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President—SIR EDWYN S. DAWES, K.C.M.G.

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SIXTIETH PAPER

(OF TRANSACTIONS)

LIQUID FUEL,

AND

HOW TO BURN IT.

BY

Mr. H. C. WILSON

(MEMBER)

READ AT

THE INSTITUTE PREMISES, 58, ROMFORD ROAD, STRATFORD

ON MONDAY, FEBRUARY 24th, 1896.

THE UNIVERSITY COLLEGE, CARDIFF,

ON WEDNESDAY, MARCH 18th, 1896.

AND AT THE ARTS' SOCIETY HALL, SOUTHAMPTON

ON WEDNESDAY, MARCH 25th, 1896.

PREFACE.

58, ROMFORD ROAD,

STRATFORD, E.

March 9th, 1896.

A Meeting of the Institute of Marine Engineers was held here this evening, presided over by Mr. T. F. AUKLAND, when the Paper on "Liquid Fuel," by Mr. H. C. WILSON (Member) was discussed. The Paper was read at a meeting, held on Monday, February 24th, when Mr. W. C. ROBERTS, R.N R., occupied the chair.

Arrangements are in hand for the Paper being read at Cardiff to the members of the Bristol Channel Centre, and at Southampton to the members of the Southampton Centre.

The Paper and Discussion follow.

JAS. ADAMSON,

Hon. Secretary.

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PROFESSOR A. C. ELLIOTT, D.Sc.

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CHAIRMAN:
MR. C. S. DUSAUTOY, R.N.R.

For some years past, engineers have been experimenting with various fuels and combinations of fuels, for the purpose of realising some economy upon the enormously wasteful results of firing boilers with coal or coke.

Naturally, these experiments included trials of liquid fuels, and the satisfactory results obtained from even a

crude and faulty application of hydro-carbons, for heating purposes, at once pointed out this description of fuel as being one from which great advantages in both economy and power could readily be obtained. The result has been that many more or less satisfactory methods of utilising liquid fuel for firing all kinds of boilers have been put forward within recent years.

It is quite impossible, within the limits of a short paper, to follow closely the steps of improvement that the history of this branch of the engineering profession presents. Suffice it to say that they have been many and interesting, and the subject is still occupying the attention of many of the leading scientific and practical men of the day.

Before attempting to burn liquid fuel in a boiler furnace of any description, it is necessary to study the nature of the fuel to be employed. Generally speaking, the term liquid fuel is understood to mean a certain combination of hydrogen and carbon in varying proportions. As a matter of fact, the combinations of hydrogen with carbon in a liquid form may be reckoned by hundreds, ranging from marsh gas or "Will o' the Wisp" down to the very uninflammable and semi-solid tar oils obtained from the fractional distillation of petroleum and shale oil or paraffin. There are, of course, many other grades, but for the purposes of this paper it will only be necessary to consider those that are practically adapted for the purpose of firing boilers. There seems, however, to be a general idea that liquid fuel means petroleum, that is to say, the ordinary petroleum of commerce, and one of the objects of this paper is to point out the impracticability, from a commercial point of view, of the general use of this hydro-carbon for the purpose.

The use of the ordinary American or Russian petroleum as a fuel presents some advantages, such as uniformity of quality and the absence of impurities, but the disadvantages far outweigh these reasons for its use.

In the first place, and from a commercial point of view, the price is far too high, owing to the cost of refining from the crude oil. Secondly, ordinary petroleum has a flashing point between 105° F. and the Government limit of 73° F., or "Abel's close test." These temperatures are far too low, and render the handling of quantities in proximity to fires extremely dangerous.

For some time it has been clearly recognised that a very heavy hydro-carbon is the only combination that is in all ways suitable for general use as liquid fuel. The residue of the distillation of petroleum or shale oil, known by the names of Mazouth and Astaktis, which is absolutely uninflammable, up to a temperature of 350° to 490° F., may be taken as being the particular grade of liquid hydro-carbon most suitable for the purpose of firing boilers.

Although this oil has not yet received sufficient attention from chemists and engineers to clearly define its usual composition and value as regards calorific power, still, the results of experiments show that its value in British thermal units is about 20,000 as against an average 14,000 for coal. This fact gives Astaktis a great initial advantage over coal, but before accepting the statement that one ton of Astaktis will make as much steam as two tons of good coal, it will be necessary to examine both sides of the question. Broadly speaking, the position is this, that in this country at the present moment coal has the advantage of price, but as the demand for Astaktis in England is at present small, the price is high; but the supplies of this oil are almost unlimited, and upon a larger demand being created, immense quantities might be placed on the market at a price that coal could not be raised for. I have been lately informed that Astaktis can now be obtained in the Baku district for little more than the cost of putting it into the tanks.

Again, with reference to the steam-raising powers of coal versus oil, it must not be forgotten that the

coal-fired furnace is most wasteful, and in spite of the hundreds of appliances and patent systems for improving the result, it is very doubtful if more than one half of the heat theoretically contained in each pound of coal is practically applied to the purpose of raising steam. This great loss of efficiency is chiefly owing to imperfect combustion and imperfect utilization of the actual heat given off. On the side of liquid fuel, we have a considerable increase in the theoretical calorific power, viz., 20,000 B.T.U. against 14,000 for coal; further, it has been proved that in practice almost the whole of this available heat can be taken up and transmitted to the boiler water, when the oil is burnt in a furnace that rigidly complies with the special requirements. The net result is, therefore, that in spite of its present high price in this country, oil fuel has tremendous and solid advantages over coal for many purposes, which every day are tending to increase and become more generally appreciated by engineers.

It has been contended that liquid fuel could not compete with coal in this country because of the cost of importation, but I would point out that the trade of carrying petroleum in bulk in tank steamers is increasing by leaps and bounds, and would suggest that it may at no distant date reach the point of bringing crude petroleum to this country for the purpose of being refined here, as there would be an immediate and ready use for the residue, or Astaktis, which at present is looked upon more or less as a waste product, but which will soon become almost as valuable a product as the refined oil itself. Probably the tank steamers will be the first to adopt liquid fuel throughout, and the enormous economy possible in this case will allow of freights being reduced to a point now thought impossible. The introduction of liquid fuel for the firing of marine boilers, locomotives, and factory boilers, must cause many great and far reaching changes in the engineers' profession, and in trade generally.

Many trials have been made during the past sixty years, of methods more or less successful, as anyone may

find upon a short search through the records of the Patent Office in London. The first trials of importance were practically made at Woolwich Arsenal in the year 1841, with Richardson's apparatus. Various oils were used during these trials, and an evaporation of twelve to thirteen pounds of water per pound of oil was obtained. In 1868, further trials were made at Woolwich, and in the same year the Admiralty sanctioned trials of the apparatus of Messrs. Crow & Dorsett, on the steamer *Retriever*, of 500 tons. In 1865, a Russian patented a system of pulverizing or atomizing oil by means of compressed air, and in 1870 a steamer was fitted with this apparatus. In this year, also, Admiral Selwyn took up the question, and a series of trials were made with the boilers of war ships. In 1868, Mr. Sainte Clair Deville employed his petroleum grate for firing the furnaces of his laboratory. A locomotive of the Northern Railway of France was also so fitted, and the boilers of the Imperial yacht, *Puebla*.

In this case the heavy oil contained in a tank descended by gravity through a pipe, fitted with a cock, and fixed above the furnace grate. At this point the pipe divided up into thirteen small tubes, each fitted with a cock, which distributed a fine jet of oil the whole length of each bar of an iron grid placed vertically in the furnace. The interior of the furnace was composed of fire bricks in the form of an arch. Midway in the furnace was an arrangement of bricks, disposed so as to increase the heating surface. This heating surface in the *Puebla* was about 40 square feet. The result of the trials made on the 8th June, 1868, were satisfactory. With coal, the boiler developed 63 h.p , with a pressure of 80 lbs. per square inch, and 240 revolutions; with oil, 65 h.p. was obtained.

It was not until the year 1874 that liquid fuel was practically used for the purposes of trade. It was about this time that the Volga Railway commenced to use oil for locomotives, and at the present time there are more than seventy-two locomotives fired with

Astaktis on the Volga and on the Caspian. In 1880, a launch, called the *Billy Collins*, was fitted with a liquid fuel apparatus, constructed by the Hydro-Carbon Gas Company, and worked on the Thames for some time. The results were most satisfactory. The ease with which the fires were regulated, by simply opening or shutting the oil valves, was especially so.

In a paper read before the Institute of Mechanical Engineers (1883), Mr. Urquhart, Locomotive Superintendent of the Griazi-Tsaritsine Railway, gives the practical results of the employment of liquid fuel in locomotives. They show that, compared with anthracite, it realizes an economy of 40 per cent. on the weight and 55 per cent. on the cost. In comparison with bituminous coal, oil gave an economy of 49 per cent. on the weight and 61 per cent. on the cost, the evaporative power being 11·35 lbs. of water per lb. of oil, the theoretical power being 16·2 lbs. The Central Pacific Railway have also used oil with the best results.

In England, some trials were made at Portsmouth, with the view of determining the relative values of oil and coal as fuel for war ships. Colonel Sadler conducted the trials, which gave complete satisfaction and were in favour of oil. The steamer *Himalaya*, of 800 tons and 100 h.p., fired with liquid fuel, by means of the Tarbutt apparatus, made the voyage to Leith and back to London at a speed of eight-and-a-half knots; with coal she only made seven knots. In the type of locomotive now in use on the Russian railways, the oil reservoir is placed in the tender, between the two sides of the water tank, and in the place formerly occupied by the coal. Each tank is fitted with a gauge glass, which indicates the quantity of oil in the tank. For a six-wheeled locomotive, the capacity of this tank is about three-and-a-half tons.

Although the duty on tar oil is very high at present in France, still, in 1885, Mr. Allest made some very interesting trials on board the torpedo boat *Aube*. The oil was burned in a state

of vapour, and each furnace was fitted with two burners. During the trials, which lasted for five hours, these burners worked with perfect regularity, the pressure in the boiler being kept at the maximum.

Perhaps the best known application, on a large scale, of liquid fuel, is that of the locomotives on the Great Eastern Railway. Mr. Holden, of the Stratford Works, has designed the method, by means of which he is able to burn oil and coal at the same time. This is effected in the following manner: The oil is thrown into the firebox in the form of fine spray obtained by air pressure by means of a special form of injector. This spray enters the firebox just above the firebars, which are covered with a thin layer of coal or coke in an incandescent state. The results obtained are greatly in favour of oil, and the apparatus does not require any great alteration to be made in the existing fireboxes. Mr. Holden's system has been adopted on the Argentine-Mexican railways, and has been on trial in England on the North Eastern, Lancashire and Yorkshire, and Metropolitan District Railways.

In England there has recently been constructed a torpedo boat, of about 86 tons displacement. She has a double bottom; this is divided up into eight watertight compartments, which are used as tanks or bunkers for oil, and holds about fifteen or sixteen tons. As these compartments are emptied of oil they are run up with water, so that the draught and stability of the boat remain always the same. Her engines are ordinary triple expansion. The almost automatic working of the fuel apparatus allows of the crew being greatly reduced. For example: one man only is required to look after the fires. The boiler is of the ordinary locomotive type, with the special fittings necessary for liquid fuel burning. It is fitted with thirty-one oil jets, fed by means of a Worthington pump, which draws the oil from the double bottom and delivers it into a cylindrical tank, where it is put under air pressure before reaching the jets. When all the jets are working together in

the furnace, it presents the appearance of a mass of flame, without ashes, smoke, or smell. It is possible to put out the jets separately or all at once. In one trial made she went twenty-one knots and developed 1,203 h.p. Then twenty-one jets were shut off suddenly, after which the steam did not rise sufficiently to blow off at the safety valve. The result of all trials up to the present time has been to show that there are only two ways of burning liquid fuel, viz., either by means of atomizers for large powers, or gasifiers for small powers. It necessarily follows, seeing that heavy oil is most uninflammable in bulk, that the only way to burn it is to finely divide it up into the form of gas, vapour, or spray. This spraying is best produced by means of an atomizer, which is, generally speaking, an apparatus for introducing a stream of the oil into the centre of a stream of air or steam, the effect of which is to break up the oil into fine spray. In this form the oil readily catches fire and burns in a perfectly regular and safe manner, so long as the supplies of oil and air or steam preserve their proper proportions. The effect of any considerable variation in either is to extinguish the flame or throw out the oil in an undivided state. The apparatus known as the atomizer has been brought to such a state of perfection that these difficulties may be considered practically as non-existent, when used for the purpose of firing boilers. The great question is whether it is better to use steam or heated air as the dividing medium. There is much to be said both for and against each system, but I am rather in favour of the use of superheated steam, especially for marine work.

I now come to what may be considered as being the most important part of the liquid fuel question, and that is, the proper and best means of fully utilizing the heat obtained from a jet of burning oil, for the purpose of raising steam in a boiler. In the numerous instances I have referred to, the combustible liquid has been employed in a manner that is not at all perfect, and evidently had not been sufficiently studied. In short, the arrangement of the apparatus used did not permit of

the complete utilization of the calorific energy stored up in the fuel:—that is to say, of the sum of the heat units set free by the combustion of the hydrogen and carbon. At the time of the first trials, the oil was allowed to fall drop by drop on to a flat heated surface of fire brick, and the necessary air for combustion was supplied by natural draught, or by a fan. It is needless to say that this method is defective in principle and was soon abandoned.

At the present time all the apparatus in use, although differing as to detail, act on the principle of atomizing the oil by means of compressed air or steam, and projecting it in the form of vapour into the furnace of the boiler. With this arrangement it is absolutely necessary that the furnace be fitted with fire-bricks inside, in order to maintain the temperature at a sufficiently high degree, otherwise the combustion of the heavy hydro-carbon is incomplete, and consequently produces smoke. This manner of employing the liquid combustible is exceedingly defective, and contrary to the natural laws of combustion, and, further, to the perfect utilization of the heat produced.

When the combustion takes place at the pressure of the atmosphere in a single furnace, and that of restricted capacity, in the interior of which the temperature is very high, there escapes a great proportion of dissociated elements among the products of combustion, which pass through the tubes in the boiler. In these tubes the gases are unable to renew their combinations, on account of their being too highly diluted by nitrogen, carbonic acid, and also by the steam given off with them. It is well known that combustible gases become uninflammable when diluted by a too strong proportion of vapours or gases that are incombustible, and that in all these furnaces, such as described, especially those in the interior of which the heat is very intense—notably those with firebrick linings—a great proportion of these combustible elements escape without being completely oxidised, and this by reason of a complex phenomena of

dissociation, of which the intensity decreases on the augmentation of the pressure of the medium where the combustion takes place, and the lowering of the temperature of this medium. This, therefore, condemns the arrangement of the single furnace, and above all, of firebrick linings.

The conditions to fulfil in order to obtain a complete and rational combustion are:—

1. The division of the furnaces, in order to have a number of burning jets, between which the air is able to get in sufficient quantity to assure the integral combustion of the carbon and hydrogen contained in the fuel.

2. To receive the heat produced by the foregoing means of combustion on to a large metallic surface covered with water, and in permanent contact with the flame and where the combustion is effected.

This arrangement provides that the flame does not attain a too high interior temperature, and, consequently, does away with dissociation. It is also possible to keep the temperature, if desired, no higher than that necessary for ignition.

The heating system patented by a firm in Paris is the first to comply with these necessary conditions. In this system the flame produced by the combustible liquid is projected into a combustion tube surrounded by the water to be heated, and forming a series of Bunsen burners, in the interior of which the combustion is continued and completed in such a manner, that there is nothing comes out but incombustible gases without colour, the heating power of which is utilized by the usual means of tubes, &c.

It will be understood that the important principle of this system consists of the arrangement of combustion tubes traversed inside by flame and divided into several

sections, between which the air is able to get in sufficient quantity, each one of these sections having its orifice of escape smaller than the mouth or entry of the one next to it, and placed at a distance apart, determined by the relative areas of the orifices under consideration, and of the volume and velocity of the jet used, so as to obtain between each interval a constant drawing in of the air necessary—and sufficient to maintain the combustion without smoke, during the transit of the section that follows this interval. This system is exceedingly simple, and permits of the rapid and complete combustion of enormous volumes of gas or vapours of hydro-carbons, or other vapours in the interior of long and narrow metal tubes surrounded with water; and consequently not presenting other than a relatively very cold contact a result hitherto considered by Specialists as a material impossibility. The question of contact must not be lost sight of, because, in the large single furnaces, the combustion of gases or vapours, which is easily obtained when the surrounding plates are very hot, becomes almost impossible with the plates, comparatively speaking, cold, unless the above arrangement is made use of.

It must be remembered that the combustion of gaseous jets surrounded by air takes place solely at their periphery or outside edge, and the interior is formed of a cone of unburned molecules of such a kind, that the quantity of gas burned all over the surface of a nearly cylindrical flame, such as exists in the furnaces described, is the same at any one point as at any other. In these furnaces the combustion is absolutely complete, that is to say, there is no escape of carbonic oxide such as takes place in boilers fitted with a single furnace, where the loss of combustible, from this fact alone, is very considerable, because the calorific power of carbonic oxide is about 4,000 British thermal units, or about one-fifth the value of the initial fuel. The loss of fuel due to smoke and soot in other furnaces is also very important.

At some evaporation trials made at the end of last year with this boiler, as specially designed for liquid

fuel, the results were as follows:—With coal tar oil, the boiler evaporated 15·23 lbs. of water, from and at 212° F., per lb. of oil burned. This oil has only a theoretical calorific power of 16,048 B.T.U. With Astaktis, the boiler evaporated 18·82 lbs. of water from and at 212° F., per lb. of oil burned. This oil has a theoretical calorific power of between 19,800 and 20,000 B.T.U. The theoretical maximum heating power of Astaktis may be taken as equivalent to an evaporation of 20·5 lbs. of water from and at 212° F. The amount of oil consumed for this result, on a trial of one hour exactly, was 69·75 lbs. or 31 kilogrammes. This oil was atomized by steam from a small auxiliary generator at a pressure of 30 lbs. per square inch, and superheated to a temperature of about 900° F. or 500° C This boiler is about 55 per cent. lighter than an ordinary coal-fired boiler, and 35 per cent. lighter than the other descriptions of liquid fuel boilers.

DISCUSSION

AT

58, ROMFORD ROAD, STRATFORD,

MONDAY, FEBRUARY 24th, 1896.

CHAIRMAN:

MR. W. C. ROBERTS, R.N.R.

The CHAIRMAN: I am sure you have all been highly pleased and interested with the very able Paper that Mr. Wilson has just read. The subject is certainly a very interesting one to engineers generally, although I dare say there are very few gentlemen present who have had experience in burning oil. But if coal fails us at any time we have always oil to fall back upon. It is difficult to get it in sufficient quantities at the different ports, but it is coming to the front as a material for use instead of coal, and it will get rid of a good deal of hard swearing. There would be no need for heaving up ashes or cleaning fires. I think it deserves our serious consideration, and if you have any questions to ask I am sure Mr. Wilson will be very pleased to answer them.

Mr. E. N. HENWOOD (Visitor): We are indebted to the author for a very interesting contribution on this important subject. It would be of further service, however, if Mr. Wilson could inform the meeting whether he was able to gauge by pyrometer the heat generated in the furnaces constructed on M. Siegle's system, and whether he was able to melt fire-bricks as a proof of the heating power available. I have found, during the thirteen years that I have been employing oil fuel on my system, that an evaporation is obtainable considerably in excess of that obtained by any other system, one of the proofs thereof being that, in my furnaces, Gainster fire-bricks, of high refractory power, such as are used for steel furnaces, are melted like glass, and it is important to observe that the heat so generated is in no way injurious to the boiler tubes, as it is so equally distributed. One ton of oil on my system has evaporated more water than can be evaporated by from three to four tons of best Welsh coal. The combustion is so perfect that you can see as small an article as a pin's head at a distance of ten feet through the furnace. It is important to bear in mind that the conditions and arrangements which are suitable and necessary for burning coal, admitted by many to be a costly, cumbersome, dirty and obnoxious fuel, are unsuitable in many ways for the employment of oil fuel, and any hybrid arrangement for working the two fuels in combination will only lead to a repetition of disasters of which there have been too many already. On a recent date there was an explosion at a brewery, causing the death of the acting stoker, which is a repetition of a like accident, when the furnace front was blown off at some tar works. But there is still more serious danger lurking in any system of oil firing by injecting it over the fire bars, even when they are partially protected by a layer of incandescent coal or some other material. The danger consists in the enormous heat that is evolved from the oil fuel causing the fire bars to melt and collapse, resulting in a serious disaster, probably entailing the loss of the vessel's steaming power, and consequent easy destruction by foundering or capture

by the enemy. Yet another and serious loss is inherent in a coal-fired boiler of the ordinary circular shell type, in the cold ashpit and the constant opening of the furnace doors, whereby an excess of cold air is repeatedly admitted, which tends to diminish the steaming power and is highly injurious to the boiler. On my system the fire bars are removed and a fire brick chamber of strong fire-resisting bricks is built up in the furnace and the front closed entirely, saving an opening for the injector, and a small door for lighting up, which is closed and locked and so maintained after the fire has been lighted for the whole voyage during which steam has to be maintained. The necessary amounts of oil, steam and air are controlled by suitable valves, and, as the combustion is perfect and extremely rapid, it is necessary that the vital air be supplied with the requisite rapidity. This, then, ushers in a departure from the crude system of steam raising at the present time, and as it may fairly be stated that heat is the primary source of power in the mechanical world, it will no doubt be admitted that its control and maintenance should be in the hands of an able and intelligent officer, who should be responsible for the equable maintenance of the steam pressure. Let me give as an instance the case of my steam yacht *Ruby*, which ran on the Thames for some time with oil fuel. We had the most perfect combustion without any trouble whatever. A steam pressure of 100 lbs., with a constant and unvarying cold-feed water supply, was maintained without any attention whatever when running at full speed for any length of time, and the unvarying pressure of 100 lbs. was particularly noticed by the Admiralty Staff Engineer, on the four hours' trial which he attended. The Chief Engineer to the Board of Trade was on board at the same time, and according to a letter which I have received, the Chief Engineer Surveyor to Lloyd's Register reported favourably to the Committee on the trial which he attended. The old system of using coal had better be got rid of with all possible dispatch, and although ten years have elapsed since Sir Edward Reed, the late eminent member for Cardiff, advocated in the House of Commons the

formation of oil fuel depots in the place of coaling stations, no steps have been taken to carry out this sound recommendation. It will be apparent that in a very short space of time a vast amount of oil fuel could be stored at every available coaling station, for all the old iron vessels of the Navy could easily be converted into tanks, and moored at the various ports, and kept supplied by the fleets of tank steamers now engaged in the trade. In some of the British Colonies there are immense supplies of oil fuel, only requiring to be drawn upon, and other sources are also available, quite apart from Russia. Again, let me remind you of the opinion of one of our most eminent naval officers of high rank, who, not long ago, told me that what he most feared in the next naval engagement was the demoralization of the stokehold crew. In this I entirely concur, and from whatever point we look at this phase of the question, we are constrained to admit that a stoker's life is no better than a dog's life, and no man who can take up any other employment ever becomes a stoker. I feel sure it will also interest the meeting to know that a 100 horse power water-tube boiler of the Babcock type was recently fitted at an electric lighting station with my system, and was seen by numerous scientists, including that eminent shipbuilder and engineer, the late Sir Edward Harland, who was delighted, and remarked that no one would have imagined twenty years ago that so large a boiler —150 lbs. working pressure—could be fired so cleanly, without labour, and at the same time we could sit in easy chairs close to the furnace doors, as we were then doing, without discomfort. Before sitting down, I should like to ask Mr. Wilson whether, in the system that he has described, there is any special arrangement for admitting more or less air, as may be required, or whether it is allowed to come in through those openings just as it chooses. I do not know whether valves have been arranged to make the supply of air constant or equable, as the case may require.

Mr. LESLIE ROBINSON (Visitor): When I was in Paris I had the opportunity of seeing in operation the

boiler that Mr. Wilson has described, and although I had not the opportunity of going into it thoroughly, it certainly seemed to me to be working most admirably. As far as the question of radiation is concerned, I held my hand against the side of the boiler, in close proximity to a temperature of 1,700° Centigrade, and the absorption was such that the side of the boiler was perfectly cool. I must express my regret that your worthy President (Mr. Durston) was not able to be here to-night, because I wish we could have heard from him what our Admiralty are doing or hope to do in reference to this question. Mr. Wilson has not alluded to the fact, and possibly it may not be known to all of you, that the navies of the Triple Alliance, that is to say, the vessels of Italy, Austria and Germany, have adopted a system invented by an Italian engineer, named Cuniberti, and this system is running in these three navies at the present moment, and giving very satisfactory results. Our own Admiralty were going to carry out some experiments on Mr. Thornycroft's *Daring*, but owing to the recent mobilization those experiments have been delayed. There is no doubt, however, that we are beginning to look out, especially in the Navy, for this liquid fuel. The Government of America have afforded opportunities for Mr. Melville, who is working in the same direction, and there is no doubt that there is a tremendous future for liquid fuel, especially for the United States and Russia. On the occasion of my visit to Paris I had an opportunity of talking to M. Normand, who has built the fastest boat afloat—a vessel making 31 knots—and he told me he was perfectly sure that if he had employed liquid fuel he could have made 34 knots. Those who are accustomed to speeds of 10, 12 or 14 knots an hour, or even 18 or 20, can hardly realize what it is to be in a torpedo boat, travelling at from 30 to 34 knots an hour. When you have had an opportunity of travelling in boats going at that speed, you will know what tremendous arduous work it is, and there can be no doubt that liquid fuel offers possibilities in this connection which nobody can afford to ignore. Our own position is a very difficult one. At the present moment we are

dependent upon others for the supplies of liquid fuel, and for that reason the Admiralty is a little chary of adopting it. But Mr. Durston has shown such pluck in reference to tubulous boilers that I am sure he is convinced we are on the right path, and that we shall soon see practical and successful experiments in our own Navy in this connection. I have not had the pleasure of seeing the paper beforehand; but no doubt when we have it in our hands there will be many points to be raised on the subject, and I have made these few remarks because I had the opportunity of seeing the boiler described in operation. I believe most sincerely—and there are very good reasons for believing—that engineers will have to turn their attention to this question. Having regard to the lessons taught by the late war between China and Japan, we shall have to make every effort to increase the speed of our vessels, and I do not anticipate that in this respect the British Navy will be found behindhand.

Mr. WILSON: In reply to questions that have been raised, I may say, with reference to Mr. Henwood, who asked me if the temperature which usually obtains in Siegle's furnace is known. I say, yes. Many experiments to find out the exact temperature have resulted in showing an average temperature of 1,700° Centigrade, or 3,000° Fahr. That temperature begins shortly after the entrance of the flame here *(indicating a point in the diagram)* and continues until very nearly the end of the last section. You may take as an average right through of 3,000° Fahr. As to the fire bricks in the furnace, the great object of M. Siegle's arrangement is to do away with any refractory material altogether. Mr. Henwood has described a state of things which I take to mean fused fire bricks; but I cannot help thinking that the amount of heat given in order to produce that result would have been better employed in heating the water in the boiler. Our great object is to do away with the use of fire bricks. Then I have been asked to explain what I mean by dissociation. I believe it to be a fact that if you heat the hydro-carbons up to a certain

temperature you will separate the constituent parts, so that each goes its own way,and where you have a firebox, the phenomenon of dissociation is frequently met with. The intense heat caused by throwing this vapour on a layer of solid fuel, and also by the fire-brick back, is so great that the fuel is split up and the parts proceed to get away to the tubes and up the funnel without being burnt. You sometimes look into the firebox and say "What a beautiful white flame you have," but if you have a too intense heat in one place, you simply split up the fuel. The more intense the heat you have in one particular part of the furnace, the more likely you are to throw a great part of your fuel away, and if you were to analyse the funnel gases, you would find that the hydrogen and the carbon had been split up and not burnt. Then about the air supply. I said in my paper that the annular spaces between each section were calculated with special reference to the area of the tubes, and the supply of air is as nearly automatic as possible. The velocity of the flame is sufficient of itself to draw in just sufficient air for combustion, and no more. If you go to the root of the funnel and examine the gases —catch a bucketful of the gases and analyse them—you will find there is nothing but carbonic acid gas.

Mr. HENWOOD: What about noise?

Mr. WILSON: There is a small amount of noise, but it is not much, especially with the new injector that the Company is now using. The Company has brought out a type of injector of their own, and I am told that with that there is not much noise. Further than that, there is no reason why these injectors should not be cased and boxed in to some extent, provided, of course, there is free ingress for the air supply.

Mr. MELSOM: I should like to ask a question with regard to the air supply in this furnace. Suppose you have six jets in use, and you want to reduce the boiler power to a point for which three jets would suffice; what is the effect with regard to the air supply?

Mr. WILSON: If you suddenly want to reduce your steam-making power there is no difficulty in shutting off the flame at three of the jets, but it will be necessary to shut off these spaces *(referring to drawing)*, as otherwise it is possible that a small portion of the unburnt gases would collect in the empty spaces, and when you subsequently came to start these three jets again there will be an explosion. An accident of the kind actually happened a short time ago at a brewery in London, and a man was killed. M. Siegle has provided a special arrangement for preventing the accumulation of these explosive gases.

Mr. J. H. THOMSON (Chairman of Council): I have much pleasure in proposing a vote of thanks to Mr. Wilson for his paper. Mr. Wilson, in this case, has not done justice to himself, inasmuch as he did not give the Council sufficient time to put the paper in the hands of the printer. Had it been printed as usual, there would, no doubt, have been a fuller discussion. We are much obliged to Mr. Wilson for the interesting paper he has read, and on a future occasion, when the paper has been printed and in the hands of members, I have no doubt there will be a very full discussion upon it.

Mr. HAWKS (Member): I have much pleasure in seconding the motion. It is a very interesting paper, and instructive to us all. On a subsequent occasion I hope to have the pleasure of giving you an account of some experiments with Mr. Henwood's apparatus.

Mr. WILSON: I am very much obliged to you for the way you have received my poor effort on this subject. In the first place, some sort of apology is due from me to the Council for being somewhat behindhand in supplying them with the paper; but really I have been so very busy, and the principal part of the data that I have laid before you has only reached my hands within the

last few hours. I hoped to have had some more figures to lay before you, but my principal object is to raise a discussion on the subject. I have now been connected with liquid fuel for some two-and-a-half years, and my thoughts have been pretty often turned towards it, and I cannot help saying that I feel convinced we are within measurable distance of the use of liquid fuel being a very general thing. I have had this arrangement before my eyes pretty constantly; in fact, I have almost dreamt about it, and I feel quite sure that there must be something in it.

Mr. HAWKS: I am glad to find that we have among us such an enthusiastic advocate of the oil question, but may I remind Mr. Wilson that there is a great deal yet to be done with coal? I hope to be present at the adjourned discussion, and that Mr. Wilson and I will have an opportunity of exchanging opinions on this question.

ADJOURNED DISCUSSION

AT

58, ROMFORD ROAD, STRATFORD,

On MONDAY, MARCH 9th, 1896.

CHAIRMAN:

MR. T. F. AUKLAND.

The CHAIRMAN: The business this evening is the discussion on "Liquid Fuel," but before we commence, it may be that Mr. Wilson, the author of the paper, has some further remarks to make to initiate the discussion.

Mr. WILSON: I do not know that at present I have anything to add. When the paper was read at our last meeting the discussion was started, and I am now in the position of a man who stands up to be shot at. Before I elaborate anything on what I have said I should like to hear some questions put to me, and I will endeavour to answer them to the best of my ability.

Mr. E. N. HENWOOD (Visitor): I have much pleasure in endorsing my opinion that this Institution is indebted to the author for a valuable contribution on this subject, and since the 24th ultimo I have had the opportunity of considering most of the points, and will endeavour to deal with them in a way tending to increase the interest already manifested on this most important matter. As to the continued use of coal as a steam-producer, I most emphatically denounce it as a disgrace to our civilization that we still have men employed in such work.

The Registrar-General of Shipping has published records, showing that while among the ordinary population the percentage of suicides is one in 10,000 —among stokers it is one in 900. We ought therefore to take the opportunity of improving the conditions under which stokers work.

In time of war we should undoubtedly suffer from an inadequate supply of trained stokers, and for the want thereof—if still under the thraldom of "dirty King Coal"—would probably suffer serious loss.

Let me place on record the opinions recently expressed to me by one of our most distinguished Naval officers of high rank—viz: that what he feared in the next Naval engagement, was the "demoralization in the stokehold crew," in this I concur, and would point out that the men have to work under probably less exciting conditions than their shipmates on deck, and are liable not only to be scalded like lobsters, but drowned like rats in a trap.

During the operation of coaling, or even taking in a supply of 600 tons at, say, Madeira, the vessel is rendered uninhabitable.

As indicative of the immense loss occasioned, it may not be very far from the mark to say, that of every ton of coal taken on board one-third is lost in smoke and soot, one-third in ashes, and from the balance alone is any benefit obtained.

There are other drawbacks incidental to the use of coal, such as cold ashpit, injury from opening of furnace doors to coal, or to clean fires. This last operation, in a vessel steaming 20 to 30 knots an hour at sea, will probably be found a source of more disasters than can be imagined, and the Naval commanders will frequently be placed in awkward circumstances.

Let me record the opinion expressed by a steamship owner who saw the *Ruby* working with oil-fuel--viz: that "he was convinced that coal was *doomed* as a steam-producing agent, as it was costly, cumbersome, dirty, and offensive."

There still remains much to be said as to the frequent explosions in coal-bunkers causing loss of life, and underwriters state they constantly have to pay for damage resulting therefrom.

Therefore it behoves every engineer—who has his country's prosperity and "command of the sea" at heart, to use every effort to bring about the abandonment of costly, cumbersome, dirty, and offensive coal at the earliest possible moment.

It is necessary to point out the dangers attending, and inherent to any "hybrid" system of squirting oil-fuel in any shape over incandescent coal, when the coal is laid on fire-bars in the usual way. Years ago it was found that the heat which can be evolved from oil-fuel causes the fire-bars to melt and collapse.

It may be argued that this is not found to be so now, but, in reply, I would emphasize the warning, as its recurrence would cause a serious disaster on any torpedo-destroyer or other vessel, and it is very easily brought about. Even keeping the bars well covered with coal is no protection, as oil-fuel simply destroys the coal, and the inconsumable ash affords no protection to the bars. If engineers therefore adopt such arrangements, they will have to put up with the consequences, which may involve serious loss of life, and of the vessel also. The system of the Italian engineer, Camberti, comes under this description, according to the information supplied me from Italy, and although it was stated in the "Pall Mall Gazette" of 18th ultimo, that this system was to be fitted to H.M.S. *Gladiator*, it does not appear to be correct.

It may be that the Government, having such a large command of coal, do not look with favour on any system which would displace it, notwithstanding that oil-fuel would augment the steam-enduring powers, and the "ability to maintain command of the seas," of all war vessels, by over three times what it now is, and would relieve from the stokehold a large body of men who might be made efficient combatants.

When steam vessels displaced sailing vessels, it became necessary to form coal depôts, so now, when oil-fuel is so immeasurably superior to any other fuel for steam raising, it would not be so great a difficulty to replace or add oil-fuel supplies to the existing stations.

It will no doubt be admitted that "heat is the primary source of power," and that it should be the aim of every engineer to obtain the greatest amount of heat from the minimum amount of fuel. Therefore, as every ounce of fuel has to to be paid for, its consumption should be under the control of an intelligent engineer-officer, who should be responsible for the most efficient use of what may be termed the principal motive-power

in a vessel; so that on no occasion should there be permitted any loss by smoke, or by the admission of too great an amount of air.

Because, as you are no doubt aware, we, as yet, have no commercial means of supplying pure oxygen; and as every volume of air is composed of only about one-fifth part of oxygen, and the rest nitrogen, which does not support combustion, yet we are obliged, in order to get a sufficient supply of oxygen, to pass into the furnace a vast quantity of air in order that the carbon and hydrogen may have a sufficient supply for their perfect combustion.

I now give Dr. Lardner's exposition on hydrogen, with which my experience coincides:

"If pure hydrogen, compressed in a bladder or other chamber, be allowed to issue from a small aperture, a light applied to it will cause it to be inflamed. It burns tranquilly without explosion, producing a pale yellowish flame and a very feeble light, but *intense* heat. This is the effect attending the gradual and continual combination of the hydrogen, as it escapes from the orifice, with the oxygen of the surrounding air."

Now, I maintain that no scheme which simply provides for taking in as much air as may happen to come, either in a dead calm or when blowing a gale, can meet the requirements of a properly constructed and scientifically arranged oil-fuel furnace.

The oil and steam being supplied at intensely rapid rates, and the oil-fuel being in the form of vapour, it is essential that the vital air be supplied at a corresponding rate, in sufficient quantity and under proper control. When this is so arranged, extremely beautiful and transparent heat is evolved, of such high degree or power that even Lowood Gannister firebricks are melted like butter, and this heat has, by a metallurgical chemist, been estimated as about 5,000° Fah.

I do not wish anyone to imagine that the melting of firebricks is any detriment to my system; it is not so, but as Robert Stephenson said of the supposed cow on the railway—it is rather awkward for the bricks. I may also point out that the heat stored up by the bricks is not wasted, it is simply accumulated, and is given back again when the water inside the boiler begins to cool down, so that for many purposes it will be a valuable adjunct and will act in a far more preferable way than the ordinary banking up when coming to anchor for several hours.

Further, I maintain that it would not be possible to dissociate steam, except by means of a chamber constructed of highly refractory material, which is not in direct contact with comparatively cold iron plates covered by water.

Probably some skilful engineer may yet discover a material, such as asbestos, which will stand; at the same time I do not wish it to be understood that the whole of the bricks are melted instantly, and from tests made, believe a suitable chamber would last for a six weeks' voyage without requiring repair.

If it be alleged that steam can be dissociated in a comparatively small iron tube surrounded by water, then it will be found that the iron tube must become red-hot, in which case the red-hot iron absorbs the dissociated oxygen, and in a very short time becomes oxidized.

I am in perfect accord with the author in his condemnation of the ordinary type of boiler, as being unsuitable and wasteful, but would observe that notwithstanding their unsuitableness, it is possible with oil-fuel to obtain very much greater evaporation without priming.

There is recorded in "Iron" of 26th March, 1886, and in the "Times" of 27th March, 1886, a brief

report on the working of my earlier system on the S.S. *Ryde*, of 100 I.H.P. in the London Docks, the boiler being of the ordinary marine return multitublar type, 8½ feet diameter and 7½ feet long, having two furnaces 2½ feet diameter with one combustion chamber, viz :—

"The special feature claimed by Mr. Henwood is the proper proportioning of the steam, so that he uses every atom of its hydrogen, and thus obtains the most effective results."

The engineer scientist who made this report also attended a trial on the *Ruby* in 1887, when she was for several months under steam day and night continuously, and a report on her performance was made by the Editor of the "Engineer," and published in that paper of the 11th November, 1887.

Mr. Hawks also attended a moderately long trial and his report can be seen. On the same occasion two other engineer experts were on board, and one of them being an official from one of the railway companies, after critically watching the working for some three hours, voluntarily expressed his opinion in the following words: "he could not have believed it to be so perfect if he had not seen it."

In the earlier part of 1887 the proprietors of some Tar and Liquor Works fitted up my system on a Lancashire boiler about 30 feet long, with two furnaces of 3½ feet diameter, and it was kept running continuously for 28 days and nights at 50 lbs. pressure with great success. The parties then discovered that the Stourbridge firebricks, which had always stood any heat they could generate, succumbed to the heat generated by my system, and for some three weeks a quantity of molten fireclay was kept in the lower part of the furnace.

Since then my system has been fitted to a Babcock and Wilcox water-tube boiler of large size, said to be

equal to 800 I.H.P., having 70 square feet of grate surface, and after it had been run with oil-fuel for a few days, the boilermakers expressed their fear that the cast-iron headers would be unable to stand the heat, as the circulation of the water was bad, and so they forced the proprietors of the works to discontinue using oil.

Subsequently, as recorded in "Engineering" of 3rd May last, my system was fitted to a Babcock and Wilcox boiler of 106 N.H.P., working at 150 lbs. pressure, and in order to relieve the proprietors from all fear about the cast-iron headers, a firebrick baffle was fitted to protect them. The boiler was then run with great success, notwithstanding the fact that the steam drum was not lagged, as it ought to have been, and, for want of the lagging, a lot of heat was lost through the orifices on each side of the drum and the enclosing brick walls. It was seen in operation by many scientists and engineers, including the late Sir Edward Harland, Bart., M.P., who was particularly pleased with it in every way, and remarked that no one would have imagined, even 20 years ago, that it would be possible to fire such a boiler without labour, and at the same time sit down in easy chairs in front of it.

I hope I have shown what is, in my judgment, the most effective method of employing oil-fuel.

Yet, as unreasonable objections have been made to the abstraction of steam from the boilers, let me endeavour to arrest all such objections by supplying efficient evaporators, and therefore ample supplies of condensed feed-water.

Reverting to what I have before described as the primary source of power, viz: "heat," and maintaining that the major part of the heat evolved is from hydrogen, I am of opinion that it will be found considerably cheaper to use as much hydrogen as possible, and no more oil-fuel than is absolutely necessary.

I do not observe that the author has made any reference to the question of consuming steam from the boiler—and the consequent loss of water.

It would take too long to enumerate the transcendent advantages of oil-fuel; but it will be apparent to all, that it can be run on board by hose pipes, and vessels can be refuelled at sea by means of a hose attached to a hawser, between the two vessels, and it can be carried in the double bottoms—saving them from corrosion, and, in properly divided compartments, would cause no injury to the vessel even if only partly full. Then we have increased endurance of boilers. The saving of all coal bunkers, and their utilization for freight-earning cargo.

It may be of interest to state that a calculation, made on a fair basis, shows that the benefit of oil-fuel to the owners of a 7,000 ton mail steamer, trading from England to the Cape, would be about £10,000 per round voyage of six weeks.

The author lays stress on the advantages of a specially designed boiler for oil-fuel. I am glad to find he so fully coincides with my views on this matter; but I must observe that it was necessary to show the adaptability of the oil-fuel system to the boilers at present in use.

He refers to a boiler in a torpedo boat that had 31 oil jets fitted to it; this is, I believe, the one built by Messrs. Doxford in 1887; but if my system had been applied, *one* injector would have sufficed for all the requirements.

The "Rational" or Monsieur Siegle's boiler is, perhaps, a clever device, but is not, in my judgment, one that will give the best results; and why the author should advocate an arrangement which is to prevent dissociation of the steam used, I am at a loss to discover.

While the arrangement appears to be simple, it appears to lack the important and accurate control of the air supply, and I am of opinion that the addition of cold air at the several sections will have the effect of diminishing the evaporative effect.

As to the combustion being absolutely complete, it would be well if the products of combustion were to be analysed; and if I accurately understand the author, he does not by this arrangement intend to dissociate the steam, and so it is, consequently, a total loss.

As it will no doubt be asked why, in view of so many advantages, the system is not adopted by steamship owners. One can but deplore the utter absence of enterprise, and the determination not to be the first to carry out any departure from the old and dirty coal system.

Mr. N. S. HAWKS (Member): I do not know that anything that I can say will throw much light on this subject, but I should like to ask Mr. Wilson to what he refers when he says in his paper—

"On the side of liquid fuel we have a considerable increase in the theoretical calorific power, viz., 20,000 B.T.U. against 14,000 for coal; further, it has been proved that in practice almost the whole of this available heat can be taken up and transmitted to the boiler water, when the oil is burnt in a furnace that rigidly complies with the special requirements."

Is that a modern calculation—a modern result—or does it refer to something that took place ten or twelve years ago.

Mr. WILSON: It refers to three or four months ago when there was a very able article in the "Engineer" on this subject.

Mr. HAWKS: Thank you. I am very much obliged to Mr. Wilson for his able paper, but while I think

that oil has a future I can never believe that it will take the place of coal. A day or two ago there was a report in the newspapers of the destruction of an oil steamer after burning for three weeks. Perhaps other gentlemen also saw the report, and to my mind, at all events, it points to the fact that such a fuel can never be used in passenger steamers unless we can ensure safety against catastrophes of that kind. The only experience that I have had of oil-fuel was in the case of a trial of Mr. Henwood's system on a steam yacht, and I will read you a portion of a report I made on that subject. It was as far back as the year 1887 that I was requested to see this apparatus of Mr. Henwood's. It would take me too long to read this report, but I will sum it up in a few words. We had a trial for two hours, running at 288 revolutions per minute, with a consumption of 50 lbs. of green oil per hour, the pressure being maintained at 100 lbs., and the I.H.P. 23. It was stated that using coal, under similar conditions of weather, the engines made 240 revolutions per minute, with a consumption of 130 lbs. per hour, the engines indicating 20 H.P. That was an ordinary tank boiler lined with bricks, and so far as that trial went it was very satisfactory; but in my report I went on to state that I could not give the evaporative effect of the oil as against coal, and I do not know that any engineer would to-day recommend this system for use on any sea-going ship. My opinion is that until we are perfectly assured that all danger in the way of explosiveness is eliminated, oil-fuel cannot be adopted for passenger steamers, at any rate, for an explosion of the oil is certainly much more likely than an explosion in coal bunkers. Allusion has been made to the very few explosions that have occurred on oil ships, but if we had as many oil steamers flitting about as there are steamers with coal bunkers, I am afraid we should hear of a few more accidents.

Captain FROUD (Secretary, Shipmasters' Society): I should like to say a few words on this subject, not as an expert, but as relating some experiences. In the year 1891, a paper on this question was read before the

Shipmasters' Society, and it seemed to have the effect of opening up the subject to some extent. It was a paper on Liquid Fuel for Ocean Steamers, and we have received some letters on the subject, certain portions of which will perhaps be of interest to the present meeting. The first letter that I shall quote from is from a friend of mine in the Levant—a merchant largely interested in petroleum, and writing under date November 30th, 1895, he says: - "The use of this fuel (astakti) is convenient for steamers running to Batoum and for local consumption. The *Ayrshire* (s), 500 tons net register, 900 tons D.W., of 95 N.H.P compound engines, used to burn eight tons of coal per 24 hours on 9 to 9½ knots, with steam ready in four hours. Now, with the use of astakti, the same speed is obtained on a consumption of five tons of this fuel, and steam can be had in two hours. We may mention, besides, the economy in firemen, which should be taken into consideration. All the steam engines in the Caucasus, also in the Caspian Sea and up the Volga, are using this kind of fuel. We understand that any quantity is always obtainable, and the actual price is £2 per ton f.o.b."

The next letter is from the master of a steamer called the *Mineral*, which traded in South American waters for some years until she was burnt. The letter is dated, Talara, Peru, February 1895, and the Captain says:—"*Re* oil-fuel for ocean steamers. I must say that there is a decided balance in favour of it. For instance, compare our results:—With a consumption of 7 tons of oil in 24 hours we use 1·47 lb. per I.H.P. and get steam 64, and speed 7·45; with a consumption of 11¼ tons of coal in 24 hours we use 2·43 lb. per I.H.P. and get steam 63, and speed 7·3. This result for rather an old compound job ship is good. The steam keeps steady, and revolutions regular. I find it answers very well indeed, and cannot speak too highly of it, and feel sure that in the future it will cause a revolution in the coal fuel in some parts of the world, especially on this coast. But I find that in the burning of it, too much

care cannot be taken to keep water from getting with the oil to the burners, which will put the fires out, and if no one is there to shut the valve or re-light it, it will cause a gas to accumulate, and when re-lit will cause an explosion and probaly blow the furnace fronts out. I may say that since our first commencement to burn oil-fuel, both main and donkey, we have not had an accident or the least trouble with it."

The next letter relates an earlier experience. It is from the captain of the *Eco*, a little steamer that was engaged in the same trade. He says:—"That the residual oil is superior to coal as fuel there can be no doubt from the following facts. This steamer on her trial trip, under most favourable circumstances, steamed 8·5 knots, and on her passage out to Payta, steamed about eight knots on a consumption of six tons of coal per day. She now steams 8·5 knots, with a consumption of $3\frac{3}{4}$ tons of oil-fuel, and can be pushed to run 9 to 9·5 knots, with a very slight increase in the daily consumption. The extra speed obtained is owing to the fact that a steady pressure of steam is always maintained with oil-fuel, whereas with coal it is impossible, owing to the necessity of cleaning fires, &c."

I think that is about all I have to say, except, perhaps that to my mind one great advantage which oil-fuel has over coal is that oil-fuel may be consumed with the furnaces and ashpits kept closed continuously which means regularity of steaming, and upon the occasion of the paper being read before the Shipmasters' Society, testimony was borne to the great value of Mr. Holden's system of burning oil-fuel. I suggested at that time that an advantage would be gained by using air under pressure instead of steam, and that, of course, would bring about the possibility of keeping the doors closed. After this paper had been in circulation for about a year, I received a communication from San Francisco, and I am sorry to say that I cannot read it to you, because I could not find it. A copy of the paper was sent to him, and his reply he

said in effect:—"I am very pleased to be able to tell you that the use of compressed air is found to be the best in a small steamer using oil-fuel running from this place. After running for two or three years with steam, compressed air was used in its place, and the result we find to be very satisfactory."

I do not know whether all this is within the scope of this paper, but at any rate it brings out the practical results of burning oil-fuel at sea. With regard to the objection to oil-fuel based on its supposed explosive properties, I asked the opinion of an expert, who will probably be considered an authority on the subject—Professor Vivian B. Lewes—and in his reply he says:—"I should say that with properly constructed tanks, there would not be the slightest danger in using any mineral oil which had a fairly high flashing point."

One word for myself. I believe it is the custom for these steamers to carry the oil in tanks or reservoirs between decks. Anyhow, it is my idea that it shall be drawn by the syphon from where it is stowed. It would make the cutting off of the oil very much easier, and the trim of the ship could be better maintained.

Mr. HAWKS: I should like to ask if the letters read by Captain Froud relate to compound jobs.

Captain FROUD: Two of them do.

Mr. HAWKS: At the present day we are generally dealing with high pressures and triple expansion engines.

Captain FROUD: There was a considerable economy in each case.

Mr. HAWKS: We have been made aware of the fact that during the past five or six years the consumption of coal has been reduced by quite ten per cent., and we have engines running now with a con-

sumption of a pound of coal per I.H.P. I should like to know whether anybody here has experienced a consumption of oil-fuel so low as that? Of course this is a question that has to be looked at all round.

Mr. LESLIE ROBINSON (Visitor): The gentleman who had just sat down had spoken of a consumption of one pound of coal per I.H.P., which was a very low figure indeed, and I do not think that under ordinary conditions of working they were likely to arrive at such a result. But results even lower than that had been obtained in connection with some trials conducted by the French Admiralty. Those trials, however, were made under very exceptional circumstances in boats which were fitted with special appliances for reducing the consumption. Mr. Henwood was reported to have stated at the last meeting that one ton of oil, on his system, evaporated more water than could be evaporated by from three to four tons of best Welsh coal. This statement would appear to require some explanation, and the meeting would doubtless be glad of any further information that Mr. Henwood could give them on that subject.

Mr. HENWOOD: There are two or three points in regard to which some explanation appears to be required, and the first one I have noted is as to the safety of this oil. Reference has been made to a vessel that exploded or was destroyed by the oil catching fire, but the oil which that vessel would be carrying was not oil intended for use as fuel. The oil which I have always advocated for use as fuel is oil of the lowest possible grade, and of such an uninflammable nature that you would have to heat it up to 300 degrees before it would catch fire. Now, we know that only a few years back there was a fire at Rouen on an oil vessel which was being unloaded during the night. A thunderstorm came on, and it was alleged—I believe it was proved, for the captain told me so himself, although he was away from the ship at the time—he believed that the lightning having struck the ship ran down the masts

and caught the inflammable vapour from the highly explosive oil on board, and that vessel remained burning for a considerable time. But the oil in this case was of lamp-burning quality, and contained a considerable quantity of naphtha. The oil that we would use as fuel would have had all the naphtha taken out of it, and in the case of green oil, I have found that even if white hot iron bolts were dropped into it the oil would not take fire. The next point raised is as to the evaporation per pound of fuel. You will find it recorded that by means of oil-fuel 46 lbs. of water can be evaporated per pound of fuel, and my authority for that will be found in the Transactions of the Institution of Naval Architects. You will also find it recorded if you look up "Technology" at the Patents Office. If the evaporation is accurately gauged it will be found that we are very close to, if not actually in advance of, 46 lbs. per pound of fuel, and this is not after dinner speaking by any means.

Mr. A. W. ROBERTSON (Vice-President): I think that we, as an Institute, must feel very much obliged to Mr. Wilson and Mr. Henwood for the papers which they have submitted. They have been very interesting, and I will venture to say that they will be very valuable if they are the means of creating an incentive for furthur inquiry into this question of the use of liquid fuel, with a view to its ultimate development as a commercial success. It is not a new project by any means. Mr. Henwood can go back, I presume, some twenty-five or thirty years, and Mr. Wilson told us the other night that he has been giving a great deal of attention to it for some time. But still, up to the present time, oil-fuel has not been brought forward as a commercial success. I will say, without any hesitation, that we have got at the present time a body of gentlemen as shipowners in this country, and a body of gentlemen as superintending engineers who are quite prepared to throw prejudice on one side and introduce oil-fuel if they can see a commercial gain. There is always the "if," and Mr. Wilson introduced that "if" very

frequently. Speaking broadly, all schemes for using oil-fuel have proved a failure until the introduction of this wonderful fuel, which in the paper is called astakti. According to Mr. Wilson that is the fuel of the future, and I venture to say that, if Mr. Wilson can convince the shipowners first, and the superintending engineers afterwards, or should we reverse it and say, the superintending engineers first, and the shipowners afterwards? this oil will very soon be introduced as the oil of the future. We all know that many trials have been made with oil-fuel. I can remember going on board the *Himalaya* that Mr. Wilson refers to. I was very much struck with the simplicity of the arrangement, and I was very much interested in the trial. She went to Leith and back, but I do not now remember exactly the grounds on which that trial was not reported upon favourably by the experts who went with her. So far as I can understand it, one of the great objections to oil-fuel is its great want of manipupulating power. I believe that that is a great objection to liquid fuel. Mr. Henwood has admitted that himself, and I think that Captain Froud also referred to it. There is a tendency to choke up (Mr. Henwood expressed dissent). Well, I will not dwell on that point, but I will say that there is the great objection in the case of a vessel suddenly stopped at sea, that the oil would have to be put out, and that, I think, was one of the great objections in the case of the *Himalaya* — the question of the danger arising from the accumulation of explosive gases. If you do convince the shipowners that there is no danger, then I am quite sure prejudice will vanish. But there is a something which prevents the shipowners using oil as fuel which is not prejudice. If Mr. Wilson has got over the difficulty of the danger from the accumulation of explosive gases, the difficulty of manipulation so that its use can be easily regulated, and the oil easily ignited after stoppage, I should certainly think that the introduction of this oil-fuel is practically assured. Our friend's paper that he has read this evening is very sentimental at the commencement, and I was very delighted to hear Mr. Henwood

come forward with such very kindly expressions about fireman. It does an old engineer's heart good to hear Mr. Henwood speak as he has spoken about firemen. I must admit that my experience at sea dates back twenty years, but I do not remember that during my sea service any of the firemen died under the stress of work, in fact, they seemed to thrive under it. But I think that if Mr. Henwood had only extended his compassion a little further he might have included the engineers. As soon as the oil-fuel is introduced he does away with the firemen, but what about the engineers? He says, that by burning oil-fuel you can do away with firemen in the future, but he might also have said: If you introduce the oil engine you can do away with the engineers as well as the firemen. I am somewhat inclined to think that the oil engine is more likely to become the engine of the future than the burning of oil in the boiler of the future. In the course of his paper Mr. Wilson makes this remark—

"Probably the tank steamers will be the first to adopt liquid fuel throughout, and the enormous economy possible in this case will allow of freights being reduced to a point now thought impossible."

Fancy Mr. Wilson introducing this idea of reduced freights as an inducement to shipowners. I should have thought he would have preferred to keep that in the background. The very thought of reduced freights is enough to frighten shipowners, seeing that with the freights paid now they are too often unable to make ends meet.

Mr. J. D. CHURCHILL (Member): I should like to ask Mr. Henwood at what price this oil-fuel can be put down in this country?

Mr. HAWKS: What would be its price in the event of oil being generally adopted for fuel?

Mr. J. F. REDMAN (Member): Captain Froud urges me to tell the meeting what I had said to him on this subject. It was simply that by the courtesy of Mr. Holden I had been to Cambridge and back on an express engine burning liquid fuel, and that I had never before seen steam pressure and water level managed like it, not a breath of steam was wasted. If a signal was against us the oil was shut off and put on again when the line cleared. The fire box was filled as it were with a luminous cloud. Coming back, I think only some half dozen shovels full of coal were put on the fire. I liked the combination of being able to use coal as well as oil, as giving two strings to your bow. The specific use of oil alone would, doubtless, run up the price of the article unduly, but at present the cost for a given power in London is practically the same as coal. I have been furnished with details for the fitting of some donkey boilers, and if times improve I hope to have this reserve power put in my hands, as on an emergency in working cargo we could work direct from a barrel containing the oil with a flexible suction pipe.

Mr. HENWOOD: With reference to Mr. Robertson's remarks as to difficulty said to arise in using oil fuel, I may state that during all the years I have been working it I have never found any difficulty whatever. As to the supposed difficulty of re-lighting it after a stoppage, it is just as easily set on again as a gas burner, and so silently does it do its work that the people on board a ship do not know whether the fires are under way or not. Then as to the cost of the oil. There are people who will be very glad to enter into a contract for the supply of the oil for a considerable period at from 25s. to 40s. per ton, delivered in England. You can thus calculate what an enormous saving would result from its use.

The CHAIRMAN: I should like the author of the paper to give us a little information about the commercial advantages which he expects to derive from the use of liquid fuel, and also what is the saving in

bulk, weight for weight, of liquid fuel over coal. When this question has been mooted, we have heard that by the adoption of liquid fuel a considerable addition is made to the cargo space for the benefit of the shipowner. We have also heard that the speed has been increased, and then comes the question of the expense of liquid fuel as against coal. As far as freights are concerned at the present time, I am quite sure that shipowners would not wish that freights should be reduced in the slightest degree. I suppose that the steamers employed in the carriage of this oil—tank steamers—generally get very good freights indeed. These steamers are generally very expensively kept up, and that could not be done unless they got very good remuneration indeed for the goods they carry. I wish I could say more that would be of some interest or service to the institution, but this is a matter that I have not been able to go into. Not being a professional engineer, I can only speak on the question as we find it operates upon us in the City in connection with shipping business.

Mr. H. C. WILSON: When I made a few remarks at the opening of the meeting I said that I was here to-night to be shot at, and I think you will agree with me that I have been shot, if not riddled; at any rate, I will do my best to answer the questions that have been put to me. First of all I will take the questions of Mr. Henwood. He asked a question about the supply of air into the furnace, and appeared to me to think that the draught from the funnel would alter the air supply to the furnace. But it is the velocity of the flame going in that makes the draught. We do not want a funnel, and can do without one. Then there is the other point about the use of steam in the furnace. It is quite optional whether you use steam or air, and it need not necessarily be cold air; we have boilers running in which heated air is supplied to the furnaces. Another point is about the oxidization of the boiler plates owing to the affinity of the gases for the iron. These furnaces have been running for a

round twelve months. They are at work now, and the latest advices that I have with regard to them is that they are in perfect condition. There is more or less damage done to the plates by the sulphur contained in the coal which is not the case when oil is used. The next point is as to the loss of steam in the boiler, or more properly speaking the loss of water owing to the steam required to vaporize the oil. In my paper I think I stated that the steam necessary to vaporize or atomize the oil burnt was produced by an auxiliary boiler or generator, and that the steam was not taken from the main boiler at all. The gases when they escape from the apparatus that is called the funnel are condensed to some extent, and the hydrogen contained in the steam is condensed and forms fresh water, and we find that we get sufficient distilled water in that way to make good the loss in our fresh water supply, that is the auxiliary feed. Mr. Hawks made a point of the danger of the explosion of this oil in the tanks or bunkers. That has been met by Mr. Henwood. The lighter grades of oil are not suitable for use as liquid fuel because they cost too much. It is the waste products that we want, and they have to be heated up to 420° before they give off any vapour at all. Captain Froud read to me remarks about the price of oil-fuel, but the price quoted, I think, related to the year 1891.

CAPTAIN FROUD: No, 1895, £2 per ton.

Mr. WILSON: My personal opinion about the price of coal against oil is that the whole matter is a question of supply and demand which must be left to regulate itself. At the present time with all due deference to Captain Froud, I do not think that there is sufficient demand in this country for oil of this grade to warrant it being sold at a low price. I do not think that if you tried to get a bulk sample of astakti here in London it could be got. I have not been able to get a quotation myself. There is practically no demand for it. At the Beckton Gas Works you can get a

quotation for green oil, the calorific power of which is considerably less than that of astakti, and I think the price comes out at something like 6s. a barrel of 42 gallons—about 36s. a ton. But if a large supply of astakti were available the price would go down; it would go up at first, but it would go down afterwards, the demand would regulate the supply. Then with reference to the remarks of Mr. Robertson, who spoke of the commercial success of oil-fuel, I do not think myself that there is any great prejudice in the minds of either shipowners or engineers, but I think we have another man to deal with. What about the insurance man? We may see that there is no danger in the system, but does the insurance man see it?

The CHAIRMAN: Experience will soon regulate that. If you get several losses rates will go up; if there are no losses rates will go down.

Mr. WILSON: But before you start you have to get some reliable data to go upon, and unless you can get something like a reasonable rate for insurance this difficulty will continue. Reference has been made to the case of a necessity arising for the sudden stoppage of these fires at sea, but it is not absolutely necessary to put the fires out. If you wanted to leave this room for ten minutes you would not turn the gas out, you would simply turn it down. The same thing can be done with oil-fuel.

Mr. ROBERTSON: Have you found by experience that it is manipulated as easily as gas?

Mr. WILSON: Perfectly, so that the danger of explosion in the furnace from the accumulation of gases is reduced to a minimum. Then there is the idea of doing away with the boiler altogether—that is to say, adopting the oil engine as a marine engine. I am quite prepared to admit that the less gear we have got between the source of energy and the work to be done, the better we are off, and the better the

results that we shall get. But as to using an oil engine for that purpose I do not think that there is an oil engine yet out, leaving everything else out of the question, which will burn anything like the quality of oil that I propose to use as liquid fuel. In using oil-fuel you can certainly manage to do away with a large staff of firemen. One man can look after all the fires.

With regard to Mr. Robertson's remarks on the paragraph in the paper which reads: "Probably the tank steamers will be the first to adopt liquid fuel throughout, and the enormous economy possible in this case will allow of freights being reduced to a point now thought impossible." I think Mr. Robertson has missed the meaning of the paragraph in question, as he expresses sympathy with the shipowners on the prospect of reduced freights. What is really meant is this: that great economies in the fuel and wages bill, and considerable increase in carrying capacity will allow the shipowner to accept freights much lower than those now ruling, and still leave a good margin of profit. The working expenses of a ship, especially a tank ship, are not down to an irreducible minimum when it is possible to effect great saving in two at least of the most important items of expenditure, viz., fuel and wages. It does not matter to what figure the freight goes so long as working expenses allow of a profit.

With regard to the remark by the Chairman about the saving in weight, I believe I am well within the mark when I say that, bulk for bulk, oil-fuel is half the weight of coal, so that in a ship using oil-fuel half the space that would otherwise be required for coal would be available for cargo. There are a great many other points upon which I should like to say a few words but the subject is so large - I think we have only just commenced to touch the fringe of it—that one could talk about it for hours, and I do not propose going into the matter further to-night. As far as the use of oil

for motive power is concerned in this country, we must not forget, leaving marine work on one side for a moment, that there are many people engaged at the present moment in bringing out auto cars, all worked by oil, and I think that by the end of the year we shall see a very great difference in the condition of our roads. This firm that I am connected with is going to send one of their patent oil-propelled waggons—not a cart but a waggon—to run at the Crystal Palace Exhibition in May. Then you will be able to see the Siegle system working with heavy oil. Many of these machines are made to run with very light stuff. I have no doubt whatever you will find that the consumption of oil for motive power in this country will be very considerably increased before the end of the year. I think I have covered most of the ground dealt with by the several questions, but if there are any further questions I shall be very pleased to do my best to answer them.

THE CHAIRMAN: I think we ought to return to the author of the paper a very warm vote of thanks, for the very excellent paper he has brought before us, and for the very good discussion that it has evoked. I think that these two meetings, when this subject has been under discussion, have been full of very considerable interest to those who have been present, and the author deserves a very hearty vote of thanks for the way in which he has brought the matter before us. In the absence of anyone else doing so, I should like to propose a very hearty vote of thanks to Mr. Wilson for his paper.

Mr. F. COOPER: I have very much pleasure in seconding the motion. We have all been very much interested in this paper and discussion, although I do not think that within the next year or two we are likely to have to cope with liquid fuel as marine engineers.

The motion was carried unanimously.

Mr. WILSON: Well, gentlemen, I am very much obliged to you for your vote of thanks, and if, by placing this matter before you, I have been able to draw your attention to an arrangement which may come into general use for marine work, I shall have achieved my object. The seconder expressed the opinion that it will still be some time before we as marine engineers will be much bothered with liquid fuel. For that gentleman's information, I may state that there is now running on the Seine a boat of considerable size burning oil-fuel, and when they have done running her there for the information of the French Admiralty, she will be started on the Thames, and that within this present summer. At any rate I believe so, and I have no doubt that some engineers—English engineers possibly—will be put in charge of her. So that some engineers will be bothered with liquid fuel before many months are over.

A vote of thanks to the Chairman concluded the meeting.