the fuel oil required is purchased from Algeciras, leading to a cost reduction of $11,739.39.

7.4.10 PRODUCT VOYAGE 1

The fuel oil consumption, for the Product tanker, is as follows: a) 14 knots laden: 31 mt/day, b) 14 knots in ballast: 28 mt/day, c) discharging: 8 mt/day, d) loading: 5 mt/day, e) at anchor idle: 5 mt/day and f) at port: 5 mt/day.

Table 7.25: Product Voyage Details (12/8/02 – 1/3/03).

PORT OF	ARRIVED	SAILED	REASON
Conakry	-	12/8/02 0830	Discharging
Algeciras	12/14/02 0530	12/14/02 1500	Bunkering
Suez	12/19/02 2300	12/20/02 2200	In Transit
Yanbu	12/22/02 0730	12/23/02 1330	Loading
Suez	12/24/02 2230	12/25/02 1830	In Transit
Algeciras	12/31/02 2000	1/3/03 0200	Discharging & Bunkering

BUNKERS	MT	USD
ROB COM. VOY.	250/150	131/125
RCVD AT: Algeciras	750	131
RCVD AT: Algeciras	508	144
TOTAL	1,658	
ROB COMP. VOY.	987	
CONSUMED	671	
COST	$ 171,402.00	

Table 7.26: Bunkering Cost Minimisation (lower Algeciras price).

	Conakry	Algeciras	Suez	Yanbu	Suez	Algeciras
Ci		168	148.4	39.2	42.625	190.65
Qi		970.25				287.75
ROBi		232	1,051.6	986.0	933.8	719.8
ROBdi	400	1,200.0	1,025.2	976.4	910.5	987
COST	$ 167,922.33					

In this voyage, optimising the bunkering planning and lowering the fuel oil prices at Algeciras from $131 to $130.51 and $144 to $143.51 [see Appendix 9], resulted in gaining a profit of $3,479.67.

7.4.11 PRODUCT VOYAGE 2

Table 7.27: Product Voyage Details (3/18/01 – 5/2/01).

PORT OF	ARRIVED	SAILED	REASON
San Fransisco	-	3/18/01 2200	Discharging
San Fransisco	3/18/01 2200	3/19/01 0900	-
Ulsan	4/8/01 0500	4/10/01 0030	Loading & Bunkering
Los Angeles	4/30/01 0900	5/2/01 2330	Discharging & Bunkering

BUNKERS	MT	USD
ROB COM. VOY.	408/505	124/152
RCVD AT: Ulsan	500	152.5
RCVD AT: Los Angeles	301	189
TOTAL	1,714	
ROB COMP. VOY.	694	
CONSUMED	1,020	
COST	$ 133,139.00	

Table 7.28: Bunkering Cost Minimisation (lower Ulsan and Los Angeles price).

	San Fransisco	Ulsan	Los Angeles
Ci		458.85	529.7
Qi		757.35	43.70
ROBi	913	451.65	670.3
ROBdi	910.5	1,200.0	694
COST	$ 122,973.49		

In this voyage, optimising the bunkering planning and lowering the fuel oil prices at Ulsan and Los Angeles from $152.5 to $151.6 and $189 to $186.71 [see Appendix 9], respectively, resulted in saving $10,165.51.

7.4.12 PRODUCT VOYAGE 3

Table 7.29: Product Voyage Details (12/22/00 - 2/7/01).

PORT OF	ARRIVED	SAILED	REASON
San Juan (Puerto Rico)	-	12/22/00 0850	Discharging
San Juan (Puerto Rico)	12/22/00 0850	12/23/00 1300	Bunkering
Bonny	1/7/01 2200	1/15/01 0900	Loading
Houston	2/5/01 0606	2/7/01 2348	Discharging & Bunkering

BUNKERS	MT	USD
ROB COM. VOY.	207/500	171/153
RCVD AT: San Juan	399	174
RCVD AT: Houston	1,000	124
TOTAL	2,106	
ROB COMP. VOY.	1,163	
CONSUMED	943	
COST	$ 193,426.00	

Table 7.30: Bunkering Cost Minimisation (lower Houston price).

	San Juan	Bonny	Houston
Ci		326.2	546
Qi	213.7		1,185
ROBi	707	583.5	0.0
ROBdi	909.7	546.0	1,163
COST	$ 183,389.10		

In this voyage, optimising the bunkering planning and lowering the fuel oil prices at Houston from $124 to $123.38 [see Appendix 9], resulted in saving $10,036.9.

8 CONCLUSIONS

As discussed, marine fuel oil is a product of the refining process that is not profitable to produce for the oil refineries in large quantities, specifically from the 70's onwards. Its deteriorating quality through the years has created a headache to those involved in the shipping industry.

It is of vital importance for any seagoing engineer or mariner to be able to avoid the potentially catastrophic losses arising from loading marine fuel oils of unsuitable quality or insufficient quantity. Ship's officers, operators and managers must understand the pitfalls of the bunkering process and the steps which should be undertaken in the event of a dispute arising and be aware of the fuel purchasing management concept.

Regulations on the air pollution from ships in the EU will place an additional burden on those involved in the industry. These regulations have not been ratified yet, and both IMO and the EU should examine the situation in a delicate manner. The benefits in the form of reduced emissions from a reduced content of sulphur in bunker fuels should be estimated. The economic benefits of the reduced emissions should also be estimated. Other possible methods to reduce ship emissions, such as obligatory connection to an electrical grid during port visits should be evaluated.

Most importantly, the option of emissions trading, as the International Bunker Industry Association (IBIA) suggests, may be an alternative solution to the approach of consuming low-sulphur fuel oil. "The emissions trading scheme incorporated into the US Clean Air Act amendment which came into force in 1990 was the precursor to the idea of flexible mechanisms within the Kyoto Protocol." [Ref. 11, 2003] Under the trading scheme, in the land based industry of generating electricity, each country pays in advance in order to release to the air a specific amount of emissions for each calendar year. During the course of each year, countries may trade purchased emissions rights among themselves. At the year ending, those with emissions above their bought quota pay the equivalent amount of money. It would be of interest to determine the benefit of such a solution for the shipping industry. Of course, vessels with trading patterns within Europe will have to be favoured to others. "Perhaps the lack of knowledge on the subject of emissions trading has resulted in little consideration until recently of using the mechanism to achieve SO_x emissions reductions for shipping. There is history of evidence indicating that where there is a demand for a solution, that demand stimulates the creation for solutions. And there is no doubt that an efficient market has proved over time to be the most effective way we know of discovering price. Emissions trading enables these two ingredients to come together in what will undoubtedly result in achievement of substantially lower emissions, at appreciably lower cost than a regulated option." [Ref. 11, 2003] Ratification of Annex VI and of any imposed EU legislation, under the sulphur reduction option, would result in the entire freight rate being utilised by the running costs. Thus, ratification of Annex VI should be accompanied by an approximate increase of 20% in the daily freight rates, so that as before ratification shipping companies could cover their management fees, investment cost and have a required return on investment.

One may ask whether the overall cost increase in freight rates, will reduce the amount of cargo or ton-miles shipped. As discussed, the major importers of oil are Japan, Europe and the USA. Europe, within which emissions regulations will apply for certain, 'consumes' fuel oil that mainly comes from the North Sea offshore oil production platforms and Russia. In order to observe such a reduction in ton-miles shipped, a feasible solution might be to construct an integrated system of pipelines that will carry oil from one country to another. An increase in freight rates has to outweigh the risk (i.e. explosion, terrorist attack, etc.) of having such a system passing through European countries for this solution to stand. Japan, an island by itself, relies heavily on foreign imports and will most probably not be able to restrain an increase in freight rates. Lastly, the US from the 70s oil crisis and onwards is experiencing a growth in oil demand while its own production cannot entirely supply this growing demand. Besides, in three of the five routes studied the US is an importer of oil and thus oil consumption is dependent on these foreign imports.

As far as risk management is concerned, for a shipping company managing a fleet of tankers it is difficult to implement a successful bunker price management strategy. A liner company would be more profitable in doing so, since the ports within which its vessels operate are known.

It should be remembered that all freight departments are judged on how they charter shipping versus the spot market, which is usually two weeks out in the future. By definition, this almost insures that they will be judged favourably. The real question to be asked is 'What did they do when the risk was taken?' For example, if a trader wins a spot tender 90 days in the future using a freight department estimate of Worldscale 150 for the bid, but by the time the cargo loads, it has jumped to Worldscale 300, then the trader is probably going to lose much money for the company. However, the freight department will be judged on how they did their chartering in the spot market (i.e. at

Worldscale 300). Management will be happy with the freight department and critical of the trading department when in fact the freight department allowed the market price to double without any proactive risk management activity.

Market makers will enter into the freight market, and have similar impact as Wall Street had on the oil markets in the 1980s. They will capture inefficiencies of the bid versus ask. Moreover, instead of a shipowner having to enter into a timecharter agreement when markets are low, he/she may hedge against high bunker prices and low freight rates using the risk management tools discussed. In so doing, he/she will avoid worrying about the quality of fuel oil purchased by the charterers. Of course, most shipowners add a clause in the Timecharter Party Agreement stating the minimum quality characteristics fuel oil should have. Still, one bunkering is enough to destroy a marine engine in service

Concerning the bunkering planning and fuel oil purchasing optimisation, taking into account that a vessel will make about ten to fifteen voyages per year, an operator may save: a) $40,000-$65,000 for a VLCC, b) $45,000-$65,000 for a Suezmax, c) $200,000 - $300,000 for an Aframax and d) $70,000 - $120,000 for a Product tanker per year. However, it needs to be emphasized that there are practical constraints and implications of such a means of reducing voyage cost.

In relation to the bunkering planning minimisation algorithm, an operator should be reluctant merely storing in a vessel's fuel oil tanks the required fuel oil quantity that a vessel will consume until the next bunkering port [see Paragraph 7.4.7]. To avoid compromising the vessel's redundancy, additional fuel oil should be purchased. Moreover, there may be either a limiting quantity, due to tight availability, or a minimum quantity to be purchased in a port, thus restraining either in the upside or in the downside the quantity of fuel oil purchased. Additionally, although worldwide bunker prices move together in the long run, there are short term deviations between prices. Whatever the case, an operator in view of increasing/decreasing bunker prices will decide to either stock up fuel oil or to wait prices to drop, so as to avoid bunkering at a higher cost. In other cases, an operator may be bound by the Tanker Voyage Charter Party agreement not to bunker while loaded or while in ballast a vessel may not be given enough time to bunker at a desired port. On the other hand, a shipowner may add a bunker deviation clause in the Charter Party agreement allowing him a small and customary deviation in the trade. This may not usually be unlawful, but the scope of what is 'customary' has always been very narrowly interpreted at law. One such clause is the P&I Bunker Deviation Clause, 1948 which reads:

'The vessel in addition to all other liberties shall have liberty as part of the contract voyage and at any stage thereof to proceed to any port or ports whatsoever whether such ports are on or off the direct and/or customary route or routes to the ports of loading or discharge named in this charter and there take oil bunkers in any quantity in the discretion of owners even to the full capacity of fuel tanks, deep tanks, and any other compartment in which oil can be carried whether such amount is or is not required for the chartered voyage.'

Regarding fuel oil purchasing, it needs to be noted that due to lack of information, the necessary calculations were carried out assuming all suppliers, within a port, offering fuel oil at the same price. This may be seen as a naïve assumption to make, but nevertheless when buying fuel oil, one should evaluate the different prices on offer and exploit, based on water content and NSE, any arbitrage opportunities that may appear. In addition, one should bear in mind that the research herein uses historical data to evaluate the cost savings presented. Both in terms of the fuel prices and the fuel quality statistics, the data used were true at the time of the voyage. The former are settled daily and the latter are issued on a quarterly basis. Thus, an operator may not know the price of the fuel on the bunkering date until it is purchased and the fuel quality statistics until the quarter ends. By and large, when considering minimising the bunkering cost, an operator may only assume a price for the fuel to be purchased and when negotiating this price with the fuel suppliers based on the water content and NSE, he/she will do so according to past data. Finally, regarding fuel oil purchasing, an operator should ensure the purchased fuel oil does not compromise the engine's performance. In this respect, bunker alerts are issued by the DNV Petroleum Services to warn operators of any off-spec fuel.

APPENDICES

Appendix 1

INVITATION FOR SAMPLING

Request from master to charterers' port agents and bunker supplier to attend during representative sampling.

FROM: ______________________________
COMPANY: ______________________________
TO: ______________________ DATE: ______________________
TIME: ______________________________
AT: ______________________________
RE: MV ______________________________

Samples of bunkers ______________________________

Dear Sirs,

[In accordance with charterparty conditions] I hereby request you to ensure that representative samples of the bunkers to be supplied to the ship will be taken and sealed in the presence of competent and authorised representatives of charterers and the ship, such samples to be taken during bunkering at the ship's manifold. The ship will require two samples.

It will be of assistance to you to know that the ship has facility for drawing continuous samples at the manifold. If no joint samples are taken during bunkering by a satisfactory alternative system, only those samples drawn at the manifold by the ship's representatives will be regarded as representative samples.

I shall be grateful if you will advise me as soon as possible what arrangements have been made by you or the bunker supplier in respect of bunkering and sampling.

Yours faithfully
Master ______________________________
Ship's authorised personnel: ______________________________

Make and model of sampling equipment: ______________________________
Make and model of main engine: ______________________________

Appendix 2

LETTER OF PROTEST

Protest by master for failure of charterers' port agents or bunker supplier to attend during representative sampling.

FROM: ____________________
COMPANY: ____________________
TO: ____________________ DATE: ____________________
TIME: ____________________
AT: ____________________
RE: MV ____________________

Samples of bunkers ____________________

Dear Sirs,

I hereby make a formal protest that you and the bunker supplier have failed to participate in the proper obtaining and sealing during bunkering time of representative samples of the bunkers supplied to the ship.

In particular:

[ ] No samples have been drawn by you and supplied.
[ ] Ready sealed samples have been supplied.
[ ] Samples were drawn in a method which is unsatisfactory and susceptible to gross error.

I hereby give you notice that the vessel has taken her own samples during the bunkering operation [which were sealed in the presence of charterers or bunker supplier's representative] [in the absence of a response to my invitation to attend joint sampling] and only these samples will be regarded as representative. Two sealed samples drawn by the ship are available to you on request.

Yours faithfully
Master ____________________

Make and model of sampling equipment: ____________________
Make and model of main engine: ____________________

Appendix 3

LETTER OF PROTEST

Protest by master in the event of a bunker quantity dispute arising.

FROM: ____

COMPANY: ____

TO: ______________________ DATE: ______________________

TIME: ____

AT: ____

RE: MV ____

Dear Sirs,

I hereby do lodge protest in respect of * ____

____

____

____

I must therefore - on behalf of my owners - hold you fully responsible for all consequences, losses, claims and or costs incurred thereby.

Further on behalf of my owners and or any other party concerned, I reserve their rights to refer to this matter at a future date.

Yours faithfully

Master ____

Chief Engineer: ____

Acknowledged: ____

NOTE: * Here insert details of the event/matter and reasons for which you submit the protest.

Appendix 4

LETTER OF PROTEST

Notification by master to charterers' port agents and bunker supplier that fuel does not conform with specifications required by the vessel.

FROM: ____
COMPANY: ____
TO: _____________________________ DATE: ___________________________
TIME: ____
AT: ____
RE: MV ____
Bunkers loaded at ____

Dear Sirs,

I hereby give you notice that an analysis carried out on this ship of a representative sample of the bunkers supplied by you indicates the deficiencies listed below. The fuel is therefore outside the specification of fuel suitable to the ship's engines and auxiliary machinery and has been submitted for further analysis.

Deficiencies were noted in:

1. Density [ ]
2. Viscosity [ ]
3. Pour point [ ]
4. Water content [ ]
5. Salt Water [ ]
6. Compatibility [ ]
7. Catalytic fines [ ]

Owners await charterers' instructions and until these are received, the ship cannot proceed. In the meantime, the ship's engineering staff will use their best endeavours to protect the ship's engines (including the slowing and stopping of the ship's machinery when necessary). Owners hold charterers fully responsible for any damage, delays, poor performance, over-consumption or any other loss or expense arising as a direct or indirect consequence of your failure to supply suitable fuel.

Yours faithfully
Master ____

Make and model of sampling equipment: _______________________________
Make and model of main engine: ______________________________________

Appendix 5

ANNEX VI OF MARPOL 73/78
REGULATIONS FOR THE PREVENTION OF AIR POLLUTION FROM SHIPS

REGULATION 14: SULPHUR OXIDES, SO_x

General Requirements

1) The sulphur content of any fuel oil used on board ships shall not exceed 4.5% m/m.
2) The worldwide average sulphur content of residual fuel oil supplied for use on board ships shall be monitored taking into account guidelines to be developed by the Organization.

Requirements within SO_x Emission Control Areas

3) For the purpose of this regulation, SO_x emission control areas shall include:
   a) the Baltic Sea area as defined in regulation 10(1)(b) of Annex I; and
   b) any other sea area, including port areas, designated by the Organization in accordance with criteria and procedures for designation of SO_x emission control areas with respect to the prevention of air pollution from ships contained in appendix III to this Annex.
4) While, ships are within SO_x emission control areas, at least one of the following conditions shall be fulfilled:
   a) the sulphur content of fuel oil used on board ships in a SO_x emission control area does not exceed 1.5% m/m;
   b) an exhaust gas cleaning system, approved by the Administration taking into account guidelines to be developed by the Organization, is applied to reduce the total emission of sulphur oxides from ships, including both auxiliary and main propulsion engines, to 6.0 g SO_x/kWh or less calculated as the total weight of sulphur dioxide emission. Waste streams from the use of such equipment shall not be discharged into enclosed ports, harbours and estuaries unless it can be thoroughly documented by the ship that such waste streams have no adverse impact on the ecosystems of such enclosed ports, harbours and estuaries, based upon criteria communicated by the authorities of the port State to the Organization. The Organization shall circulate; the criteria to all parties to the Convention; or
   c) any other technological method that is verifiable and enforceable to limit SO_x emissions to a level equivalent to that described in sub-paragraph (b) is applied. These methods shall be approved by the Administration taking into account guidelines to be developed by the Organization.
5) The sulphur content of fuel oil referred to in paragraph (1) and paragraph (4)(a) of this regulation shall be documented by the supplier as required by regulation 18 of this Annex.

6) Those ships using separate fuel oils to comply with paragraph (4)(a) of this regulation shall allow sufficient time for the fuel oil service system to be fully flushed of all fuels exceeding 1.5% m/m sulphur content prior to entry into a SO_x emission control area. The volume of low sulphur fuel oils (less than or equal to 1.5% sulphur content) in each tank as well as the date, time, and position of the ship when any fuel-changeover operation is completed, shall be recorded in such log-book as prescribed by the Administration.
7) During the first 12 months immediately following entry into force of the present Protocol, or of an amendment to the present Protocol designating a specific SO_x emission control area under paragraph (3)(b) of this regulation, ships entering a SO_x emission control area referred to in paragraph (3)(a) of this regulation or designated under paragraph (3)(b) of this regulation are exempted from the requirements in paragraphs (4) and (6) of this regulation and from the requirements of paragraph (5) of this regulation insofar as they relate to paragraph (4)(a) of this regulation.

REGULATION 18: FUEL OIL QUALITY

1) Fuel oil for combustion purposes delivered to and used on board ships to which this Annex applies shall meet the following requirements:
   a) except as provided in sub-paragraph (b):
      i) the fuel oil shall be blends of hydrocarbons derived from petroleum refining. This shall not preclude the incorporation of small amounts of additives intended to improve some aspects of performance;
      ii) the fuel oil shall be free from inorganic acid;
      iii) the fuel oil shall not include any added substance or chemical waste which either:
         (1) jeopardizes the safety of ships or adversely affects the performance of the machinery, or
         (2) is harmful to personnel, or
         (3) contributes overall to additional air pollution; and
   b) fuel oil for combustion purposes derived by methods other than petroleum refining shall not:
      i) exceed the sulphur content set forth in regulation 14 of this Annex;
      ii) cause an engine to exceed the NO_x emission limits set forth in regulation 13(3)(a) of this Annex;
      iii) contain inorganic acid; and
      iv) (1) jeopardize the safety of ships or adversely affect the performance of the machinery, or
         (2) be harmful to personnel, or
         (3) contribute overall to additional air pollution.
2) This regulation does not apply to coal in its solid form or nuclear fuels.
3) For each ship subject to regulations 5 and 6 of this Annex, details of fuel oil for combustion purposes delivered to and used on board shall be recorded by means of a bunker delivery note which shall contain at least the information specified in appendix V to this Annex.

4) The bunker delivery note shall be kept on board the ship in such a place as to be readily available for inspection at all reasonable times. It shall be retained for a period of three years after the fuel oil has been delivered on board.
5) a) The competent authority of the Government of a Party to the Protocol of 1997 may inspect the bunker delivery notes on board any ship to which this Annex applies while the ship is in its port or offshore terminal, may make a copy of each delivery note, and may require the master or person in charge of the ship to certify that each copy is a true copy of such bunker delivery note. The competent authority may also verify the contents of each note through consultations with the port where the note was issued.

   b) The inspection of the bunker delivery notes and the taking of certified copies by the competent authority under this paragraph shall be performed as expeditiously as possible without causing the ship to be unduly delayed.
6) The bunker delivery note shall be accompanied by a representative sample of the fuel oil delivered taking into account guidelines to be developed by the Organization. The sample is to be sealed and signed by the supplier's representative and the master or officer in charge of the bunker operation on completion of bunkering operations and retained under the ship's control until the fuel oil is substantially consumed, but in any case for a period of not less than 12 months from the time of delivery.
7) Parties to the Protocol of 1997 undertake to ensure that appropriate authorities designated by them:
   a) maintain a register of local suppliers of fuel oil;
   b) require local suppliers to provide the bunker delivery note and sample as required by this regulation, certified by the fuel oil supplier that the fuel oil meets the requirements of regulations 14 and 18 of this Annex;
   c) require local suppliers to retain a copy of the bunker delivery note for at least three years for inspection and verification by the port State as necessary;
   d) take action as appropriate against fuel oil suppliers that have been found to deliver fuel oil that does not comply with that stated on the bunker delivery note;
   e) inform the Administration of any ship receiving fuel oil found to be noncompliant with the requirements of regulations 14 and 18 of this Annex; and
   f) inform the Organization for transmission to Parties to the Protocol of 1997 of all cases where fuel oil suppliers have failed to meet the requirements specified in regulations 14 or 18 of this Annex.
8) In connection with port State inspections carried out by Parties to the Protocol of 1997, the Parties further undertake to:
   a) inform the Party or non-Party under whose jurisdiction bunker delivery note was issued of cases of delivery of noncompliant fuel oil, giving all relevant information; and
   b) ensure that remedial action as appropriate is taken to bring noncompliant fuel oil discovered into compliance.

Appendix 6

VLCC VOYAGE #2

Bunkering Cost Minimisation (3/24/01 – 5/13/01).

	Ulsan	**Singapore**	**Ras Isa**	**Fujairah**	**Ulsan**
Ci		469.2	690	292	1,241
Qi		2,583.3		0	
ROBi		1,995.8	3,859.1	3,505.1	2,199
ROBdi	2,465	4,549.1	3,797.1	3,440	2,060
COST	$ 342,929.36				

Singapore quality comparison (380 cSt). [Ref. 30, June 2001]

Product: IFO 380 cSt, 50 °C							
Quantity: 1,999.7 mt							
Supplier	Price ($)	Density (g/ml)	Viscosity (cSt)	Water (%v/v)	Al (mg/kg)	NSE (MJ/kg)	Sulphur (%m/m)
BP	132.75	0.985	346	0.2	14	40.03	3.60
EXXONMOBIL	132.75	0.980	344	0.1	3	40.12	3.70
FAMM	132.75	0.984	344	0.3	13	40.02	3.51
SHELL	132.75	0.982	327	0.1	2	40.17	3.52

Density/Aluminium

ExxonMobil offers the fuel with the lowest density and low aluminium content.

Viscosity

All four fuels are within the tolerable limits, i.e. the tolerance of 7.4% (408 cSt for IFO 380 fuels).

Water Content

BP: 1,999.7mt × 0.2% = 3.999mt
  3.999mt × $132.75/mt = $530.92 = $0.27/mt
EXXONMOBIL: 1999.7mt × 0.1% = 1.9997mt
  1,9997mt × $132.75/mt = $265.46 = $0.13/mt
FAMM: 1999.7mt × 0.3% = 5.999mt
  5.999mt × $132.75/mt = $796.38 = $0.40/mt
SHELL: 1,999.7mt × 0.1% = 1.9997mt
  1.9997mt × $132.75/mt = $265.46 = $0.13/mt

Net Specific Energy

Of the four suppliers, ExxonMobil offers a superior fuel, but not in terms of the Net Specific Energy; Shell may provide a 'better value for money' fuel.

Energy MJ EXXONMOBIL: 1,999,700 kg × 40.12MJ/kg = 80,227,964 MJ
  SHELL: 1,999,700 kg × 40.17MJ/kg = 80,327,949 MJ
Difference (SHELL - EXXONMOBIL) Δ MJ = 99,985 MJ
Cost / MJ Bunker Price: $132.75/mt = $132.75/1,000kg = $0.13/kg

$$\frac{\$0.13/kg}{40.17MJ/kg} = \frac{\$0.13}{40.17MJ} = \$0.00330/MJ$$

Value Δ MJ — 99,985 MJ × $0.00330/MJ = $330.42

Saving — $\frac{\$330.42}{1,999.7mt} = \$0.17/mt$

SHELL

Price:	$132.75/mt
Water:	$0.00
Net Specific Energy:	-$0.17
	$132.58/mt

Shell is therefore selected and the shipping company may negotiate to purchase fuel from ExxonMobil at $132.58 rather than $132.75, as Shell comparatively offers this price advantage. Or even at a lower price from Famm, which offers fuel oil with the highest water content and the lowest Net Specific Energy. Compared to Shell's fuel oil, based on the same calculations, Famm's fuel oil may be purchased at a price of $132.05.

For the port of Fujairah similar calculations are performed.

Fujairah quality comparison (380 cSt). [Ref. 30, June 2001]

Product: IFO 380 cSt, 50 °C							
Quantity: 583.572 mt							
Supplier	Price ($)	Density (g/ml)	Viscosity (cSt)	Water (%v/v)	Al (mg/kg)	NSE (MJ/kg)	Sulphur (%m/m)
EXXON	137	0.967	355	0.1	3	40.51	2.97
FAMM	137	0.974	370	0.1	1	40.27	3.44
TEXACO	137	0.980	352	0.2	4	40.35	2.79

Density/Aluminium

Exxon offers the fuel with the lowest density and has low aluminium content.

Viscosity

All three fuels are within the tolerable limits, i.e. the tolerance of 7.4% (408 cSt for IFO 380 fuels).

Water Content

EXXON: 583.572 × 0.1% = 0.584mt

0.584mt × $137/mt = $79.95 = $0.14/mt

FAMM: 583.572 × 0.1% = 0.584mt

0.584mt × $137/mt = $79.95 = $0.14/mt

TEXACO: 583.572 × 0.2% = 1.167mt

1.167mt × $137/mt = $159.90 = $0.27/mt

Net Specific Energy

Of the three suppliers, Exxon offers a superior fuel, with the lowest water content and highest Net Specific Energy. Let us see how this compares to Famm's fuel that is inferior.

Energy MJ EXXON: 583,572 kg × 40.51MJ/kg = 23,640,501.72 MJ
FAMM: 583,572 kg × 40.27MJ/kg = 23,500,444.44 MJ

Difference (EXXON - FAMM) Δ MJ = 140,057.28 MJ

Cost / MJ Bunker Price: $137/mt = $137/1,000kg = $0.14/kg

$$\frac{\$0.14/kg}{40.51MJ/kg} = \frac{\$0.14}{40.51MJ} = \$0.00338/MJ$$

Value Δ MJ 140,057.28 MJ × $0.00338/MJ = $473.66

Saving $$\frac{\$473.66}{583.572mt} = \$0.81/mt$$

EXXON

Price:	$137/mt
Water:	-$0.10
Net Specific Energy:	-$0.81
	$136.09/mt

Therefore, if fuel oil were to be purchased from Famm, the price could be negotiated to as low as $136.09.

VLCC VOYAGE #3

Bunkering Cost Minimisation (3/24/01 – 5/13/01).

	Durban	Qeshm Island	Off Dubai	Jebel Dhanna	Kharg Island	Tabangao
Cj		741.75	14.49	31.60	103.44	1,152.82
Qj		1,500.04	790.09			
ROBj		1,713.25	3,180.80	3,103.20	2,914.41	2,496.33
ROBdj	2,455	3,195.29	3,134.80	3,017.85	3,649.15	2,441
COST	$ 321,912.24					

Qeshm Island quality comparison (380 cSt). [Ref. 30, June 2001]

Product: IFO 380 cSt, 50 °C							
Quantity: 1,500.04 mt							
Supplier	Price ($)	Density (g/ml)	Viscosity (cSt)	Water (%v/v)	Al (mg/kg)	NSE (MJ/kg)	Sulphur (%m/m)
GLOBAL	148.5	0.969	378	0.0	0	40.52	3.03
GLOBAL ENERGY	148.5	0.972	382	0.1	3	40.37	3.17

Density/Aluminium

Global offers the fuel with lower density and aluminium content.

Viscosity

Both fuels are within the tolerable limits, i.e. the tolerance of 7.4% (408 cSt for IFO 380 fuels).

Water Content

GLOBAL: $0.00/mt

GLOBAL ENERGY: 1,500.04mt × 0.1% = 1.50004mt

1.50004mt × $148.5/mt = $222.76 = $0.15/mt

Net Specific Energy

Of the two suppliers, Global offers a superior fuel to Global Energy's. Let us see, how much one can save in total.

Energy MJ GLOBAL: 1,500,040 kg × 40.52MJ/kg = 60,781,621 MJ

GLOBAL ENERGY: 1,500,040 kg × 40.37MJ/kg = 60,556,615 MJ

Difference (GLOBAL - GLOBAL ENERGY) Δ MJ = 225,006 MJ

Cost / MJ Bunker Price: $148.5/mt = $148.5/1,000kg = $0.15/kg

$$\frac{\$0.15/kg}{40.52MJ/kg} = \frac{\$0.15}{40.52MJ} = \$0.00366/MJ$$

Value Δ MJ 225,006 MJ × $0.00366/MJ = $824.61

Saving $$\frac{\$824.61}{1{,}500.04mt} = \$0.55/mt$$

GLOBAL

Price:	$148.5/mt
Water:	-$0.15
Net Specific Energy:	-$0.55
	$147.8/mt

Global is therefore selected and the shipping company may negotiate to purchase fuel from Global Energy at $147.8 rather than $148.5, as Global comparatively offers this price advantage.

For the port of Dubai similar calculations are performed.

Dubai quality comparison (380 cSt). [Ref. 30, June 2001]

Product: IFO 380 cSt, 50 °C							
Quantity: 790.09 mt							
Supplier	Price ($)	Density (g/ml)	Viscosity (cSt)	Water (%v/v)	Al (mg/kg)	NSE (MJ/kg)	Sulphur (%m/m)
ADNOC	125.5	0.946	347	0.1	0	41.16	1.87
FAL	125.5	0.979	362	0.3	5	40.16	3.34

Density/Aluminium

Adnoc offers the fuel with lower density and aluminium content.

Viscosity

Both fuels are within the tolerable limits, i.e. the tolerance of 7.4% (408 cSt for IFO 380 fuels).

Water Content

ADNOC: 790.09mt × 0.1% = 0.79009mt

0.79009mt × $125.5/mt = $99.16 = $0.13/mt

FAL: 790.09mt × 0.3% = 2.37027mt

2.37027mt × $125.5/mt = $297.47 = $0.38/mt

Net Specific Energy

Of the two suppliers, Adnoc offers a superior fuel to Fal's. Let us see, how much one can save in total.

Energy MJ	ADNOC: 790,090 kg × 41.16MJ/kg = 32,520,104 MJ	
	FAL: 790,090 kg × 40.16MJ/kg = 31,730,014 MJ	
Difference	(ADNOC - FAL)	Δ MJ = 790,090 MJ
Cost / MJ	Bunker Price: $125.5/mt = $125.5/1,000kg = $0.13/kg	

$$\frac{\$0.13/kg}{41.16MJ/kg} = \frac{\$0.13}{41.16MJ} = \$0.00305/MJ$$

Value Δ MJ   790,090 MJ × $0.00305/MJ = $2,409.05

Saving $\frac{\$2{,}409.05}{790.09mt} = \$3.05/mt$

ADNOC	
Price:	$125.5/mt
Water:	-$0.25
Net Specific Energy:	-$3.05
	$122.2/mt

Adnoc is therefore selected and the shipping company may negotiate to purchase fuel from Fal at $122.2 rather than $125.5, as Adnoc comparatively offers this price advantage.

Appendix 7

SUEZMAX VOYAGE #1

Bunkering Cost Minimisation (2/22/03 – 3/21/03).

	Savona	Messina	Piraeus	Dardanelles	Bosporus
Ci		71.5	75.92	28.08	26
Qi			0		
ROBi		1,120.5	1,044.3	1,013.3	950.7
ROBdi	1,192	1,120.3	1,041.3	976.7	938.7
	Novorossiysk	**Bosporus**	**Dardanelles**	**Fos**	
Ci	65	72.5	14.5	232	
Qi			2,624.2		
ROBi	873.7	740.0	713.5	3,009.4	
ROBdi	812.45	727.95	3,241.4	2,949.437	
COST	$ 342,929.36				

Piraeus quality comparison (380 cSt). [Ref. 32, December 2002]

Product: IFO 380 cSt, 50 °C							
Quantity: 1099.237 mt							
Supplier	Price ($)	Density (g/ml)	Viscosity (cSt)	Water (%v/v)	Al (mg/kg)	NSE (MJ/kg)	Sulphur (%m/m)
BP	177	0.990	360	0.1	5	40.08	3.33
MOTOR	177	0.991	383	0.2	5	40.03	3.40
SHELL	177	0.960	333	0.1	2	40.75	2.52

Density/Aluminium

Shell offers the fuel with the lowest density and aluminium content.

Viscosity

All three fuels are within the tolerable limits, i.e. the tolerance of 7.4% (408 cSt for IFO 380 fuels).

Water Content

BP: 1,099.237mt × 0.1% = 1.0992mt
1.0992mt × $177/mt = $194.56 = $0.18/mt
MOTOR: 1,099.237mt × 0.2% = 2.1985mt
2.1985mt × $177/mt = $389.13 = $0.36/mt
SHELL: 1,099.237mt × 0.1% = 1.0992mt
1.0992mt × $177/mt = $194.56 = $0.18/mt

Net Specific Energy

Of the three suppliers, Shell offers a superior fuel. Let us see, how much one can save in total, compared to Motor's high water content, low NSE fuel.

Energy MJ MOTOR: 1,099,237 kg × 40.03MJ/kg = 44,002,457 MJ
SHELL: 1,099,237 kg × 40.75MJ/kg = 44,793,908 MJ

Difference	(SHELL - MOTOR)	Δ MJ = 791,451 MJ
Cost / MJ	Bunker Price: $177/mt = $177/1,000kg = $0.18/kg	

$$\frac{\$0.18/kg}{40.75MJ/kg} = \frac{\$0.18}{40.75MJ} = \$0.00434/MJ$$

Value Δ MJ: 791,451 MJ × $0.00434/MJ = $3437.71

Saving $$\frac{\$3,437.71}{1,099.237mt} = \$3.13/mt$$

SHELL

Price:	$177/mt
Water:	-$0.18
Net Specific Energy:	-$3.13
	$173.69/mt

Shell is therefore selected and the shipping company may negotiate to purchase fuel from Motor at $173.69 rather than $177, as Shell comparatively offers this price advantage.

For the bunkering at the Dardanelles, the author assumes that fuel was purchased from either Canakkale or Gelibolu, but since the DNV Fuel Quality Statistics book does not have any statistics on any of the two, further calculations are not performed. In any case, significant savings are already observed, due to not bunkering at Piraeus.

SUEZMAX VOYAGE #2

Bunkering Cost Minimisation (5/21/02 – 6/14/02).

	Wilhelmshaven	**Le Havre**	**Corpus Christi**
Cj		77.72	870
Qj		1,901.52	0
ROBj	1,251	1,141.28	2,072.0
ROBdj	1,219	2,942.0	1,877
COST	$ 288,080.28		

Le Havre quality comparison (380 cSt). [Ref. 31, September 2002]

Product: IFO 380 cSt, 50 °C							
Quantity: 1,498.10 mt							
Supplier	Price ($)	Density (g/ml)	Viscosity (cSt)	Water (%v/v)	Al (mg/kg)	NSE (MJ/kg)	Sulphur (%m/m)
MOBIL	151.5	0.985	333	0.1	3	40.32	2.87
SHELL	151.5	0.978	362	0.1	4	40.29	3.28
TOTAL	151.5	0.987	322	0.0	3	40.35	2.78

<u>Density/Aluminium</u>

Shell offers the fuel with the lowest density and low aluminium content.

Viscosity
All three fuels are within the tolerable limits, i.e. the tolerance of 7.4% (408 cSt for IFO 380 fuels).
Water Content
MOBIL: 1,498.10mt × 0.1% = 1.4981mt
1.4981mt × $151.5/mt = $226.96 = $0.15/mt
SHELL: 1,498.10mt × 0.1% = 1.4981mt
1.4981mt × $151.5/mt = $226.96 = $0.15/mt
TOTAL: $0.00/mt

Net Specific Energy
Of the three suppliers, Total offers a superior fuel to the other two. Let us see, how much one can save in total, compared to Shell's fuel low-density fuel.

Energy MJ SHELL: 1,498,100 kg × 40.35MJ/kg = 60,448,335 MJ
TOTAL: 1,498,100 kg × 40.29MJ/kg = 60,358,449 MJ
Difference (SHELL – TOTAL) Δ MJ = 89,886 MJ
Cost / MJ Bunker Price: $151.5/mt = $151.5/1,000kg = $0.15/kg

$$\frac{\$0.15/kg}{40.35MJ/kg} = \frac{\$0.15}{40.35MJ} = \$0.00375/MJ$$

Value Δ MJ 89,886 MJ × $0.00375/MJ = $337.49

Saving $$\frac{\$337.49}{1,498.1mt} = \$0.23/mt$$

TOTAL
Price: $151.5/mt
Water: -$0.15
Net Specific Energy: -$0.23
$151.12/mt

Global is therefore selected and the shipping company may negotiate to purchase fuel from Global Energy at $151.12 rather than $151.5, as Global comparatively offers this price advantage.

For the port of Corpus Christi similar calculations are performed.

Corpus Christi quality comparison (380 cSt). [Ref. 31, September 2002]

Product: IFO 380 cSt, 50 °C							
Quantity: 403.46 mt							
Supplier	Price ($)	Density (g/ml)	Viscosity (cSt)	Water (%v/v)	Al (mg/kg)	NSE (MJ/kg)	Sulphur (%m/m)
ENJET	156	0.988	364	0.2	28	40.18	3.04
VALERO	156	0.988	322	0.1	13	40.38	2.57

Density/Aluminium
Valero's fuel has the same density as Enjet's fuel, but Enjet's high aluminium content may compromise an engine's operation and performance.

Viscosity
Both fuels are within the tolerable limits, i.e. the tolerance of 7.4% (408 cSt for IFO 380 fuels).

Water Content
ENJET: 403.46mt × 0.2% = 0.80692mt
0.80692mt × $156/mt = $125.88 = $0.31/mt
VALERO: 403.46mt × 0.1% = 0.40346mt
0.40346mt × $156/mt = $62.94 = $0.16/mt

Net Specific Energy
Of the two suppliers, Valero offers a superior fuel to Enjet's. Let us see, how much one can save in total.

Energy MJ — ENJET: 403,460 kg × 40.18MJ/kg = 16,211,023 MJ
VALERO: 403,460 kg × 40.38MJ/kg = 16,291,715 MJ
Difference — (VALERO - ENJET) Δ MJ = 80,692 MJ
Cost / MJ — Bunker Price: $156/mt = $156/1000kg = $0.16/kg

$$\frac{\$0.16/kg}{40.38MJ/kg} = \frac{\$0.16}{40.38MJ} = \$0.00386/MJ$$

Value Δ MJ — 80,692 MJ × $0.00386/MJ = $311.74

Saving — $$\frac{\$311.74}{403.46mt} = \$0.77/mt$$

VALERO
Price: $156/mt
Water: -$0.15
Net Specific Energy: -$0.77
$155.08/mt

Valero is therefore selected and the shipping company may negotiate to purchase fuel from Enjet at $155.08 rather than $156, as Valero comparatively offers this price advantage.

SUEZMAX VOYAGE #3

Bunkering Cost Minimisation (5/25/01 – 6/20/01).

	LOOP	Cayo Arcas	Freeport	Bilbao	La Coruna
Ci		93.6	145	732.25	46.4
Qi			799		600.4
ROBi		670.4	427.2	491.7	432.7
ROBdi	764	572.2	1224	479.1	963
COST	$ 175,554.73				

Freeport quality comparison (380 cSt). [Ref. 30, June 2001]

Product: IFO 380 cSt, 50 °C							
Quantity: 799 mt							
Supplier	Price ($)	Density (g/ml)	Viscosity (cSt)	Water (%v/v)	Al (mg/kg)	NSE (MJ/kg)	Sulphur (%m/m)
BORCO	125.45	0.983	357	0.4	9	40.18	2.87

At Freeport the only fuel oil supplier that delivers IFO 380 is Borco and its fuel's quality data may be found in the above table.

Corunna quality comparison (380 cSt). [Ref. 30, June 2001]

Product: IFO 380 cSt, 50 °C							
Quantity: 600.4 mt							
Supplier	Price ($)	Density (g/ml)	Viscosity (cSt)	Water (%v/v)	Al (mg/kg)	NSE (MJ/kg)	Sulphur (%m/m)
FORESTAL	128.5	0.974	340	0.5	4	40.46	2.30
REPSOL	128.5	0.985	359	0.0	10	40.47	2.48

Density/Aluminium

Forestal's fuel is superior to Repsol's fuel both in terms of density and aluminium content.

Viscosity

Both fuels are within the tolerable limits, i.e. the tolerance of 7.4% (408 cSt for IFO 380 fuels).

Water Content

FORESTAL: 600.4mt × 0.5% = 3.002mt

3.002mt × $128.5/mt = $385.757 = $0.64/mt

REPSOL: $0.00/mt

Net Specific Energy

Of the two suppliers, Repsol offers a superior fuel to Forestal's. Let us see, how much one can save in total.

Energy MJ FORESTAL: 600,400 kg × 40.46MJ/kg = 24,292,184 MJ

REPSOL: 600,400 kg × 40.47MJ/kg = 24,298,188 MJ

Difference (RESPOL - FORESTAL) Δ MJ = 6,004 MJ

Cost / MJ Bunker Price: $128.5/mt = $128.5/1,000kg = $0.13/kg

$$\frac{\$0.13/kg}{40.47MJ/kg} = \frac{\$0.13}{40.47MJ} = \$0.00318/MJ$$

Value Δ MJ 6,004 MJ × $0.00318/MJ = $19.06

Saving $$\frac{\$19.06}{600.4mt} = \$0.03/mt$$

RESPOL	
Price:	$128.5/mt
Water:	-$0.64
Net Specific Energy:	-$0.03
	$127.83/mt

Repsol is therefore selected and the shipping company may negotiate to purchase fuel from Forestal at $127.83 rather than $128.5, as Repsol comparatively offers this price advantage.

Appendix 8

AFRAMAX VOYAGE #1

Bunkering Cost Minimisation (2/20/03 – 3/30/03).

	Lawe-Lawe	**Singapore**	**Suez**	**Dardanelles**	**Bosporus**	**Odessa**	**Bourgas**
Cj		208	936	104	20.8	52	58
Qj		316.05	1,888.517				
ROBj		623.7	0.0	1,749.5	1,693.7	1,624.2	1,512
ROBdj	831.7	936.0	1,853.5	1,714.5	1,676.2	1,570.217	1,500
COST	$ 400,321.96						

Singapore quality comparison (180 cSt). [Ref. 32, December 2002]

Product: IFO 180 cSt, 50 °C							
Quantity: 1,004.5 mt							
Supplier	Price ($)	Density (g/ml)	Viscosity (cSt)	Water (%v/v)	Al (mg/kg)	NSE (MJ/kg)	Sulphur (%m/m)
BP	209	0.985	199	0.2	12	40.21	3.08
GLOBAL ENERGY	209	0.979	184	0.2	8	40.25	3.19
SHELL	209	0.982	172	0.1	1	40.19	3.41

Density/Aluminium

Global Energy offers the fuel with the lowest density and low aluminium content.

Viscosity

All three fuels are within the tolerable limits, i.e. the tolerance of 200 cSt for IFO 180 fuels.

Water Content

BP: 1,004.5mt × 0.2% = 2.009mt

2.009mt × $209/mt = $419.88 = $0.42/mt

GLOBAL ENERGY: 1,004.5mt × 0.2% = 2.009mt

2.009mt × $209/mt = $419.88 = $0.42/mt

SHELL: 1,004.5mt × 0.1% = 1.0045mt

1.0045mt × $209/mt = $209.94 = $0.21/mt

Net Specific Energy

Of the three suppliers, Global Energy offers the fuel with the highest NSE, but Shell may provide a 'better value for money' fuel for having low water content.

Energy MJ GLOBAL ENERGY: 1,004,500 kg × 40.25MJ/kg = 40,431,125 MJ

SHELL: 1,004,500 kg × 40.19MJ/kg = 40,370,855 MJ

Difference (GLOBAL ENERGY - SHELL) Δ MJ = 60,270 MJ

Cost / MJ Bunker Price: $209/mt = $209/1,000kg = $0.21/kg

$$\frac{\$0.21/kg}{40.25MJ/kg} = \frac{\$0.21}{40.25MJ} = \$0.00519/MJ$$

Value Δ MJ 60,270 MJ × \$0.00519/MJ = \$312.95

Saving $\frac{\$3,12.95}{1,004.5mt} = \$0.31/mt$

GLOBAL ENERGY

Price:	\$209/mt
Water:	+\$0.21
Net Specific Energy:	-\$0.31
	\$208.9/mt

Global Energy is therefore selected and the shipping company may negotiate to purchase fuel from Shell at \$208.9 rather than \$209, as Shell comparatively offers this price advantage.

For the Suez Canal similar calculations are performed.

Suez quality comparison (180 cSt). [Ref. 32, December 2002]

Product: IFO 180 cSt, 50 °C							
Quantity: 1,200.067 mt							
Supplier	Price (\$)	Density (g/ml)	Viscosity (cSt)	Water (%v/v)	Al (mg/kg)	NSE (MJ/kg)	Sulphur (%m/m)
COPETROL	177	0.950	199	0.1	1	40.82	2.80
EXXONMOBIL	177	0.949	174	0.1	0	40.83	2.73
MOBIL	177	0.948	176	0.1	2	40.86	2.70

Density/Aluminium

All three fuels have similar density and aluminium content.

Viscosity

All three fuels are within the tolerable limits, i.e. the tolerance of 200 cSt for IFO 180 fuels.

Water Content

COPETROL: 1,200.067 × 0.1% = 1.200mt

1.200mt × \$177/mt = \$212.41 = \$0.18/mt

EXXONMOBIL: 1,200.067 × 0.1% = 1.200mt

1.200mt × \$177/mt = \$212.41 = \$0.18/mt

MOBIL: 1,200.067 × 0.1% = 1.200mt

1.200mt × \$177/mt = \$212.41 = \$0.18/mt

Net Specific Energy

Of the three suppliers, Mobil offers a superior fuel, with the highest Net Specific Energy. Let us see how this compares to Copetrol's denser fuel with the lowest NSE.

Energy MJ	COPETROL: 1,200,067 kg × 40.82MJ/kg = 48,986,735 MJ
	MOBIL: 1,200,067 kg × 40.86MJ/kg = 49,034,738 MJ
Difference	(MOBIL - COPETROL) Δ MJ = 48,003 MJ
Cost / MJ	Bunker Price: \$177/mt = \$177/1,000kg = \$0.18/kg

$$\frac{\$0.18/kg}{40.86MJ/kg} = \frac{\$0.18}{40.86MJ} = \$0.00433/MJ$$

Value Δ MJ 48,003 MJ × \$0.00433/MJ = \$207.94

Saving $\frac{\$207.94}{1{,}200.067mt} = \$0.17/mt$

MOBIL

Price:	\$177/mt
Water:	\$0.00
Net Specific Energy:	-\$0.17
	\$176.83/mt

Therefore, if fuel oil were to be purchased from Mobil, the price could be negotiated to \$176.83.

AFRAMAX VOYAGE #2

Bunkering Cost Minimisation (11/25/02 – 1/22/03).

	Texas City	Southwest Pass	Convent	Norco	St. Eustatius	Singapore
Cj		52	39	0	394.4	2,320
Qj					2,432.3752	1,107.1438
ROBj		1,722.8	1,663.8	1,614.8	1,160.2	1,233.0
ROBdj	1,774.8	1,702.8	1,614.8	1,554.6	3,553.0	2,266.4
COST	\$ 573,913.61					

St. Eustatius quality comparison (180 cSt). [Ref. 32, December 2002]

Product: IFO 180 cSt, 50 °C							
Quantity: 1,349.783 mt							
Supplier	Price (\$)	Density (g/ml)	Viscosity (cSt)	Water (%v/v)	Al (mg/kg)	NSE (MJ/kg)	Sulphur (%m/m)
STATI	154.7	0.981	200	0.3	14	40.38	2.53

At St. Eustatius the only fuel oil supplier that delivers IFO 180 is Stati and its fuel's quality data may be found in the above table.

Singapore quality comparison (180 cSt). [Ref. 32, December 2002]

Product: IFO 180 cSt, 50 °C							
Quantity: 2,189.736 mt							
Supplier	Price (\$)	Density (g/ml)	Viscosity (cSt)	Water (%v/v)	Al (mg/kg)	NSE (MJ/kg)	Sulphur (%m/m)
BP	178.5	0.985	199	0.2	12	40.21	3.08
GLOBAL ENERGY	178.5	0.979	184	0.2	8	40.25	3.19
SHELL	178.5	0.982	172	0.1	1	40.19	3.41

Density/Aluminium

Global Energy offers the fuel with the lowest density and low aluminium content.

Viscosity

All three fuels are within the tolerable limits, i.e. the tolerance of 200 cSt for IFO 180 fuels.

Water Content

BP: 2,189.736mt × 0.2% = 4.3795mt

4.3795mt × \$178.5/mt = \$781.74 = \$0.36/mt

GLOBAL ENERGY: 2,189.736mt × 0.2% = 4.3795mt

4.3795mt × \$178.5/mt = \$781.74 = \$0.36/mt

SHELL: 2,189.736mt × 0.1% = 2.1897mt

2.1897mt × \$178.5/mt = \$390.87 = \$0.18/mt

Net Specific Energy

Of the three suppliers, Global Energy offers the fuel with the highest NSE, but Shell may provide a 'better value for money' fuel for having low water content.

Energy MJ	GLOBAL ENERGY: 2,189,736 kg × 40.25MJ/kg = 88,136,874 MJ
	SHELL: 2,189,736 kg × 40.19MJ/kg = 88,005,490 MJ
Difference	(GLOBAL ENERGY - SHELL) Δ MJ = 131,384 MJ
Cost / MJ	Bunker Price: \$178.5/mt = \$178.5/1,000kg = \$0.18/kg

$$\frac{\$0.18/kg}{40.25MJ/kg} = \frac{\$0.18}{40.25MJ} = \$0.00443/MJ$$

Value Δ MJ 131,384 MJ × \$0.00443/MJ = \$582.66

Saving
$$\frac{\$582.66}{2{,}189.736mt} = \$0.27/mt$$

GLOBAL ENERGY

Price:	\$178.5/mt
Water:	+\$0.18
Net Specific Energy:	-\$0.27
	\$178.41/mt

Global Energy is therefore selected and the shipping company may negotiate to purchase fuel from Shell at \$178.41 rather than \$178.5, as Shell comparatively offers this price advantage.

AFRAMAX VOYAGE #3

Bunkering Cost Minimisation (2/20/03 – 3/30/03).

	Lavera	**Skikda**	**Algeciras**	**New York**
Cj		60.5	128.1	1,006.5
Qj			2,709.13	0
ROBj		594.3	96.3	1,706.5
ROBdj	654.8	224.4	2,713.0	1,290
COST	$ 455,133.84			

Algeciras quality comparison (180 cSt). [Ref. 32, December 2002]

Product: IFO 180 cSt, 50 °C							
Quantity: 1,500 mt							
Supplier	Price ($)	Density (g/ml)	Viscosity (cSt)	Water (%v/v)	Al (mg/kg)	NSE (MJ/kg)	Sulphur (%m/m)
CEPSA	168	0.984	183	0.1	9	40.21	3.17
REPSOL	168	0.974	163	0.1	6	40.56	2.57
RYTTSA	168	0.972	172	0.1	5	40.62	2.47

Density/Aluminium

Ryttsa offers the fuel with the lowest density and aluminium content.

Viscosity

All three fuels are within the tolerable limits, i.e. the tolerance of 200 cSt for IFO 180 fuels.

Water Content

CEPSA: 1,500mt × 0.1% = 1.50mt
1.50mt × $168/mt = $252= $0.17/mt
REPSOL: 1,500mt × 0.1% = 1.50mt
1.50mt × $168/mt = $252= $0.17/mt
RYTTSA: 1,500mt × 0.1% = 1.50mt
1.50mt × $168/mt = $252= $0.17/mt

Net Specific Energy

Of the three suppliers, Ryttsa offers the fuel with the highest NSE; let us see how much one can save compared to Cepsa's fuel oil.

Energy MJ CEPSA: 1,500,000 kg × 40.21MJ/kg = 60,315,000 MJ
RYTTSA: 1,500,000 kg × 40.62MJ/kg = 60,930,000 MJ
Difference (RYTTSA - CEPSA) Δ MJ = 615,000 MJ
Cost / MJ Bunker Price: $168/mt = $168/1,000kg = $0.17/kg

$$\frac{\$0.17/kg}{40.62MJ/kg} = \frac{\$0.17}{40.62MJ} = \$0.00414/MJ$$

Value Δ MJ 615,000 MJ × $0.00414/MJ = $2,543.57

Saving $\frac{\$2,543.57}{1500mt} = \$1.70/mt$

RYTTSA
Price: $168/mt
Water: $0.00
Net Specific Energy: -$1.70
$166.3/mt

Ryttsa is therefore selected and the shipping company may negotiate to purchase fuel from Cepsa at $166.3 rather than $168, as Ryttsa comparatively offers this price advantage.

For the port of New York similar calculations are performed.

New York quality comparison (180 cSt). [Ref. 32, December 2002]

Product: IFO 180 cSt, 50 °C							
Quantity: 1,209.13 mt							
Supplier	Price ($)	Density (g/ml)	Viscosity (cSt)	Water (%v/v)	Al (mg/kg)	NSE (MJ/kg)	Sulphur (%m/m)
BP	173.9	0.982	184	0.4	13	40.20	2.89
CHEMOIL	173.9	0.972	178	0.2	9	40.52	2.65
FAMM	173.9	0.973	173	0.2	2	40.18	3.62

Density/Aluminium
Chemoil's and Famm's fuels have low density and aluminium content.

Viscosity
All three fuels are within the tolerable limits, i.e. the tolerance of 200 cSt for IFO 180 fuels.

Water Content
BP: 1,209.13 × 0.4% = 4.8365mt
4.8365mt × $173.9/mt = $841.07 = $0.70/mt
CHEMOIL: 1,209.13 × 0.2% = 2.4183mt
2.4183mt × $173.9/mt = $420.54 = $0.35/mt
FAMM: 1,209.13 × 0.2% = 2.4183mt
2.4183mt × $173.9/mt = $420.54 = $0.35/mt

Net Specific Energy

Of the three suppliers, Chemoil offers a superior fuel, with the highest Net Specific Energy. Let us see how this compares to BP's denser fuel with not the lowest NSE, but with high water content.

Energy MJ BP: 1,209,130 kg × 40.20MJ/kg = 48,607,026 MJ
CHEMOIL: 1,209,130 kg × 40.52MJ/kg = 48,993,948 MJ
Difference (CHEMOIL - BP) Δ MJ = 386,922 MJ
Cost / MJ Bunker Price: $173.9/mt = $173.9/1,000kg = $0.17/kg

$$\frac{\$0.17/kg}{40.52MJ/kg} = \frac{\$0.17}{40.52MJ} = \$0.00429/MJ$$

Value Δ MJ: 386,922 MJ × \$0.00429/MJ = \$1,660.56

Saving: $\frac{\$1,660.56}{1,209.13mt} = \$1.37/mt$

CHEMOIL

Price:	\$173.9/mt
Water:	-\$0.20
Net Specific Energy:	-\$1.37
	\$172.33/mt

Therefore, if fuel oil were to be purchased from BP, the price could be negotiated to \$172.33.

Appendix 9

PRODUCT VOYAGE #1

Bunkering Cost Minimisation (12/8/02 – 1/3/03).

	Conakry	**Algeciras**	**Suez**	**Yanbu**	**Suez**	**Algeciras**
Cj		168	148.4	39.2	42.625	190.65
Qj		970.25				287.75
ROBj		232	1,051.6	986.0	933.8	719.8
ROBdj	400	1,200.0	1,025.2	976.4	910.5	987
COST	$ 168,538.75					

Algeciras quality comparison (380 cSt). [Ref. 32, December 2002]

Product: IFO 380 cSt, 50 °C							
Quantity: 750 mt							
Supplier	Price ($)	Density (g/ml)	Viscosity (cSt)	Water (%v/v)	Al (mg/kg)	NSE (MJ/kg)	Sulphur (%m/m)
CEPSA	131	0.986	344	0.0	8	40.34	2.81
REPSOL	131	0.983	373	0.0	8	40.48	2.46
RYTTSA	131	0.983	370	0.0	8	40.49	2.43

Density/Aluminium
All three fuels have similar density and aluminium content.

Viscosity
All three fuels are within the tolerable limits, i.e. the tolerance of 7.4% (408 cSt for IFO 380 fuels).

Water Content
CEPSA: $0.00/mt
REPSOL: $0.00/mt
RYTTSA: $0.00/mt

Net Specific Energy

Of the three suppliers, Ryttsa offers the fuel with the highest NSE; let us see how much one can save by negotiating to buy fuel at a lower price from Cepsa.

Energy MJ CEPSA: 750,000 kg × 40.34MJ/kg = 30,255,000 MJ
RYTTSA: 750,000 kg × 40.49MJ/kg = 30,367,500 MJ

Difference (CEPSA - RYTTSA) Δ MJ = 112,500 MJ

Cost / MJ Bunker Price: $131/mt = $131/1,000kg = $0.13/kg

$$\frac{\$0.13/kg}{40.49MJ/kg} = \frac{\$0.13}{40.49MJ} = \$0.00324/MJ$$

Value Δ MJ 112,500 MJ × $0.00324/MJ = $363.98

Saving $$\frac{\$363.98}{750mt} = \$0.49/mt$$

RYTTSA

Price:	$131/mt
Water:	$0.01
Net Specific Energy:	-$0.49
	$130.51/mt

Ryttsa is therefore selected and the shipping company may negotiate to purchase fuel from Cepsa at $130.51 rather than $131, as Ryttsa comparatively offers this price advantage. Thus, when bunkering from Algeciras on 1/3/03, fuel oil can be bought at $143.51 rather than $144.

PRODUCT VOYAGE #2

Bunkering Cost Minimisation (3/18/01 – 5/2/01).

	San Fransisco	Ulsan	Los Angeles
Cj		458.85	529.7
Qj		757.35	43.70
ROBj	913	451.65	670.3
ROBdj	910.5	1,200.0	694
COST	$ 123,755.18		

Ulsan quality comparison (380 cSt). [Ref. 30, June 2001]

Product: IFO 380 cSt, 50 °C							
Quantity: 500 mt							
Supplier	Price ($)	Density (g/ml)	Viscosity (cSt)	Water (%v/v)	Al (mg/kg)	NSE (MJ/kg)	Sulphur (%m/m)
CALTEX	152.5	0.980	338	0.0	5	40.26	3.38
SK	152.5	0.965	362	0.0	0	40.49	3.23
TEXACO	152.5	0.984	342	0.0	9	40.50	2.45

Density/Aluminium

SK offers the fuel with the lowest density and aluminium content.

Viscosity

All three fuels are within the tolerable limits, i.e. the tolerance of 7.4% (408 cSt for IFO 380 fuels).

Water Content

CALTEX: $0.00/mt

SK: $0.00/mt

TEXACO: $0.00/mt

Net Specific Energy

Of the three suppliers, Texaco offers the fuel with the highest NSE; let us see how much one can save by negotiating to buy fuel at a lower price from Caltex.

Energy MJ	CALTEX: 500,000 kg × 40.26MJ/kg = 20,130,000 MJ
	TEXACO: 500,000 kg × 40.50MJ/kg = 20,250,000 MJ
Difference	(TEXACO - CALTEX) Δ MJ = 120,000 MJ
Cost / MJ	Bunker Price: \$152.5/mt = \$152.5/1,000kg = \$0.15/kg

$$\frac{\$0.15/kg}{40.50MJ/kg} = \frac{\$0.15}{40.50MJ} = \$0.00375/MJ$$

Value Δ MJ 120,000 MJ × \$0.00375/MJ = \$450.37

Saving $$\frac{\$450.37}{500mt} = \$0.90/mt$$

TEXACO

Price:	\$152.5/mt
Water:	\$0.00
Net Specific Energy:	-\$0.90
	\$151.6/mt

Texaco is therefore selected and the shipping company may negotiate to purchase fuel from Caltex at \$151.6 rather than \$152.5, as Texaco comparatively offers this price advantage.

Los Angeles quality comparison (380 cSt). [Ref. 30, June 2001]

Product: IFO 380 cSt, 50 °C							
Quantity: 301 mt							
Supplier	Price (\$)	Density (g/ml)	Viscosity (cSt)	Water (%v/v)	Al (mg/kg)	NSE (MJ/kg)	Sulphur (%m/m)
CHEM OIL	189	0.987	349	0.5	7	40.29	2.31
FAMM	189	0.986	339	0.2	5	40.55	1.96
TESORO	189	0.988	308	0.6	9	40.22	2.26

Density/Aluminium

Famm offers the fuel with the lowest density and aluminium content.

Viscosity

All three fuels are within the tolerable limits, i.e. the tolerance of 7.4% (408 cSt for IFO 380 fuels).

Water Content

CHEM OIL: 301mt × 0.5% = 1.505mt

1.505mt × \$189/mt = \$284.45 = \$0.94/mt

FAMM: 301mt × 0.2% = 0.602mt

0.602mt × \$189/mt = \$113.78 = \$0.38/mt

TESORO: 301mt × 0.6% = 1.806mt

1.806mt × \$189/mt = \$341.33 = \$1.13/mt

Net Specific Energy

Of the three suppliers, Famm offers the fuel with the highest NSE; let us see how much one can save by negotiating to buy fuel at a lower price from Tesoro.

Energy MJ FAMM: 301,000 kg × 40.55MJ/kg = 12,205,550 MJ

TESORO: 301,000 kg × 40.22MJ/kg = 12,106,220 MJ

Difference (FAMM - TESORO) Δ MJ = 99,330 MJ

Cost / MJ Bunker Price: \$189/mt = \$189/1,000kg = \$0.19/kg

$$\frac{\$0.19/kg}{40.55MJ/kg} = \frac{\$0.19}{40.55MJ} = \$0.00466/MJ$$

Value Δ MJ 99,330 MJ × \$0.00466/MJ = \$462.97

Saving $\frac{\$462.97}{301mt} = \$1.54/mt$

FAMM	
Price:	\$189/mt
Water:	-\$0.75
Net Specific Energy:	-\$1.54
	\$186.71/mt

Famm is therefore selected and the shipping company may negotiate to purchase fuel from Tesoro at \$186.71 rather than \$189, as Famm comparatively offers this price advantage.

PRODUCT VOYAGE #3

Bunkering Cost Minimisation (12/22/00 - 2/7/01).

	San Juan	Bonny	Houston
Cj		326.2	546
Qj	213.7		1,185
ROBj	707	583.5	0.0
ROBdj	909.7	546.0	1,163
COST	\$ 184,123.80		

San Juan quality comparison (380 cSt). [Ref. 30, June 2001]

Product: IFO 380 cSt, 50 °C							
Quantity: 399 mt							
Supplier	Price (\$)	Density (g/ml)	Viscosity (cSt)	Water (%v/v)	Al (mg/kg)	NSE (MJ/kg)	Sulphur (%m/m)
HARBOR FUEL	174	0.982	338	0.4	9	40.45	2.07

Density/Aluminium

At San Juan the only fuel oil supplier that delivers IFO 380 is Harbor Fuel and its fuel's quality data may be found in the above table.

Houston quality comparison (380 cSt). [Ref. 30, June 2001]

Product: IFO 380 cSt, 50 °C							
Quantity: 1,000 mt							
Supplier	Price ($)	Density (g/ml)	Viscosity (cSt)	Water (%v/v)	Al (mg/kg)	NSE (MJ/kg)	Sulphur (%m/m)
BP	124	0.987	337	0.1	6	40.14	3.29
FAMM	124	0.990	326	0.1	9	40.05	3.42
HMS	124	0.982	346	0.1	1	40.25	3.16

Density/Aluminium

HMS offers the fuel with the lowest density and aluminium content.

Viscosity

All three fuels are within the tolerable limits, i.e. the tolerance of 7.4% (408 cSt for IFO 380 fuels).

Water Content

BP: 1,000mt × 0.1% = 1.00mt
1.00mt × $124/mt = $124 = $0.124/mt
FAMM: 1,000mt × 0.1% = 1.00mt
1.00mt × $124/mt = $124 = $0.124/mt
HMS: 1,000mt × 0.1% = 1.00mt
1.00mt × $124/mt = $124 = $0.124/mt

Net Specific Energy

Of the three suppliers, HMS offers the fuel with the highest NSE; let us see how much one can save by negotiating to buy fuel at a lower price from Famm.

Energy MJ FAMM: 1,000,000 kg × 40.05MJ/kg = 40,050,000 MJ
HMS: 1,000,000 kg × 40.25MJ/kg = 40,250,000 MJ
Difference (HMS - FAMM) Δ MJ = 200,000 MJ
Cost / MJ Bunker Price: $124/mt = $124/1000kg = $0.12/kg

$$\frac{\$0.12/kg}{40.25MJ/kg} = \frac{\$0.12}{40.25MJ} = \$0.00308/MJ$$

Value Δ MJ 200,000 MJ × $0.00308/MJ = $616.15

Saving $\frac{\$616.15}{1,000mt} = \$0.62/mt$

HMS
Price: $124/mt
Water: $0.00
Net Specific Energy: -$0.62
$123.38/mt

HMS is therefore selected and the shipping company may negotiate to purchase fuel from Famm at $123.38 rather than $124, as HMS comparatively offers this price advantage.

REFERENCES

1. BRACKEN R. and SALTHOUSE M., "Bunker Claims Prevention", Anchorage Press, UK, 2000
2. DAVIES M.E., PLANT G., COSSLETT C., HARROP O. and PETTS J.W., "Study on the economical, legal, environmental and practical implications of a European Union system to reduce ship emissions of SO_2 and NO_x", BMT Murray Fenton Edon Liddiard Vince Limited, August 2000
   URL:
   http://www.europa.eu.int/comm/environment/enveco/taxation/ship_emissions/mainfinal.pdf, Date accessed: June 2003
3. DeMERS D. and WALTERS G., "Guide to Exhaust Emission Control Options", BAE Systems, March 2000
4. DRAFFIN N., "A Question of Quality", The Baltic, March 2002
5. ELEY D. and BURAK S., "Fuel Oil - Changes, Challenges, Contamination and Catastrophe", Marine FuelTech, London, 12th June 2000
6. FLEISCHHACK G.C. and RULFS H., "Technical bunker guide", Hamburg, 1997
7. GUNNER T.J., "Paper on possible EU Air Pollution Directive - Operational Complications and Problems with respect to the use of Low Sulphur Bunkers", Agenda for the 10th Meeting of the INTERTANKO Hellenic Forum to be held in Athens, 19 September 2001
8. HERON B., "The role of bunker quality in a changing market", Proceedings of the 6th International Symposium on Marine Engineering, Tokyo, 23rd to 27th October 2000
9. HOPKIN P., "Holistic Risk Management in Practice", Witherbys, London, 2002
10. INOUE K., "Marine fuel qualities as they are and will be. My experiences as a field service engineer of large and slow speed diesel engines for ocean going ship propulsion", Proceedings of the 6th International Symposium on Marine Engineering, Tokyo, 23rd to 27th October 2000
11. LEIGH-JONES C., "Shipping and Sulphur", BIMCO Review 2003, Book Production

Consultants, 2003

12. LIDDY J.P., "Marine fuels - now and in the future", Propulsion 2000 - The great debate, London, 1999
13. LIDDY J.P., "Marine Fuels - Today's Quality, Tomorrow's Availability", CIMAC Congress, Copenhagen, 1998
14. LINTEC TESTING SERVICES, "IMO Puts Onus on Owners and Suppliers", Marine Engineers Review, May 2003
15. NOMIKOS N. and ALIZADEH A., "Risk Management in the Shipping Industry: Theory and Practice", The Handbook of Maritime Economics and Business edited by Costas Th. Grammenos, LLP, London, 2002
16. PETER L.J., "Why things go wrong", Guild Hall Publishing, London, 1985
17. STAMATOPOULOS D.S., "Εγχειρίδιο Καυσίμων και Λιπαντικών για την Ναυτιλία", MFC - Marine Fuel Consultants, Athens, 1993
18. STEWART P., "Hedging Marine Price Risk", Global Energy Business, September/October 2001
19. THOMPSON R.V., "Quality and Reliability applied to the Marine Industry", Paper 1-1 presented to the 5th ISME Symposium, Yokohama, 1995
20. TØNNESEN I., "A Buyer's Perspective on Fuels and the Supply Industry", Marine FuelTech, London, 12th June 2000
21. VANN K., "Freight Trading: The Emerging Commodity Market", Energy Convergence: The Beginning of the Multi-Commodity Market edited by Peter C. Fusaro, John Wiley & Sons, New York, 2002
22. WALKER S.A., "Fuel quality trends & supply developments", Marine FuelTech, London, 12th June 2000
23. WRIGHT, A.A., "International Exhaust Emission Controls, Marpol Annex VI", ASME Fall Technical Conference Paper, October 1999
    URL: http://www.asme.org/divisions/ice/links/oct99conf_WRIGHT2.pdf,
    Date accessed: June 2003
24. WRIGHT A.A., "Marine Exhaust Emission Controls – The Fuel Factor", Surveyor, ABS, Spring 2003
25. "Advice on the costs to fuel producers and price premia likely to result from a

reduction in the level of sulphur in marine fuels marketed in the EU", April 2002, URL:
http://www.europa.eu.int/comm/environment/air/pdf/020505bunkerfuelreport.pdf, Date accessed: June 2003

26. "Avoiding bad bunkers", TANKEROperator, February 2002
27. "Custody Transfer Sampling, DNV Petroleum Services official position on sampling", DNV Petroleum Services
28. "Directive of the European Parliament and of the Council amending Directive 1999/32/EC as regards the sulphur content of marine fuels", Brussels, 20th November 2002, URL: http://europa.eu.int/eur-lex/en/com/pdf/2002/act0595en01/2.pdf, Date accessed: June 2003
29. "Discussion Paper - A Community Strategy on Air Pollution from Seagoing Ships", European Commission, Brussels, January 2001 URL: http://www.intertanko.com/pdf/weeklynews/discussionpaper.pdf, Date accessed: June 2003
30. "Fuel Quality Statistics, Volume 21 Number 2", DNV Petroleum Services, June 2001
31. "Fuel Quality Statistics, Volume 22 Number 3", DNV Petroleum Services, September 2002
32. "Fuel Quality Statistics, Volume 22 Number 4", DNV Petroleum Services, December 2002
33. "Implementation of Accreditation Scheme for Bunker Suppliers in Singapore", Bunker Bulletin, Ref: 09/2003, DNV Petroleum Services, 30th May 2003
34. "Short Delivery of Bunkers?", Bunker Supplement No.2, February 2001, URL: http://www.intertanko.com/members/artikkel.asp?id=2275, Date accessed: June 2003
35. ISO 8217:1996