

The Influence of Modern Refinery Technique on Marine Fuel Oil Quality

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The paper examines the suggestion that marine fuel oils may have altered in quality due to changes in refinery processes, and concludes that modern manufacturing methods favour the production of high quality fuel oils. The consumer simultaneously benefits from superior product control technique.

Consideration is given to the value of the specification tests by which fuel oil quality is frequently assessed, and an account is given of experiments conducted to verify the utility of certain of these tests. A practical study of a fuel oil additive is also described.

The suggestion is made that modern oil burning practice is more demanding than previously.

INTRODUCTION

It is the prerogative of the middle-aged to refer in laudatory terms to "the good old days", even in the case of so progressive a community as the petroleum industry, which after all is less than 100 years old even now. One hears glowing references to things as they were less than a generation ago. Even in the proceedings of this Institute the fuel oils of the early 1920's have been praised in comparison with those available in latter years.

It should perhaps be stated in parenthesis that this paper deals in the main with the conventional use of fuel oil for underboiler purposes. The employment of bunker fuel oils in motor ships has been widely discussed in other communications to various learned societies and will, therefore, receive only minor consideration here.

When "modern" fuel oils are under consideration it is perhaps natural to be influenced by what one knows or has read of developments in refinery technology in the years between the 1920's and 1950's. It is easy to praise the straight run Mexican fuel oils of thirty years back while at the same time forgetting their high viscosity and sulphur content, and frequently very high ash formation. Rather does the layman tend to remember that modern developments such as cracking have increased the percentage of gasoline which can be obtained from crude oil, following this thought with the excusable assumption that the lesser quantity of fuel oil obtained from the crude has deteriorated in quality due to the withdrawal of the "more valuable" hydrocarbons.

Examine this assumption a little more closely. What in fact has happened in these thirty intervening years? In the first place there has been a phenomenal shift in the location of the main oil producing areas of the world. At one time these were almost entirely in North America and in the Caucasian areas, but the period after World War I saw the latter replaced in importance by Mexico and a few years later still by Venezuela. In the last decade or so an even more remarkable change has occurred in the balance of oil power and now the Middle East is second only to the U.S.A. as a producing centre. These various changes have had certain effects upon marine fuel oil quality and even more worthy of consideration is the effect of improvements in refinery treatment and technique.

REFINERY PROCESSES—DISTILLATION AND CRACKING

Up to about forty years ago practically all the fuel oil on

the world markets was produced by straight distillation of crude oil, the residues of varying viscosities and other characteristics being sold for steam raising and allied purposes. In 1912, however, an important change took place. Burton introduced the first thermal cracking process, quickly followed by Cross, Dubbs and others, with the ultimate development of the thermal cracker as we know it today.

The object of cracking is to break down complicated hydrocarbons of high molecular weight into others of low molecular weight and different physical and chemical characteristics, which in this case means the production of more gasoline. Later on it was found that the motor spirit thus produced was of better quality, i.e. of higher anti-knock value, than many of the old straight run gasolines of similar distillation range. The cracking process, therefore, became a tool to improve gasoline quality just as much as to increase its quantity. Now these cracking processes did not end with the production of gasoline—other materials were manufactured, including fuel oil and certain distillates of a somewhat aromatic and olefinic character. It must be admitted that in the early days of cracking some of these distillates and residues were not entirely satisfactory; for that matter neither was the gasoline, and many years of experimentation and research went into the improvement of these processes in order to ensure that the products which were made would retain their characteristics and not deteriorate with age or when in contact with certain materials.

In the meantime, however, the seeds of doubt were sown; largely, no doubt, by the very unfortunate choice of terminology. A cracked teacup is very much less desirable than an unsullied new one—one might, therefore, reason that a cracked gasoline with a rather unexpected odour is surely less satisfactory than one prepared by a simple conventional distillation process. Cannot, therefore, cracked gas oils and fuel oils also be expected to have some undesirable properties? In fact many investigators were at some pains to point out how in theory such materials *must* be inferior. In 1935 Dr. H. H. Blache of Copenhagen surprised many of his contemporaries by assuring them that cracked Diesel fuels resulted in cracked pistons, a challenge which was energetically taken up by J. J. Broeze in "Gas and Oil Power" in April 1936. If cracked gas oils were undesirable, then cracked fuel oils, being the "bottom of the barrel" must be even more so—or so some were prepared to argue, without, always, much in the way of practical or scientific data.

In the author's view, cracked fuels started off under the distinct disadvantage of a nomenclature which automatically invited suspicion. This suspicion was heightened and in fact

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confirmed in the view of many people by operating difficulties resulting from the early use of these fuels. It is realized now, of course, that changes in chemical constitution lead to variation in the speed of combustion of the products concerned and, if due allowance is made for this, whether in a motor car engine, a marine Diesel engine, or in a fuel oil burner, the effect of such chemical change can be largely nullified. It may even prove to have an advantage. To take only one sample case, the higher specific gravity of the "unsaturated" hydrocarbons found in cracked fuels resulted in noticeably higher calorific values on a volumetric basis, the result being apparent as more miles per gallon or as lower volumetric fuel consumption. Thus the low specific gravity paraffinic gasolines of 1914 would not be suitable for the market today, quite apart from their poor anti-knock characteristics.

There has been a tendency to associate cracked (unsaturated) fuels with instability in one form or another. Stability is a term capable of many definitions but from the point of view of the marine engineer it can be said that a stable fuel oil is one which does not deposit undue quantities of undesirable organic material in tanks, lines, or heaters. Some of the fuel oils produced from the older thermal cracking process, by reason of too long a residence time in the cracking plant (and sometimes for other reasons) were not in conformity with this rather simple definition of stability. Sometimes these fuel oils did throw down heavy carbonaceous deposits. At other times, even if a fuel oil were in itself stable, it might show incompatibility—that is to say, on mixing with another grade (as in the case of bunkers taken into a ship's tank already containing some other fuel), sludge would sooner or later be formed.

It would probably be fair to say that before 1930 there was comparatively little organized knowledge regarding the factors which resulted in fuel oil instability, nor of the means which could be invoked to suppress it. It so happened that the amount of cracked fuel oil at that time was relatively small and the actual cases where practical problems developed were few. Nevertheless it was evident that such cases might become more frequent unless something were done to correct the situation, and the petroleum industry found itself faced with the need to devise a scheme of refinery operation which would minimize the tendency towards sludge deposition. From early on it was found that there was a very definite influence exercised by the manner and order in which blending operations were carried out in the refinery to produce the finished grade. Many modifications were carried out in the cracking processes themselves in so far as the temperatures, pressures, rates of throughput and so on were concerned in order that the resultant products would be stable even when subjected to the various heating stages which fuel oil has to go through, not only in the course of sea transportation but also in storage and immediately before use.

By the beginning of World War II the teething troubles associated with the production of underboiler fuel oils by thermal cracking processes were a thing of the past. However, with the operation of the first commercial catalytic cracking unit in 1936 and the subsequent rapid exploitation of this valuable new tool under the stimulus of global warfare, it is not surprising to find a similar attitude of disquiet and a revival of old fears among some oil fuel users.

It is a fallacy to suppose that the tendency to equip new refineries with catalytic cracking rather than with thermal cracking will result in a sudden fundamental alteration in the properties of marine fuel oil as known today. It must be borne in mind that only a minority of the refineries in existence are equipped with catalytic crackers. In fact, outside of U.S.S.R. and the satellite countries, there are at the moment something like 600 oil refineries, large and small, known to be in operation, but only just over 25 per cent of these (about 160) have catalytic cracking units. In the case of Europe, where there are some ninety refineries, the number of catalytic crackers, including those in the United Kingdom, is eighteen, or 20 per cent.

Such figures, however, do not give the complete picture,

since where new cracking facilities are being built, the emphasis is markedly toward catalytic units, with the result that new capacity planned for the next few years indicates that catalytic cracking will rapidly overhaul thermal methods. Nevertheless, even where catalytic crackers have been built, or are planned, the essential basic processes of straight distillation and, to a large extent, thermal cracking, will exist concurrently and it is the "traditional" residuals from these processes which are likely to form the basis of marine fuel oils for years to come.

The aim of catalytic cracking is essentially the same as that of thermal cracking, i.e. the production of more gasoline from each barrel of crude oil; and this is done, as with thermal cracking, by breaking down large molecules into smaller ones more suitable as motor and aviation gasoline components. The resultant gasoline is obtained in greater yield and, what is more important, with higher octane number than by the method of thermal cracking.

There has been criticism, in some uninformed quarters, that if more and more of the top class products are "taken out of the crude", then what is left must be of steadily deteriorating value. As it happens this is very much a mis-statement of what actually takes place.

First of all, the feedstock to a catalytic cracker is a distillate, prepared by a conventional straight distillation of the crude. In this the crude is topped to produce, in addition to the normal light distillate products, a vacuum distillate of more or less heavy lubricating oil consistency and a viscous straight run residue. Catalytic cracking of the distillate produces, in addition to gasoline components, a certain amount of cycle oil, which is an "aromatic" distillate with viscosity about that of Diesel fuel. This cycle oil is an extremely valuable fuel oil component, for in addition to its normal properties as a cutter stock (i.e. to reduce viscosity), its chemical nature makes it an excellent peptizer or stabilizer for asphaltene containing residues. In fact, by its use, the risk of producing an unstable fuel oil is practically negligible. It might be noted here that such a blend is not a "catalytically cracked fuel oil"—it is the loose terminology and not the fuel oil which is at fault!

Now what about the residue from the catalytic cracker, the so-called "bottom of the barrel"? This is simply coke—and this is burned in the process itself. In other words, the catalytic cracker produces no residue comparable with the liquid residue of its thermal counterpart, but, as mentioned earlier, a straight run residue is obtained during the operation of preparing the catalytic cracker's feedstock, and it is this residue, to the extent which it remains after the refinery's own needs for fuel have been satisfied, which is blended off into commercial fuel oils.

THE MODERN REFINERY

This brief survey of refinery processes in so far as they directly affect fuel oil production, introduces the main theme, the influence of modern technique on marine fuel oil quality.

The modern integrated refinery is a huge chemical workshop concerned with the manufacture of a number of products, ranging from liquefiable gases, industrial solvents and (quite often) chemicals on the one hand to the more conventional liquid fuels, lubricants and bitumens on the other. No longer does the refinery merely "fractionate" the crude as was the case when the only tools available comprised distillation and solvent extraction techniques. Instead, the original material is completely transformed, many of its constituent parts being broken down and their molecules remade to give completely different products, generally better suited to the job than those they replace. Thus, in the literature of production technology, are found such terms as thermal cracking, catalytic cracking, catalytic reforming, catalytic dehydrogenation, hydrofining, catalytic polymerization, thermal reforming, vis-breaking, isomerization, cyclization, etc. The more exacting the performance required of an individual product, the greater in general is the degree of chemical transformation of the base material (and, of course, the higher the cost to producer and consumer).

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It may be asked what is the overall effect of this radical change in manufacturing technique on fuel oil quality?

In the first place, it would be idle to pretend that degradation products of one kind or another do not result from the complexity of operations carried out within a modern refinery. There is a significant volume of liquid combustible material, including extracts from specialized refining processes, which does not conform with the conventional standards of commerce. So long as this material is combustible, it is consumed in the refinery's own furnaces.

Here, then, is the real "bottom of the barrel", the material which does not find its way into market grades of fuel oil. For every 1,000 tons of crude processed, the average modern refinery may be expected to consume about 100 tons of fuel (including gas) and it may be of more than passing interest to indicate some of the properties of the material which such refinery furnaces do in fact have to negotiate. At the Stanlow refinery of the Shell Refining and Marketing Company, the main refinery fuel has a viscosity so high that it is quite immeasurable but it has been calculated from its blending value as having a viscosity of about 10,000,000 seconds Redwood I at 100 deg. F., that is to say about 3,000 times as viscous as the heaviest marine fuel oil grade sold at most European and American ports. This fuel, incidentally, may also contain about 20 per cent hard asphalt, yet it is burned at 80 per cent thermal efficiency in the furnaces to give clear smoke stacks.

Now this fact is of great importance in any discussion on quality. On the one hand, unsaleable material is being consumed to the satisfaction of the refinery engineer. On the other there are the much superior market grades which, in spite of modern improvements in quality, still produce the occasional criticism.

WHAT CONSTITUTES "QUALITY" IN FUEL OIL

It is necessary, therefore, to enquire at this point what is meant by this reiteration of the word "quality". What is it that constitutes good or bad quality in a fuel oil? Unfortunately there is no simple answer. The same fuel used by different operators in dissimilar equipment under varying conditions may give totally different results. The same fuel oil may in fact be regarded by one user as being of excellent quality while another may be dissatisfied. Thus there would appear to be no absolute standards of quality and it is necessary to fall back in the first instance upon a number of arbitrary standards by which the properties of a fuel, and, based upon experience, the effect when burned under certain conditions, can be assessed.

SPECIFICATIONS

One is thus led to a study of fuel oil specifications and their interpretation. This is a subject on which there is a good deal of uncertainty in the mind of the average user. It is a science which as yet he has perhaps only imperfectly studied and there are virtually no textbooks which give him much help, though the subject has been touched upon by the Institute of Petroleum⁽¹⁾.

A true "specification" makes use of various standard tests of a chemical, physical or mechanical nature which have been carefully developed over many years by the petroleum industry. The tests are sometimes quite empirical in nature, but they are generally repeatable within narrow limits if the testing technique is closely followed. The maximum (or minimum) values which are specified for each test comprise the "specification". Consider, then, the points of a specification which are of value to the fuel oil engineer.

THE CONVENTIONAL TESTS TO ESTABLISH "QUALITY"

The most widely used bunker fuel oil specification, whether actually quoted or tacitly agreed upon, is that known as "Bunker C Grade". The usually accepted version of this requires:—

Flash point (Pensky-Marten closed cup)	...	...	minimum 150 deg. F.
Water	...	...	maximum 1 per cent

Sediment	...	...	maximum 0.25 per cent
Viscosity, Saybolt Furol at 122 deg. F.	...	...	maximum 300 seconds
(This viscosity limit is equal to about 6,500 seconds Redwood I at 100 deg. F. or, say, 84 deg. Engler at 50 deg. C.)			

The tests which this specification includes are now considered.

Viscosity

This is a measure of the resistance of the fuel to flow. The viscosity varies with the temperature and as the temperature rises the viscosity of most fuel oils drops rapidly, as will be seen from Fig. 1.

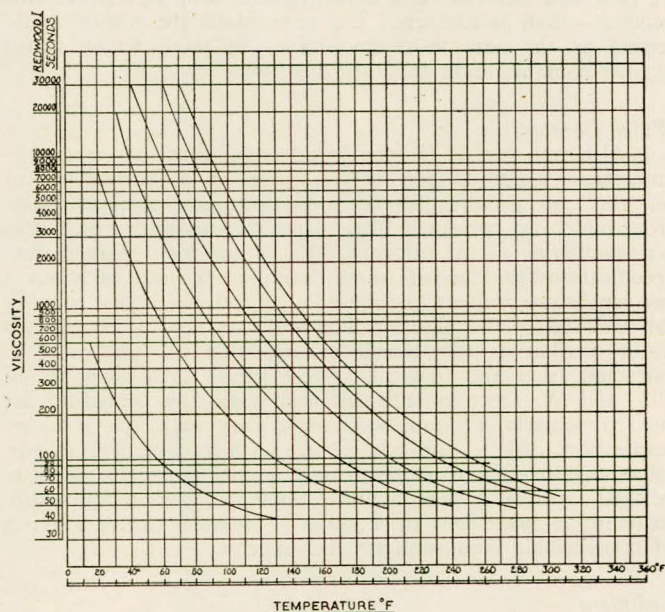


FIG. 1

Viscosity is rightly regarded as being perhaps the most important laboratory test for fuel oil, since it not only indicates the relative ease of handling the fuel in storage but also indicates the degree to which it should be preheated in order to arrive at the correct atomizing temperature, since most burners will operate at their best when the viscosity of the fuel oil lies within a certain predetermined range. All fuel oil specifications will, therefore, normally include a viscosity limit.

In discussing viscosity a uniform reference temperature must be used, and this, in the case of fuel oils, is generally 100 deg. F. or 122 deg. F. (50 deg. C.). The fuel oil with a viscosity of, say, 3,000 seconds Redwood I will be less fluid and, therefore, more difficult to pump than one with a viscosity of 2,000 seconds Redwood I at the same temperature. It does not follow, however, that the same relative result will apply at all temperatures, since each fuel has its own viscosity/temperature curve. Most fuels show Newtonian flow, that is, a linear relationship between shearing stress and rate of shear, but where sufficient paraffin wax is present, however, at low temperatures it may become non-Newtonian, i.e. the viscosity depends upon the shearing stress applied. In the latter circumstances neither the conventional viscosity nor the pour point is a guide to pumpability, since, contrary to the opinion generally held, some fuels are capable of being satisfactorily pumped at temperatures below the pour point⁽²⁾. Fortunately, however, in systems where the oil storage is adequately heated, problems of pumpability due to wax content will not arise and the viscosity genuinely reflects the fluidity of the fuel.

Flash Point

With the object of ensuring safety from fire risk, Lloyd's laid down many years ago that the minimum flash point of oil

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fuels should be 150 deg. F. Any fuel oil giving off vapour which, under the standard conditions of the flash point test, is inflammable below this temperature is unacceptable. However, contrary to the belief held in some quarters, the flash point, except as a safety precaution, is immaterial. The pre-heating temperature is not governed by the flash point, as is fairly adequately demonstrated by the fact that certain bunker fuels with flash points up to 300 deg. F. and even higher are atomized and burned quite satisfactorily at temperatures of, say, 250 deg. F. or thereabouts.

So far, then, there is one test which indicates the ease of handling the fuel and another which demonstrates whether it possesses an ample margin of safety from the fire risk point of view and has not been contaminated with a more volatile product—such as gasoline. The tests which the author would regard as the next most important are those which guard against contamination in other directions.

Water Content

Although one is frequently informed that in certain circumstances up to 15 per cent of water can be burned in fuel oil, this can produce several unpleasant consequences, apart from which no consumer likes to pay for material which does not contribute to the calorific value of his fuel. Bunker fuel specifications as a result usually stipulate a limit of about 1 per cent water content, though as a general rule actual supplies fall well below this figure. The water content is determined by a distillation test which ensures that all the water is extracted from the fuel oil. Some other tests, such as the B.S. and W. (bottom sediment and water) by centrifuge are not particularly accurate and, while they may give a rough impression, can be misleading. Any water contained in fuel oil as delivered from a bunkering terminal is usually likely to be fresh, whereas water obtaining ingress to bunker tanks subsequently is more likely to be saline. Salt water can be a source of considerable inconvenience and expense.

Sediment

Sometimes the figure reported by the centrifuge test for B.S. and W. is referred to as the "sediment" content but this may include many things, including water, and is not really a satisfactory nor closely repeatable test. Generally the sediment content is determined by carefully washing with a suitable solvent (benzol) and filtering off the insoluble matter. The so-called Bunker "C" grade limit for sediment is 0.25 per cent but it is rare in these days for fuel oil with sediment more than 0.1 per cent to be marketed. It will, therefore, be seen that there are fairly strict controls to prevent undue contamination of the fuels as normally put on the market.

Specific Gravity

So much for what may be regarded as the conventional tests for "quality". However, except in the case of pure chemicals it is seldom that with any commodity there is an exactly definable standard of quality; it is rather a case of each knowing what he likes. In the case of marine fuel oils, for example, some users have a theory that specific gravity is a criterion of quality. In actual fact specific gravity alone is almost meaningless since it varies with the chemical constitution of the fuel and this can be in turn affected by the refinery treatment which it undergoes. Thus a low specific gravity of, say, under 0.95 may mean that we are dealing with a medium viscosity fuel oil obtained by distillation from a paraffinic crude; it could be a lower viscosity fuel oil from the straight distillation of a naphthenic or asphaltic crude, or it could be a cracked material or relatively high specific gravity cut back with, say, marine Diesel fuel, again to give a low viscosity. This does not by any means exhaust the possible combinations which may result in either low or high specific gravity.

There is admittedly a connexion between specific gravity and calorific value. With any pair of fuels the one with the lower S.G. is likely to have the higher calorific value per pound

and the other one a higher calorific value per gallon, so any attempt to discriminate by this means will depend to some extent on how the user buys his fuel. What the specific gravity does not do is to indicate the flash point, the viscosity or, in fact, hardly any other characteristic, and thus is not a reliable guide to, say, atomization temperature or pressure.

THE SEARCH FOR "X"

In the foregoing section the tests called for by the "C" grade specification have been examined, and specific gravity has been thrown in for good measure. The marine engineer realizes that these are the accepted tests for quality and are thus the maximum that he can normally expect to have given to him when he takes bunkers. Nevertheless, he finds that some fuel oils suit his ship better than others—just as, with identical equipment and the same fuel any two ships will show differences in consumption, for example. It is not unreasonable that, disregarding for a moment the complications of speed, route, wind, currents, load and other variables which effectively prevent any voyage from being identical with another, he will suspect some unknown factor in the fuel as the cause of unforeseen variations in performance. This may then be followed by a comparison of past with present deliveries and a criticism of modern refinery techniques.

What are the main causes of complaint from an oil-fired steamship? Higher fuel consumption perhaps, "dirty fuel", inefficient combustion resulting in smoke and smuts from the stack. If the suggestion of a dirty fuel is belied by the examination of representative samples showing little or no sediment and water, are there any less conventional tests which will demonstrate why some fuels seem more satisfactory than others? It is this quest for "X", the unknown quantity, which prompts certain buyers to ask for additional test data, the significance of which may be imperfectly understood by user and supplier alike. Consider, then, some of these factors.

Calorific Value

Since the primary purpose of burning fuel oil is to produce heat, one might expect that the most important individual characteristic would be the calorific value. Admittedly with solid fuels there are extremely wide variations in calorific value between one variety and another, but with petroleum fuel oils the calorific value range is so limited that it seldom needs to be considered. For example, it is very unlikely that a delivery of marine fuel oil will have a calorific value below 18,000 B.Th.U. per lb. gross, and until one gets into the Diesel fuel range it is rare that a figure above 19,000 B.Th.U. per lb. will be encountered. Most commercial marine fuel oils, in fact, have a calorific value between about 18,200 and 18,500 B.Th.U. per lb., i.e. a range of only 2 per cent, or one ton in a daily consumption of 50 tons. An increase in fuel consumption aboard ship, therefore, which can be affected by so many other conditions, can seldom if ever be explained in terms of slight differences in calorific value between one delivery and another.

Conradson Carbon and Asphaltenes

There have been many attempts to ascertain a relationship between various empirical tests employed in the oil industry and the combustion characteristics of a fuel oil as represented by its tendency to produce stack solids, and two of these tests, viz. the Conradson carbon and asphaltene determinations, can always be counted upon to start a discussion.

The Conradson carbon test consists of burning, under standard but highly artificial conditions, a small quantity of the fuel to leave a coke-like residue. To achieve this the air supply is strictly limited and while these combustion conditions could be induced, under certain conditions in a Diesel engine, they are most unlikely to arise in marine underboiler practice. The test has found application as a rough and ready guide to the tendency of a fuel to form carbonaceous deposits in a Diesel engine, but it is highly risky to deduce from this that the Conradson figure has any quantitative significance in relation to the combustion characteristics of fuel oil in a boiler.

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The asphaltene determination consists in treating the fuel with any one of a number of volatile, non-aromatic solvents, when part of the fuel is precipitated as a dark brown solid material. This precipitate is called the "asphaltenes" and it is important to specify the solvent used, because the quantity and nature of the "asphaltenes" obtained depends upon the dilution ratio and nature of the solvent. It is very important to remember this, particularly when examining the asphaltene figures from a laboratory which has not followed the standard Institute of Petroleum method or which does not specialize in the examination of petroleum.

Are asphaltenes more difficult to burn than the rest of the fuel? If so, should not the Conradson reflect the difference by producing more carbonaceous deposit from a fuel of "high" asphaltene content than from one of "low" asphaltenes? This is what people mean by their predilection for either of these tests, whether they say so in precisely these terms or not, and more than one user has made the suggestion that the asphaltene content of present-day fuel oil is higher than used to be the case.

Since reliable data are comparatively few (and, of course, the I.P. asphaltene test itself has been subject to development and closer standardization over the years) it is difficult to be dogmatic on the latter point, but the author has records of over 15 per cent hard asphalt in the straight run Mexican fuel oils of thirty years ago.

It is not the intention to claim here that the asphaltene/Conradson controversy is now only of historical interest, particularly as in the search for the unknown factor to serve as an index to fuel oil quality, certain operators still have interesting theories regarding the usefulness of both tests. In any case, the author is concerned in this paper principally with demonstrable facts rather than theories, but it is worth noting that any theory purporting to relate combustion characteristics with asphaltene or Conradson figures must be able to accommodate the following hard facts.

Asphaltene figures determined on marine fuel oils will vary with the origin and method of manufacture, as will the specific gravity, sulphur, flash point and most other characteristics. They are also, to some extent, related to the viscosity, but only as a secondary consequence. If, therefore, changes are observed in the combustion of any individual fuel oil, one must not be precipitate in deciding which (if any) of so many factors is responsible.

Again, the ratio of asphaltenes to Conradson carbon can vary considerably from one straight run fuel to another and in addition it is possible to deasphaltize a fuel oil without significantly affecting its Conradson carbon value. These facts are presented without explanation or theory, but the following account of an attempt to obtain some practical data in the laboratory to show whether differences in asphaltene percentages have any effect, and whether there is consequently any case for specifying particular limits for asphaltenes, will be of further interest.

The problem was approached with the object of determining the effect of the asphaltene content of fuel oil both on the quantity of solids in the flue gas and on the general ease of burning the fuel. Five fuels were taken with (as will be seen from Table I) a very wide range of asphaltene percentages. In selecting the fuels, consideration was also given to experimenting with materials of widely varying viscosity and other characteristics. For example, the three fuels with asphaltene contents between 2.5 and 3.1 per cent have viscosities ranging from 569 to 2,800 seconds Redwood I at 100 deg. F., while the three fuels with viscosities between 1,700 and 1,960 seconds Redwood I at 100 deg. F. cover an asphaltene range from 3.1 to 10.25 per cent.

It will be seen that there is no correlation at all between the asphaltene content of the fuels used and the solids they produce. This is well demonstrated by fuels D and C. The asphaltene content of C is about four times as high as that of D, but the latter gives some 50 per cent higher weight of solids produced.

There is a certain amount of correlation between total solids and viscosity although no difference was noticed between the oils during the test in regard to their combustion properties and all were, in fact, burned with equal ease. It has not, in fact, been possible to correlate the percentage of solids with any other factor although there is a certain limited trend for the solids to increase with rise in carbon/hydrogen ratio. Here again, however, there is an anomalous result as fuel C with C/H ratio 8.15 produces a lower percentage of solids than both fuels D and E which have C/H ratios of about 7.7. It would seem, therefore, that further investigation is necessary to identify the property in a fuel responsible for the variation in stack solids, since it is fairly evidently not the asphaltene figure which establishes this characteristic.

Ash

In considering the many factors which can influence the combustion of fuel oil, one should not overlook the effect of ash. At the same time it should be regarded in proper perspective. When one thinks of the high ash of some coals, amounts of 5 to 10 per cent being common and 15 to 20 per cent quite a possibility, figures of the order of 0.05 per cent to 0.10 per cent (such as may be found in marine fuel oils) seem extremely low. It is, therefore, not the amount of ash which is found in fuel oil, but its constituents which may need consideration.

The elements which have been identified in the ash from fuel oils of different sources include:—

Aluminium	Manganese
Barium	Nickel
Calcium	Potassium
Chromium	Silicon
Copper	Sodium
Iron	Titanium
Lead	Vanadium
Magnesium	Zinc

TABLE I

	Fuel A	Fuel B	Fuel C	Fuel D	Fuel E
Viscosity, seconds Redwood No. 1 at 100 deg. F.	569	1,700	1,720	2,800	3,710
Asphaltenes, per cent weight	3.1	3.1	10.25	2.5	9.2
Conradson carbon, per cent weight	7.5	8.8	15	9.7	13.5
Flash point (P.M. closed), deg. F.	220	235	200	244	192
Sulphur, per cent weight	2.3	2.7	1.8	2.9	2.7
Pour point, deg. F.	10	35	30	50	20
Specific gravity at 60°/60° F.	0.937	0.948	0.985	0.968	0.976
CO ₂ per cent	12.0	12.0	12.1	12.0	12.0
Solids in flue gas, per cent weight of oil burnt	0.13	0.15	0.145	0.185	0.24
Deposit on metal surfaces of combustion chamber, per cent weight of oil burnt	0.02	0.03	0.045	0.065	0.07
Deposit in flue, per cent weight of oil burnt	0.025	0.02	0.02	0.045	0.05
Deposit on refractory lining of combustion chamber, per cent weight of oil burnt	0.01	nil	nil	0.02	nil
Total solids, per cent weight of oil burnt	0.185	0.20	0.21	0.315	0.36

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These elements arise (a) from the presence of small quantities of organo-metallic compounds which, like sulphur, are an integral part of the crude petroleum; (b) from traces of silica, silicates and salts derived from the oil-bearing strata; and (c) from the water frequently associated with the crude. Despite the elaborate measures taken at the oil field to free the crude from inorganic, insoluble materials (i.e. salts, silicates, etc.) the principal constituents of the ash of fuel oil are usually iron and silicon (either as silica or silicates). Invariably these elements are inadvertently introduced into the fuel after manufacture and this emphasises the need for strict control over tankage and handling facilities on the part of producer and consumer alike. It is unfortunate that water ballast must frequently be taken on board ships in harbours or estuaries, where mud or silt is very likely to be present in quantity. Apart from the possibility of aiding the formation of sludge, such material may include fine sand particles which have an erosive effect on burner tips.

The only other elements (apart from sulphur, about which much has been written elsewhere⁽³⁾) which normally occur in significant amounts and give rise to complaint and controversy are vanadium and sodium.

Vanadium occurs in crude petroleum in an oil soluble form. There are relatively few crude oils which are entirely free from this element and in the process of distillation it becomes concentrated in the heavier fractions used as fuel oil. Vanadium is generally reported as occurring as a porphyrin complex^{(4), (5), (6), (7)}, i.e. as a substitution product of porphine, which consists of four pyrrole rings coupled by methyne groups. Porphyrin complexes form the basis of the respiratory pigments in plants and animals and can be obtained from derivatives of chlorophyll and hæmoglobin. Recent work, however, has shown that for at least one fuel oil, the vanadium does not appear to be present as a porphyrin, but in some other oil soluble form and that no methods are available for preparing fuel oils free from vanadium other than distillation or cracking⁽⁸⁾, i.e. by converting it to a distillate, which, from the point of view of cost, is out of the question.

Whatever the form in which vanadium really occurs in fuel oil, it is clear that it is not in an insoluble form like silica and the bulk of the iron. Hence it is not amenable to removal by centrifuging, nor is the vanadium complex water-soluble. Moreover, upon combustion vanadium is manifested as an oxide (usually the pentoxide) and despite a number of ingenious suggestions, no processes other than conventional refinery techniques are available for its removal. Hence where trouble is encountered which can be proved to be due to vanadium attack (and there are many misconceptions on this point), the line of approach must be in some direction other than an expensive treatment of the fuel oil. Several investigators have devoted attention to these other remedies, for example, the reduction of ash deposition by combustion control so that each droplet of fuel oil burns down and leaves the combustion chamber as a hard, dry particle of carbon containing an appreciable proportion of the ash⁽⁹⁾. While most of such work has been done in connexion with gas turbines, it is believed that parallel effects would be experienced in oil fired steam boilers.

Salt

Among the elements which have been mentioned as forming the constituents of fuel oil ash is sodium, together with any ingredients of sea water. Generally speaking, the sodium content of any fuel will be largely determined by the sea water present and, as most specifications impose a limit for water content, this factor is usually well under control.

Some years ago the slagging and spalling of refractories caused a great deal of concern, particularly in the Royal Navy. Various suggestions were put forward to account for this, such as the use of fuel oil containing vanadium compounds, long periods of high powered operational steaming, or extension of periods between refits. Investigation into this by Gray and Killner⁽¹⁰⁾ showed that the failure was not due to the type of fuel oil but to the introduction of a material capable of reacting

with the firebricks, namely sodium chloride. This is decomposed at high temperatures and reacts with the alumina and silica of the firebrick producing silicates and/or aluminates, the temperature of formation of which may be lower than the fusion temperature of the original materials.

The resultant deterioration of the brickwork was at times serious. Much consideration has since been given to the prevention of unnecessary water admixture in bunker fuel tanks. Water ballasting may at times be unavoidable, but if it is resorted to every endeavour should be made to prevent ultimate admixture of oil and sea water. Water displacement systems, which fortunately are rare, should certainly not be encouraged owing to the risk of emulsification. While this risk is not great, it is obviously unwise to take any positive action which would encourage this undesirable feature.

The suggestion may be put forward that alkalis such as caustic soda are used in certain modern oil refining processes and that this practice may increase the possible danger due to salt in the fuel oil. It is, therefore, desirable to get this into proper perspective. There are, in fact, four possible sources of alkaline metals in fuel oils, namely:—

- (1) from water present in the crude oil;
- (2) from oil-soluble salts present in the crude oil;
- (3) by contamination of the fuel with salt or fresh water during transport and handling after manufacture;
- (4) and occasionally from the use of minute quantities of caustic soda during the processing of particularly corrosive crudes.

It is difficult to obtain a representative figure for item (4) since obviously this will vary according to the crude oil and the practice at the individual refinery. A survey of the total sodium content likely to be introduced, however, by (1), (2) and (4) in total shows it to be of the order of about 0.004 per cent Na, corresponding to the salt contamination which would be introduced by the presence of about 0.3 per cent sea water. In other words, the salt content from all other sources is likely to be less than that which occurs by contamination with sea water in the ship itself. In this connexion the author arranged for some hundreds of determinations of salt content in fuel oil prior to shipment from the refineries. All types of fuel oil were included in the review, from low viscosity Admiralty type fuels up to the highest viscosity commercial underboiler fuel oils. As would be expected, the results varied widely, from less than 0.001 per cent up to 0.024 per cent salt. The weighted average of these determinations came out at 0.006 per cent salt, equivalent to about 0.2 per cent of sea water, or rather less than the amount of water which in any case is liable to find its way into bunker fuel tanks at sea.

Stability

The oil refiner has many devices, sometimes highly individual ones, for controlling product quality. In many cases there is recourse to carefully standardized tests but whether they are fully written-up routine control tests or research tools, or whether they are that elusive "know-how" which comes after many years of practical experience, they all help to provide the assurance of quality which lies behind the supplies from recognized petroleum companies. An extremely good example of this occurs in regard to fuel oil stability.

Some of the residual fuels produced in the early days of cracking, and this applies particularly to the period before 1930, were prepared from "high level" thermal cracking processes which gave rise to a product of doubtful thermal stability. During the intervening years, considerable search has been devoted towards the production of a control technique which would ensure the stability of fuel oils both on storage and on heating⁽¹¹⁾. It must be admitted, however, that in a majority of cases these tests have shown a certain specificity. That is to say that in the hands of a person who thoroughly understands them and applies them to fuels manufactured by a particular refinery, operating perhaps on only one or two crudes, such tests may provide just the information which is required, but on being applied to fuels of different origin they may fail to

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be an effective criterion. This is not surprising, since each individual test arises in the normal way as a result of an individual problem at a particular refinery. The technique of the test is, therefore, primarily devoted towards overcoming that particular refinery's problem. Variables such as quantity, temperature, time, reagents and so on which provide the experimenter with appropriate information on a fuel from, say, Californian sources may not apply to the fuels of quite different chemical and physical properties derived from Indonesian crudes. While, therefore, the oil supplier may be chary of a request to guarantee stability or compatibility by any of the published methods, the buyer can usually be certain that the manufacturer has fully satisfied himself, probably by private research methods of his own, that the product he is offering for sale is of satisfactorily stable quality. Attempts to introduce a popular stability test into a specification may, therefore, do more harm than good if in this way the manufacturer is discouraged from carrying out his own research methods which in the long run probably form the greater safeguard to the consumer.

As an example of the kind of stability research having immediate practical bearing on the production of stable fuel oils, the efforts of Butlin, Van Kerkvoort and Nieuwstad are particularly worthy of note.

Butlin⁽¹²⁾ shows how the compatibility of a fuel oil and a gas oil may be assessed in terms of two indices, the xylene equivalent of the fuel and aniline point of the gas oil. In a later paper⁽¹³⁾ he shows how this aniline point/xylene equivalent relationship may be improved by making allowance for the surface tension of the diluent.

Van Kerkvoort and Nieuwstad⁽¹⁴⁾ describe a technique for the determination of the "dry sludge" content of fuel oil, in which the fuel is filtered under pressure (and at an elevated temperature in the case of heavy fuel oils) through hardened filter paper using a specially designed apparatus. The great value of this technique is that it gives a reliable method of estimating the suspended organic matter present in the fuel (i.e. "dry sludge") which may be formed during manufacture, storage or heating.

ADDITIVES

Many attempts have been made to overcome alleged deficiencies in the quality of both past and present-day fuel oil by the use of non-petroleum additives. The claims made for such materials are varied, and include resolution of sludge and prevention of its formation, reduction of soot, reduction and prevention of boiler deposits, easier atomization, lowering of viscosity and pour point and increased calorific value. Some, it is claimed, will combat the effects of sulphur, while others are stated to "repair the damage" done to the fuel in manufacture and generally compensate for the supposed poor quality.

Confronted with such diverse (and sometimes mutually contradictory) claims, the somewhat bewildered fuel oil user may well ask whether the use of such materials is justified.

The answer to that question is that it all depends on what the user expects to get from the additive. If it is merely to be a substitute for normal care in storing and handling the fuel, or a substitute for the proper maintenance and operation of the oil burning equipment, then he will get little satisfaction from an additive. On the other hand is there any justification for believing that an additive will have a positive improving effect on the performance of a fuel? The answer here requires careful qualification.

Many of the problems which beset both the engineer and deck officer involve poor combustion, high fuel consumption, fluxing and spalling of brickwork and soot or ash on decks and awnings. Poor combustion, with its resultant excess of stack solids, may be due to some inherent defect of the fuel, to improper operation of the combustion equipment or to sludge getting through to the burner.

Considerable investigation has been carried out on the effect of inorganic additives to improve combustion and work done by the U.S. Bureau of Mines⁽¹⁵⁾ is of interest in this connexion. Sodium carbonate, and to a lesser extent sodium

chloride, tend to improve combustion and to cause deposited soot to burn more readily. Unfortunately, however, these would inevitably tend to increase troubles due to deposit formation on the boiler tubes and slagging of the refractory brickwork. In other words, they could promote difficulties greater than those which they seek to overcome.

There is also evidence that copper chloride reduces the ignition temperature of soot, but here again a decrease in soot formation might increase troubles due to corrosion and deposit formation. From basic knowledge, therefore, there is some reason for supposing that additives in small quantities may influence the burning of residual fuel oil, but whether the net result of using particular additives would be beneficial or harmful can only be determined by practical trials in the installations concerned.

Whilst many proprietary additives are supposed to separate water from the fuel, the reverse claim is made for some others, i.e. that the additive will absorb water so that it all passes through to the burner as a homogeneous mixture. On the face of it this appears to be offering an exchange of water-free tanks for (possibly) damaged brickwork.

It is part of the policy of the major petroleum companies to examine the more widely publicized fuel oil additives, because apart from the natural desire to keep abreast of invention in the field of petroleum, the addition of foreign matter to a fuel oil for any purpose may bring with it detrimental side effects, or, in the extreme case, actually impair the quality of the fuel. It may, therefore, be of interest to describe a series of investigations with which the author has been closely associated, on a well publicized example of what we may call the "general purpose" additives. The material was given an extensive trial, not only in the laboratory, but on a small scale combustion unit and finally at sea. The laboratory bench trials were intended to show whether the product eliminated sludge or inhibited the formation of emulsions or promoted demulsification. So far as could be ascertained the effect was negligible and certainly not greater than that of Teepol, creosote and a variety of other materials.

The combustion rig trials were carried out in an experimental combustion chamber, using both straight run and thermally cracked residual fuels. The fuel oils were first of all burned without any additive. The test was re-run, using the recommended dosage of additive; a third run was carried out in which the fuel oil was contaminated with sea water and, finally, a fourth in which the water-contaminated fuel contained the appropriate amount of additive. There was no significant difference between the performance of the dry fuels when burned with and without the additive. The fuels emulsified with 4 per cent of sea water showed, as would be expected, an increase in the weight of deposits but no significant difference was established between the stack solids figure for the doped and undoped fuels. No positive conclusions could, therefore, be drawn from this series of experiments.

While these results are illuminating, it is felt that within the scope of the present paper experiments carried out at sea will be of greater interest and are, therefore, given in more detail. In order to demonstrate whether a particular additive had any effect upon sludge and combustion generally, it was decided to operate a steam turbo-electric tanker of 18,000 tons dead weight on bunker fuel oil treated with the same additive as already described. The tanker is fitted with three 3-pass header type boilers with air heaters generating steam at 450lb. per sq. in. pressure and a temperature of 720 deg. F.

Since the layout of the ship's fuel system did not permit the two boilers which were to be used to be supplied respectively with treated and untreated fuel, the comparative trials had to be carried out on successive voyages. The programme of trials was as follows:—

No. 1. Additive used in proportion of 1 part to 2,000 parts of fuel. Duration of trial about 1,160 hours' steaming.

No. 2. Untreated fuel used, duration about 580 hours.

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- No. 3. Fuel containing 5 per cent of sea water in emulsified form, duration 430 hours.
- No. 4. Fuel containing 5 per cent of sea water in emulsified form, with the addition of additive in the proportion of 1 part to 2,000 parts of fuel. The duration was about 450 hours.
- No. 5. A final "blank" trial using untreated fuel.

To ensure that the results of successive trials would be truly comparative, it was essential to standardize the operative procedure on board and also to eliminate, as far as possible, the personal element where observations, other than instrument readings, were concerned. Accordingly an extra second engineer was carried, responsible only to the chief engineer, and whose sole duty was the conduct of the trials.

The fuel for the experiments was drawn from a single batch of about 10,000 tons set aside for the purpose. It was of normal viscosity for a marine fuel oil, namely approximately 3,500 seconds Redwood I at 100 deg. F., but before being selected it was tested to ensure that it was capable of forming a stable emulsion with 5 per cent of sea water.

In addition to the usual boiler room instrument readings, particular attention was given to the condition of oil fuel filters, and during the trials in which sea water was added to the fuel, the water content of the fuel at various heights in the settling tanks and at the burners was periodically checked. The contents of the settling tanks were allowed to stand for about 10 hours before being used, in accordance with normal procedure. The insides of the fuel tanks were also examined at intervals for the presence of sludge.

The greatest importance was attached to determining the effect of the additive on the deposits formed on the external surfaces of the boiler pressure parts. One of the boilers was cleaned externally at the beginning of each trial whilst the other, which had been steaming for 5 months without cleaning when the trials began, was allowed to remain in that condition as a check on the claim that the additive would remove deposits already existing.

At the end of each trial a careful inspection of the furnace and surfaces of each boiler was carried out, the same two investigators, one a research chemist specializing in fuel technology and the other a marine engineer, being particularly detailed to carry out these investigations throughout the whole series of tests. In addition, at each inspection a set of photographs was taken as a complete record of the appearance of the furnace, generating tubes, superheaters and air heaters of the two boilers in use.

The additive manufacturers made a number of claims for their product and the measures described were specifically designed to show whether these were justified. The claims were:—

- (i) To improve atomization of the fuel, thereby improving combustion.
(This would be reflected in higher CO₂ meter readings, lower uptake temperatures and overall fuel consumptions and lighter desposits on the external surfaces of the boiler pressure parts.)
- (ii) To dissolve and eliminate existing accumulations of sludge in tanks and lines.
(This would be revealed by the inspections of tanks and filters and by a reduction in the steam pressure required at the oil fuel heater.)
- (iii) To prevent further formation of sludge.
- (iv) To remove combustion deposit and soot from the boiler heating surfaces and prevent further accumulation.

(Differences here would be revealed by the results of the successive boiler inspections and by the photographic records.)

So far as claims (ii) and (iii) were concerned the tests were inconclusive. Tankers do not normally use their fuel tanks intermittently as water ballast tanks. The ship used for the trials conformed with normal practice in this regard and at no time, either before or during the trials, was any sludge found

in tanks, lines or filters. During trials (3) and (4) there was no indication that the additive accelerated the separation of water from the fuel oil/sea water emulsion in the settling tanks.

The interpretation of the results of the boiler surface inspections and the photographic records was not easy as fairly wide variations in type and amount of depositions are to be expected even when running under supposedly uniform conditions. The rate of deposition normally experienced on the boilers in this ship, particularly on superheater and air heater surfaces, left plenty of room for improvement. However, the most careful examination failed to reveal any significant change in deposition rate which could be attributed to the use of the additive, or any removal of deposits already existing; nor did direct observation or any of the instrument readings suggest that there was any change, either for better or worse, in the combustion (claims (i) and (iv)).

If the ship had been one in which sludge was normally present in tanks and fuel lines, it is a matter for supposition whether the use of this or another additive might have effected an improvement in general operation of the boilers; that is a matter on which these trials threw no light. It is a fact that in this ship during the period of eight months occupied by the trials no improvement (nor, for that matter, deterioration) of any kind was detected.

To avoid any misunderstanding it should be again emphasized that these trials were concerned with one specific additive. The fact that they did not succeed is no indictment of additives as a class: in fact, as already stated, there is evidence, from fundamental considerations, that certain materials added extraneously can influence combustion in different ways. Fuel oils, however, vary in their physical and chemical characteristics, and it is evidently proving extremely difficult to find an additive which will economically satisfy all the usual claims with all types of fuel.

CONTINUING THE SEARCH

Earlier in this paper the possibility was considered of a factor, so far undetermined, which might be made to serve as an overall criterion of quality in marine fuel oil. Examination of the conventional and the less orthodox laboratory tests so far available has shown this to be a dream far from realization. The quality of a fuel oil is not necessarily safeguarded by the imposition of a series of empirical requirements which, while possibly of value in the case of one fuel, may have little or no importance with another. The speed of bunkering may be seriously hindered by the request for test characteristics which may involve elaborate laboratory experiments.

Additives, though promising in theory, have yet to prove their economic advantage. It would thus appear that research has failed to unearth a philosopher's stone which will make all fuels good and the new ones better.

This, however, does not mean that the quest for a new measure of quality has been in vain. If the philosopher's stone is unattainable it is an indisputable fact that in the search for it the combined studies of chemists, physicists and chemical engineers have evolved manufacturing, blending and testing techniques which have very markedly improved the quality of the heavy residual grades which go to make up the world's bunker fuel oils.

In short, the influence of modern refinery techniques is demonstrated by the production of fuel oils of a quality superior to those formerly available, while more scientific product control methods ensure the maintenance of the standard set. There may still be no agreement, however, as to what constitutes the "best" fuel oil since in any case this conception is inseparable from the equally insoluble query as to what is the "best" equipment in which to burn it.

THE ROLE OF OIL FIRING EQUIPMENT

It is perhaps worth emphasizing that there can never be one worldwide commercial bunker fuel oil of closely restrictive analytical characteristics. The widely differing nature of the many crude oils and the different processes in use at refineries

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have the effect of producing unavoidable variations in fuel oils bunkered at different times and places. During a worldwide voyage it is possible for a steamship to bunker marine fuel oil with viscosity approaching the limit of the "C" grade specification, i.e. about 6,500 seconds Redwood I at 100 deg. F., and elsewhere to find fuel oil from another source with a viscosity of, say, 70 seconds Redwood I at 100 deg. F. Most marine engineers will agree that it is wrong to decide arbitrarily that either of these fuels is the better. Providing the ship is appropriately equipped, e.g. with suitable heating coils, it is rarely that difficulties are caused when using more viscous fuel oils. Rather is difficulty likely to be encountered when using a fuel with viscosity very much lower than that to which the engine room staff have been accustomed. Under certain conditions it may be difficult to maintain full steam or, despite the fact that these lower viscosity fuel oils generally have a higher calorific value than the more viscous grades, there may be an increase in fuel consumption. Such difficulties may occur, for example, when operating on the low viscosity bunker fuels available at some Far Eastern ports. A complaint in such circumstances may appear to take on the appearance of refusing to accept a premium fuel oil, but the fact is that it is necessary to appreciate that a somewhat different technique is required to consume the lighter product satisfactorily.

It is well known that the output of a pressure jet nozzle varies with the viscosity of the fuel supplied to it, and that the behaviour of the sprayer in this respect is contrary to that of plain orifices in that the thinner the fuel, the less passes through at a given pressure. Whilst this is generally well known, the magnitude of this effect, particularly with certain types of sprayer, is not always appreciated. For example, tests carried out with a well known make of pressure jet atomizer showed that whereas with a fuel oil heated to give a viscosity of 100 seconds Redwood I at the nozzle, the output was 29 g.p.h.; when a low viscosity fuel oil was used (approximately 40 seconds Redwood I at 100 deg. F.), with the oil reaching the nozzle at 100 deg. F., the output fell to 25 g.p.h.—a decrease of approximately 14 per cent in output. Conversely, in order to maintain the same output from a given sprayer with the low viscosity fuel, it would be necessary to raise the oil pressure by 35 per cent. Where low viscosity fuels are likely to be bunkered, larger sprayers should be provided unless the equipment is capable of delivering the fuel at considerably higher pressures than are required when operating on the heavier bunker fuels. The latter need preheating to bring them to the viscosity required at the sprayer—normally in the region of 80 to 100 seconds Redwood I.

Providing such measures are taken to maintain the required output from the oil burning equipment when using the low viscosity fuel, there should be no difficulty in maintaining steam with efficiency at least equal to that obtained with the heavier fuels. There should be, in fact, a saving in the steam required with the higher viscosity grades. The necessity for employing unusual operating conditions as regards oil pressures or nozzle sizes for a given load may upset the rate of the operation of the boilers and thus lead to a lower efficiency until operators are aware of the reasons for the change and have become accustomed to them.

Unfortunately, in some cases and particularly where the fuel pump is of the rotary type, it is not always possible to get even normal working pressures when using low viscosity fuels, so that the extra 35 per cent needed to make up the loss of throughput due to the characteristic of any pressure jet nozzle may never be achieved.

Pump manufacturers should bear the existence of these low viscosity fuels in mind to ensure that any equipment supplied is capable of delivering "thin" fuel oils at full atomizing pressure.

As a result of the presentation of the facts given in this paper, the conclusion can reasonably be drawn that marine fuel oils today are at least as good and often better in quality than those of a generation ago. Concurrently, it will doubtless be accepted that much more is expected from the oil fuels

of today. For instance, there has been a steady tendency to increase the quantity of fuel burned per cubic foot of furnace space. This increase has been most marked in Naval boilers, but even in the merchant service there has been an increment of something like 10 to 15 per cent. Unless such changes are matched with a big improvement in burner and air director design, increased boiler deposits are very likely to follow. Moreover, the continual search for greater boiler efficiencies, resulting in lower stack temperatures, are bound to emphasize low temperature corrosion problems.

Yet another point to bear in mind is that pressure jet atomizer throughputs have shown marked increases over the last two decades. Although it will probably be agreed that an increase in atomizing pressures from 120lb. per sq. in. to 300lb. per sq. in. is all to the good, the improvements due to this may not quite offset the disabilities which may arise due to these higher throughputs and consequent coarser atomization. It is perhaps not out of place also to refer to the much greater flame length brought about by the substitution of one large throughput burner in place of the two or three previously used.

It is not the object of this paper to discuss points such as these in any detail, but their influence in determining the users' attitude to fuel oil quality is by no means negligible.

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Discussion

MR. W. SAMPSON (Vice-President) said he thought he had been chosen to open the discussion because he was a representative of the Papers Committee of the Institute. He would like to confirm most strongly that for a long period it had been felt that marine engineers knew too little about fuel oil. They had had to take what they could get. They were brought up to understand coal (its ash and moisture and ash melting points, and so on). They knew very little about fuel oil except its calorific value and approximate make up, viz. 85 per cent carbon, 11 per cent hydrogen, but very little about its characteristics.

It was very kind of Mr. Martin to give his time and his great experience to enlighten engineers on this mysterious subject. Many experienced technicians or technologists would follow him in the discussion, and he would therefore confine himself to three points in the paper.

The first point was the very important one of additives. He was pleased to see from the paper that an actual trial was made, and the results were striking. They were inconclusive, but they were striking in this sense: that no one additive would suit all the different types of fuels. No ship today ever obtained a constant quality of fuel. Fuels were better than they used to be, according to Mr. Martin, but as there was no constancy Mr. Martin's word of caution should be taken very seriously to heart when choosing an additive.

Secondly, he was disappointed in one particular and most vital respect. Mr. Martin had not said enough about sulphur. He had mentioned that it had all been said before. One must therefore look at the index to the paper and read another paper. But that was not the point. The point was that sulphur content had risen from $\frac{1}{2}$ -1 per cent and was now in the neighbourhood of $3\frac{1}{2}$ -4 per cent. That was what shipowners were being given today. It was a question of how troublesome it was. The point was that the attainment of high boiler efficiency with a high sulphur content was most difficult. Shipowners bought their fuel at a high cost and carried it as cargo in bunkers. If they had to accept 3 or 4 per cent depreciation of boiler efficiency, it meant a tonnage of 3 or 4 per cent more fuel to be burned and carried and paid for.

For 88 per cent boiler efficiency one must have funnel temperatures, even with extremely low radiation loss on the boilers, as low as 290 to 310 deg. F. Roughly, the dew point went up 40 degrees for every 1 per cent of sulphur. With a rise from 2 to 4 per cent sulphur the dew point went up 80 deg. F. Therefore the designer could not design a boiler and an air heater in the ordinary conventional way if he were expected to produce a funnel temperature corresponding to 88 per cent efficiency without warning his client that he would have a lot of air heater trouble and corrosion.

A large number of ships at the present time had had fires in their air heaters and some had the air heater taken out entirely. They were running funnel temperatures as high as 400 deg. F., which he felt, as a designer, was disgraceful. They were throwing all that heat away because they could not face

the renewals, the cleaning and the corrosion risks with modern regenerative devices.

All marine engineers would like regenerative devices on their boilers so that they could get up to 90 per cent efficiency. But it seemed to him that they had had to retreat during the last few years and drop their boiler efficiency. This meant that shipowners were buying and carrying 2 to 3 per cent more fuel than three or four years ago. Mr. Martin had said that these various minerals in the fuel could be removed in the refinery at terrific cost, but he did not isolate the sulphur from the other extremely small percentages of minerals and so on. If Mr. Martin could tell them once and for all that it was completely impossible to get this sulphur out of the oil in the refinery except at a very high cost, it would give a shipowner the opportunity, when considering new construction, to decide whether he could still afford to pay for fuel at a higher cost provided it was lower in sulphur content.

Lastly, Mr. Martin had said very truly that the fuel must have the correct apparatus to burn it. But it is necessary to correct an impression that might have been made unconsciously that one of the factors against the burning of fuel oil was that over recent years higher furnace rates were being used. As a matter of fact, it was confirmed that the burning of fuel oil was not entirely a question of atomization. It was bound up with better mixing of the air and the use of higher pressures, and better mixing of the air into the atomized fuel. As burners improved, one obtained better combustion with the higher than with the lower rates. One could burn the fuel within the furnace at the higher ratings with good burners better than at lower furnace ratings, because of the higher temperature at which the fuel was burned.

MR. H. F. JONES said he was glad of the opportunity to comment on the paper. He sincerely congratulated Mr. Martin and said he knew of no one better in this country to present such a paper.

It was the duty of anyone who mounted the rostrum to be critical in order to promote discussion. His own major criticism was that the paper overall was somewhat too much on the defensive. He would have preferred Mr. Martin's opening remarks to be on the following lines:

"The author trusts that all who are interested in the paper appreciate that the petroleum industry, in supplying their ships with liquid B.Th.U.'s (or calories) that can be burned with a minimum of manual effort, has performed and is performing a notably satisfactory service. Whether such fuel is purely or wholly cracked, catalytically or thermally cracked, or uncracked is largely beside the point". The point at issue was, "Will it burn satisfactorily? Does it meet the bunker 'C' grade specification?" The evidence in the paper was that it would and that it did meet these conditions.

To ensure the latter point and to control the influence of petroleum refinery technique on modern marine fuel quality, the petroleum industry spent thousands of pounds annually

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on research, testing and technical services. Many of the aspects covered by such work were described in the paper.

That was the broad criticism he would like to make, and he hoped the audience agreed with him and that the author also agreed or at least would digest this criticism!

To turn to points of detail, on page 26, the author, in mentioning the components of catalytic cracking, referred to cycle oil as a valuable fuel oil component for reducing viscosity and promoting stability. As the author made only passing reference to pour point a little further in the paper (page 27), it might be as well to add that the cycle oil in question tended to aid in reducing the pour point of the fuel oil in which it was blended. The pour point was an empirical test, giving some idea of the temperature to which the oil should not be allowed to fall, but as Mr. Martin said, it did not necessarily follow that the fuel oil was completely unpumpable at that temperature.

On page 27, the author tended to overmagnify the significance of liquid combustibles, including extracts, which did not conform to conventional standards. Perhaps he had in mind acid sludge, but in a modern refinery, such as the Esso refinery at Fawley, acid sludge did not exist, as acid was not used in processing. This illustrated that some progress was being made, in these enlightened days, as compared with what some people called "the good old days".

A liquid petroleum product not contaminated with mineral acids was and could be a combustible fuel if properly handled in respect of temperature control and suitable burners. As a matter of interest, some Esso tankers used heavier fuel (that was to say, more viscous fuel) than the fuel delivered to customers as bunker fuel.

There was a small point on page 28. Mr. Martin said that specific gravity was almost meaningless from a quality angle. That was correct, but it was an essential feature for the ship's engineer and bunker departments for checking the quantities.

On page 29, Mr. Martin took up the question of asphaltenes. He himself had some doubt as to whether they were related to viscosity, unless the author's remarks were confined to the same crude. He had rightly qualified his remarks, however, by the statement that this was a secondary consequence.

It was stated in the second column on page 29 that "there is no correlation at all between the asphaltene content of the fuels used and the solids they produce". This was tied up with Table I. He was in disagreement with the author on this point. His group conducted, as a check test, a specially modified method for asphaltene content. This test was used at more than one refinery running certain types of crude. It gave quite a good check on stack solids, with which it could be correlated.

This disagreement served, however, to endorse another important point made by the author, namely, that although a special test coupled with certain crudes and refinery technique could be successful in checking quality, it would be unsound to adopt the method as a cure-all. He therefore supported the author's warning that it was necessary to guard against general interpretation of some of the tests that were heard of from time to time.

The author drew some of his conclusions from Table I. The results as between any two of the fuels would vary with combustion conditions at the time of testing. Variations in atomization, viscosity at the burner tip, or secondary air might give quite different results. More details were therefore needed in connexion with the test in Table I. Further, by varying the percentage of CO₂, say down to 9 and up to 13 per cent, quite different conclusions might be arrived at.

Mr. Sampson had already referred to sulphur content. The author had made passing reference to it. It might be as well, therefore, to point out that no one in the petroleum industry liked it, but it was in the oil as it came from mother earth. It so happened that there was more of it in Middle East crudes which were now used in Europe and other parts

of the Near East. There was no known way of removing it economically from residual fuels, so it had to be accepted. There was no alternative other than to pay a very much higher price for special fuels, and this was generally out of the question. No doubt Mr. Martin would deal with this in more detail in his reply to the discussion, if time permitted. He believed it had been estimated that the cost of, say, halving the sulphur content by specially processing high sulphur residuals might result in the price of the resultant fuel oil being at least that of gas oil.

In his concluding remarks, the author commented on the value of modern fuel refining. He himself felt that the reason for the greater reliability of fuels was that more was known about blending and stability, and possibly the author had placed a little too much emphasis in his remarks on the influence of modern refining technique.

Finally, when they left the building that night, they should all thank heaven there was a barrel which had a bottom to it. They could rest assured that the petroleum industry would make the most of the bottom of that barrel and in doing so would provide them with a satisfactory fuel!

MR. BRYAN TAYLOR, B.Sc.(Eng.) (Member) said that he fully endorsed Mr. Sampson's opening remarks. There had been a number of papers recently on oil fuels, particularly in regard to gas turbine operation, but the question of boiler firing had been somewhat neglected.

One of the problems on which he had been engaged for the past year or two was the wastage of boiler refractories. From an early stage in the investigation it was apparent that fuel oil quality and the efficiency of combustion was of primary importance in this connexion. When the problem was discussed with superintendent engineers, chief engineers and others, it was often said that the quality of the fuel oil had deteriorated in comparison with what was being used a few years ago. But exactly what the difference was he had never been able very clearly to ascertain. It seemed to boil down to the fact that the fuel was more difficult to burn; in other words, it was more difficult to obtain rapid and complete combustion which was necessary to avoid deposits on the tubes, damage to the brickwork, and so on. He had thought the paper would supply the answers and explain the differences, but in this he was disappointed.

He could not speak from personal experience of the deterioration of oil, but in view of the repeated statements he had heard about it, it seemed that there must be some basis for it. He had recently come across a paper* read before the American Society of Mechanical Engineers last year, which had a bearing on the subject, and he thought that some extracts from this paper would be of interest. He did not think the authors would come within the classification of the uninformed, referred to by Mr. Martin, because the first author was the leader of the Fuels Section of the Chemical Laboratory (Research and Development Division) of the Babcock and Wilcox Company in America. Referring to the problem of deposits on the convection heating surfaces, the authors of this paper said:

"This seems to have accelerated to the point where with some types of oil fuels, their removal is a serious problem. It is difficult to say just what has caused the problem to become serious in recent years, but various reasons have been advanced, such as the advent of catalytic cracking with resulting greater concentrations of residual—[a point to which Mr. Martin had referred at some length]—the increase in pressure and temperature levels of steam generating units and other reasons".

Obviously, they thought the quality of fuel oils had not improved.

On the next page the authors said:

"A survey of the analyses of heavy residual fuel oils

*McIlroy, J. B., and Lee, R. B. "The Application of Additives to Fuel Oil and Their Use in Steam Generating Units". A.S.M.E. paper 52-A-160, presented at the annual meeting, New York, 30th Nov. to 5th Dec. 1952.

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and fuel oil ash extending back over some twenty years in the Company's records discloses the same ash constituents to be present today but with a definite trend towards higher sulphur, vanadium and alkali content. There is also a definite increase in the amount of ash. The survey showed a wide variation in the amount of certain constituents, with a definite trend from the relatively low alkali, sulphur and vanadium contents of the earlier fuels to the high alkali, sulphur and/or vanadium content generally found in the ash from currently available residual fuel oils".

This went some way towards answering the question as to what had happened within recent years. It might well be that these remarks applied only to fuels bunkered at United States ports but he would be glad to have the author's comments.

Mr. Jones had already commented on the results shown in Table I on page 29 of the paper. The test results given in this table seemed to show conclusively that the asphaltene content did not influence the combustion properties or the quantities of deposits. That was rather surprising, but there seemed to be no doubt about it. It was noted that the CO₂ values were relatively low, and here again that had been touched upon by Mr. Jones. Some further information on the burners and the pressures and temperatures used would be of interest in this connexion.

The extent of the deposits that occurred on heating surfaces and refractories was largely governed by the fusing temperature of the ash constituents. From the remarks in the paper to which he had referred, it seemed that those constituents having a low melting point now seemed to predominate in the ash and therefore probably accounted for the tendency for deposits to be more serious.

It would be expected that ash deposits would be more severe when the temperatures were higher, so that the particles of ash were molten, or at least sticky, by the time they reached the surfaces. He would be glad to know from the author whether the furnace temperatures obtained during the tests referred to in Table I were comparable with marine boiler practice. The relation between the extent of slag deposits and furnace temperature was particularly noticeable in the case of brickwork, because in boilers having a comparatively low forcing rate and consequently a low furnace temperature, deposits on the walls were practically non-existent. As the forcing rate went up, more slag tended to build up on the walls. It was for that reason that so much trouble had been experienced on naval boilers with slag erosion, because of the high forcing rate, as compared with merchant service boilers.

With regard to brickwork wastage, it would seem that in merchant ship boilers the main trouble was spalling, which was caused by thermal stresses arising from rapid changes in temperature. Slag erosion was not such a serious problem, so that evidently the question of contamination of the fuel by salt water was not so serious in normal merchant ship operation. However, the presence of slag on the faces of the brickwork resulting from impurities in the oil, and probably the presence of sea water, did have the effect of modifying the structure of the refractory material and making it more liable to break down under temperature changes. The constituents of the fuel ash, and particularly the alkali content, were therefore of considerable significance.

From analyses which had been made in connexion with the investigation which was being carried out by the B.S.R.A., apart from silica and alumina which, of course, originated from the firebrick, the composition of the slag would appear to be mainly sodium and some potassium alkalis, iron oxide, calcium oxide, and a small proportion of vanadium, but the last-named did not seem to be a major problem in brickwork wastage. It was debatable where the sodium came from. The author said that it must nearly all come from sea water, but that remained to be proved.

He asked whether the author had had the additive used in his tests analysed. Did it contain any of the materials which, from the theoretical point of view, would be expected to improve

combustion, and so on? Any engineer would treat with suspicion any preparation put on the market with extravagant claims that it was a cure for all ills, so he was not unduly surprised to find that in this particular case the additive was useless.

Since it was obviously out of the question to mention the names of proprietary articles in a paper, it was unfortunate that the impression was bound to be created, even though the author had qualified his statement, that all additives were unlikely to produce any good effects. In the American paper from which he himself had quoted, it was said that a most exhaustive series of tests had been carried out on both a model set-up and a power station boiler. It was found with the particular oil used that the addition of alumina in the model test did have the effect of making the deposits less adherent and quite easily removed. In the power-station boiler it was found that the addition to the fuel of dolomite, which happened to be available in the locality, had a very good effect. It seemed, therefore, that additives could serve a very useful purpose in certain applications but, as had been pointed out by other speakers, it was a different question when it came to finding an additive that would give all the desired results with all the different types of fuel.

Everyone would agree with the author's closing remarks that many of the present-day troubles could be attributed to inadequate burner and register designs. He did not think the importance of this aspect of boiler design could be overstressed, and it was probably not an understatement to say that the majority of problems such as soot on the decks, deposits on the heating surfaces and excessive wastage of refractories could be largely attributed to shortcomings in the burners used.

COM'R(E) E. F. J. WOODS, R.D., R.N.R. (Member) said that in dealing with the various aspects of modern refinery technique the paper left the impression that there was a trend towards more and more by-products being obtained from the crude, and at the same time great efforts were made to keep pace with changes in the characteristics of the residues which were eventually used as commercial boiler fuels.

Knowledge and experience gained in marine service and in industry on combustion, tank inspection, boiler examination, and also problems which beset the consumers of oil fuel, ranging from the phenomena of "thixotropy" of certain types of fuels in ships' bunkers to sludging in small users' tanks ashore remote from water contamination, prompted the following questions on the catalytic cracking process:

- (1) As the "feedstock" to the "cracker" is a distillate, would this distillate normally have been left in the fuel oil?
- (2) Is not the use of "cycle oil" from the "cracker" as a stabilizer for asphaltene-containing residues not in the nature of an additive?
- (3) Is it not a fact that oils now emulsify with water more readily than they used to do?
- (4) Has the new technique in any way affected the sulphur content of fuel?

The refinery chemists and engineers had set a high standard of tests to ensure that good quality boiler fuel was delivered to the users, but they were handling large bulk quantities under certain set conditions. It was after delivery to the consumers that their control of conditions usually ceased.

In the construction and shape of fuel bunkers it was never possible to pump out entirely the residue of one consignment of fuel before refuelling. It was considered that this created localized mixtures remote from the drag of pump suctions and under varying temperature conditions tended to form sludge deposits. These did not become apparent until they increased in formation, joined together, and were drawn along to the pump suctions. Refuelling from various sources with different grades of fuel aggravated this state of affairs, and heavy sludge deposits gradually fouled the whole system and showed a marked deterioration in combustion conditions.

Usually signs of sludge contamination could be observed from the gummy state of burner tips, ridged coked carbon

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deposits on the side and floors of combustion chambers, "birds-nesting" in superheaters, and dense deposits in economizers and air preheaters. There was also a build-up of caked carbon on flat surfaces which gradually broke away and created considerable nuisance when discharged from the stack. Carbon, by being particularly absorbent to sulphur gases, increased the danger of corrosion attack and damage to clothing.

It was perhaps in the stability of these various sludge-forming mixtures that the consumer could exercise some control by the use of fuel additives.

Although the additive trials reported in Mr. Martin's paper were not conclusive, the main object was surely missed when they were carried out on a vessel which had no sludge problems, as basically it was the troubles arising from heavy sludge formation that created a demand for, and necessitated the use of, these additives.

The varied claims from manufacturers of fuel additives did give a general impression that they were "miracle makers". But if regarded in the right perspective in proportion to dosage and what might be expected, they did show that they were an economic factor worth considering.

A recent example could be cited where one of the bunker tanks of an industrial concern had a heavy sludge deposit. A brief description on the use of an additive to disperse this sludge formation was as follows:

The tank capacity was 15 tons. The main suction was choked and unusable; the auxiliary suction could only be used down to 3½ tons when suction troubles through sludge were experienced. This meant 3½ tons of sludged fuel was left in the tank before refuelling. With 6 tons of fuel in the tank, a concentrated dose of fuel additive and solvent was applied and the contents were circulated for 48 hours. It was then found possible to maintain a suction down to 2 tons before clogging of the auxiliary suction line was experienced. Before refuelling with 10 tons, a further amount of additive and solvent was added, and when the tank was finally shut off at one ton the main suction was found to be clear. After refuelling again to the 12-ton level, the main suction was used and finally shut down at less than one ton of fuel remaining in the tank.

Over the period of seven weeks taken in dispersing and burning the sludge no troubles were experienced with the filters or burners and a high standard of combustion was maintained throughout. It was advised to use a normal dosage of fuel additive as recommended by the manufacturers to prevent further sludge formations.

With the use of a combustion accelerator in an additive, the tendency of carbon formation within the furnace was considerably reduced. This greatly assisted the operator in maintaining combustion within the design area of the combustion chamber. Very often the initial deposits which built up at the burner tip and in the combustion chamber passed unnoticed; these gradually affected combustion by impairing atomization, causing flame impingement, disrupting gas flow, creating local hot areas which led to slagging of refractories and heavy deposits of unburnt carbon in the gas passages of the boiler.

When examining a boiler externally where additives had been used, one found that carbon formations were usually less and were all of a sharp powdery nature which was easily blown or brushed away, whereas untreated fuels often gave carbon deposits which easily choked tubes with a tamping effect during cleaning operations. They also had a tendency to penetrate clothing, and cling to and irritate the skin.

With an intelligent application of an additive and its stabilizing effect on varied fuels, water was prevented from collecting in emulsified concentrations in the bunkers and could be successfully dealt with by the sludge cocks at the settling tanks. This, combined with the addition of a combustion accelerator, enabled users to exercise control on the quality of mixtures of fuels by adjusting the treatment with an additive to conform with working conditions, thus ensuring the maintenance of a high state of fuel stability and combustion over long periods.

MR. W. R. HARVEY (Member of Council), in offering the author his sincere congratulations on a very interesting paper, observed that it must be exceptional because it brought Mr. Sampson and himself in complete accord!

He was primarily interested, he said, in the burning rather than the storage of the fuel. The paper devoted considerable attention to stability, and he was disappointed that it did not deal more fully with the constituents which caused trouble after burning. These, as Mr. Sampson had pointed out, were sulphur and vanadium. One got the impression that the author was troubled about the actual burning of the fuel, but there was no great difficulty today in burning residual fuels with a reasonable CO₂. The trouble was caused by bonded deposits in the superheater or high-temperature zone and corrosion and choking in the low-temperature zone. As far as his own knowledge went, the chief causes of trouble were high sulphur and high vanadium.

The author stated that the oil companies were burning successfully a very much worse quality of residual fuel, but he overlooked the fact that they were burning it at 80 per cent thermal efficiency. That could be done very nicely on ships without any trouble, but owners would not be very pleased if it were suggested that the efficiency should be brought down to that level.

The maximum sulphur content of the oils referred to in Table I was 2.9 per cent, but as Mr. Sampson had stated, a more likely figure today was between 4 and 5 per cent.

The author was quite right in saying that the trouble was not primarily due to the quantity of ash but to its constituents, and the much higher ash content of coal did not present a difficulty. The largest percentage was left on the grate, whereas in burning oil the ash was carried through the heating surfaces.

He was surprised at the author's statement that the troublesome inorganic, insoluble materials in the oil might have some connexion with water ballast which "must frequently be taken on board ships in harbours or estuaries". He could not be absolutely certain, but he doubted whether a modern cargo ship or oil tanker ever used the bunker tanks for ballast.

The author seemed to hold out no hope that the oil companies could do anything about the vanadium content and stated that the line of approach must be in some direction other than an expensive treatment of the fuel oil, but as far as his own knowledge went, there was no known heat-resisting material that would withstand vanadium corrosion, and he could not see at the moment how it was possible to design a boiler of light weight and small dimensions where it was possible to burn the fuel and prevent the ash from being carried into the boiler.

Salt water in fuel was, of course, a definite cause of trouble, but in his experience this trouble was largely confined to naval practice and was not in great evidence in the merchant marine.

The author's remarks regarding the use of additives with fuel was disappointing. He himself appreciated only too well that a common additive could not be used with any fuel that was bunkered. However, tests had been carried out in the United States; and where the complete analysis of the fuel was known, additives could be of great value. He would have thought that, with their tremendous organization, the oil companies could have held out some hope that these residual fuels could be treated at their source where the analysis was known.

Mr. Martin was luckier in getting an analysis from his coal merchant than any chief engineer would be if he asked for the same information from the oil companies, but the oil companies could do something at the source of supply.

The author stated that

"Poor combustion, with its resultant excess of stack solids, may be due to some inherent defect of the fuel, to improper operation of the combustion equipment or to sludge getting through to the burner".

He (Mr. Harvey) had already stated that he thought the oil was burned efficiently but if the sludge was of such a size

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that it would pass the filters, it could certainly go through the burners. He would like more information as to why the author considered a decrease in soot formation might increase troubles due to corrosion and deposit formation. He had not quite grasped that.

One somewhat frightening statement in the paper was that "it is possible for a steamship to bunker marine fuel oil with viscosity approaching the limit of the 'C' grade specification, i.e. about 6,500 seconds Redwood I at 100 deg. F., and elsewhere to find fuel oil from another source with a viscosity of, say, 70 seconds Redwood I at 100 deg. F.". This was well outside his own experience, but if it were the case he doubted whether any of the oil fuel pumps available would handle such a wide variety. Oil of a greater viscosity than 3,000 seconds could be reduced by tank heating to a range suitable for the oil fuel pump but he did not think any of the oil fuel pumps supplied to date would handle the correct quantity at the required pressure if the viscosity was much below 200 seconds Redwood I.

He could not agree that marine fuel oils today were as good as or better in quality than oils of a generation ago. Before the war an owner could specify his sulphur content, and he would, at that time, refuse to buy oil with high vanadium content. He could not do either today.

He also disagreed with the statement that the higher furnace ratings interfered with combustion. If the draught were available one could get even better combustion with a higher rated furnace. He also disagreed with the statement that the higher atomizing pressure resulted in coarser atomization. He suggested the reverse was the case.

He did not like to use remarks in a discussion as part of the discussion, but he could not resist the remark made by Mr. Jones that the oil companies were very successfully scraping the bottom of the barrel to someone's advantage. He wondered whose!

COMMANDER G. D. BLOOMER, R.N., said he was one of those "uninformed quarters" to which Mr. Martin had referred. He realized that this most interesting paper had been devoted to commercial bunker fuels as opposed to Admiralty type fuels, but he would like to make one point and ask one question about the latter.

The majority of marine engineers, and certainly the vast majority of those in the Navy, would probably agree that the qualities which most influenced the esteem in which they held a fuel were cleanliness of combustion and pumpability. By cleanliness of combustion he meant not only the amount but the character of the solids formed. Mr. Martin had shown in his paper that pumpability was related to viscosity and wax content. Owing to the increased demand for middle distillates, less gas oil was now available, it was said, than formerly for cutting back residuals, with the result that the Admiralty had been forced to accept more and more viscous fuels. The majority of complaints levelled at fuel in the Navy were due to this increased viscosity, and the corresponding increase in handling difficulties, particularly with waxy fuels.

He agreed with Mr. Martin that the increase in viscosity, which from the Navy's point of view meant a degradation of quality, was not due to changes in refinery technique but to changes in the pattern of world demand. Was it not possible to meet this changed demand in time, and economically, by further changes in refinery technique, which he understood, was now being done in the United States?

DR. A. C. MONKHOUSE said he was interested in Mr. Martin's lament about the use of the word "cracking". It seemed to have been given an interpretation different from that which the oil refineries had intended, but this was general in many kinds of industry. He had heard gasworks coke described as coal from which all the goodness had been taken. He hoped the oil industry would not alter such names as "cat crackers" and "kitten crackers" or such expressions as "cycle oil", which had nothing to do with bicycles! He would be sorry if any criticism Mr. Martin might receive led to an

alteration in the terminology of this very virile industry. Perhaps if he received any more complaints he might point out that one had to crack a nut to get out the kernel!

He himself was more accustomed to burning solid fuel, and he had always thought it a relatively simple matter to burn oil. It was a liquid; it contained no ash: given the right amount of air and the famous three T's—time, temperature and turbulence—there should be no difficulty in getting correct combustion.

Coal was a material with a high ash content, and a lot of coal was being burned as pulverized fuel, where a good proportion of the ash went straight into the boiler flue; so burning coal was a very difficult problem. Tarry matter and gases were also evolved, and for these reasons he thought it should be easier to burn oil than coal. The difficulty with oil was in storage, pumping and atomizing.

While it was admittedly possible to design apparatus which could burn almost any type of oil, as Mr. Martin had rightly pointed out, he would like to know whether the equipment on the average ship would be capable of handling and burning satisfactorily all the types of oil which might be received.

If he might offer a solution in the search for "X", he would have said it was "uniformity", because a change in fuel oil required changes in the operation of the boiler. Was Mr. Martin satisfied that the ship's engineer knew that he had a change in the quality of his fuel? For example, there was its viscosity. He would like to see more education in the burning of fuel and perhaps some simple means of testing it. The equipment side was also important. Unless one had the right equipment one could not burn these varying types of oil and that was why he pressed for uniformity.

He had been astonished at the oil-burning ships he had seen. How often one saw smoke coming from their stacks! The "Queens" even were not without reproach in this respect. He did not know whether the picture in the corner of the lecture hall was of an oil-burning ship, but it did not seem to have achieved proper combustion.

Sulphur had been referred to in the discussion as an inert material, but heat could be obtained by burning it, and some chemical works raised steam by this means. They used the sulphur dioxide for other things than corrosion, for example, the production of sulphuric acid. He felt very strongly that corrosion difficulties would increase as the sulphur content of fuels continued to rise. The same thing happened in land installations and even with coal-burning installations. Attempts had been made by air recirculation to keep the temperature of the air preheaters up, but limited space and other factors increased the difficulty in marine boilers.

MR. F. JACOB said that Table I was very instructive, but he would be glad of further information. Two or three of his points had already been anticipated—sulphur and vanadium content, and the combustion conditions under which the experiments were carried out.

He would like to emphasize the importance of vanadium. It formed certain compounds which were exceedingly corrosive. They destroyed the protective oxide layer on steel surfaces.

He would like to know what was the melting point of the ash in the flue gas. When the ash was solid it might be fairly harmless, but as soon as it melted and became sticky it was dangerous.

With regard to the dew point of the vapours, as long as they were in vapour form they passed harmlessly into the funnel, but as soon as they condensed, they became corrosive. What was the dew point of these vapours?

The combustion conditions of a boiler during lighting-up were different from those during normal working. How far was the composition of the flue gases affected by that?

Last but not least, boilers burning heavy fuel were already suffering severely from the effect of additions like sulphur and vanadium. How much further was this position to deteriorate if the fuel became heavier and heavier? Was there a limit to the amount of such harmful elements in modern boiler oil?

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MR. E. P. GIBSON said he had come to the meeting as a guest and thought the paper was really an education. It might surprise some people that he had never burned oil in his life. As a solid fuel man, however, he had been struck by one paragraph in the paper, and some of the observations and tests he had made from time to time might be helpful. They related to soot.

The paper said that considerable investigation had been made, and the use of sodium carbonate and sodium chloride to improve combustion and so on was mentioned. With oil the flame was continuous, and combustion conditions could not be controlled in an oil-fired furnace in the same way as they could be controlled with solid fuel.

Some two or three years ago an engineer had called his attention to the American practice of cleaning off soot in the boilers by chemical means. American power stations, he was told, put material into the boiler under certain conditions which kept it free from soot. He had pointed out that the B.E.A. had generated a lot of steam for many years and frankly he did not believe this was possible. But he had been given some of the material to try and certain experiments had therefore been carried out.

The plant used was Babcock boilers, and they had chain grate stokers, of course. One hundred tons of fuel was used per day and the availability of the plant was anything from a fortnight to three weeks. An air gun was made, and experiments were carried out with weights varying from 4 to 7. When the weight was right soot began to leave the heating surfaces of the boilers, bird-nesting was reduced, and the draught through the boilers was improved. Combustion conditions were not impaired at all. One of the constituents of the mixture was undoubtedly sodium chloride.

One point must be mentioned. When the powder was put into the furnace there must be complete quiet with no velocity of gas through the boiler. All the draught must be off and there must be no forced or induced draught. The powder was sprayed on when the furnace was on zero conditions and was left for three minutes. The draught was then put on and a white cloud was created in the body of the boiler. The soot and bird-nesting became a flock and fell off the tubes, and the lighter particles went away and out of the setting. This caused great surprise, and the experiments were continued. The compound was still being used, and there had been no complaints. One very large power station in the south eastern region with a 65,000lb. boiler was using it with great success.

The question which interested him when using oil fuel was "How can we get a state of zero pressure within the furnace in order to use this compound? How can we shut off the draught on oil flame without putting the boiler out? How can we get a coking heat to coke the compound, as in a solid fuel furnace, so that after three minutes the draught can be opened up to produce the cloud which will chemically remove the soot?"

He hoped that what he had said would lead to some experimental work, and he proposed to give a figure which had been obtained by direct experiment—a figure which was not theoretical at all. For 500 square feet of heating surface 1lb. of compound was required. It was no good talking about the quality of the fuel. This would only lead one up the garden path! He had gone into the boiler house himself and had conscientiously carried out experiments.

In addition to this, there was a compound that would help to improve the life of the brickwork and stop the ignition arches from cracking. It was black and it was made by a very well known firm. When the boilers were down for re-bricking this mixture was applied with a brush and the furnace was then brought straight up to temperature. The boiler should, of course, be dried out first with a slow fire. The temperature required was some 2,600 deg. This compound minimized sulphur deposits and clinker on the side walls and ignition arches.

One large power station was keeping the boilers clean by keeping the humidity at a maximum through control of

the preheat air. The station engineer, on looking through the log sheets, found boiler availability terrible during the summer but not so bad during the winter. On looking into this, he found it was due to atmospheric conditions. There was more moisture in winter than in summer. He therefore provided humidity control on the preheaters correlating to winter conditions and his boiler availability increased.

MR. G. J. GOLLIN said that he proposed to confine his remarks to sulphur. It had been said that 1 per cent increase in sulphur sent up the dew point by 40 degrees. This was a curious statement, in the light of the results of tests which had been published in the journal of another learned institution.

These tests were carried out by the British Coal Utilization Research Association on a refinery boiler evaporating 40,000lb. steam per hr. on five grades of oil with sulphur content varying from 0.8 to 4 per cent. At 0.8 per cent the dew point was 255 deg. F. It slowly climbed up and at about

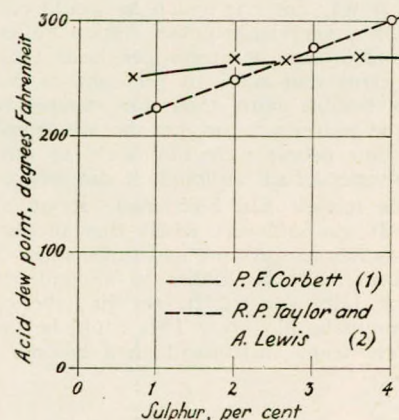


FIG. 2

3 per cent it was about 300 deg. F. It rose very little after that. Very careful measurements had been taken over a period of three months, and they showed that the acid dew point only changed from 255 degrees for under 1 per cent sulphur up to about 305 degrees for 3.5 per cent sulphur. Thus, the change in the dew point was not appreciable.

What did change was the quantity of acid which was deposited. This increased as the sulphur increased, but the dew point remained roughly the same.

Any sensible boiler designer who wished to take avoiding action would regard 300 deg. F. as safe and would base his design on that figure. But 300 deg. F. did not refer to the gas temperature. It referred to the mean between gas temperature and incoming air temperature on a contra-flow air heater and outgoing temperatures on a parallel heater. It was the temperature of the metal surfaces that counted.

What did they do on land? They considered the various ways of curing cold-end corrosion. One could take an air heater that was naturally contra-flow, because this was the most efficient way, and make it parallel flow, and one lost 2 or 3 per cent of efficiency. One could heat the air before it went in. That sent up the exit gas temperature and again one lost efficiency.

He had once discussed this problem with the chief engineer of an enormous and very important continental factory. He had gone through all the methods of curing the trouble, and in the end the engineer said, "Well, every method you describe means that I shall lose at the most with certain methods 3 per cent of my fuel bill each year and at the best 1 per cent. Young man, 1 per cent of my fuel bill will cost me £5,000 a year. It is my habit to change certain of my air heater tubes every year at the cost of another £1,000. Go back to England!"

That, he suggested, was a lesson designers of land boilers

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had learned. When power stations had had to be put up over the last three years in the Middle East, the boilermakers realized they had to have a fuel with perhaps 4 or 5 per cent sulphur, and they took the necessary avoiding action.

On a rough calculation, a boiler which evaporated about 100,000lb. of steam per hr. would, by a curious coincidence, consume about £100,000 worth of fuel per annum. By knocking efficiency down 1 per cent to avoid corrosion, one sacrificed £1,000 a year. At sea the same action should be taken as on land. It must be recognized that for efficiency one must either construct one part of the air heater of materials that were resistant to corrosion or else divide the air heater into two zones. In one zone the metal surfaces would be above the acid dew point and this would be regarded as permanent. The other zone would be designed in such a way that it was expendable and readily and quickly renewable. This had proved to be the best method on land, and he would like to see it followed at sea.

There was one method that appeared to be infallible but unfortunately it was not one which he would recommend for use at sea. On a very large power station boiler evaporating about 150 to 200 tons of steam per hour they had found by trial and error that with 10 per cent of pulverized fuel they had no trouble with their low temperature surfaces. The ash in the pulverized fuel hit the ash from the oil and removed it. But people were not likely to put one burner in ten on pulverized fuel, although it did work!

A curious remark had been made about high intensity combustion. It was said very wisely that all one wanted was the three T's—time, temperature and turbulence. But although the temperature might be higher in a combustion chamber fired at 10 or 11lb. per cu. ft. per hr., the completion of combustion might be illusory. This could be proved because in the last few years, instruments had become available for

sampling the gases to see to what extent complete combustion was obtained in the combustion chamber. For example, in gas turbines combustion sometimes looked remarkably good, but if the gases were filtered it was another story when making allowance for the high air/fuel ratio.

One speaker had said that in his case combustion in high intensity chambers was perfectly good but the trouble was corrosion and chokage in the low temperature zone. He would suggest that corrosion and chokage in the low temperature zone were sure symptoms that something was wrong in the high temperature zone.

Dr. Whittingham, of B.C.U.R.A., showed on the test bench that if carbon monoxide was put into flames it would oxidize more SO_2 to SO_3 . The figures indicated that normally some 3 to 4 per cent SO_2 was changed into the enemy, SO_3 . He had seen practical proof of the results obtained on the chemist's test bench in a power station boiler where the working of the burners was defective. Certain parts of the combustion chamber were rich in CO. The life of the plates of the air heater was shortened to a remarkable extent, because the condensation of acid was greatly increased.

One last point: it was his personal opinion that acid would condense more freely on a surface coated with flocculent soot than on surfaces kept clean. Where the burners were working badly there would be soot on the low temperature surfaces. More acid would collect in that soot and it was the soot loaded with acid that was most destructive.

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2. Taylor, R. P., and Lewis, A. 1952. " SO_3 Formation in Oil-Firing". Conference "Chaleur et Industrie", Paris. Section 24, Group II, Paper No. 154.

Correspondence

MR. A. G. ARNOLD (Member) thought the paragraphs entitled "Water Content" and "Specific Gravity" were particularly interesting. The statement made therein by such an authority as Mr. Martin would no doubt help many people to understand these terms better. He thought Mr. Martin might have added "danger" to "inconvenience and expense" when mentioning salt water mixed with the fuel.

On page 25, Mr. Martin referred to the statement made by the late Dr. H. H. Blache of Copenhagen before the Politechnical Association at Oslo in 1935, and stated that the challenge was energetically taken up by J. J. Broeze in "Gas and Oil Power" in April 1936. He was pleased that Mr. Martin did not say "successfully" taken up. That might have been inferred, but he did not think it would be correct. Through the courtesy of the editor of "Gas and Oil Power", he had looked up what Mr. Broeze did say. At the time the late Dr. Blache made reference to cracked fuel, he was in close contact with him and fully conversant with the modifications that were made in the design of the pistons at that time. This modification was made, not with the intention of enabling the engines referred to to burn this cracked fuel successfully, because this ultimately proved to be impossible, but rather to enable them to complete their voyages, etc. The trouble was very serious, as all those who had to do with vessels trading the particular routes where this cracked oil was more prevalent would well remember. In his own company's case, the trouble reached such proportions with one motor vessel that it was necessary to withdraw her from the particular service. She was replaced by a steamer and this vessel had double ended Scotch boilers in excellent condition, but it was not very long before they

were confronted with serious trouble on these. The fuel used was again of the cracked variety, similar to that which was referred to by Dr. Blache. The modifications to the pistons involved merely the machining out of the cracked portion of the piston and the insertion of a screwed plug. He himself, and, he thought, many others, considered this to be an excellent emergency repair. It certainly did enable many vessels to come home without any great delay, as would have been the case had they had to wait for replace pistons to be made either at the ports they were in or made in Europe and sent to them.

It was pleasing to be able to record that very much better results were now being obtained.

MR. W. SEYMOUR ROQUES (Associate) found the author's reference to fuel additives generally in keeping with that shown by most of the large oil companies. He was told they were constantly examining these additives with a view to combining them with their own fuels after refining.

The author spoke of a "general purpose" additive, and certainly, at this stage, with so many various types of fuel, a "general purpose" additive was quite impossible if the full advantages that a good additive could offer were expected.

As far as the effect of the additive on the combustion spaces was concerned, not only did the type of fuel need to be considered, but also the design and layout of the boiler. In fact, each combustion deposit problem must be treated individually if the full benefits were to be obtained from an additive. It was his opinion, therefore, that the mixing of additives in bulk oils, which might be going to several types

Author's Reply

of vessels, was impracticable. For the same reason, a "general purpose" additive was also unlikely to work efficiently as each combustion problem must be studied individually.

There were many boilers, both in ships and on land which were now able to stay in service for much longer periods between cleanings due to the use of the correct additive.

He was most surprised that the author could make no report on the capabilities of the additive for removing sludge, and if he were using a good additive, he could only presume there was no sludge present in the tanks.

It was estimated that 80 per cent of the sludge found in bunker tanks was an oil and water emulsion, and it was the function of the additive to break this emulsion so that the good burnable fuel was recovered, and the water allowed to settle off in the customary manner.

An additive should not aim to allow water to pass with the fuel into the furnace, but rather to keep the water out at all costs. It was this function that partially assisted their claims for a saving in fuel, and certainly for better heating surface conditions.

Author's Reply

MR. MARTIN, in reply, said that he was most gratified by the reception given to his paper and by the variety and virility of the discussion, to which representatives from so many sources had contributed.

Mr. Sampson was disappointed that he had not said very much about sulphur, but perhaps subsequent speakers had made up for this lapse. It was quite deliberate because there had been many papers about sulphur in recent years but not many on some of the other and equally important aspects of fuel oil quality. He had therefore thought it better, on con-

economical means of removing sulphur from residual fuel oil. He emphasized the expression "economical" since it was possible to distil the fuel oil and obtain a distillate of characteristics akin to gas oil. It was then quite practicable to remove most of the sulphur from the distillate, at a cost, but it must be remembered that in starting the desulphurization process with something which was virtually gas oil already, the resultant product, which would have to bear the costs of the desulphurization process, would be more expensive than gas oil. He was not prepared to quote Mr. Sampson a precise figure

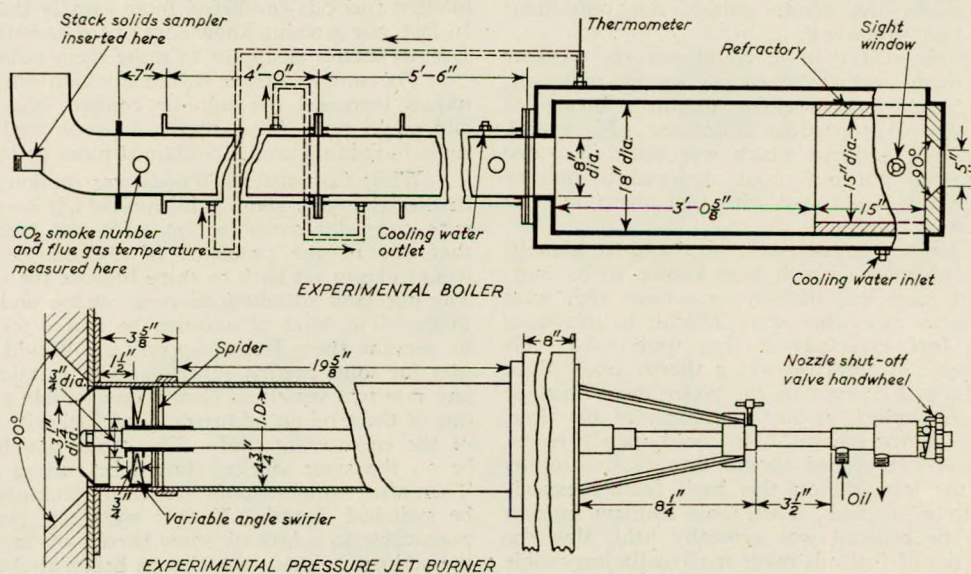


FIG. 3

sideration, to give relatively less prominence to sulphur on this occasion. Nevertheless, he felt he had to refer to comments by Mr. Sampson and Mr. Harvey where he felt a wrong impression had been created. Pre-war, few fuel oils with sulphur contents of $\frac{1}{2}$ to 1 per cent were on the bunker market. In fact, if one went back to 1920 it was not unusual to find Mexican fuel oil with sulphur content around 4 per cent, which was not very different from current supplies. The speakers might be unlucky in having bought their fuel oil in the wrong places, but he himself had not experienced fuel oil with 5 per cent sulphur.

He would comment very briefly on the suggestion of taking the sulphur out in the refinery. There was no known

but tentative calculations had indicated an increase of the order of £10 to £12 per ton over the cost of fuel oil, which he felt put the proposition out of court on economic grounds.

Mr. Jones criticized the paper for being too much on the defensive. They were his only unkind words and he would point out that he had begun his remarks by saying that the audience were pretty hard-bitten cases and a little defence at the start was not a bad thing! He agreed with what Mr. Jones had said about specific gravity and about cycle oil.

In his remarks about asphaltenes Mr. Jones implied that there was great importance in having a standardized test, and he pointed out that different answers could easily be obtained because they were not necessarily using the same methods of

The Influence of Modern Refinery Technique on Marine Fuel Oil Quality

estimation. It might help him to know that in the test on asphaltene content and also in the later test on additives a bench rig was used. The burner was a pressure jet atomizer with a forced draft air supply, and provided with adjustments to give variable and easily controlled combustion conditions. The combustion chamber was 18 inches in diameter, the radiation and convection sections each having 20 sq. ft. of heating surface. It was rigged up purely for *ad hoc* experimental work such as this. (See Fig. 3.)

Mr. Bryan Taylor referred to an A.S.M.E. paper by McIlroy and Lee. He remarked that the analyses of fuel oils over twenty years ago gave different sulphur and vanadium figures from the analyses of fuel oils today. Of course they could! He was not a bit surprised at that. In the first place it was very likely that the authors were referring to work done in America on American fuels. Twenty years ago America was not importing any fuel oil; therefore, it was not unreasonable that the Babcock and Wilcox records of that time related to indigenous fuels originating from Texas, California, or elsewhere in the United States. Many of these fuels, unlike the Mexican fuel oils to which he had referred earlier, were very low in sulphur and vanadium. At the present time America was a net importer of fuel oil and he was fairly sure that experimenters testing fuel oils today would necessarily have to examine a large proportion of fuel oils imported from other sources. Thus, quite apart from the fact that there were different manufacturing processes and new techniques in the oil industry, these people were almost certainly testing fuels of different origin from those of twenty years ago.

If America increased her imports, as undoubtedly she would, she would be importing Middle East fuels to a very large extent; though the vanadium might not go up, the sulphur probably would. That, as Mr. Jones had said, was not the fault of the oil industry but was the way the stuff came out of the earth. It did, however, help to explain the apparent discrepancy in the results which not only these authors but others had produced.

It would be appreciated that he could not say whether the additive he had mentioned contained any specific materials, as by doing so he might inadvertently commit a breach of etiquette by giving away the product concerned. He would, however, repeat that the additive which was tested was one of the so-called "general purpose" kind, designed to prevent sludge and emulsions. It was tested with that object in view and not as a combustion catalyst.

Alumina and dolomite had been mentioned and he, himself, had spoken of some chemicals which were known to be combustion catalysts. A snag was that in some cases they were expensive while in other cases they were difficult to introduce uniformly into the fuel, especially if they were solid. He realized that the subject of additives was a thorny one. Even in the field which he had covered in the paper there must be some additives which worked, at any rate some of the time, if they were to stay on the market. He could merely report that an unbiased examination had shown inconclusive results with those chosen for test and on this basis further experiments were not felt to be justified. Their work had lent support to the view (which he believed was generally held) that the differences in properties of fuel oils made it virtually impossible to select one additive which could satisfactorily deal with all types of problem in all fuel oils.

Mr. Taylor had referred to the CO₂ values obtained in the rig tests, but 12 per cent was not considered by the experimenters as being low. Examination of a very large number of actual installations indicated that this was typical of good operating results. Furthermore, by adopting 12 per cent as a standard there was a reasonable belief that this could be maintained whatever fuel was being burned.

As regards the furnace temperatures mentioned in Table I, he felt the following information would be of interest. The combustion chamber, as already mentioned, was 18 inches in diameter. About 28 per cent (i.e. approximately 6 sq. ft.) of the total heating surface of the radiation section was covered with refractory lining. The dimensions of this combustion

chamber were minute compared with those of a marine or land boiler and the proportion of heating surface covered with refractory was low.

Due to these circumstances and the small dimensions of the body of hot gas present, it was probable that the average temperature conditions in this small chamber were of the order of 1,350 deg. C. near the burner and 1,000 deg. C. at the exit. The minimum temperature at the combustion chamber was therefore some 100 to 150 degrees Centigrade lower than one would expect in a full sized boiler with an appreciable refractory surface. All the fuel oils used in this test were burned at temperatures designed to give a viscosity of 87 seconds Redwood I and at an atomizing pressure of 210lb. per sq. in. Thus, fuels "A" to "E", varying in viscosity from 569 to 3,710 seconds Redwood I at 100 deg. F., were burned at temperatures varying from 177 deg. F. up to 246 deg. F. The pressure of 210lb. per sq. in. and the viscosity of 87 seconds Redwood I were considered to be reasonably representative of those employed on board ship.

Commander Woods had asked a number of questions, the first of which enquired whether cracking feedstock would normally have been left in the fuel oil. It rather depended on what he meant by "normally". Whether the process involved was distillation, thermal cracking or catalytic cracking, certain distillates were removed and directed towards their most appropriate use. If there were no catalytic cracking process, the distillate "feedstock" would not just be left in the fuel oil—it could equally be thermally cracked.

In reply to the second question, he said that his idea of an additive was a *small* proportion of something put in to promote combustion or to produce some other effect. Cycle oil did not fall within this definition. It was another entire component and was no more an additive than gas oil would be if used for a similar purpose, such as to reduce viscosity. In reply to the third question, it was not his experience that modern fuel oils emulsified more rapidly than they used to do. In fact, our growing knowledge of the constitution of asphaltene systems should enable us to make them more resistant.

The simple answer to the question whether modern techniques increased the sulphur content was that they did not and could not. They might, however, redistribute it so that some individual grades contained more or less.

While Commander Woods was speaking he had had some further thoughts about additives which he would like to leave with them for consideration. He had been told many times that one of the problems of the marine engineer—and he would like to get back to ships because the subject that evening was not land installations—was sludge and emulsions in fuel tanks. The kind of additive he had described was supposed to prevent them from happening. Would it not be a good idea for some marine superintendent to take sister ships, or at any rate two vessels as closely comparable as possible, running one of them on an additive-doped fuel with the full knowledge of the engineering staff. The other, which preferably should be on the same service, should be run as a control "blank". Then after sufficient data had been accumulated, the two might be switched round. If that were not possible it might be practicable to substitute some barrels of, say, Diesel fuel minus the additive without the change being disclosed, to see whether the improvement or otherwise were maintained.

What he felt about all this was that when anyone was given an additive to test he tried to have everything just so. Whether it was in the laboratory or in a ship, conditions and observations were as perfect as they could be—just as they were in the tanker trials. In such circumstances there possibly was an improvement in combustion conditions, but whether this was due to the care that had been taken beforehand or whether the additive had any influence, no one could tell unless an attempt were made to provide a scientific control in the form of a run on undoped fuel. Even then, of course, owing to the problems of wind, weather, and so on, strict correlation would be most difficult.

It was interesting to note how speakers contradicted each other on the subject of additives. Commander Woods wanted

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to add them to combat the problems which arose *before* combustion of the fuel, namely to arrest sludge. However, he also proposed a combustion accelerator. Mr. Harvey wanted the fuel oil to be treated at source. Both Mr. Harvey and Mr. Gibson, he thought, were endeavouring to counter the problems arising *after* combustion of the fuel.

Suppose there were an indiscriminate addition of a dope to, say, 10 million tons of bunkers at oil refineries throughout the world. As little as 0.1 per cent of an additive costing one dollar per gallon would add two shillings per ton on the price of the oil fuel and add a million pounds to the oil fuel bill to be paid by the world's shipping. Three additives to do different jobs might treble this. Such figures, of course, were only guess-work but indicated that one could not embark upon such a programme of treating fuel oil at the refinery without full economic and technical justification for it.

Turning to Mr. Harvey's other comments, he said that some cargo vessels had used their double bottom space for sea water ballast when not carrying bunkers. He agreed, however, that the naval problem was the more important. Mr. Harvey later on asked why it was considered that a decrease in soot formation might increase deposit troubles. Work on gas turbines had shown that if a partial sacrifice in fuel economy could be accepted, deposit formation could be reduced by atomizing the fuel more coarsely to give slightly more inefficient combustion. The mechanism of the action was believed to be that a coating of carbon rendered the ash particles less cohesive. Conversely, therefore, it was possible that if combustion could be improved and soot formation decreased by additives or otherwise, deposit formation might show some increase. Some experimental work had, in fact, confirmed this.

He greatly appreciated Dr. Monkhouse's breezy contribution, which to some extent had tidied up some earlier parts of the discussion. He and some other speakers had referred to the need of the chief engineer to know the viscosity of his bunker supplies. He thought, however, that the shipping companies were perfectly well aware that they could get details of the properties of the fuel which a vessel bunkered at any time. It was standard practice with most petroleum companies to give the most important features on the engineer's receipt. He believed that viscosity would almost invariably be given and also in all probability the specific gravity, water content and occasionally other features. Of course, if the chief engineer went into a port which had no convenient laboratory facilities and asked for a lot of additional information, such as vanadium content, he would probably not be able to get it because, frankly, there were no routine determinations of vanadium and certainly the local bunkering staff would not be informed on such matters.

In reply to Commander Bloomer he said that increased viscosity, where it had occurred, *was* in the main due to the pattern of world demand, and further changes might well be

expected as the result of technical development. Whether fuels became lower or higher in viscosity later on was anyone's guess, since all the time there was new production and new refinery methods. Only a day or two earlier another find of oil had been notified in Australia. If this proved to be on the scale of California, Texas or Kuwait, the whole pattern of fuel oil quality might undergo a change which, at this stage, could not be forecast.

Another person who was asking him to make forecasts was Mr. Jacob. All he could say in such a discussion was that one would not expect sulphur contents to rise appreciably higher than they were running in the Middle East fuels at the present time. As to viscosity, there was a limit in the bunker "C" grade specification, which had existed long before he came into the industry and was still being used. At the time of its inception, most of the fuel oil burned in this part of the world came from Mexico and it was exported from there right up to the "C" grade viscosity limit of about 6,500 seconds Redwood I at 100 deg. F. People were seldom called upon to burn fuel oils of that viscosity now, but even if they went up to that limit again, and he was not saying they would, it was no new thing. This brought him back to the point he had made a little earlier in the paper—was the real problem, in fact, not the quality of the fuel oil but the job it had to do and the way in which it was burned?

He regretted that he had no data to reply to Mr. Jacob's question regarding the melting point of the ash in the tests which they had carried out. As for the acid dew point of the vapours, it was probable that this lay between 280 deg. F. and 300 deg. F. The gases passed out of the apparatus at a temperature far above the dew point but there might have been some condensation in the 20 square feet of surface in the convection section, which was water cooled.

Mr. Gollin had dealt very convincingly with this question of dew points and he felt there was nothing further to add on this subject.

Dealing with the written contributions, he was glad to see that Mr. Seymour Roques concurred regarding the impracticability of a general purpose additive. On the other hand the incorporation of a specific additive in individual ships, depending upon the characteristics of individual sludges, presented an extremely difficult practical problem.

In connexion with Mr. Arnold's comments he quite agreed with the remarks about salt water contamination. He felt, however, that there might have been some confusion in the reference to the cracked fuel oil used by the steamer with double ended Scotch boilers. This was likely to have been residual fuel oil, whereas the late Dr. Blache was referring to distillate Diesel grades. In any event it was safe to say that great improvements had been made in fuels, both distillate and residual, in the two decades which had intervened since Dr. Blache's paper was written.

INSTITUTE ACTIVITIES

Minutes of Proceedings of the Ordinary Meeting Held at the Institute on Tuesday, 8th December 1953

An Ordinary Meeting was held at the Institute on Tuesday, 8th December 1953, at 5.30 p.m., when a paper by Mr. C. W. G. Martin, F.R.I.C., F.Inst.Pet., M.Inst.F., entitled "The Influence of Modern Refinery Technique on Marine Fuel Oil Quality" was presented and discussed. Mr. Stewart Hogg (Chairman of Council) was in the Chair. 116 members and visitors were present and ten speakers took part in the discussion. A vote of thanks to the author was proposed by the Chairman and awarded by acclamation. The meeting ended at 8.15 p.m.

Local Sections

Merseyside and North Western

A meeting was held at the Temple, Dale Street, on Monday, 4th January 1954, at 6.30 p.m., when Mr. E. Elliott (Member) read a paper entitled "Marine Refrigeration". Mr. G. Pickering (Chairman of the Section) was in the Chair and the meeting was attended by sixty-eight members and visitors.

Mr. Elliott's paper, which avoided an historical survey, dealt with the manner in which plant is designed to suit given conditions, and described some of the calculations involved therein, taking as a simple example a group of provision chambers in a cargo ship. A description was then given of the hermetically sealed motor compressor units which, with the increasing use of A.C. current aboard ship, are now of considerable interest to the marine engineer.

A lengthy discussion, in which many members took part, was closed by Mr. C. W. Reed, who proposed a vote of thanks which was carried with enthusiasm.

Annual General Meeting

The Chair was taken by Mr. G. Pickering and thirty members were present at the Annual General Meeting, which was held on 11th January 1954. Following the adoption of the Report on the Activities for 1953, and the Income and Expenditure Account for 1953, the Chairman announced the election of Messrs. R. F. Capey, C. W. Reed and J. L. Snowdon (Members) to the Committee. He warmly thanked the retiring Committee members, Mr. W. L. Coventry and Mr. V. L. Farthing, for the valuable services which they had rendered for the past year.

The Chairman announced that there had been no other nominations for the offices of Honorary Treasurer or Honorary Secretary and that therefore Mr. J. E. Shields and Mr. G. H. Cornish would continue to carry out these duties. He thanked these gentlemen for their work in the past year, and paid tribute to their zeal and ability.

Reviewing the events of the past year, the Chairman said that he looked back with pride and satisfaction on what had been achieved. He thanked all members who had contributed to the success of this first year and paid special tribute to Mr. L. Baker for his work in organizing the formation of the section and for his continued guidance and wise counsel. He also thanked the members of the Social Sub-Committee for their work in organizing the very enjoyable dinner dance.

The meeting adjourned for a committee meeting at which Mr. T. McLaren, B.Sc., was elected Chairman and Mr. C. G. Binks, Vice-Chairman.

Taking the Chair, Mr. McLaren thanked the members for

their confidence and said that he would, to the best of his ability, maintain the high standard set by Mr. Pickering. He then called upon Mr. V. L. Farthing to propose a vote of thanks to Mr. Pickering.

Mr. Farthing spoke of the difficulties which beset the launching of any new project and mentioned a number of analogous enterprises. Such conditions demanded of the Chairman great wisdom and firm guidance. These were qualities that Mr. Pickering had shown in full measure and he thought that all members owed a great debt to their first Chairman. The vote of thanks was accorded with acclamation.

The Committee for 1954 was constituted as follows:—

Chairman: Mr. T. McLaren, B.Sc. (Member).

Vice-Chairman: Mr. C. G. Binks (Member).

Vice-President: Mr. L. Baker, D.S.C.

Mr. R. F. Capey (Member).

Mr. R. H. Dickinson (Associate Member).

Mr. E. Elliott (Member).

Mr. G. Keenan (Associate Member).

Mr. C. W. Reed (Member).

Mr. J. L. Snowdon (Member).

Honorary Treasurer: Mr. J. E. Shields (Member).

Honorary Secretary: Mr. G. H. Cornish, B.Eng. (Member).

North East Coast

At the Annual General Meeting of the North East Section, which was held at Newcastle upon Tyne on 15th January 1954, the following members were elected to the committee:—

M. Adams (Member)

J. L. Black (Member)

L. S. Candlish (Member)

E. C. Cowper (Associate Member)

S. H. Dunlop (Member)

W. Embleton (Member)

J. G. Gunn, B.Sc. (Member)

A. W. Jones, B.Sc. (Associate Member)

W. R. Jones (Member)

J. H. Kirby (Associate Member)

E. T. Middleditch (Member)

J. Orange (Member)

Commander(E) J. R. Patterson, O.B.E., D.S.C., R.N. (ret.) (Member)

H. White (Member)

W. M. Youngson, M.B.E. (Member)

Mr. W. M. Youngson was elected honorary treasurer and Mr. A. W. Jones was elected honorary secretary.

Scottish

The first Students' meeting held by the section on 15th January 1954 proved to be very successful.

For this occasion a discussion on "The Junior and Apprentice Engineer's First Trip to Sea" had been arranged and was conducted by Mr. Stewart Hogg (Chairman of Council). The members of the panel were: Mr. T. McLaren, B.Sc. (Member) and Mr. R. Barton, engineer superintendents, Mr. J. W. Walters, personnel superintendent, and Mr. J. R. Cresswell, chief engineer. Mr. J. Stuart Robinson (Secretary) was also present as a visitor.

Mr. T. A. Crowe (Chairman of the Section) introduced

Institute Activities

Mr. Hogg, who then gave a short address to the 121 students and members present. In the lively discussion which followed, forty-five students and members took part and, on the proposal of Mr. Crowe, the speakers were accorded an enthusiastic vote of thanks for having given their services and also for the masterly manner in which they had dealt with the many, varied queries.

South Wales

The South Wales Section held a junior lecture at the Cardiff Technical College on Wednesday, 13th January 1954, when Mr. A. G. Arnold (Member) presented his lecture, "Marine Diesel Engines". It was a most successful event, there being ninety-eight students and members present. Dr. A. Harvey, B.Sc., presided; Mr. David Skae (Vice-President) proposed the vote of thanks to the author, which was seconded by Mr. H. S. W. Jones (Member), and Mr. J. H. Evans (Vice-Chairman of the Section) proposed a vote of thanks to the Chairman.

Mr. Skae also presented the Institute prize to J. E. Barnes, the most outstanding marine engineering apprentice under the new training scheme at the college.

Junior Section

Gravesend

The meeting held on Wednesday, 3rd February 1954, at the Gravesend Technical College for the lecture by Mr. J. Hodge, M.A., on "Gas Turbines", was very successful. The author gave a most interesting description of gas turbines which was greatly appreciated, and a large number of questions were asked afterwards by members of the audience. The total attendance was over eighty, which included a party of twenty cadets from H.M.S. *Worcester*, and a number of members of the Gravesend Engineering Society.

Mr. Fox, the new headmaster of the college, took the Chair, and expressed the thanks of the audience to Mr. Hodge for his lecture. Mr. F. A. Everard (Member) represented the Council at the meeting and gave particulars of the services offered by the Institute to junior members.

Membership Elections

Elected 11th January 1954

MEMBERS

Eric John Armstrong
Alexander Walter Bell
Norman Buckland
Charles Carr Clark, Rear Admiral(E), O.B.E., D.S.C.
William Arthur Craven
Robert Sewell Ellis
Ernest Evelyn Freeth
James Charles Gill
John Gauld Imlach
Walter Kilchenmann, Dipl. Ing.
Thomas Hartley Lees
Robert James McCracken
John Malcolm McDonald
William Henry Metherell, Lieut. Cdr.(E), M.B.E., R.N.
John Henry Norgate
Hugh Harper O'May
Charles Henry Rance
John Henderson Smith
Herbert Henry Sweeney
Leon Titterton
Albert Vandeghen
Frederick Wilton Weaver
Francis George Hilliard White
Andrew Wilkinson, Lieut.(E), R.N.
George Yellowley

ASSOCIATE MEMBER

Donald James Fowler

COMPANIONS

Samuel Thomas Ackland
William MacGillivray

ASSOCIATES

Reginald Frederick Guy Astley
Gershom Henry Bassey
Gur Dial Bhilotra
Ronald Edward Burfitt
Robert John Butcher
Harry Convy
William Alfred Corp
Allan Herbert Thomas Culpeper
Leslie William D'Rozario
Archibald Gillies
Leslie Allan Goddard
John Green
John Stevenson Greenhill
Joseph Hanover
Clifford Somerville Harnett
Ronald Humphreys
Thomas Graham Irving
George Henry Charles Jenner
Anthony Stephen King
Peter McGregor McGregor
William Gordon Murrison
Andrew Thomas Russo
Damodar Bapusaheb Sawant
Dennis Russell Smith
Robert Leonard Starling
Cyril Cecil Lloyd Thompson
Frederick Cunningham Turnbull
John Henry Turnbull

GRADUATE

Hugh Leslie Owen Thompson, Lieut.(E), R.N.

STUDENTS

John Burgess Brodie
William David Cherry
Brian Edward French
John Trevor Griffiths
Warwick John Hood
John Joseph McCarthy
David Moore
George William Porter
Alasdair Somerled MacDougall Scott
John Anthony H. Smith

PROBATIONER STUDENTS

David Airey
Bryan George Beesley
David Wyndham Brinsdon
Brian Scott Clark
Donald MacDonald Fletcher
Robert Gibson
William David Guild
Gerrard Allan Hart
Michael George Andrew Korrie
Iain Leonard Bentley Moffat
Patrick John Noble
Roderick Meshach John Pedge
Peter Henry Ryder
David McGoun Tree
James Doggart Vance
Colin Stuart Walker
Ian Kemp Watson

TRANSFER FROM ASSOCIATE TO MEMBER

Rusi Jehangirji Anjirbag
Thomas Denny Armour
Subhan Ali Ayubi
Ronald Bates
Percival Hamil Brook
Frank Aldersley Lawrence
Graham Renwick
James Forrest Stevenson

TRANSFER FROM ASSOCIATE TO ASSOCIATE MEMBER

Kurt Schwarz, B.Sc.

Institute Activities

TRANSFER FROM GRADUATE TO ASSOCIATE

Michael Bedell Dodson
James Brennan Neilson

TRANSFER FROM STUDENT TO GRADUATE

Mohamed Zahir Navaz
Gian Chand Sahni

TRANSFER FROM PROBATIONER STUDENT TO STUDENT

David John Heaslip
John Every Wilkinson

Membership Elections

Elected 3rd February 1954

MEMBERS

John Henry Musgrave Austin
John Braid
William Edward Brennan
Arthur Drummond Bridgwater
Donald Herbert Ernest Charlwood
John Frederick, Lieut. Cdr.(E), R.N.
Robert Gray
Ernest William Hounsell
John Howey
Malcolm Mackenzie
Theodore N. Michael, M.Sc.
Matthew Russell
Robert Sheen
Fred Smith

ASSOCIATE MEMBER

John McNamee

COMPANION

Cornelis van Daalen

ASSOCIATES

Robert James Ashton
Richard Dennis Bolitho
John Butterfield
Austin James Campbell
Archibald Edward Collings
David Eric Stanley Cragg
Peter Hayward Trussler Dawson
John Hampson Dean
Bernard Foley
David Preston Fairman
Arthur Foreman
Estanis Gallo
Syed Mahmood Hassan
Lambros Kalafatis
Frederick Lowes
Douglas McInnes Macintyre
John William Makin
Thomas William Noble
Kenneth Herbert Perry
Ronald William Evan Quinton
Kenneth Bert Smith
Gerald McNeil Windle

GRADUATE

Gordon Trevor Stickland

STUDENTS

Brian Hull
John Michael Tomkins

PROBATIONER STUDENTS

Kenneth Allport
Dennis William Baker
David Barwell
Donald Frank Brown
Desmond Edward Byrne
Norbert Cranny
Francis Devitt
Richard Dunford
G. Evans
Stuart Edward Goakes
Victor George Hamer
Stanley Arnold Hill
Brian Dudley Ireland
Kenneth Russell Jones
Richard Arthur Jones
N. Law
John McGrail
William Terence Maher
Michael Charles Mills
Richard Nicholson
Edward Gerald Owen
Roger Paveley
Dennis Grantham Pearson
James Anthony Poole
Leonard Raymond Povall
John Anthony Robinson
Ian Charles Smith
Alan Thornton Stanley
Peter Barrie Walker
William White
Christopher James Young

TRANSFER FROM ASSOCIATE TO MEMBER

Tom Sherburn
Sydney Trotter
Dudley Vincent

TRANSFER FROM ASSOCIATE TO ASSOCIATE MEMBER

Gur Dial Bhillotra, B.Sc.
Gordon John Talbot

TRANSFER FROM GRADUATE TO MEMBER

Brian Patrick McConnell, Lieut. Cdr.(E), R.N.
Peter Martin, B.Sc.

TRANSFER FROM GRADUATE TO ASSOCIATE MEMBER

Desmond Quinn

TRANSFER FROM STUDENT TO ASSOCIATE

Kenneth Gordon McColl, B.Eng.

TRANSFER FROM PROBATIONER STUDENT TO STUDENT

Peter Young Coles
Douglas Inglesent
Roy Mason
Kevin Francis Ponsford
Harold David Senior

OBITUARY

JOSEPH LAWRENCE DUNN (Member 9441) was born in Canada in 1889 and lived at Kingston, Ontario, most of his life. He was apprenticed to the Montreal Transportation Company from 1909-13 and remained with the company as a fitter for another year. He served with the Canadian Expeditionary Forces for the duration of the 1914-18 war. For the greater part of his career he was employed at sea, with the Boland-Cornelius steamships and the Hall Corporation. In 1939 he joined the Royal Canadian Navy and was appointed commandant of the Royal Canadian Naval School for Engineers of the Merchant Service, with the rank of Lieutenant Commander(E); on his release in 1945, he was awarded the M.B.E. Lieutenant Commander Dunn was also principal of the Dunn School of Steam Engineering at Kingston.

He was a Member of the Institute of Power Engineers of Canada, a Member of the Dominion Association of Stationary Engineers, and had been a Member of the Institute since 1942.

FRANCIS REYNOLDS ELLIOTT (Member 7120) was born in 1896. He served an apprenticeship in Belfast with Barbour and Coombe, Ltd., and the Belfast Harbour Commissioners. From 1917-19 he gained experience as a journeyman fitter with Harland and Wolff, Ltd., and the Belfast Harbour Commissioners. For the next thirteen years he was a seagoing engineer with Glen and Co., Ltd., of Glasgow, serving for several years as chief engineer; during this time he superintended the building of ships in Burntisland for the company's Baltic trade. He was then employed by Short and Harlands, Belfast, in charge of the construction of inner and outer nacelle sections for Stirling bombers, and left this employment to take charge of Admiralty repairs at Pollock Dock, Belfast. In 1932, Mr. Elliott obtained an Extra First Class Board of Trade Certificate and returned to sea in ships owned by Glen and Company, whom he served for the rest of his life; after the second world war he took part in returning Lease-Lend ships to the U.S.A. He died suddenly on 2nd September 1953.

Mr. Elliott had been a Member of the Institute since 1932.

ALBERT CECIL GOODER (Member 10969) died after a long illness on 4th January 1954. He was born on 6th August 1893 and served an apprenticeship with Richardsons, Westgarth and Co., Ltd., Middlesbrough, from 1910-14. He served in the Army throughout the 1914-18 war and then spent five years at sea, from 1919-24, as fifth and fourth engineer in steamships of the Ellerman Hall Line, Ltd. He obtained a First Class Board of Trade Steam Certificate in 1924 and was appointed an engineer surveyor to the National Boiler and General Insurance Co., Ltd., Manchester, in 1925, a position he held until September 1953 when he was obliged through ill health to retire. Until his death he was a very active member of the Engineer Surveyors' Association and served as their President for the year 1950-51.

Mr. Gooder was a Member of the Institute from 1946 and was elected to membership of the committee of the Kingston upon Hull and East Midlands Section in 1953.

WILLIAM THOMAS KIRWAN (Member 14286) died suddenly, after an operation, on 16th October 1953, at the age of fifty-five. He served an apprenticeship with D. R. Anthony and

Son, Dublin, and first went to sea in 1917, serving in various companies until 1929, when he joined the Anglo-Saxon Petroleum Co., Ltd. He was employed by this company until he retired in August 1953, since 1939 as chief engineer in many of their vessels, and his death so soon after his retirement is much regretted.

Mr. Kirwan had been elected to membership of the Institute in April 1953.

WILLIAM LYONS (Member 6797), who died on 8th October 1953, was born in 1890. He went to sea in 1912 and obtained a First Class Board of Trade Steam Certificate. In 1920 he joined Burns, Philp and Company and remained with them until his death; the whole of this period was spent at sea except for three years, from 1942-45, when Mr. Lyons was superintendent of American small ships at Townsville. He was elected to membership of the Institute in 1931.

ANDREW MCARTHUR MORISON (Member 11281) was born in 1885 and educated at Allen Glen's School, the Royal Technical College, Glasgow, and Glasgow University. His apprenticeship was served with David Rowan and Co. Ltd., from 1901-03, and the London and Glasgow Engineering Co., Ltd., from 1903-06. For a short period, in 1908-09, he was assistant to William Anderson, consulting engineer of Glasgow; in 1909 he joined the firm of McArthur Morison and Company of Glasgow, first as assistant to Mr. W. McArthur Morison and then as his partner. He was also surveyor to the Registro Italiano Navale.

Mr. Morison was a founder member of the Society of Consulting Marine Engineers and Ship Surveyors, a Member of the Institution of Naval Architects, and was elected a Member of the Institute in 1947.

JAMES VINCENT O'SULLIVAN (Member 4203), a native of Cork County, Ireland, was born in 1890. He served an apprenticeship with the City of Cork Steam Packet Company and spent eight years at sea, including the period of the First World War, obtaining a First Class Board of Trade Certificate. He first joined the United Fruit Company of New York, to whose service he was to devote so many years, in 1920, sailing in the *Ulua* on her first voyage for the company. In 1924 he left the company on leave of absence to attend Liverpool Technical College for two years before joining Esplin and Sons, who were then constructing steamers for the United Fruit Company, as engineer surveyor.

He returned to the United Fruit Company in 1928 as assistant port engineer, New York, and was promoted surveyor in 1929, assistant superintendent of new construction in 1930, hull superintendent in 1933 and new construction superintendent in 1943. In 1930 he was closely concerned in the construction of the company's six mail ships at Newport News; he was considered to be an authority on requirements for steamships in the tropical trades. Mr. O'Sullivan died in London after a short illness on 8th October 1953. He was elected to membership of the Institute in 1920.

WILLIAM HENRY PRESTON (Associate 12942) was born in 1901 and died very suddenly on 7th January 1954. He served

Obituary

an apprenticeship in H.M.S. *Indis*, Devonport, from 1917-22, and for the next ten years sailed as engine room artificer in destroyers, cruisers and battleships. From 1932-42 he was at sea in cruisers and battleships with the rank of commissioned engineer: in 1942 he was promoted senior commissioned engineer and came ashore to employment first as technical liaison officer at a Ministry of Labour Government Training Centre for eighteen months, then as factory officer and engineering lecture officer for artificer apprentices in H.M.S. *Fisgard* until 1946. From 1946-49 he was engineer officer of H.M.S. *Pelican* with the Mediterranean Fleet and for the next year he was instructor in H.M.S. *Raleigh*, the Stokers' Training Establishment, Devonport. He was engineer officer of H.M.S. *Tremadoc Bay* for a short time, then, from May 1950, he had been attached to the parent ships of the Reserve Fleet at Devonport for engineering duties and also as welfare officer for the men in the *Orion*. He was actually on duty until two hours before his death.

Lieutenant Preston was elected an Associate of the Institute in 1950.

GEORGE TURNBULL REED (Member 8311) was born in 1897. After an apprenticeship with George Clark, Southwick Engine Works, Sunderland, interrupted by service in the Durham Light Infantry in the First World War, the greater part of his sea-going service was spent with the Silver Line, Ltd., commencing in 1926, followed by promotion to chief engineer in 1927 and by the appointment in 1936 as superintendent in Hong Kong. He returned to England on leave in 1939 and, the Japanese war intervening, he was appointed superintendent in the United Kingdom, based in Liverpool, until 1946.

From mid-1946 he served as superintendent in Calcutta until, six months later, he returned to Hong Kong to reassume his position as superintendent there. In 1948, after a short leave in England, Mr. Reed again returned to Hong Kong, having been appointed assistant engineer-manager for the Hong Kong and Whampoa Dock Company, being promoted shortly afterwards to engineer manager. He held this position until his death on 20th July 1953 after a long illness in the Matilda Hospital, Hong Kong.

Mr. Reed was elected a Member of the Institute in 1936.

DAVID DOUGLAS ROBB (Member 6754) died on 1st January 1954, aged fifty-eight. He served an apprenticeship with J. I. Thornycroft and Co., Ltd., and then went to sea; until 1919 he was in the Royal Naval Reserve and then joined the Union Castle Line. In 1924 he was appointed second engineer in the Southern Railway Company's steamers and was promoted chief engineer in cargo boats in 1925 and in cross-Channel passenger ships in 1931. Lieutenant Commander Robb was awarded the D.S.C. for his services in connexion with the Dunkirk evacuation when he was chief engineer in the *Isle of Guernsey*, then a hospital ship. After Dunkirk, he rejoined the Navy and was flotilla engineer officer for the radar training ships on the *Isle of Sark*; he was later appointed chief engineer of an aircraft carrier. He returned to his work with the Southern Railway Company after the war and was chief engineer of the *Falaise* at the time of his death. Lieutenant Commander Robb was the British Railways representative of the Merchant Navy at the Coronation in Westminster Abbey in June 1953 and received the Coronation Medal.

He was a member of the Council of the Navigator and Engineer Officers' Union and had been a Member of the Institute since 1931.

WILLIAM WILKIE ROLLO (Member 11869) was born in 1891. He was apprenticed to the Caledon Shipbuilding and Engineering Co., Ltd., Dundee, from 1912-17, and for the next five years sailed in ships of various companies, the Saint Line, the Brocklebank Line, the New Zealand and Federal Lines, and the Ben Line. He obtained a First Class Board of Trade Steam Certificate in 1916, and from 1918 until he died on 26th December 1953 he served the Ben Line Steamers, Ltd., as chief engineer for the last twenty-six years.

Mr. Rollo was a Member of the Institute from 1948.

JOSEPH ERRINGTON RUTTER (Member 2414) was born in 1882. His apprenticeship was served with Palmer's Shipbuilding and Iron Company, Jarrow on Tyne. From 1903-12 he was employed by Apar and Company, Calcutta, four years as junior and five years as chief engineer, leaving the company only when it was sold. He qualified for a First Class Board of Trade (Straits Settlements) Steam Certificate and, in 1925, for a First Class Motor Endorsement, the first ever granted in Singapore. From 1912-15 he was shop and yard foreman at the Hong Kong and Whampoa Dock Co., Ltd., and from 1915 until he retired in 1936 he served as chief engineer with the Straits Steamship Company, Singapore, the last eleven years being spent in motor ships. This period included two years' transport service with the Indian Expeditionary Forces, from 1917-19. In 1934 he supervised the construction and installation of machinery, both steam and Diesel, for the company's new ships, including their first motor ship, m.v. *Marudu*, built by Workman, Clark and Company, at Belfast, and with machinery installed by Burmeister and Wain at Copenhagen.

From 1936-40, Mr. Rutter acted occasionally as consulting engineer and inspector of machinery for the Planters Engineering Co., Ltd., of London; in 1941 he offered his services to the Admiralty and served as temporary overseer on the Admiralty emergency repair staff at Southampton. He resigned this position in 1942, for reasons of health. He died on 22nd March 1953.

Mr. Rutter had been a Member of the Institute since 1910.

JOHN SNELL (Member 3727) was born in Devonshire in 1892 and died at Auckland, New Zealand, on 16th November 1953. He served an apprenticeship with W. White and Sons, of Cowes, Isle of Wight, from 1909-14, and then spent the next eight years at sea in ships of the New Zealand Shipping Co., Ltd. He obtained a First Class Board of Trade Steam Certificate in 1921. Mr. Snell joined the Auckland Farmers' Freezing Company, New Zealand, in 1933 as a shift engineer, and held this position until his death.

He was a member of the New Zealand Institute of Refrigeration Engineers; he first joined the Institute as an Associate Member in 1919 and was transferred to full membership in 1922.

FREDERICK IRVAN SHARMAN (Member 12629) died suddenly on 19th January 1954 at the age of fifty-four. From 1915-20 he was a boy artificer in the Royal Navy and served as an engine room artificer in H.M. ships from 1920-27. He was promoted commissioned engineer in 1928 and sailed in H.M.S. *Calcutta* for two years before taking up an appointment as assistant technical officer at the Mechanical Training Establishment at Chatham. In 1932 he returned to sea and except for a further short period as officer in charge of leading stokers' training at the M.T.E., Chatham, he continued his service in H.M. ships until 1945, as engineer officer from 1941, first in the *Campbell* and then the *Zest*. In 1943 he was promoted Acting Lieutenant(E). In 1946 he was appointed (as Lieutenant(E)) assistant to the Engineer Rear Admiral on the staff of the Commander-in-Chief at the Nore, and was employed until his death on the production of instructional films and in writing technical books for the Engineer-in-Chief's department of the Admiralty. Whilst acting as Flotilla Engineer Officer in 1943, he was mentioned in despatches, and in 1945 was awarded the D.S.C. for work during Russian convoys. His experiences during these arctic actions led him to devise an ingenious life-saving apparatus which, unfortunately, was not adopted officially. He was promoted lieutenant-commander in May 1953.

As far as his Naval duties allowed, he took a keen interest in local politics, and had recently been elected president of his local ward committee. He leaves a widow and one son; his eldest son, a flight engineer in the Royal Air Force, was lost on operations during the war, and his surviving son is serving with the Royal Navy.

He was elected a Member of the Institute in 1949.