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DEVELOPMENT OF MARINE FUEL STANDARDS

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Development of Marine Fuel Standards

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SYNOPSIS

The Chairman of the BS Marine Fuel Standards Sub-Committee describes the progress to date on the draft standards. The Committee, which consists of representatives from the British shipowners, diesel engine and boiler manufacturers, and international fuel oil suppliers, has been working for the past two years on fuel standards for merchant ships. The author explains why standards are essential, discusses the philosophy behind the proposals and describes the standards in detail, highlighting the implications for the future.

HISTORICAL BACKGROUND

There cannot be many other commodities, which have been marketed in such large quantities, for so long, without any quality controls that are recognisable by the customer.

The reason for this is fairly obvious when one remembers how the use of residual fuel first evolved in marine diesel engines. In December 1947 a full account of an endeavour to burn normal grades of boiler fuel, namely residual fuel, was given before this Institute[1]. This account was followed by others in the next few years[2, 3, 4]. Shipowners were anxious to change existing vessels to burning residual oil and similarly insistent in ordering new tonnage capable of burning such fuels. There was little time or indeed little need to worry about a fuel specification since, with the possible exception of the Americas, the available fuel oil was of a fairly consistent quality and gave few problems.

In the 1930s and 1940s numerous attempts were made to specify the various quality limits for distillate fuels intended for use in diesel engines of different types for all kinds of applications. Even at that time experience had shown that only by setting very wide limits could a specification hope to meet acceptance. Narrow limits inevitably imply the restriction to one source only, and the heavier the fuel the wider must the tolerances be if there is to be any choice left between one crude and another.

It was considered[5] that restrictive specifications are not necessarily wrong. The particular fuel on which an engine was developed may suit it so well that the user may be prepared to pay a special price for it. But this is an abnormal case and it cannot be too strongly emphasised that, if there should be a general insistence on special specifications, users would be adopting a policy which could only lead to shortage of supplies, and an increase in price out of proportion to anything that is likely to be gained.

Figs. 1 and 2[6] show the gain in popularity of the diesel powered ship on a world basis. This growth has not been at a uniform rate in various countries and Table I[6] shows the situation in the past decade for selected countries.

In 1976, the Technical Research Policy Committee of the General Council of British Shipping undertook a review of the problems associated with fuel in ships of the British merchant fleet. This was reported to a conference of this Institute in 1979[7]. While evolution has taken place in vessels' propulsion systems, developments have also occurred in oil refining. All these changes have materialised because of the requirement to balance the refinery product barrel with that of the consumer.

Similarly, there have been a series of continuous developments on the part of the diesel engine designer. Inter alia, advances have been made with medium speed, trunk piston type engines. The earliest record found showed that residual fuel was used in the medium speed engines of *Princess of Vancouver* which was launched in 1955. Since then, progressively smaller cylinder bore sizes and higher speed engines have utilised residual fuel. There has been a significant increase in power per cylinder for both medium and slow speed engines.

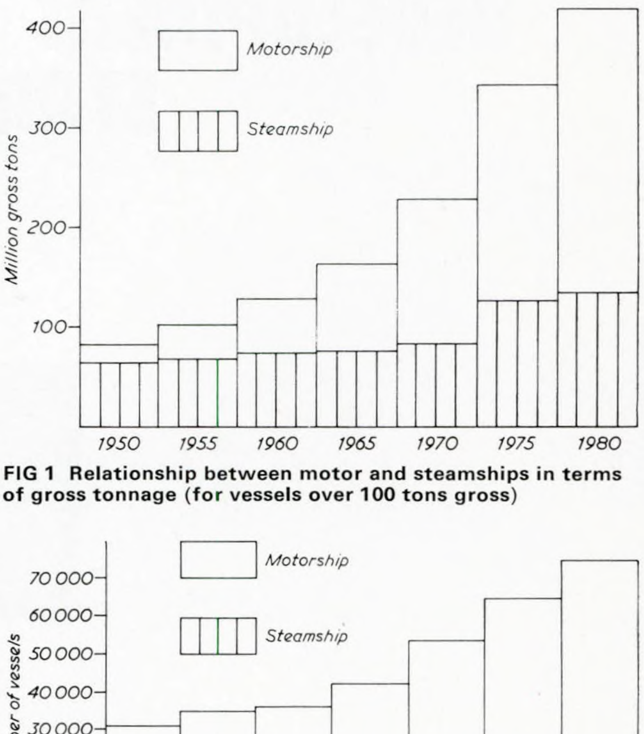

FIG 1 Relationship between motor and steamships in terms of gross tonnage (for vessels over 100 tons gross)

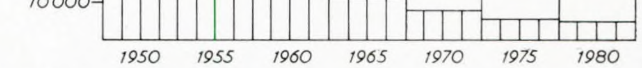

FIG 2 Relationship between motor and steamships in terms of numbers (for vessels over 100 tons gross)

INTRODUCTION

For the majority of shipowners, bunkers account for a significant part of the vessel's operating cost. The exact proportion depends upon the type and size of vessel, and the trade in which it is employed. It has long been recognised that the propulsion machinery for large ocean going vessels should be capable of operating on residual-oil based fuels. This is fundamentally a question of economics because of the cost difference between marine diesel or distillate fuels and marine fuel oil. The commitment of the marine industry to the use of heavy fuel is now such that it is extremely unlikely that adequate amounts of distillate would be available to

Table I. Percentage of diesel powered ships and number of ships in various gross tonnage groups.

Flag	*Year*	GROSS TONNAGE GROUPS 1000–19999		20000–99999		100000–OVER	
"World"	1970	77%	15882	54%	1226	3%	3
	1975	89%	19802	64%	2035	8%	44
	1980	93%	23735	79%	2895	8%	58
UK	1970	80%	1451	34%	81	0%	0
	1975	90%	1344	55%	147	0%	0
	1980	93%	1072	72%	157	0%	0
USA	1970	11%	219	2%	1	0%	0
	1975	20%	202	8%	11	0%	0
	1980	26%	247	14%	29	0%	0
Norway	1970	98%	914	87%	238	25%	2
	1975	99%	635	92%	264	24%	16
	1980	99%	427	96%	193	23%	16

enable any significant reversion of the world's merchant fleet back to distillate fuel.

It has been estimated that the world's merchant fleet consumes some 150 million tonnes of marine fuel oil per year. Of this total some 80 per cent is residual fuel, as distinct from distillates which are used in smaller craft and auxiliary engines.

Fuel for the marine market, with the exception of distillates, is at present ordered by viscosity. This procedure does not define the other more important characteristics of the fuel. As long as viscosity remains the sole criterion for ordering marine fuels, shipowners remain unaware of these other characteristics. Similarly, the designers of the machinery and fuel systems are not always suitably informed of the fuel characteristics to which they should be designing.

Major oil suppliers have traditionally produced marine fuel oil to their own internal manufacturing standards. However, at present, marine fuels are not covered by any internationally agreed specifications. This is somewhat surprising, bearing in mind that this is a commodity for which shipowners currently pay around US $35000 M per year.

In 1978, the General Council of British Shipping initiated the setting up of a Working Group to consider the development of a standardised specification for marine fuels. During the formation of this Group it was quickly realised that, to be meaningful, it was essential that all interests of the marine industry were represented. This Group is now known as the British Standards Marine Fuel Standards Sub-Committee.

At present, the Group comprises representatives of the international oil suppliers, engine builders, and British shipowners. The objective of the Group is to draft a marine fuel specification for consideration by the International Standards Organisation (ISO).

In January 1980, the British Standards Institution made a formal proposal to Technical Committee 28 – Petroleum Products and Lubricants of ISO, that an international standard for marine fuel should be prepared. This proposal for new work was accepted by the ISO/TC28 meeting held in Ottawa in June 1980, and a working group was set up under UK convenorship.

By the middle of 1980 the Group considered that basic agreement had been reached, and that a proposal was sufficiently advanced for it to be submitted to the first meeting of the ISO Working Group on the subject of marine fuel specifications. This ISO Working Group is designated ISO/TC28/SC4/WG6 – Marine Fuels.

PRIORITIES OF THE SHIPOWNER, ENGINE BUILDER AND OIL SUPPLIER

In the ideal world the shipowner wants the maximum quality control at the minimum price: in fact, two diametrically opposed requirements. Also, those shipowners who trade world wide need to have reasonably assured access to fuel oil of some defined quality. Further, in concurring to any specifications, shipowners are mindful of their existing installations, as well as those which they will order in the future.

The real priority of the engine builders is to match that of their customer, namely the shipowner, and consequently realise that their engines must burn residual fuels in order to compete in the marine market. Usually this is synonymous with fuel having a widely varying quality and broadly similar to the product used for steam-raising plant.

The major oil suppliers recognise the use of residual fuels in marine diesel engines, and that there is an obligation for them to regulate the quality of the fuel so that it can be used economically and safely. In theory, this might not sound so difficult to achieve but, in practice, there is a wide divergence of opinion from different engine builders on the fuel quality limitations that should apply for their own engines. Equally, there is wide divergence in the design of onboard fuel handling systems. The inevitable question, therefore, is whether the ship should be designed for the fuel, or the fuel for the ship. Usually, the answer lies somewhere in between these two extremes. The major problem facing the bunker supplier today is the impact of secondary conversion processes. These processes are an increasingly essential requirement if refiners are to continue to meet the demand. The main priority of the oil refinery is to maintain flexibility of the refinery product barrel against the consumer needs. Hence, the real problem for the supplier is to weigh the requirements of the refiner against the technical limitations of the particular application.

ASPECTS OF A SPECIFICATION

The work carried out by the Group has been concerned with the development of a series of marine industry specifications for different grades of marine fuel oil, which define the maximum or minimum permissible values of the fuel quality criteria. In practice, the fuels supplied will frequently have many quality points below the maximum and above the minimum.

It is considered essential that a specification should be REASONABLE, USEFUL and ECONOMIC.

For example, it would not be reasonable to include requirements for which there was no technical importance, or which demanded closer precision than is normally possible in commercial testing.

The specification of a particular parameter must serve some obvious purpose and contribute to the usefulness of a complete specification. For example, one would not expect colour to be specified for residual marine fuel oil as it would not serve any useful purpose.

In being economic the specification must not be needlessly restrictive. Hence, the determination of any parameter must be made with due regard to the effect that this has on the manufacturing process which, if too restrictive, could lead to an uneconomic price to the user or, because of other factors, very limited availability.

PROPOSAL

Table II defines a range of marine fuels. In general no attempt has been made to define suitability for particular engine systems or particular applications. This course has been adopted because of the wide diversity of engine systems and applications.

CLASSIFICATION of the grades has been made alphabetically as a means of reference for convenience. This matter will be the subject of further discussion within the ISO forum. The prefix 'M' has been used, pending recommendations from ISO/TC28/SC4/WG1.

Grade MA is a distillate fuel for emergency purposes, and the parameters meet the requirements given in the United Kingdom's Department of Trade Merchant Shipping Notice M843 (Appendix 1). Grade MB is a distillate fuel. Grade MC is composed of mainly distillate with a small proportion of residue. Grades MD to MJ are residual fuels, with progressively increasing viscosity and wider control limits.

The control limits for DENSITY, like many other parameters, were agreed after considerable discussion. For grades MD to MI inclusive, the value is the current technical limitation related to the effective removal of water with centrifugal purifiers. For grade MJ there is no density parameter, as this is a fuel for use where there is no requirement for centrifuging. It is likely that some of the fuel supplied to this grade could have a density exceeding 1.0 @ 15°C.

The KINEMATIC VISCOSITY for grades MD-MJ is quoted in centistokes (cSt) at 80°C. The temperature of 80°C has been selected because of possible non-Newtonian behaviour of a limited number of heavy residual fuels at 50°C. The approximate equivalents in cSt @ 50°C and Redwood seconds No. 1 at 100°F are as shown below.

cSt @ 80°C	15	25	45	75	100	130
cSt @ 50°C	40	80	180	380	500	700
Redwood seconds No. 1 @ 100°F	300	600	1500	3500	5700	8000

Grades MD-MJ inclusive cover a range of six viscosities between 15 and 130 cSt at 80°C. All these grades require heating in storage, and throughout the system. Grade MC is for ships which do not have storage heating capability. A knowledge of viscosity is necessary for the determination of the heating required for the storage and handling of the fuel, and the temperature range for satisfactory atomisation of the fuel at the injector nozzle or burner. It should be appreciated that residual fuel oil cannot exactly conform to the widely published charts for viscosity/temperature relationships which are based on averaged data. In general these differences are small for lower viscosity fuels but become wider as viscosity increases. Vessels fitted with viscometric control should not be operationally affected by such variations.

The minimum value of FLASH POINT for grades MB-MJ is in accordance with the various current national legal requirements, to ensure fuel can be handled safely on board. For grade MA the flash point is the minimum allowed for machinery situated outside the machinery spaces (Appendix 1).

POUR POINT determines the lowest temperature at which the marine fuel can be handled due to excessive amounts of wax coming out of solution. At a lower temperature the fuel will gel, therefore preventing flow. For grades MB and MC, which are intended to be suitable for unheated engine systems, two pour points are considered necessary. By sub-division of the year into the periods 1st December to 31st March and 1st April to 30th November, account is taken of the ambient conditions experienced in the Northern Hemisphere in winter. This form of sub-division is similar to that existing already in various national specifications.

For the residual grades MD-MJ inclusive, the values given were set by a technical limitation of the design constraints of existing ships' fuel handling systems, namely the pipelines between the bunker tanks and the machinery space. It should be noted that there is no direct relationship between the pour point and the viscosity of marine fuel oil. For the higher-viscosity marine fuel oils pour point does not normally give any operational problems as the temperature required for pumping would be adequately in excess of the pour point.

The CLOUD POINT is the temperature at which wax begins to crystallise from a distillate fuel. This parameter is only applicable to grade MA, and is a technical limitation in order that emergency equipment can start and operate at an ambient temperature of −15°C. (Appendix 1.) For ships trading in exceptionally low ambient temperature conditions, special grades of fuel outside the scope of this specification would be required.

The CARBON RESIDUE may be defined as the tendency of a fuel to form carbon deposits under high temperature conditions in the absence of air. Carbon residue may be expressed as either Ramsbottom Carbon or Conradson Carbon Residue. This parameter is generally considered to give an approximate indication of the combustibility/deposit forming tendencies of the fuel. The range of values in grades MD-MI inclusive are set mainly by the requirements of future refinery processing.

The range of SULPHUR values shown, takes into account the sulphur levels of the major crude sources throughout the world.

The ASH value is related to the inorganic material in the fuel oil. The actual value depends upon firstly, the ash present in the crude oil, secondly, the refinery processes employed, and thirdly, upon possible subsequent contamination during transportation due to sand, dirt and rust scale. Vanadium, and other contaminants such as nickel, silicon, aluminium, sodium and iron are the usual major contributing components.

SEDIMENT BY EXTRACTION defines the insoluble residues

Table II. Suggested grades and specifications of fuels to be used by the marine trade when ordering fuels.

GRADE	MA		MB		MC		MD		ME		MF		MG		MH		MI		MJ	
INSPECTION	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Density at 15°C	—	—	—	0.90	—	0.920	—	0.990	—	0.990	—	0.990	—	0.990	—	0.990	—	0.990	—	—
Viscosity Kinematic cSt at 40°C	1.5	5.5	—	11.0	—	14.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Viscosity Kinematic cSt at 80°C*	—	—	—	—	—	—	—	15	—	25	—	45	—	75	—	100	—	130	—	130
Flash Point PM (Closed) °C	43	—	60	—	60	—	60	—	60	—	60	—	60	—	60	—	60	—	60	—
Pour Point (Upper) °C 1Dec-31 Mar	—	—	—	0	—	0	—	24	—	30	—	30	—	30	—	30	—	30	—	30
Pour Point (Upper) °C 1 Apr-30 Nov	—	—	—	6	—	6	—	24	—	30	—	30	—	30	—	30	—	30	—	30
Cloud Point °C	—	-16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ramsbottom carbon on 10% residue, % by mass	—	0.20	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ramsbottom carbon, % by mass	—	—	—	0.25	—	2.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Conradson carbon, % by mass	—	—	—	—	—	—	—	12.0	—	14.0	—	20.0	—	22.0	—	22.0	—	22.0	—	—
Sulphur, % by mass	—	1.0	—	2.0	—	2.0	—	3.5	—	4.0	—	5.0	—	5.0	—	5.0	—	5.0	—	5.0
Ash, % by mass	—	0.01	—	0.01	—	0.05	—	0.10	—	0.10	—	0.15	—	0.20	—	0.20	—	0.20	—	0.20
Sediment by extraction, % by mass	—	0.01	—	0.02	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sediment (Total Existent)	—	—	—	—	—	†	—	†	—	†	—	†	—	†	—	†	—	†	—	†
Water, % by volume	—	0.05	—	0.25	—	0.30	—	0.50	—	0.80	—	1.0	—	1.0	—	1.0	—	1.0	—	1.0
Cetane Index	45	—	35	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ignition Quality	—	—	—	—	†	—	†	—	†	—	†	—	†	—	†	—	†	—	—	—
Vanadium, mg/kg	—	—	—	—	—	100	—	250	—	350	—	500	—	600	—	600	—	600	—	600
Aluminium, mg/kg††	—	—	—	—	—	—	—	30	—	30	—	30	—	30	—	30	—	30	—	—

* An indication of the approximate equivalents in kinematic viscosity at 50°C is given below:—

Kinematic viscosity at 80°C	15	25	45	75	100	130
Kinematic viscosity at 50°C	40	80	180	380	500	700

† Considered important but currently no standard test method available.
††An acceptable test method has to be agreed.

remaining after extraction of the fuel by toluene. These insoluble residues are contaminants such as sand, dirt and rust scale. Such insoluble residues are not derived from the fuel. The oil industry consider that with respect to marine fuels the sediment by extraction test is only applicable to grades MA and MB.

TOTAL EXISTENT SEDIMENT is the combination of inorganic and hydro carbon sediments existing in a fuel as delivered. This test is aimed at limiting the maximum amount of sludge present that might be potentially separated at filters and in centrifuges. The Institute of Petroleum is actively developing a test method. It is considered that the compatibility of components used in a specific fuel delivery will be covered by this new test method. When a test for Total Existent Sediment has obtained international acceptance consideration will be given to the control limits for the residual grades

The control limits for WATER are in line with existing national standards, and are at levels traditionally accepted by the market.

The CETANE INDEX is an empirical measure of ignition quality and is applicable only to grades MA and MB. This index is calculated from mid-boiling point and gravity, that is to parameters which relate indirectly to the chemical composition of the fuel. For grade MA a minimum value of 45 is proposed to ensure satisfactory starting of emergency equipment, for which purpose this grade is intended. For grade MB a minimum value of 35 recognises some present national standards.

It is recognised that some criteria of IGNITION QUALITY are required that would be applicable to grades MC-MI inclusive. Unfortunately, there is no recognised test method that defines the behaviour of the residual fuels as covered by grades MC-MI inclusive. The criteria need to be identified, a test method developed and agreement reached between all parts of the marine industry.

VANADIUM is a metal contaminant that is present in all crude oils in an oil soluble form. The levels depend on the crude oil source, with those from Venezuela and Mexico having the highest levels. Vanadium levels are also related to the concentrating effect of the refinery processes used in the production of marine fuel oil. There is no economic process for removing vanadium from either the crude oil or residue. The level may be reduced by dilution with distillates which do not contain the contaminant. Such dilution incurs a cost penalty in proportion to the amount of distillate added for the purpose.

Inclusion of a control limit for ALUMINIUM is considered to provide a convenient means of restricting the quantity of catalytic fines in the delivered fuel. The Institute of Petroleum will propose a test for aluminium which will be acceptable to the industry. It should be appreciated that the control limits proposed are a control for marine fuel oils as delivered over the ship's rail. The lower levels that may be necessary for certain machinery systems, it is considered, can be achieved by suitable shipboard pre-treatment.

PARAMETERS CONSIDERED BUT NOT INCLUDED

In addition to the parameters shown in Table II, various other parameters were the subjects of discussion before agreement on the Table was reached by the Group.

Marine fuel oil is purchased by the shipowner to produce heat for conversion into work. Hence, from this viewpoint, the characteristic of SPECIFIC ENERGY should be worthy of consideration in the specification. The oil industry has emphasised that a limit on specific energy would not be meaningful, as such a limit would be based on the other parameters already defined within the specification. The specific energy is not controllable in the manufacture of marine fuel oil, except in a secondary manner by the specification of other properties. A method of calculation is described in Appendix 2. Further consideration of specific energy is discussed in Appendix 3.

The inclusion of ASPHALTENES in the specification was considered. It was agreed that this should not be included as there was insufficient evidence available to indicate that this parameter gives any better indication of a fuel's combustion/deposit-forming tendencies than carbon residue. From trials it would appear that there is no simple relationship between asphaltenes and combustion performance. It should be noted that the term asphaltene used in the genetic sense covers a wide range of heavier hydro-carbon structures. "Asphaltenes" used in the normal analytical sense, only defines a certain group of asphaltenes.

Consideration was given to the inclusion of SODIUM in the specification. This was because of concern over the low melting temperature of sodium/vanadium complexes of certain critical ratios. As already discussed, the amount of vanadium present in a delivery of marine fuel oil is a function of the crude oil sources and the concentrating effects during refining of those crudes in the production of the marine fuel oil. Fuels leaving a refinery in general have sodium levels below 50 mg/kg. Salt water contamination may be a significant source. A 1% sea water contamination represents a potential 100 mg/kg increase. The oil supply industry consider that it is impractical to have a meaningful control level. It is generally thought that effective shipboard centrifuging of the fuel will reduce this contaminant to an acceptable level.

Concern has been expressed with respect to the COMPATIBILITY of one fuel oil with another. In simplistic terms one fuel oil is considered compatible with another when the resultant mixture does not precipitate asphaltenes, which are normally referred to as sludge. The oil industry consider that it is not practical to incorporate compatibility as a control parameter in a fuel specification, as the supplier has no control over the type or origin of the marine fuel oil previously bunkered. The general recommendation is that mixing and blending of fuel from different sources on board ship should be avoided as far as is practicable.

TEST METHODS

It is fundamental to any specification that every defined parameter can be determined by means of an internationally agreed test method. For the great majority of parameters such test methods exist, and these are listed in Appendix 4.

At present, TOTAL EXISTENT SEDIMENT is determined by various in-house tests. The industry is actively developing a test acceptable to all parties. When such a test has been agreed consideration will be given to control limits for grades MC-MJ inclusive.

For ALUMINIUM, the Institute of Petroleum is actively seeking agreement on an acceptable test method to cover the applicable concentrations.

As already stated, a parameter that defines IGNITION QUALITY is considered essential for grades MC-MI inclusive. To date, the Group is not aware that an acceptable criterion has yet been defined by workers in this field, and it is considered that it may be some time before a suitable test method is developed. Following this, there will be a further period before agreement is reached on limits acceptable to all sides of the industry.

LIMITATIONS TO THE PROPOSED SPECIFICATION (TABLE II)

During the numerous discussions that were held in the development of the proposal, it was concluded that it was not possible totally to meet all the requirements of the shipowner and engine builder. This particularly applied to the maximum limits in the proposal for vanadium and carbon residue with respect to the light intermediate residual grade MD. It is appreciated that some shipowners in their quest for economy now operate engines on light residual fuel which were originally designed for distillate grades. Further, it is realised that the remaining service life of such engines may be in the order of ten years, and that shipowners will continue to want to operate such installations on the most economical grade of fuel oil possible.

In this case, shipowners should request at the time of ordering lower levels of vanadium and of carbon residue. The fuel supplier at that particular bunkering station will then be able to advise the availability of such a fuel.

Considerable in-depth discussion has taken place as to the feasibility of the production and availability of a grade similar to MD, but within limits of 10 per cent Conradson carbon residue and 150 mg/kg vanadium. It was concluded that on a world wide basis it would have a low availability and in some geographical areas the availability would be zero. This situation arose because of the crude source type used and the known committed amount of secondary conversion processes that are planned in the next few years.

There was considerable debate on the desirability of incorporating a low pour point fuel of an MD type grade for ships without tank heating. The oil industry was not prepared to define such a grade in an international specification because of the very small requirement and difficulty in production.

GAS OIL

It is recognised that gas oil as a fuel has certain applications on some merchant ships. Consideration was given by the Group to the inclusion of specific parameters for such a fuel. After debate, it was concluded that nothing would be gained in an attempt to create a gas oil specification that would be applicable on a world wide basis. It should be appreciated that gas oil is already subject to various national marketing specifications, and that such marketing specifications are applicable when vessels order such a class of fuel.

CONCLUSIONS

It is considered that the proposal, if implemented, would do much to reduce the present concern that exists with respect to marine fuel oil. Furthermore, engine designers will be able to design engines that take proper account of the likely extreme fuel quality. Shipowners, as the end users, would be able to carry out a systematic techno-economic evaluation for new tonnage. In the case of existing machinery systems, it is hoped that engine manufacturers would be able to advise the most suitable grade within the proposed series. When an engine is unable to use one of the proposed grades this should be clearly stated by the engine builder. Then, the shipowner can determine the implications of using a better quality fuel on the trade routes on which he operates.

In the future, further work within the industry may suggest that there is a technical necessity to consider the incorporation of alternative or additional parameters in the specifications. Any such proposals would require full discussion and agreement with all facets of the industry.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the commitment of the British Standards Marine Fuel Standards Sub-Committee who have debated constructively at length the various aspects of the proposal. Acknowledgement and thanks are expressed by the Group for the invaluable help given to them by their colleagues in the petroleum industry, engine builder and shipowner organisations. Finally, the author wishes to thank the Group for their agreement to the timely publication of this paper.

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APPENDIX 1

DEPARTMENT OF TRADE MERCHANT SHIPPING NOTICE No. M.843

LIFEBOAT ENGINES AND OTHER COMPRESSION IGNITION ENGINES USED IN AN EMERGENCY

Notice to Shipowners, Superintendents and Chief Engineers

1. Ships' motor lifeboats are required to be put into service quickly in the event of an emergency and to be operated under a wide variety of climatic conditions. To ensure that lifeboat engines may operate satisfactorily in cold climates, starting and running tests at an ambient temperature of –15°C are carried out on prototype engines. When in service it is essential that the correct type of fuel oil and the right grade of lubricating oil are used to enable the engine to be started and run at low ambient temperatures.

2. Generally the problem in respect of lubricating oil is not so acute. The amount of running is relatively small and consequent renewal of the oil is infrequent, whilst the procurement of suitable multigrade lubricating oils rarely presents a problem.

3. Although not so often appreciated, the selection of fuel oil requires the same degree of care and attention when low temperature operation is considered. Not only can the fuel oil become more viscous at lower temperatures, but there is also the problem associated with the formation of crystals which can cause blockage and stop the flow of fuel to the engine. Special fuel oils are available for low temperature operation and are of course readily available in areas of the world where such temperatures are regularly experienced. However, when ships ply worldwide, particularly between tropical and temperate zones, it is necessary to make sure that any fuel oil taken on board for use in engines such as lifeboat engines would be suitable in an emergency for the lower ambient temperature of –15°C. In this context, the term "engines" also includes emergency generators and emergency fire pumps which are usually subject to the outside ambient conditions encountered in service.

4. Both the Merchant Shipping (Passenger Ship Construction) Rules 1965 and the Merchant Shipping (Cargo Ship Construction and Survey) Rules 1965 permit fuel oil of a lower flash point—ie not less than 43°C (110°F)—to be used in emergency generators. Such machinery as lifeboat engines and emergency fire pumps would be considered to fall within the same category and consequently be permitted to use the lower flash point fuel. It must be pointed out, however, that the flash point of the fuel oil is not necessarily a guide to its suitability for use at low temperatures. It is therefore essential in all cases to raise the question of its suitability with the supplier.

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APPENDIX 2 – SPECIFIC ENERGY

Specific Energy can be calculated with a degree of accuracy for normal purposes from the relative density of a fuel, and applying corrections for any sulphur, water and incombustibles (ash) that may be present. The empirical formula given below is quoted in 'Petroleum Fuels for Oil Engines and Burners' BS 2869. 1970 Amendment 2.

Specific Energy (gross) MJ/kg $= (51.916 - 8.792d^2)(1 - (x+y+s)) + 9.420s$

where d is the relative density at 15°C
x is the proportion by mass of water (% divided by 100)
y is the proportion by mass of ash (% divided by 100)
s is the proportion by mass of sulphur (% divided by 100)

APPENDIX 3 – FURTHER CONSIDERATION OF SPECIFIC ENERGY

During the period 1974-76 a study by the Department of Commerce Maritime Administration (MARAD) [9] included an analysis of some 120 marine fuel oil samples on a world wide basis. Statistical analysis of this data showed that the mean Specific Energy (Gross) to be 43.657 MJ/kg and a standard deviation to be 0.27 MJ/kg. By consideration of two standard deviations, 90% confidence limits may be calculated. This shows that a variation of ± 1.24% existed. Although the samples used in this study were representative of marine fuel oil, it was concluded by MARAD that more extensive sampling would be needed to improve the validity of the statistical base.

Figure 3 shows the relationship of gross specific energy MJ/kg to variations in sulphur and density. It should be noted that correction for ash and water may be made by subtracting 0.01 Q (% ash + % water), where Q is the gross specific energy for the density under consideration at zero sulphur content.

A recent analysis from another source of some 558 bunker receipts from 95 ports over the period of a year (1979) showed that over 95% of the marine fuel oil in this sample had a density greater than 0.940 at 15°C. The lowest recorded value being 0.9. Unfortunately, the data did not record the sulphur levels, and it was concluded that these were in the range 1-4%.

From the second analysis, ignoring the minor correction for the effect of ash and water, the gross specific energy of 95% of the fuels bunkered in the above sample would lie within the boundary ABCDEFG in Fig 3. It is considered that the amount of low sulphur crudes used in the production of marine fuel oil is low. This is because of the desirability to

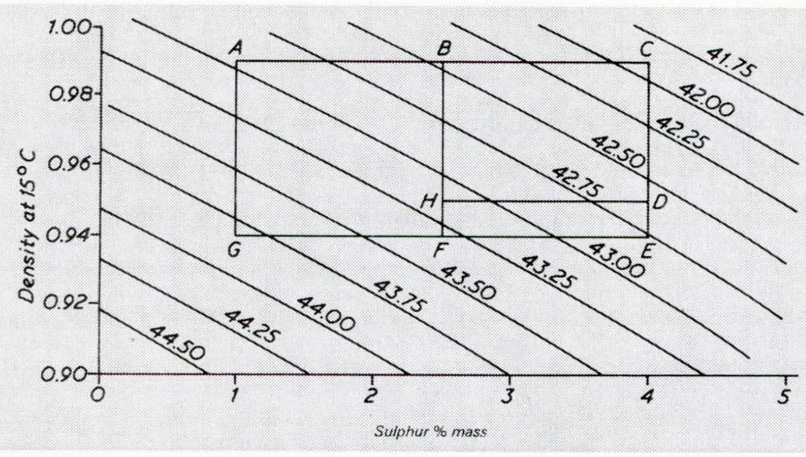

FIG 3 Relationship of gross specific energy MJ/kg to variations in sulphur and density

use such crudes in the production of fuel for the inland market. It has been estimated that low sulphur marine fuel oil accounts for less than 5% of the residual marine fuel oil market. From further analysis of the sample it was concluded that the sulphur content lay within the range 2.5-4.0%. Hence, over 90% of the fuel oil in the same analysis would be contained in the boundary BCDEFH. With respect to density it was found that over 85% of the bunkerings recorded a value greater than 0.950. Hence, some 85% of the bunkerings were within BCDH. By consideration of the arithmetic mean of the specific energy within the boundary BCDH, the variation is ± 1.4%.

It should be noted that the accepted reproducibility of the determination of specific energy in a bomb calorimeter is 0.40MJ/kg[10]. Based on the arithmetic mean of the specific energy in the boundary BCDH, the accepted reproducibility is in the order of ± 0.95%.

In practical terms it is concluded that for the greater majority of bunkerings in the future there will be negligible variation in the gross specific energy value. When low density fuels with a low sulphur content are bunkered the variation could be as much as + 4.5% based about the arithmetic mean of the sample continued within the boundary BCDH.

Note

After the author had finished his presentation, a panel answered questions from the floor. The panel consisted of:

The author;

Mr M. V. Elliston BSc, CEng, FIMarE (representing the General Council of British Shipping);

Mr W. Lowe BSc, CEng, FIMarE (representing the manufacturers of diesel engines);

Mr P. J. Newbery FIMarE (representing the international fuel oil suppliers).

APPENDIX 4 – INSPECTION TEST METHODS FOR MARINE FUELS

The references of various inspection test methods which are applicable to marine fuels are as shown below.

	ISO	BSI	ASTM	IP
Density at 15°C	3675	4714	D1298	160
Viscosity Kinematic @ 40°C cSt)				
@ 80°C cSt)	3104	4708	D445	71
Flash Point PM (Closed) °C	2719	2839	D93	34
Pour Point (Upper)°C	3016	4452	D97	15
Cloud Point °C	3015	4458	D2500	219
Ramsbottom Carbon % mass	4262	4451	D524	14
Conradson Carbon % mass	4263	4380	D189	13
Sulphur % mass	—	—	D2622	—
Sulphur % mass	—	—	—	336T
Ash % mass	6245	4450	D482	4
Sediment by Extraction % mass	3735	4382	D473	53
Sediment (Total Existent)	—	—	—	—
Water % volume	3733	4385	D95	74
Cetane Index	(4264)[1]	4701	D976/66[2]	218
Ignition Quality	—	—	—	—
Vanadium mg/kg	—	—	D2788	—
Vanadium mg/kg	—	—	—	288T
Aluminium mg/kg	—	—	—	—

Notes: 1 At DIS Stage (Draft International Standard)
2 Being Revised

Discussion

MR A HILLAND: In his opening remark the author states: 'There cannot be many other commodities, which have been marketed in such quantities, for so long, without any quality controls that are recognizable by the customer.'

The statement is probably very true. The introduction of a standard is thus welcome. Table II, a result of an impressive job effected by the British Standards Marine Fuel Standards Sub-Committee, is a step forward. The limiting technical values will certainly be debated and questioned. For the customer it is useful to know the maximum-minimum values of certain parameters of the fuel bunkered. This will enable people to build up experience and thus to some extent counteract difficulties, but will not in itself solve the problems. Too many uncertainties are still connected to some of the parameters, and some assumed important ones even lack a test method.

From the customer side no doubt a number of technical questions will be asked and coupled with those the commercial aspects will be brought forward. It would therefore be of primary interest to have the author's or the panel's view on the kind of savings one can expect on the unit price, moving down the alphabetic scale of the different grades.

The bunker account now represents the highest single cost item for a ship in normal service. Any efficient ship management organization is consequently devoting a major effort to control and minimize bunker expenses. Assuming a price difference on the various grades, there obviously will be a struggle to move to a less expensive grade.

Engine builders, on their side, are presenting limiting values of the same parameters in Table II for each type of engine. It is, however, recommended that treatment of fuel oil is carried out on board the ship, thus influencing the usability.

Further intensive work is being carried out to improve onboard treatment. This may be mechanical, chemical, thermal or any combined method. The effectiveness of the various methods is disputed and it is foreseen that difficulties will arise in their formal acceptance. In other words, the utilization and trust in such equipment and methods will rest with the experience and ability of the owners.

Based on this one can foresee a discrepancy between the bunker fuel grade as it comes over the ship rail and that being recommended by the engine manufacturer. This will raise a number of questions, of which the legal implications are the most tricky and important. Has the Sub-Committee considered the risk of a ship being declared unseaworthy if a discrepancy exists between the fuel grade coming over the ship's rail and that recommended by the engine builder?

On the assumption that owners will be obliged to introduce a Marine Fuel Standard, what kind of quality guarantee is envisaged following the supply of bunkers and will this be coupled to a bunker delivery note which quotes the actual values of the various parameters?

MR A F HODGKIN, Member I Mar E: I have some opinions concerning the proposed Standard which the author has discussed. If I were to make these opinions public, they could probably be paraphrased in the style of an old war-time exhortation like 'Was your journey really necessary?'! Aside from that, I sincerely trust there are some shipowners who will be satisfied by the new Standard. I know from my own contact with the Committee during its long deliberations that, severally and individually, much hard work has been involved. Discussions have been intense, ranging widely over the subject matter.

Throughout this period I have continually admired the adroitness with which the representatives of the oil industry have consistently bent the discourse of the Committee to their will. I am not suggesting that they did not have good reason for this, or that the Chairman of the Committee has been lax. It seems they had no other choice, for it is understandable to me that the bunker fuel market is very much a 'tail-end Charlie', and the oil industry cannot be expected to modify its refining techniques solely to produce a specific fuel or fuels. The limitations set for the listed parameters of the various grades therefore seem very much to be what the refineries can produce within the foreseeable future, without jeopardizing any of the front-end processes, or, indeed, changing their current habits in any material way.

As a member of the boiler industry it is not surprising that Grade MJ is of most interest. No diesel ship will bunker this grade, if only because of the risk that the specific gravity may exceed unity. If this grade becomes widely available we wonder what percentage difference in price would exist between it and the superior grades. This must be seen as a very important issue in determining the likely competitiveness of any future steam plant and some indication from the oil industry would be welcome.

Limited in definition though a Grade MJ fuel may be, it is accepted that most boiler plant will be able to deal with it. Nevertheless, more information would be helpful in a diagnostic and corrective sense, so that shipowners may be given every assistance in the use of this potentially difficult fuel. If records could be kept of plant performance and difficulties relating to contamination levels in the fuels in use, then a pattern should evolve, enabling corrective work to be undertaken, and assisting in preparation of new designs avoiding those difficulties in future.

In some areas shipowners are being offered a service enabling an evaluation of fuel quality to be given shortly after receipt of a sample taken during bunkering. Details of this have been announced by Intertanko and Det Norske Veritas and it is believed that the Maritime Administration in the USA has similar plans.

But why should owners have to involve an outside agency in order to find out what they are buying? Even a packet of cornflakes or similar fuels must state the nature of its contents — is it too much to expect a corresponding service from bunkering stations? It is not suggested that additional limitations should be applied, but merely that indications are given at the point of delivery of sufficient parameters to provide a sound basis for dealing with any in-service problems which may arise.

If full records are kept by the user, and fed back to the plant designer, then some overall benefit should result making it more readily possible to deal with fuels upon which there is placed very little in the way of restrictions, in so far as the oil industry is concerned. Assuming that this very low grade of fuel is available in any quantity, then the provision of data as suggested should not materially affect the cost of the fuel.

Although these remarks have been aimed specifically at Grade MJ, it is likely that similar benefits could accrue to the users and designers of diesel engines if applied to other grades.

DR P G CASALE, Fellow I Mar E: It is worth repeating that the General Council of British Shipping was the driving force in requesting the BSI to set up a working group to consider the development of marine fuel standards. Through our connections with the Institute of Petroleum we were requested to nominate a person to serve on the committee. Mr Royle, a member of the same company as myself, was our representative.

I should like to say a few words, applicable to our Company, concerning our commitment to, and availability of, our products as influenced by the proposed British Standards put before you by Mr Thomas. This is also an appropriate moment to record our sincere appreciation of the work done by Mr Thomas as Chairman of the British Standards Marine Fuels Standard Sub-Committee; for his understanding of the differing viewpoints put forward and the skill with which he has always kept the Committee moving in the right direction at a quite remarkable pace.

Mr Royle's participation in the Marine Fuel Standards Sub-Committee has been with the full co-operation of our principals in New York, who recognize that customer satisfaction is of primary importance to our business. There is a possibility that the proposed standards may be adopted by the marine trade prior to their receiving ISO approval. If this should happen, then we will play our part in making them a practical reality. It would be foolish to suggest that the proposed standards are the answer to all the technical problems encountered by shipowners in using residual fuels in their diesel engines. The proposed standards are expected, however, to provide a set of realistic specifications which, although now somewhat tentative and incomplete, will nevertheless represent a suitable framework for further co-operative development of more comprehensive marine fuel standards in the future.

There may be concern about the effect of these standards on the availability of marine fuels. During our discussions on the development of the standards, considerable emphasis was placed on product availability, since it was unrealistic to agree to specification limits which meant that the petroleum industry would not be in a position to offer products for sale. We would like to reassure the shipowners that the adoption of the marine standards will have no significant effect on the availability of the fuels we supply to the marine market. Naturally, not all the grades will be available at all ports, but this is the situation today and is likely to remain so in the future.

So, to conclude, it would seem that the commercial support to the proposed standards comes down to the reaction of individual shipowners and charterers, and the views of their national and international organizations, since they are the purchasers of the fuels.

MR G W FOX, Fellow I Mar E: I have been intimately connected with the oil industry both afloat and ashore for 30 years.

May I first offer my warmest congratulations to Mr Thomas on the quality of the paper he has delivered, and praise the back-up service he has obviously received from his Committee.

Mr Thomas has today, if he will forgive me, 'preached the gospel', a gospel I have been preaching to ship operators — from technical director to chief engineer — over the past three or four years, ever since the allocation crisis. I am not sufficiently conceited to think that I have been the only member of the oil industry doing this, for I am certain that my opposite numbers in the other major oil companies have been doing the same.

To sell a product which continues to decline in quality, any saleman of integrity has to prepare his customer for this declining quality, particularly as prices will continue to soar.

I have a gut feeling, based on my experience as a marine engineer and my background in the oil industry, that at the end of the day, when agreement has been reached by the ship operators, engine builders and oil companies, the parameters of the acceptable specifications will *not* be as narrow as the operator would prefer, due to the complex variables involved.

Having appeared to put a damper on the work of the Committee, I would suggest that, though the quality of marine bunkers will continue to decline, its price soar and its availability diminish, the ship operator and the engine builder in conjunction must take the necessary steps to enable them to continue to use this residual fuel for as long as it is available.

CDR K I SHORT, Fellow I Mar E: In the late 1940s shipping companies started converting their vessels' slow-speed diesel main-propulsion engines to operate on heavy fuel because it was so much cheaper than the diesel fuel they had hitherto been using.

The heavy fuel was cheap because it was the by-product of refineries geared to the production of distillates attracting a high price. It was, effectively, a waste product which could be an embarrassment if not removed. So oil companies fell over each other to get rid of it and price rebates were customary.

Thanks largely to the development of complementary lubricating oils and the avoidance by the oil companies, who were then the principal source of supply, of bunkering unsuitable fuels into such vessels, ships by and large operated satisfactorily. There was no demand from ship owners for quality control, which might increase the price and reduce availability. It was purchased solely on the basis of viscosity and flash point. Several of those more intimately concerned with the chemistry of the oil, however, expressed some interest in a specification.

Today the situation is very different. Intermediate fuel oil (i.e. heavy marine oil cut back to usable viscosities by appropriate distillate) has deteriorated in quality and continues to do so. Its availability is restricted and promises to be more so. Numerous breakdowns and stoppages of main engines at sea have been reported and considerable increased maintenance is necessary.

This has forced owners to ask for details of the fuel they are receiving, and to consider the development of a purchase specification for it for the future.

The first hesitant steps in the production of such a specification are the subject of today's paper. I support this attempt but emphasize that I consider it to be purely embryonic; much remains to be done. For example:

DENSITY: *Has been set at 0.99 by the limiting capability of the water sealed centrifugal separator.* Is this a fair limit for future use when Epsom salt sealing medium can be used in the separator? In the long run, density could then be set higher.

POUR POINT: *Set by onboard fuel handling considerations.* If pour point depressants can be used for the crude oil coming ashore from the Beatrice Oilfield why is the pour point important, and why complicate it with seasonal differences for MB and MC?

ASH: How was this limit set?

SEDIMENT: *Acknowledged as important but no limit set, as no internationally accepted method available.* When will an international standard be available?

VANADIUM: *Set by source and refinery method.* I consider it has been set too high and this top figure could become the costing norm. We have already seen one diesel manufacturer using this high figure to suggest that it demonstrated the future advantage of the slow-speed engine over medium-speed engines!

SODIUM: Why have the oil companies advised against recording sodium? Would water washing not be beneficial?

ALUMINIUM: *The figure of 30 mg/kg is for fuel passing over the rail* before treatment onboard. This appears to be what will be supplied, not what is acceptable to the machinery. M. Gallois of SEMT recently suggested an engine limit of 20 mg/kg.

ASPHALTENES: *Nothing given for these as CCR considered to be as satisfactory.* But asphaltene per cent is not always proportional to carbon per cent. For example, on the West Coast of the USA, the former can be 150 per cent of the latter.

COMPATIBILITY: *Not considered practicable.* A reference fuel should be developed for testing fuels for compatibility.

CETANE NUMBER; DIESEL NUMBER; IGNITION QUALITY; BURNABILITY: Nothing given for these very important features. I consider it is time that it was.

To sum up, only the density and pour point have been selected to suit the ship owner, and so a ship must be designed for the fuel, as it is a question of balancing cost of special fuel against cost involved in designing to burn the worst fuel.

The proposed Specification is, I feel, more a tabulation/grading of certain important characteristics of fuel likely to be offered, than a real specification. The oil companies have stated maximum values of fuel characteristics likely to be found in fuel provided. I think it is too permissive to be truly useful. The permutations of quality within any grade are vast.

Now I should like to consider the Specification from the varying points of view of those who will be involved with the fuel.

As has been said, the oil supplier will continue to dictate what the ship owners will get.

The effect of contract law as it is now stands is to impose strict liability since it does not depend on the seller being negligent. It is, however, restricted to actions between the buyer and the seller. EEC proposals will widen strict liability by allowing any user of a defective article who suffered injury from its normal use to sue the producer for damages.

Will these considerations make the supplier resist the provision of analysis at bunkering?

I am talking specifically about the oil supplier rather than the oil company as today more oil is provided by independent suppliers who may lack the technical back-up services of the oil companies and know little in depth about what they are bunkering.

The position of the engine designer is really unchanged. Although he now knows what to expect as the worst characteristics of the fuel he does not know what combination of these he can expect in practice, either as fuel 'over the rail' or as processed on board, and will have to ask for limits for carbon, sodium, vanadium and aluminium where appropriate, accepting that this may incur increased costs and maintenance.

Last week M. Gallois related to us the story of a medium-speed engine's fuel pump bores being scored by excessive catalytic fines in a matter of days, to the extent that the pumps could no longer handle diesel fuel for manoeuvring as was the vessel's normal practice, and they had to revert to heavy fuel. He also commented on a slow-speed diesel engine which had been stopped in the Pacific by catalytic fines damage.

On the subject of onboard treatment specialists, I suggest that there has been little advance in onboard treatment equipment for only the last 20 years. The much publicized Shell/Alfa Laval recent separator trials, useful as they were by being contemporary, only really confirmed what was done and reported years ago. Arguments regarding relative merits of separators and filters are the same today as they were 20 years ago.

Much more concerted effort is needed on fuel treatment. Separators, clarifiers, precipitators, filters and homogenizers all have a part to play. It would be logical for engine designers to coordinate such work.

So far as the owner is concerned there is no change. He will be getting the same fuel given a fancy grading, principally on viscosity—or it may be even worse as the floodgates have been opened to allow an unrestricted number of bad characteristics at the same time, whereas previously oil suppliers' consciences on consideration of what was 'merchantable quality' may have persuaded them to dose down the worst of such characteristics.

The specification has only considered *availability* as far as owner requirements are concerned; burnability is of equal importance but is not included. In selecting his fuel the owner should also pay some attention to anticipated maintenance.

Then we come to three interrelated questions:

(a) How does the owner know that the fuel he receives conforms with the specification?
(b) How can the specification be enforced?
(c) How can the owner know what he is receiving in time to do something appropriate to his machinery to balance/counteract some adverse characteristic?

The responsibilities accepted by a ship charterer are fairly onerous. He already has to direct the owner to a safe port and a safe berth either of which can be the subject of legal wrangle. He currently provides the fuel to a limited specification 'reasonably fit for the purpose'; my solution is that charter parties should be designed so that owners provide the fuel.

Now we come to the end of the line, the Chief Engineer of the vessel being bunkered.

What does he do if the supplier informs him that there is a general shortage of his Grade in the area and that the fuel he is consequently offering does not quite meet the specification but it is what everyone else is using?

This may happen when contact with head office proves impossible, and he is holding up the barges and the supplier is holding him responsible for cost.

Is it the intention that such divergence from the proposed specification should be a legitimate reason for rejecting the fuel— and would it necessarily be judged a commercially sound reason?

My conclusions are as follows:

1) More effort should be devoted to sophisticated voyage scheduling and reduction of waiting time off ports, both of which can waste more money than is being saved by purchasing low quality fuels.
2) We have been waiting a long time for a positive lead. The specification is only the start, not the end, of the road.
3) Disputes on fuel quality are increasing and it would be helpful in their resolution to know exactly what was bunkered.

MR H SJÖBERG: I congratulate Mr Thomas on an interesting and important paper. I intend to question whether the fuel standard proposal takes enough care of shipowners' interests.

As I presume that the Wärtsilä Vasa Factory is not as well known here as Sulzer and Mirrlees, I think that I should give you some background information. The diesel factory where I work began producing diesel engines in 1954. Since 1963 we have carried out extensive tests with heavy fuel on medium-speed engines with cylinder diameters of 220 – 400 mm (9 – 16 in).

We have accumulated 27 000 test-engine operating hours on heavy fuel, half on viscosities exceeding 2000 sRI at 100°F, 230 cSt at 50°C, or, as the proposal puts it, 55 cSt at 80°C.

The Wärtsilä Vasa Factory took part in the development of the only two-stroke medium-speed engine that operates successfully on heavy fuel — by operating a test engine for 12 411 h in the diesel laboratory; half the time on heavy fuel.

We have designed and developed two new medium-speed engines since the first oil crisis in 1973–1974. The engines are to operate exclusively on heavy fuel, i.e. no change-over to diesel oil at low-load operation or before stopping.

I shall now comment on the fuel standard proposal. There is a need for a fuel standard, but not one that puts most of the burden on the shipowners. It is my opinion that the proposal — in the interest of the shipowners — must not become a standard without alternatives.

As engine manufacturers we are happy in the short term about the present proposal, because it will help market our heavy-fuel engines, but in the long term the proposal will cost shipowners a fortune that will not be reinvested in new ships and hence not in new engines. I shall give you two reasons why the proposal, in our opinion, is not acceptable.

First, comparatively few existing ships have fuel handling equipment, e.g. heaters, temperature control systems and centrifuges, able to cope with 0.990 density and 30 mg/kg aluminium.

One of the leading separator manufacturers recommends a maximum throughput of 30 per cent of rated centrifuge capacity and a pre-separator temperature of 98 ± 2°C when centrifuging an MF fuel. Only the latest models of self-cleaning separators are able to do this work. *New fuel treatment equipment will be very expensive.*

Second, many auxiliary engines, and trawlers' and other small ships' main engines, originally designed for operation on distillate fuels, have during the past two or three years been converted for operation on intermediate fuels of MD and ME viscosity. Engine builders are actively marketing heavy fuel conversion packages and many new engines are converted to some degree before delivery, but they are all *diesel oil engines and will never become heavy fuel engines.* We are producing such engines and know their limitations.

These converted diesel oil engines will have a very small chance to survive if run on MF fuel (1500 sRI/100°F). Most will have difficulties with the ME fuel (600 sRI). A number will not operate properly on MD (300 sRI) and some will even have difficulties with (Class B2) MC due to the vanadium content. A few of the reasons are:

- No, or ineffective, exhaust valve cooling; valve cam designed for diesel oil operation.
- Generally tuned for optimum performance at rated load; hence some blowback into inlet ports at low load is likely. This may be tolerable when operating on diesel oil but not on fuels having 12 – 20 per cent CCR.
- Most have aluminium alloy pistons. Those without ring carriers will have no chance at all due to ring groove wear. Those with ring carriers will suffer heavy top land wear. We have tried chromium-plating and oxy-hardening of the top lands in our converted engines with some success, but our heavy fuel engines are all equipped with composite steel and nodular cast-iron pistons, or with monobloc nodular cast iron.
- Design does not allow the maximum cylinder pressures necessary to burn efficiently poor-grade fuels.
- Fuel injection systems not designed for high enough injection pressures.
- Oil filtering systems will not cope with the increased contamination of lubricating oil.
- Speed- and load-governing systems will not cope with the increased resistance caused by leakage residues.
- Engines without a turbine washing system will be in great difficulties.
- Temperatures will generally be too low, especially at low loads.

Most of the money spent on converting diesel oil engines for heavy fuel operation will be lost if MD and ME are accepted unchanged as standards.

This leaves only two possibilities: first, change to MC, or even to MB in worst cases; or, second, make your own fuel specification. Both will cost a lot of money.

A third, and in the long run the cheapest, alternative would be to buy new heavy-fuel engines.

Suggestions:

	MD	ME
Density (at 15°C)	0.950	0.970
CCR (% by mass)	8	12
Vanadium (mg/kg)	150	250

MR J WILLIAMS, Fellow I Mar E: We are being invited to accept the goodwill of the oil suppliers. Cdr. Short raised the subject of the 'sale of goods' act.

I should like to ask how this can be reconciled with quality disclaimers currently being introduced in oil company contracts.

MR T K M TAM, Member I Mar E: I welcome the paper and congratulate the author on attempting to bridge the gap between shipowners, fuel oil suppliers and engine builders.

However, from the shipowners' point of view the following aspects of the proposed specification (Table II) require tightening up.

First, the specific energy content of each grade should be defined. Using the empirical formula for specific energy (gross) in Appendix 2, an increase of 1 per cent in the fuel density, water, ash and sulphur respectively could result in a 3.4 per cent decrease in the specific energy of the fuel. Due to changes in future refining processes these four parameters are likely to increase with the possible exception of the water content.

The quoted annual shipowner's fuel bill of US$ 35 000M would therefore represent an annual potential equivalent loss to the shipowner of US$ 1200M. Table II also shows in most cases the maximum values which allow oil suppliers a wide margin in which to manoeuvre for financial advantage.

Second, the proposed grades MG, MH and MI have the same maximum values for specific gravity, sulphur, ash and water, which implies that these fuels could have the same specific energy content.

By classifying this fuel into three grades, however, the specification gives the oil supplier the choice of charging the shipowner different prices for fuels with the same energy content; the only difference being the viscosity. What can the shipowner do to avoid being overcharged?

Third, the water content in grades MD to MJ inclusive (0.50 – 1 per cent) seemed high taking into account that, in a modern refinery, stringent control of the end product should be possible. Water represents an equivalent loss of energy and the specification would result in shipowners buying water in lieu of fuel to the value of up to US$ 350M per year.

MR D RHODEN, Member I Mar E: Whilst understanding the explanations given for the choice of values to be used in the proposed specifications, I concur with many of the critical views expressed by other contributors and would add the following criticisms of the specifications.

The grading of the various residual fuel specifications provides no difference in specification other than viscosity for grades MG to MI; three grades of viscosity equivalent at one end to IF380 and at the other IF700, whilst the other three residual fuel grades (equivalents IF40 to IF180) must cover variations in most of the characteristics of the fuel between the best and the worst which are suitable to be handled by installed equipment in most existing ships powered by medium-speed diesel engines.

To adopt the lowest common denominator for these specifications, with the explanation that this is in the interests of obtaining the widest possible application throughout the world merely ensures that, world-wide, suppliers will have the greatest possible latitude in respect of quality and the user is, more than before, in the position of 'take it or leave it'.

If the specifications had been chosen to give progressive variation of all those parameters which cause increasing difficulty with increasing concentration, the user could have had the possibility of choosing a cheaper grade with characteristics acceptable to his installation. As it is, the user is enjoined to negotiate his own specification with his supplier who can follow various lines, ranging from 'There is no call for such a specification' to 'Of course we can supply, but at a special premium'.

Either way the user has less bargaining power than he has if fuel of an accepted standard is being discussed. This situation is obviously to the benefit of the supplier and to the detriment of the user and the Specification Committee should therefore not be suprised at a lack of enthusiasm on the part of the users for the proposed Specification which, as with all bad news, is worse than no news!

The continuation of the practice of coupling a flashpoint of 60°C with fuel of all viscosities from distillate diesel to IF700 presents an operating difficulty in passenger ships which have settling and service tanks and centrifugal separators with open drains. The Department of Trade instructions limit the heating of oil in these installations to a temperature of 50°C, which may be exceeded only if there is a margin of 14°C between the oil temperature in the separator or oil tank and its flashpoint.

As fuels of viscosities greater than 60 cSt at 50°C require heating to temperatures of greater than 50°C for effective treatment by centrifuge, the limiting effect of having a flashpoint no higher than 60°C for all fuels will be obvious. Ships equipped with centrifuges and oil fuel tanks with closed drains will not be so limited. In all cases however, all these necessary heating processes will tend to drive off the lighter fractions present, so throwing fuel to the wind and leaving a higher viscosity fuel than was paid for.

MR D A ROBERTS, Member I Mar E: I congratulate the Committee on the degree of rationalization so far achieved.

As a specialist refiner in a smaller oil company, whose major involvement with the marine fuel problem has been its effect on marine lubricant requirements, an area where we are strong, I offer a number of comments.

Strictly, pour point is not the lowest temperature at which an oil can be handled, marine or otherwise. It is an estimate of the temperature above which one is reasonably certain there will be no handling problem. Given certain thermal histories, oils are often pumpable way below the pour point. We have, for instance, without additives, pumped an 80°F pour crude at a 50°F ground temperature continuously for over 20 years in a 700 mile pipeline.

While the trend to conversion processes was noted in the paper and frequently in the contributions from the floor, there did not seem to be adequate awareness that both catalytic and thermal cracking processes produce fuel oil components which are far more reactive/unstable than virgin residues, however heavy and thick may be the latter.

This changing chemical character of the oils with time seems to be a major problem both on the fuel and lubrication side of the problem. Conradson carbon does not entirely cover the problem.

Consider a heavy grade oil produced by atmospheric and vacuum distillation of a crude, and another from the same crude resulting from catalytic and thermal cracking. By and large the metals and silica will be higher in the latter oil and these are taken into account in the suggested grading. The Conradson carbon, as produced, may differ, but could be brought to the same level for comparison (e.g. by further distillation of the former) as initially made, but there is little doubt that the two oils would have differing stabilities. If both were stored at a temperature to ensure fluidity for say 2–3 months, it could well be that the latter fuel would either have deposited sludge or its Conradson carbon had risen due to polymerization. I was therefore surprised that ASTM method D1661 was not even listed under the parameters considered and discarded, even if more calibration steps of the thimble might be needed. The trend in the marine fuel available is to become more reactive, and some measure of this is surely required.

While the 'high' cost paid for fuel was stressed, few people present would, in their own lives and business, voluntarily make more of any product or improve its quality, where that product sells for less than the material, in this case crude oil, from which it is made. Minimization of such make to the limits of commercial technology is something everyone would do in similar circumstances.

In some ways it could be argued that the marine fuel problem has arisen because bad enough fuels were not available early enough, alongside traditional quality oils at a suitable differential to permit a just comparison between steam and diesel economics. If, as was so, almost all available fuel was suitable for diesels, a major strength of the steam option, the ability to use poorer, cheaper fuel, was destroyed. Even at this late stage, if the availability of a really 'nasty' MJ (or MZ) oil for steam propulsions could be widened, the pool of the remainder of the marine fuel could be improved or its decline slowed. If the available steamship capacity were kept, as the basis of using oil as bad as could possibly be supplied, it would be a major advantage to the diesel fleet, and would represent a fair and proper use of the strengths of each.

From the refiners' view it is a matter of how he allocates the various components into products, and his overall revenue for the fuel pool. The differential between the 'MZ' and the diesel grades has to make the steamship viable in the interest of the diesel operator as well. Without the steam units as a 'sink' for the worst components of the overall pool, proper fuel for diesels will not exist in adequate amounts and at adequate quality. Given a fixed revenue to the producer for the whole pool of marine oils, that fixed revenue needs to be charged to the two types of fuel to give rough parity of cost between the methods of propulsion, or steam will continue to decline and worsen the fuel situation for diesel.

With hindsight, it could be argued that the diesel has had a temporary fuel advantage over steam which could not be expected to go on forever; just as, on shore, fuel oil was cheaper than coal for a time despite its convenience premium. Such pricing inequilibria cannot really last.

MR H E TUNE, Fellow I Mar E: Whilst associating myself whole-heartedly with the thanks afforded to the Standards Committee for their important work, the points made in discussion on the need for flexibility and co-ordination are so important in my view as to warrant a short contribution, if only to add the maximum weight to this sector of opinion.

Standards obviously must be fundamental criteria, but in the final event practical solutions must be based upon a tripartite co-operation between suppliers, engine builders and operators. This is fundamental if we are to achieve the most economic and cost-effective systems of using the lowest acceptable grades of oil and in the least consumptions.

From the operators' point of view, in new tonnage certainly and some conversions, this will be essentially a scene of 'horses for courses'. The range of options in both graded fuel qualities and machinery capability will require to be kept sufficiently open to enable the most commercially efficient decisions to be made on the owners' ultimate choice.

The points made by both Mr Hodgkin and Cdr Short are of importance. Whilst recognizing the suppliers' problems, probably the major issue in any success in this joint exercise will lie with the maximum local information on important characteristics given to the ships at the time of bunker life. In future this will mean much more than we have been used to receiving in the past.

As operators, we appreciate the problems but we are fully prepared to play our part. If we know what we are getting then we can contribute. I would suggest that, without the contribution of the operators, success towards the future economies we all desire must be significantly inhibited.

The oil companies are earnestly requested to apply equal endeavours to these requirements.

Author's Reply

INTRODUCTION

The author thanks all those who contributed to the extensive discussion. To a great extent the contributors endorse the fact that the development of a marine fuel standard is a complex issue, and that all those concerned need to face up to the compromises required for the reality of such a standard.

It must be remembered that the production of residual-based fuel oil in a refinery is essentially a matter of selective blending of available fractions, rather than of special processing to meet specific residual-based fuel oil requirements. The objective is to meet the many, often conflicting, quality requirements of the various grades, and at the same time use up all the residual materials for which no other use or process is applicable. Such residues include not only those from crude oil distillation, but also high boiling products from catalytic and thermal-cracking processes and surplus fractions removed during the refining of lubricating oils.

PRICE FOR THE DIFFERENT GRADES

Mr Hilland raised the interesting issue of the price of the different grades as one moves across the alphabetic scale. This cannot be considered without reference to the availability of grades at different ports on a world-wide basis. At present, the grade range for the marine market embraces gas oil through to the heaviest residual fuels.

This range covers diesel oil and also the intermediate viscosity residual fuels.

In the case of diesel oil, this may be a pure distillate fuel or a distillate with a small proportion of residual, and is often referred to as a black diesel or blended diesel oil. The intermediate viscosity residual fuels have various common terminologies, which include light marine fuel oil, thin fuel oil, and inter-fuel (IF). The maximum viscosity at any port may be referred to variously as marine fuel oil (MFO), bunker fuel oil, and bunker C fuel.

In order to illustrate availability of a particular grade, three ports have been selected at random as shown in Table DI. These particular grades have then been related to the parameters given in Table II, with the results of bunker availability compared to the specification shown in Table DII.

It is not anticipated that specification to the parameters given in Table II will impose any price penalty on the shipowner or any availability restrictions.

The marine market alone does not determine the price of a grade at a particular port. This is set by market forces on the two extreme grades that are used in the production of any grade of marine fuel oil. On the one hand, there is the good quality distillate which is used in the land and air transport industries. The other extreme is the heavy residual fuel which, besides finding application in the marine industry, is also used for power generation and other industries. These other industrial requirements, which in total are larger than the marine fuel requirement, set the extremes of price. In general, the cost of inter-fuels at any port is a direct reflection of the price of the extremes at that port.

The actual price of marine fuel fluctuates in response to market forces. These fluctuations are probably greater than in most other markets, and result in price differentials between grades which are in no way reflected by any significant quality variations.

From these observations of what is rather a complex matter, it should be appreciated that the same factors will continue to influence prices in the marine market, and that the adoption of the standards should have no significant effect on prices.

Mr Hodgkin sought an indication of the price difference between MJ and the superior grades. For the reasons given above, it is likely that the difference would vary at different ports. Hence it is considered wrong to indicate any value of percentage difference.

Table DI: Bunker availability at three random ports

Current grade range	Typical availability		
	ROTTERDAM Avail.	DURBAN Avail.	WELLINGTON Avail.
Gas oil	✓	✓	✓
Diesel oil (distillate)	✓	✓	✓
Diesel oil (blended)			✓
cSt at 50°C:			
30	IF	IF	
40		IF	IF
60	IF	IF	
80		IF	
100		IF	
120	IF	IF	MFO
150		IF	
180	IF	MFO	
240			
280	IF		
320			
380	IF		
420	MFO		
460			

STABILITY AND SEDIMENT OF RESIDUAL FUEL

In the process of blending a particular grade of residual fuel, the properties of the blend are determined by the proportion and source of each of the components used in the blend, particularly with reference to stability and sediment.

Stability of residual fuel may be defined as the ability of a fuel to remain in an unchanged condition despite circumstances which may tend to cause change; or, more simply, as the resistance of an oil to breakdown. Conversely, instability would be the tendency of a residual fuel to produce a deposit of asphaltic or carbonaceous matter as a function of time and/or temperature.

Mr Roberts refers to the different methods of residual oil production. It is agreed that, by the processes described, the stability results of the blends would be different. Further, he makes reference to the ASTM method D1661. This test method is entitled 'Thermal Stability of U.S. Navy Special Fuel Oil', and the scope covers the determination of the preheater fouling characteristics of the fuel classified as Burner Fuel Oil—U.S. Navy Special.

For the test, the fuel sample is in contact for 6 h with the surface of a steel thimble, which contains a sheathed heating element. At the end of the test period, the thimble is removed and examined for sediment formation and discoloration on the surface. The test method gives three thimble ratings, namely, stable, borderline and unstable. Unfortunately the result is qualitative, and not quantitative, and it is essential that any criteria in a proposed specification can be determined quantitatively. The method is not widely used, and few laboratories are equipped to carry it out.

Other means exist for the estimation of stability, besides the ASTM method D1661 which is considered as a heater test. These other means are flocculation and hot filtration tests. It is considered that none of these tests, which are in-house methods, are sufficiently reliable for a more general and wider use. The ideal test for fuel oil stability has yet to be developed. In the meanwhile, the methods referred to can be, and are, successfully used in the fuel manufacturing process to ensure that available fuels will be stable before and after delivery.

While the consequence of residual fuel oil instability is the flocculation of asphaltenes into 'sludge', there are other far more common 'sludges' resulting from different causes. The most common is an emulsion of oil and water; but, separately or together with this, can be found various combinations of gums, resins, free carbon, sand, dirt and tank scale.

Traditionally, the oil refiners have closely controlled the asphaltene 'sludge' level by use of their in-house laboratory test methods. These methods have been based on either filtration or centrifuge techniques.

With the filtration technique a sample of fuel is filtered hot through a filter paper or an asbestos mat. On the underside of the filter paper or asbestos mat, a vacuum is applied. Air pressure is applied from above at approximately 5 bar to force the sample through the filtering medium. When carried out by personnel trained and experienced in the method, there are no reservations about its use or adequacy. However, it is recognized that there could be problems when used by inexperienced people.

The alternative in-house technique is the heated centrifuge test. This test, however, has been applied mainly to examine the sludging effect of fuel oil and distillate mixed together, where the test sample is of relatively low viscosity and moderate temperature.

It was recognized by the sub-committee that it was important to have a standard method of test which would determine the amount of sludge, present in residual fuel, that potentially could be separated at filters and in centrifuges. Initially, it was envisaged that a test method could be developed in laboratory-type centrifuges, and that this would be done by alteration of the temperature or centrifuge procedure, to determine whether sediment separation could be achieved with the range of viscosities as shown in Table II. Further, it was also envisaged, if this was successful, to correlate the results obtained from laboratory-type centrifuges with marine-type centrifuges; also that consideration should be given to an additional investigation of a filtration method.

The request for the development of a suitable test method was made by the sub-committee to the Institute of Petroleum. It is gratifying that the urgency of a suitable test method is appreciated by that body. The findings of the panel to date have been to discard the centrifuge technique, because of the centrifugal forces that would have to be imposed on laboratory glassware to simulate the marine centrifuge.

Table DII: Bunker availability at three random ports related to proposal

Current grade range	Typical availability					
	ROTTERDAM		DURBAN		WELLINGTON	
	Avail.	Spec.	Avail.	Spec.	Avail.	Spec.
Gas oil	✓	Other	✓	Other	✓	Other
Diesel oil (distillate)	✓	MB	✓	MB		
Diesel oil (blended)					✓	MC
cSt at 50°C:						
30	IF	MD	IF	MD		
40			IF	MD	IF	MD
60	IF	ME	IF	ME		
80			IF	ME		
100			IF	MF		
120	IF	MF	IF	MF	MFO	MF
150			IF	MF		
180	IF	MF	MFO	MF		
240						
280	IF	MG				
320						
380	IF	MG				
420	MFO	MH MJ				
460						

By close co-operation, the filtration technique has been developed into a simplified form when compared to existing apparatus. Modifications have led to elimination of the applied air pressure, with only a vacuum applied below the filtering medium. It is anticipated that an agreed test method for total existent sediment will be available by early 1982. As the method continues to be developed, a wide range of fuels will be examined and, from this work, limits could be set for this test method.

When the total existent sediment test method has been agreed, it is possible that further work will be required for a test method that takes into account the ageing of the oil. If such a test method is found to be necessary, it would indicate the potential sediment.

COMPATIBILITY

The possible problem of incompatibility arises when residual fuel oils are blended, using residues from different sources with diluents or 'cutters' which, although stable on their own, when blended together could give rise to instability. It is intended that the total existent sediment test method will ensure stability of individual components in a specific fuel delivery. The sub-committee is of course aware of the spot test (compatibility of Fuel Oil Blends by Spot Test ASTM D2781).

This method gives a qualitative rating for the compatibility of a residual fuel oil with a specific distillate fuel, and is valid for predicting the compatibility of the two components in the blending of light intermediate fuels. Although two samples of fuel may be compatible with the specific test distillate, it does not necessarily follow that those two samples would be compatible when mixed together. If the test is carried out by an unskilled analyst, it is possible that a higher reference number could be observed because of the effect of wax and asphaltene deposition at room temperature.

Commander Short suggests that a reference fuel should be developed for testing residual fuels for compatibility. Since residual fuels originate from different sources and processes, it would not be practicable to specify or produce such a fuel that would be applicable for an international test method. Even if such a reference fuel were possible, it is difficult to visualize how a quantitative test method could be developed as the oil supplier has no control over the type or origin of the marine fuels previously bunkered.

BUNKER DELIVERY NOTE

Several contributors from various parts of the industry have referred to a bunker delivery note, and hence the subject is worthy of examination, bearing in mind the basic triangle of supplier, shipowner and designer.

With adoption of the proposed specification, it is envisaged that the supplier would supply bunkers to the grade ordered, subject to availability, and that indication of the grade designation on the bunker delivery receipt would be a confirmation that the fuel delivery was within the limits of the specification for the ordered grade. Such a statement would be a significant step forward from the situation at present where the amount of information, recorded on a world-wide basis on suppliers' bunker delivery receipts, is variable. While the ordered viscosity, together with the actual delivered viscosity, density, water and flash point is given in the majority of cases, there are many omissions. Moreover, the inclusion of additional quality information is less frequent.

Some shipowners consider that the provision of a bunker delivery note provides confirmation that, by having an analysis of the fuel delivered, this provides assurance that the delivery meets the grade specified. Also, that with knowledge of more of the properties of the actual fuel supplied, adjustments may be made to reduce the possibility of operational problems with the machinery.

The designers of machinery systems, of whatever type and configuration, also seek information to improve their knowledge of the fuel being burnt.

Provision of a detailed bunker delivery note, available on completion of delivery, is an impracticable solution which could incur significant cost penalties to the shipowner. By the existing infrastructure arrangements at bunkering terminals, the required grade is not necessarily prepared before arrival of the vessel, and is sometimes blended just prior to delivery over the ship's rail. Hence any analysis of the fuel could not commence until delivery had started. Even if this was the case, the analytical data would only be a limited estimate of the delivered fuel quality. For a realistic analysis this would have to be carried out after delivery had been completed, on a sample which is representative of that delivery.

Analysis in the laboratory takes several hours, assuming that there is no delay because of the commitment of staff to other work. If there is a laboratory in the vicinity of the bunker terminal, this analysis may or may not cause delay to the vessel's departure. It is well known that such facilities only exist adjacent to a few terminals.

Hence the only way an analysis of the delivery could be provided would be by the establishment of, or access to, laboratories with suitably trained staff available on a 24-hour basis at every bunkering station in the world. The cost of such an operation, leaving aside the time in setting up such an infra-structure, would be considerable. This cost obviously would have to be reflected in the price of the product delivered. Also, if the shipowner was insistent on receiving the information prior to sailing, the departure time might have to be delayed. Such a delay would also be an additional cost to the shipowner.

For the majority of steamships, the shipboard treatment plant is rudimentary, often consisting only of filters and a heater. It is considered that analysis of the actual fuel delivered would only be of academic interest to the personnel on board, with respect to the efficient operation of plant in their charge.

All motor vessels have some form of fuel treatment arrangement, albeit sometimes only a filter in the case of a machinery system operating on distillate fuel. For those systems operating on residual fuel, the treatment system between the bunker tanks and machinery arrangement depends on that specified by the shipowner at the time of building, or that offered by the shipyard against a standard specification.

Whatever arrangement is fitted, the shipowner expects the equipment to be operated by his staff at maximum effectiveness. Given this premise, it is suggested that exact analysis before consumption of the fuel, above that already basically provided, will not assist the ship's staff in any material way in increasing the operational efficiency of the plant in their charge.

Knowledge of the fuel's density is essential in the selection of the correct gravity disc for a centrifuge operated as a purifier. The value of the viscosity determines the handling temperature for transfer, and is also necessary in order to establish the approximate temperature for atomization from the viscosity/temperature chart if automatic viscosity control is not provided.

With respect to pour point, it could possibly be argued that knowledge of this figure could be useful in determining the minimum amount of heating required for storage. If the fuel has a high pour point and is stored at temperatures considerably below this, there could be a possible danger of wax deposition. All of this wax may not always go back so readily into solution when the temperature of the bunker tank is raised to reduce the viscosity to a level for pump transfer.

As the author is not aware of any machinery system at present at sea which has a control loop related to carbon residue, this information is thus not of direct interest to the ships' staff from the operational viewpoint. It is acknowledged that some engines are able to operate satisfactorily at high load with a high carbon residue fuel, but have some operational difficulties in the low load condition.

Knowledge of the exact sulphur level could, in theory, allow some variation in cylinder lubrication to some engines. However, it is considered unpractical for ships' staff to change the cylinder lubrication to obtain a variation in the total base number (TBN) of the cylinder oil to match fuel sulphur variations. The amount of sulphur has a significance in calculating the specific energy of the fuel by empirical means.

A value of the actual sediment level in theory could be related to the actual desludging interval on a centrifuge.

An exact value of any water in the fuel, as long as it is below the contractual limit, is only of academic interest to the ships' staff, as there is no further action that can be taken once the centrifuges, if fitted, have been set. In any case, water can be easily and cheaply measured on board.

Information on vanadium may be of interest if the shipowner has supplied additives to the vessel for this purpose. As such additives are likely only to be supplied to machinery arrangements which are sensitive to this oil-soluble contaminant, the consequences of variable dosage—with the possibility of underdosage—could be more severe than the theoretical cost saving by dosage reduction under certain circumstances. Also, few laboratories are fitted with the sophisticated and expensive equipment necessary to determine vanadium.

A knowledge of flash point could be useful in certain circumstances, and this parameter is considered under a separate heading.

For the shipowner, analysis of the bunkers may possibly provide information that can influence the vessel's maintenance or inspection procedures.

All information on bunkers and feedback from operating vessels is useful to machinery system designers, in their desire to produce arrangements to meet the changing needs of the market-place. In any of the proposed grades of fuel there is an infinite number of combinations; knowledge of these, through fuel analysis with service experience, may help the designer to determine where his research resources, which are not unlimited, should be applied to improve his product.

On balance, it is suggested that shipowners will not wish to pay the additional cost and possibly incur delay in order to have an immediate full fuel analysis on their bunker delivery note. However, some may wish to have an historical analysis made to further their knowledge on the actual fuel received by their vessels. How this historical analysis is performed and what actions they then may take is their choice. It is important that any such analysis is carried out by accepted test methods and that all the results are quantitative.

SUITABILITY FOR PARTICULAR ENGINE SYSTEMS

In general, no attempt has been made to define suitability of any grade for particular engine systems. This course was adopted because of the wide diversity of engines and systems. From the discussion, it was clear that some contributors were concerned as to the proposed levels for some of the parameters, particularly carbon residue and vanadium. The levels proposed are a maximum, and in many cases there is a difference when compared to the current recommended values by various engine builders.

It is suggested that the reason for this is that the engine builder is making a recommendation based on actual qualities used during long service experience. Within these often conservative levels there is a record of good service experience. At the limit values for the various grades the engine builder currently has little or no experience, as the limiting values are at present only approached in a minority of fuels bunkered, or in fuels especially prepared for development purposes. This does not mean that these fuels are not applicable to all installations. It is for each engine builder to determine recommended limits and maximum limits for each engine configuration.

CARBON RESIDUE is generally considered to give an approximate indication of the combustibility/deposit-forming tendencies of a fuel. This parameter is not an indicator of how the fuel begins to burn, and hence cannot be linked with ignition quality, i.e. it is not an overall measure of combustibility. The difference between the conservative limits of some engine builders, and those proposed in Table II, reflects the present lack of long-term service experience with fuels containing high levels of carbon residue. Often it would appear that the concern is not the effect upon the engine at the full load condition, but rather the effect on some existing designs under low load operation.

The effect of VANADIUM in combination with sodium and sulphur results in two problems; namely, on the one hand, that of salts which are formed, resulting in deposits, and on the other that of the high-temperature corrosive effect. The temperature levels for these two potential problems are quite different. If the temperature of the exhaust valve and turbine blading is maintained below the critical melting temperature of certain sodium/vanadium complexes, deposits cannot adhere to the surfaces, and hence in this respect it is irrelevant as to the quantity of vanadium in the fuel.

As far as the corrosive effect is concerned, it is logical to expect this to be greater the higher the level of vanadium, although the melting temperature of the sodium/vanadium complexes would be expected to have an influence. By suitable design and selection of materials there is no reason why the intervals between inspections or overhauls should be any different from those used on distillate fuel engines.

LEGAL ASPECTS

Both Mr Hilland and Mr Williams referred to the legal aspects of bunkering. This is a complex subject because of the numerous legal systems under which bunkers may be supplied. Under most legal systems it is understood that a bunker contract is a 'contract for the sale of goods'. But the interpretation of such a contract, in the event of a dispute, depends on the jurisdiction under which the contract was made.

Under English law, the rights and liabilities which arise from the supply of bunkers are similar to those associated with any contract for the sale of goods. Apart from instances of fraud, the customer gets what he asks for—save that the doctrine *'caveat emptor'* (buyer beware) is tempered by the Sale of Goods Act 1979. This Act protects the customer as to the product's merchantable quality, fitness for purpose and answerability to its description. Adoption of the proposed specification would more clearly define the fuel, and would be far more useful in cases of dispute than the present method of contracting residual fuel by viscosity alone.

In the case of a time charter, it is usually the charterer who agrees to provide and pay for the bunkers supplied to the ship for the duration of the charter. The supply may be arranged under a worldwide contract with an oil company or be made from the 'spot' market. The bunker agreement is betwen the time charterer and the oil supplier, not the shipowner. The grade of oil to be provided should be equal or better than that agreed when the charter is fixed. By stating in the charter party an internationally agreed grade of fuel, the sometimes tortuous legal issues surrounding 'bad' bunkers and charter parties could be significantly reduced.

Under other jurisdictions different laws and codes are applicable, and the effect of each would require detailed study by legal experts. The meaning of any quality disclaimers included in an oil company contract would also require legal study, and may have different interpretations under various jurisdictions.

SPECIFIC ENERGY AND WATER

Mr Tam suggested that the energy content of each grade should be defined. Such definition for ease in the specification could only be carried out by applying the empirical formula given in Appendix 2. The inclusion of this minimum energy content would not enhance the specification in any material way. Further, it is unlikely that a fuel would be delivered which contained maximum density, water, ash and sulphur; hence the fuel delivered would be of a higher specific energy.

From Table II and application of the empirical formula in Appendix 2, the minimum energy contents of grades MG, MH and MI could theoretically be the same. The fundamental difference between these three grades is one of viscosity. Variation of viscosity has a price consideration as already described, and therefore there is no reason why the shipowner should be overcharged, when the parameters of the fuel are considered in their entirety. For these heavy grades, the limitation for the shipowner will probably be the bunker heating capability of the vessel.

The proposed values with respect to WATER content for grades MD–MJ inclusive are the same as those traditionally accepted by the marine market, and other markets which use residual fuel.

DENSITY AND POUR POINT

For grades MD–MI inclusive, the maximum value for DENSITY of 0.990 at 15°C was determined by the current technical limitation related to the need to operate centrifuges in the purifier mode. It has been suggested that possibly the density limit could be set at a higher level. Commander Short made reference to a solution of Epsom salts being used as the sealing medium in the purifier. Such a method has been demonstrated and shown to work, but the author is not aware that such a system is offered commercially by the manufacturers of centrifugal separators. If, and when, such methods become commercially available, consideration can then be given as to the revised technical limit.

Residual fuels in general, with the exception of those of low viscosity, may be considered as dependant on viscosity and not POUR POINT with respect to handling on board. Namely, the temperature necessary to reduce the viscosity sufficiently for handling purposes is higher than that of the pour point. It should be appreciated that, like many of the other residual fuel constituents, wax is a parameter that depends on crude oil quality and refinery process. Unfortunately, there is no economic process for its removal; it does, however, have a good heat content and combustion characteristics.

Mention has been made of pour point depressants, which are incorporated into some fuels by the supplier. However, the response of a fuel to a pour point depressant depends very much on the type and amount of wax present, and careful control of the blending of the depressant is required. The depressant, a wax crystal modifier, tends to prevent the growth of a three-dimensional network of crystal throughout the oil when it is cooled.

For distillate fuels the depressant usually is based on ethylene/vinyl acetate copolymers. In the case of residual-based fuels which are more complex in their structure, it is not considered that pour point depressants are suitable for shipboard application, although these materials are successfully used in the refinery.

FLASH POINT

The flash point control of a fuel provides protection against fire and explosion risk, and its value can be materially altered by the addition of small amounts of volatile fuel. In determining the minimum value for this characteristic, due account was taken of the various international and national statutory requirements. Hence, a minimum value of 60°C is proposed, this value being applicable for grades MB–MJ. It must be remembered that residual fuel, besides finding application within the marine market, is also used in the inland market, which is subject to its own legislative requirements.

Mr Rhoden in his contribution states the operating difficulty in passenger ships which have settling and service tanks, and centrifugal separators with open drains. The author would agree with this statement when applied to the heavier grades given in Table II. Unfortunately, there is not a relationship between the flash point and the viscosity of a particular grade.

The actual value of the flash point in the majority of bunkerings is determined by the flash point of the diluent, used in conjunction with the base residual material, to produce the required parameters of the grade. The characteristics of the diluent are variable on a worldwide basis. Use of highly volatile material is not possible as inclusion of such product would result in a flash point below the legal minimum.

Inclusion in the specification of a flash point higher than 60°C would overcome the operational difficulty of high viscosity fuels with respect to open drains. However, it is considered that the specification of a higher figure would not be practicable. This is because residual fuel is supplied to other markets, and that a higher figure would limit the type of diluent employed in the fuel production process. The net result would be a restriction of availability of fuel to meet this requirement.

It is concluded that each shipowner, with his knowledge of his particular fuel handling and treatment system, must determine for himself any changes that may be required in order to burn the various grades of fuel, to meet the various legislative requirements that are applicable to flash point.

For those shipowners who wish to consider use of a more viscous grade than that for which the vessel was designed, various parameters must be the subject of techno-economic evaluation. Amongst the factors which would require examination are the heating capability in the bunker tanks; possible provision of trace heating on the transfer lines; and effective draining of the lines after transfer. Also, the suction performance of the transfer pump should be examined, and, if a significant change in viscosity is envisaged, consideration may have to be given to operation of the transfer pump at a lower rotational speed.

METHODS OF FUEL ANALYSIS

It was suggested in the discussion that a fuel analysis spectrometer, which has been fitted to at least one gas turbine ship, be provided at individual bunkering stations. This type of equipment, it is understood, is capable of analysing content in fuel of up to six metals, with a tolerence of 0.5 mg/kg. The cost of this equipment is not insignificant; further, it must be remembered that the method used is not an internationally accepted test but is comparative.

Mention has also been made of gas–liquid chromatography, which is an analytical method for determination of the type of hydrocarbon structures that are present in a fuel. By this method, an assessment can be made on the combustion qualities of a fuel. The results obtained by gas–liquid chromatography, gel permeation chromatography and high-performance liquid chromatography are of interest to research workers, but are not considered to have a role in the development of an international standard.

RESPONSE TO PROPOSAL

The implementation of any proposal depends on the amount of commitment of the parties concerned. It was the General Council of British Shipping who were responsible for the initiation of this work. Their representatives consider the proposal which is principally directed towards future fuel quality, and, with this proviso, consider that Table II has achieved a measure of agreement. It must be remembered that today there are fuels in the market place with a viscosity of 380 cSt at 50°C, CCR 18–19% by mass, and vanadium 550 mg/kg.

In preparing the proposal the sub-committee has taken into account the aspect of future predicted availability, and it is appreciated that, for some of the lighter residual viscosity grades, some owners may wish to request lower limits at the time of ordering a particular consignment of fuel. The fuel supplier at that bunkering station will then be able to advise the availability of such a fuel.

As we move forward in the future, an increasing amount of secondary refining processing will be used in certain geographical areas. Also, it is expected that the high vanadium crude oils, such as those from Venezuela and Mexico, will be refined in areas where historically low level vanadium crude oils have been used.

Whilst some would consider the proposed specifications to be not as restrictive as they would like, they must remember that, without any specification acceptable to all parts of the industry, the alternative is to order residual fuel by viscosity—a method which is regarded by many as unsatisfactory.

In conclusion, marine fuel oil specifications which have national and international recognition are of importance to all facets of the marine industry. Their development and implementation must be made intelligently, and with full regard to the circumstances for which they are needed.

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