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Lecture on "Liquid Fuel."

BY MR. J. VEITCH WILSON.

READ

Monday, March 9, 1914.

CHAIRMAN: MR. JAMES ADAMSON (Hon. Secretary).

IT is, I think, somewhat unusual in the experience of any society to find two papers dealing with the same subject upon the program for the same session. I confess, therefore, that I felt considerably embarrassed when, after I had given the subject and title of my paper as "Liquid Fuel," I learned that Mr. James S. Gander, a member of your society, had undertaken to read a paper upon the same subject. It seemed to me that you were in danger of having "too much of a good thing."

I regret that an unmerciful pressure of work prevented me from being present when Mr. Gander submitted his paper to you, but, having had the pleasure of reading carefully Mr. Gander's exceedingly interesting and instructive address, I was relieved to find that neither his nor my paper can be regarded as superfluous but rather that, quite undesignedly, each may be taken as complementary in relation to the other. I hope, therefore, that Mr. Gander will not regard me as too presumptuous in seeking thus to "tag on" my amateurish efforts to his illuminating discourse, and, perhaps, to profit by the interest which he has aroused in the subject, but I should like, in advance, to relieve his anxiety and yours by explaining that, while he has mainly and profitably directed your attention to the future of the great problem which we have now under consideration, my contribution to the discussion is mainly retrospective and concerns itself with the question "Whence and what is Oil Fuel?"

Human beings may, I think, be broadly divided into two classes, prophets and historians. Mr. Gander evidently belongs to the former category and seeks to reveal to his fellows, and to promote the realisation of the great potentialities which he associates with his subject while I am content, like "Dominie Sampson," to perch on a ladder in my own little library or to ransack the musty records of the Patent Office for the information which I require. As, under these circumstances, it is evident that much of the information which I shall lay before you is derived from external sources, I shall take the liberty, in many cases of quoting the words and, in all cases, of giving the names of my authorities in order that "Honour may be rendered to whom honour is due."

Having regard now to the various suggestions which underlie the expression "Liquid Fuel," I think that we may deal with these under the following headings and in the order in which I give them:—

Liquid Fuel, Historical.
Origin and Constituents of Petroleum.
Combustion or Oxidation.
Surface Combustion.
Utilization of Liquid Fuel.
Utilization: Early Devices.
Utilization: Modern Practice.
Internal Combustion Engines.
Nature and Properties of Liquid Fuel.
Oils available as Fuel.
Fuel Values: Thermal and Commercial.

Liquid Fuel, Historical.

Upwards of fifty years ago I occupied the useful, if not lucrative, position of office boy in a shipping house in Greenock. There we were visited by many American ship-masters, who, in their leisure, used to entertain us youngsters with startling tales of the wonders of their great Continent. Among these tales I remember two. The first was that they obtained oil from boreholes or wells, as we do water in this country; the second, that, in the event of any political complications arising between our respective countries, they "guessed" they would just tow our old island across to their side of the pond and settle matters there. We accepted both statements with the respectful incredulity to which they seemed to be entitled. That would be about 1860, the time of the American civil war, and you may remember, although I did not know it then, that petroleum had been discovered in America in 1859.

In 1863 I transferred my services to a firm of petroleum importers in Glasgow where I soon learned that the "Yankee skippers'" tales of oil, which we had discredited, were not entirely of the order of the Arabian nights, but were founded upon substantial facts. This little incident, insignificant enough in itself, is interesting to me as fixing indelibly in my mind the birth, though it was destined to a long period of adolescence, of the liquid fuel industry. For, although James Young, the father of the mineral oil trade, had taken out his famous patent in 1850, it must be remembered that he only contemplated the production of lamp oil, lubricating oil, and paraffin wax, and did not deal with other articles.

Therefore, it was not till Colonel Drake "Struck ile" on 28th August, 1859, in Venango County, Pennsylvania, and revealed to an astonished world the possibilities of illimitable subplies of a new and strange material, that the first suggestion was offered that the monopoly long enjoyed by coal and wood and peat as the only practical fuels for industrial purposes, was about to be challenged by a new competitor.

It is strange now to reflect that, although Petroleum, to give it its modern name, had been unknown to western civilisation till its discovery in America by Colonel Drake in 1859, it had been known to eastern nations for upwards of three or four thousand years, and had been an article of commerce for several centuries before Europeans were aware of its existence.

It is now generally conceded that, in the frequent references in the Old Testament, from the days of Noah, upwards of 3,000 years B.C., to bitumen, pitch and slime, some kind of earth or rock oil is meant. Thus we read that:—

> B.C. 3300, Noah was ordered to make an ark of Gopherwood, and to "pitch it within and without with pitch."
>
> B.C. 2300, in reference to the Tower of Babel, "bricks had they for stone and slime had they for mortar."

B.C. 2000, we find the statement that "the vale of Siddim (now supposed to be the Dead Sea) was full of slime pits."

B.C. 1500, "He made Jacob to suck honey out of the rock and oil out of the flinty rock."

B.C. 1500, Job says "and the rock poured me out rivers of oil."

Turning to profane history we find, according to Herodotus, that the Zoroastrians, the "fire worshippers" of Persia, about 450 B.C., worshipped the eternal fires which they found in the neighbourhood of the Black Sea. It is, however, now assumed that the flames which they regarded with superstitious awe proceeded from some natural gas escaping through a fissure in the rocks or from some little oil spring oozing through the ground and accidentally ignited. This probably happened in the neighbourhood of the peninsula of Apsheron in the Caspian Sea, but the commercial value of the wells was not realized till the thirteenth century, when they became the subject of much fighting for their possession on the part of Persians, Armenians, and Russians, the victor, for the time being, taking the wells and their produce for his reward. After many changes of owners, the coveted prize finally (about 1800) fell into the hands of the Russians, who still hold it.

Suffice it now to say that, with the benefit of scientific development and abundant capital, the Russian fields contribute about one-fifth to the world's total production of oil.

If it is strange that Europe should have remained so long in ignorance of the great oil industry which was being carried on almost at its eastern gate, it is less to be wondered at that she should have been equally ignorant of a similar industry which had been carried on unobtrusively in the farther east. I refer to the mineral oil wealth of Burma, a country now under British sway. One of the first writers to call attention to Great Britain's oil resources in India was the late Charles Marvin, at one time a clerk in the Foreign Office who got himself into trouble and disgrace by the premature and unauthorized publication of a certain treaty with a foreign power. Thereafter he betook himself to journalism and seems to have given special attention to the Russian and Indian oil fields. Subsequently, with a prophetic vision of the part petroleum was likely to play in industrial developments and of the importance attaching to Britain's command of her share of the world's supplies, he published, between 1884 and 1889, a series of lurid pamphlets with such startling titles as "Baku the Petrolia of Europe," "Moloch of Paraffin," "Coming deluge of Russian Petroleum," "England a Petroleum Power," "The Coming Oil Age and the Great Canadian Oil Fields." The first of these pamphlets was published thirty years ago, and their author's predictions have been amply verified*. Burma having been for centuries a *terra incognita*, it is difficult to obtain any information regarding its early history or its industries, but it seems to be generally accepted that its oil trade had its origin in prehistoric times and that, for centuries before the country was opened up to Europeans, it had sent its products to India and other neighbouring countries. Marvin says that "An account published by Colonel Symes, in 1795, mentions that there were then 500 wells in operation, the estimated annual yield being 90,000 tons. Two years later Captain Cox estimated the yield at 92,781 tons. In 1835 Captain Hannay described the output as being still about 93,000 tons." In the U.S. Geological Survey for 1912, India, mainly Burma, is credited with 1 million tons. For the same year and by the same authority, Canada, the other British oil field, is credited with 39,000 tons.

As throwing further light upon the antiquity of eastern petroleum, I quote a few words from a recent book "Petroleum, the Motive Power of the World," by W. S. Tower and J. Roberts, who say:

> "Among the nations of the Far East, the knowledge of bitumens goes far back into the ages of the dim past. The ancient records of China describe the use of natural gas, for both fuel and light, centuries before the Christian era. Japanese history says that the 'burning water,' as petroleum was called, was first discovered and used about 615 A.D."

My purpose in occupying so much of your time in showing you the antiquity and the wide distribution of petroleum is to suggest that, if, by spontaneous exudations and accidental discoveries, so much has already been found, it seems reasonable to suppose that the world is saturated with oil, and that, by systematic investigation, supplies are likely to be discovered in every habitable quarter of the globe and in greater volume than those of our coal measures which appear to be rapidly approaching exhaustion.

* The recent British Persian "Oil deal" further justifies Marvin's predictions.

PRODUCTION.

By the courtesy of Dr. George Otis Smith, Director of the U.S. Geological Survey, who has been good enough to furnish me with a copy of their annual review of the trade, I am now enabled to submit the accompanying table showing the world's production of petroleum for the years 1907-1912.

TABLE I.—WORLD'S PRODUCTION OF CRUDE PETROLEUM, 1907-1912, BY COUNTRIES, IN BARRELS.

Source.	1907.	1908.	1909.	1910.	1911.	1912.	
	Barrels.	Barrels.	Barrels.	Barrels.	Barrels.	Barrels.	Per cent of total
United States	166,095,335	178,527,355	183,170,874	209,557,248	220,449,391	222,113,218	63·25
Russia ..	61,850,734	62,186,447	65,970,350	70,336,574	66,183,691	68,019,208	19·37
Mexico ..	1,000,000	3,481,410	2,488,742	3,332,807	14,051,643	16,558,215	4·71
Dutch East Indies	9,982,597	10,283,357	11,041,852	11,030,620	12,172,949	10,845,624	3·09
Roumania ..	8,118,207	8,252,157	9,327,278	9,723,806	11,107,450	12,991,913	3·70
Galicia ..	8,455,841	12,612,295	14,932,799	12,673,688	10,519,270	8,535,174	2·43
India ..	4,344,162	5,047,038	6,676,517	6,137,990	6,451,203	7,116,672	2·03
Japan ..	2,010,639	2,070,145	1,889,563	1,930,651	1,658,903	1,671,405	·48
Peru ..	756,226	1,011,180	1,316,118	1,330,105	1,368,274	1,751,143	·50
Germany ..	756,631	1,009,278	1,018,837	1,032,522	1,017,045	995,764	·28
Canada ..	788,872	527,987	420,755	315,895	291,096	243,614	·07
Italy ..	59,875	50,966	42,388	42,388	74,709	*a* 86,286	·02
Other ..	*a* 30,000	*a* 30,000	*a* 30,000	*a* 30,000	*a* 200,000	250,000	·07
TOTAL ..	264,249,119	285,089,615	298,326,073	327,474,304	345,512,185	351,178,236	100·00
Increase over previous year	—	7·88%	4·64%	9·77%	5·52%	1·63%	—

a = Estimated. 1 metric ton = 7.19 barrels.

From "The Production of Petroleum in 1912," by David T. Day.

Published at the Government Printing Office, Washington.

Complete returns for the World's production of Petroleum for 1913 are not yet available, but the following particulars from the U.S. Geological Survey Press Bulletin for January, 1914 are interesting as showing the production of the U.S. in the various States.

The increase in 1913 as compared with 1912 shows 20 million barrels—about 2,781,700 tons.

It is to be hoped that the total World's production may show a similar increase.

TABLE Ia.—PRODUCTION OF PETROLEUM IN U.S.A., 1913.

State.	1913.	1912.
California	98,000,000	86,450,767
Oklahoma	62,500,000	51,427,071
Illinois	22,000,000	28,601,308
Texas	14,000,000	11,735,057
Louisana	12,000,000	9,263,439
West Virginia	11,000,000	12,128,962
Ohio	8,000,000	8,969,007
Pennsylvania	7,000,000	7,837,948
Wyoming	3,000,000	1,572,306
Kansas	2,000,000	1,592,796
Indiana	900,000	970,009
New York	800,000	874,128
Kentucky	500,000	484,368
Colorado	200,000	206,052
Other States	100,000	—
Total	242,000,000	222,113,218

Origin and Constituents of Petroleum.

Having given you a hasty sketch of the early history of petroleum, we may now devote a few minutes to consideration of its origin and its composition.

Origin.—I remember that, in the early days of the mineral oil trade, much interest and speculation were aroused, among those who were engaged in the trade themselves, and many who were outside it, regarding the origin and nature of the mysterious liquid. Three theories had their respective advocates.

1st. The first, and probably most popular, was that the oil, like coal, was of vegetable origin, and was due to subterranean distillation, the gases rising till they encountered some cooler strata in which they were condensed and in which they lodged until they were released by some enterprising borer.

2nd. The second theory was that the oil was produced from beds of myriads of animalculae (either land or marine) from which oil was produced by natural distillation and condensation as in the case of No. 1.

3rd. The third theory was that the oil was produced by the action of heat and water upon the elements of which the world is composed, the carbon of the earth combining with the hydrogen of the water to produce the liquid hydro-carbons which, after untold thousands of years, we are now turning to profitable account.

Similar discussions raged about the origin of coal and shale oils. But, as in this case the coal and shale remained to tell their own tale, it was more easy to arrive at reasonable conclusions regarding the circumstances and conditions under which they were produced. And as, on careful examination, it was found that some shales contained evidences of animal life, in the shape of myriads of microscopic shells, while others afforded equally indisputable evidence of their vegetable derivation, it is probable that we owe our supply of coal and of shale in part to both sources, and it is not unreasonable to suppose that petroleum may also have a similar dual origin.

But, while there may be room for discussion regarding the particular channels through which these elements of heat and light have been handed down to us there can be no question that they are all derived from one common source, the sun's rays.

In regard to this I should like to quote to you an eloquent and illuminative passage from a strange and unexpected authority upon mechanical matters. My author is Dr. F. W. Pavy, a distinguished professor of Guy's Hospital. His work to which I now refer "A Treatise on Food," in which he traces animal life and force backwards to the prime source, the solar rays.

He has just said that, while no addition can be made to the material of the world:

> "except from the inconsiderable accessions derived from the occasional descent of a meteoric body, it is otherwise with regard to force, which, as heat and light, is constantly being transmitted to us from the sun; and, it is from the force thus derived, that life on earth originated and is maintained. Our coalfields, our forests and vegetable products generally may be regarded as containing a store of force accumulated from the vast supply continuously transmitted with the sun's rays; and, upon the principle of 'indestructibility' which has been enunciated, the force which has been employed in unlocking the elements in the combinations from which vegetable products are built up, and in forming new compounds, is contained in such compounds in a latent state."

Then the Doctor goes on to say that the energy transmitted by the sun's rays thousands of years ago may:

> "By oxidation, be set free in an active state under some form of manifestation or other. It matters not in what way—whether rapidly or slowly, or under what circumstances—whether inside or outside the living system, the oxidation occurs; the result is the same, as far as the amount of the force liberated is concerned."

Combustion or Oxidation.

Dr. Pavy's remark that latent force is to be rendered active by oxidation, calls for a brief consideration of the action of combustion which oxidation connotes. In doing this it is necessary to distinguish between two words which are often confused, viz., "combustion" and "conflagration." Both are due to the same chemical action, but may exhibit themselves in different ways. Dr. Pavy refers to them as "slow" and "rapid" respectively. The popular idea of combustion is that of some action which manifests itself in heat and light, but if we turn to the derivation of these words we find that "combustion" is derived from the latin words "con" together, and "buro" to burn, which may be effected so slowly as to be imperceptible; while "conflagration" comes from the Latin word "conflagro" which is rendered in English as "to be in a blaze."

In support of this argument I submit the following quotation from a well-known authority, Mr. Vivian B. Lewes, Professor of Chemistry in the Royal Naval College, Greenwich.

Having defined combustion as the combination of "Oxygen," which is commonly regarded as *the* supporter of combustion, with a combustible such as carbon, Mr. Lewes says:

> "Ordinary combustion is the evolution of heat and light during rapid and energetic chemical action; but, in nature there are many cases of chemical changes which are so gradual that the heat evolved, being spread over a long period of time, becomes inappreciable to our senses, and such processes we call 'slow combustion.'"

> "A tree left to rot upon the ground gradually disappears in the course of years, being oxidised up into carbon dioxide and water vapour and scarcely any evolution of heat is observed, yet the same amount of heat is generated as if the tree had been cut into logs and burned."

"When a steel watch spring is kindled in oxygen gas by means of German tinder attached to the end of it, the iron burns away with great rapidity, forming an oxide of iron and giving out great heat and light. The same weight of metal would, in the course of time, if exposed to moist air, be converted into an oxide, which, combined with water, is ordinary rust; yet no evolution of heat is perceptible, because the time over which the action is spread is so great, that at no moment of time is enough heat evolved to be perceived by our senses; yet in each the total quantity of heat evolved is the same. Another example of slow combustion is found in the action of respiration."

It would therefore seem that all animals, human beings included, are a sort of animated internal combustion engine.

We may thus, perhaps, recognise three kinds of Combustion, viz.:—

(1) Slow and imperceptible, as in the action of rotting of wood or rusting of iron.

(2) Rapid, as in the combustion of fuel in a furnace —conflagration.

(3) Instantaneous, as in the case of powder in a gun or of gas or petroleum spirit in the cylinder of an internal combustion engine—explosion.

It would appear, however, that we are mainly concerned with combustion in the second and third form, conflagration and explosion, and it behoves us now to consider the methods for giving effect to this chemical action.

Surface Combustion.

Another illustration of the truth of the statements, in the preceding paragraphs, that the action of combustion may occur without visible manifestations, is to be found in the new method of surface combustion without flame, which, invented by Professor W. A. Bone and developed by that gentleman in conjunction with Mr. C. D. McCourt, has now been put upon the market under their joint names as the "Bonecourt Surface Combustion Boiler."

The principle upon which Professor Bone's new process is founded has been long known to chemists as "Catalysis" which is applied to the power, latent in certain substances, of promoting a change in the constitution and condition of other materials without being themselves affected.

The firm, "Bonecourt Surface Combustion Limited," who control the system, have very kindly favoured me with various pamphlets in which it is fully described, and, from these, I take the following particulars:—

Professor Bone says:

"The distinguishing and essential feature of the new process is that a homogeneous mixture of gas and air, in the proper proportions for complete combustion (or with air in slight excess thereof) is caused to burn without flame in contact with a granular incandescent solid, whereby a large proportion of the potential energy of the gas is immediately converted into radiant form." The advantages claimed for the new system are:—

(1) The combustion is greatly accelerated by the incandescent surface, and may be concentrated just where the heat is required.

(2) The combustion is perfect with a minimum excess of air.

(3) The attainment of very high temperature is possible without the aid of elaborate "regenerative devices."

(4) Owing to the large amount of radiant energy developed, transmission of heat from the seat of combustion to the object to be heated is very rapid."

Professor Bone enumerates the following as among the materials described as "Catalytics" which possess the property of promoting flameless combustion, "porous porcelain, fireclay, magnesia, platinum, gold, silver, copper, nickel, ferric oxide, nickel oxide, copper oxide, asbestos.

By way of illustrating the action of his process, Professor Bone exhibited the following experiment:—

"A mixture of hydrogen and oxygen in their combining proportions (electrolytic gas) is maintained in an enclosed glass chamber at a temperature of (say) 450 C, (842 F.) a tendency is observed to form steam, but the rate of change is negligibly small. When there is brought into the system some solid porous material at the same temperature, so that a large surface is exposed to the gases, the rate of change is at once rapidly accelerated in the layer of gas immediately in contact with the hot surface. Steam diffuses outwards from the surface and the supplies of hydrogen and oxygen at the surface diffuse inwards to replace the gases consumed. Thus combustion proceeds heterogeneously at the surface until the transformation of the original electrolytic gas into steam is complete."

Professor Bone describes several forms in which his process may be utilized for heating generally, for chemical and metallurgical operations, for manufacturing purposes and for steam raising.

The following description will explain the process in operation :—

A diaphragm is composed of granules of fire-brick bound together in a suitable way; the diaphragm forms the front of a shallow metallic chamber of the same area as the diaphragm; gas and air in suitable proportions are admitted to the chamber by a pipe at the back, and, passing through the diaphragm, are ignited in front. More air is admitted till a fully aerated mixture is obtained. The flame soon becomes non-luminous and diminishes in size; a moment later it retreats on to the surface of the diaphragm which at once assumes a bluish appearance; soon, however, the granules at the surface attain an incipient red heat; finally, the whole surface layer of granules become red hot and an accelerated "surface combustion" comes into play."

When it is desired to apply the principle to a steam boiler, the ordinary tubes are replaced by special tubes of 3in. diameter which are filled with fire-clay, fire-bricks or similar material, the space of the firebox is taken by a gas chamber through which the mixture of gas, and air is driven or sucked into the tubes in which it is ignited and burns with non-luminous heat.

The inventors claim that by this process steam may be raised from the cold in about twenty minutes.

Despite, however, the fact that the potential value of liquid fuel was speedily recognized, in regard to which I shall have something to say to you shortly, I think that it will be generally conceded that the practical utilization of liquid fuel, for the generation of heat and power, either in furnaces or in internal combustion engines, has been reserved for the twentieth century even, perhaps, for the half dozen years immediately preceding that which is now current.

Utilisation.

Of the two methods of utilizing liquid fuel, in furnaces or in internal combustion engines, it is probable that the efforts of inventors would be, in the first place directed to the former as we know that, although the idea of an internal combustion engine or explosion engine operated by gunpowder or by turpentine or some other volatile liquid, had been simmering in men's minds for upwards of a century, it did not assume a practical shape till Otto placed his engine upon the market in 1876 or 1877, and we know that it was not till the success of the Otto engine had demonstrated the feasibility of his principle that the idea of substituting light hydro-carbon spirit or oil for gas was introduced.

But whether the fuel is to be used in a furnace or in some form of internal combustion engine, a great "Diesel" or the smallest petrol motor, the same governing principle obtains, viz., that the combustible shall be intimately and rapidly combined with the oxygen which is necessary to effect combustion. Two actions are thus called for, viz., introduction or injection and combination, before the third, or chemical action or combustion is effected and it will now be convenient to consider some of the arrangements required for this purpose.

Early Devices.

Two mechanical actions are involved in the introduction of fuel whether to a furnace or to an internal combustion engine, "Injection" and "Combination."

Injection.—There are three methods in use for effecting this:

By a current of air, gas or steam.

By force pump.

By suction, as in automobile engines.

In furnaces the first-named is more common, and we, therefore, deal with it first.

The principle, with which you are all well acquainted, is that a fluid (air, gas, or steam) flowing at a high velocity, is able to impart motion to, and to carry with it some quantity of another liquid. The principle is seen in operation in that, to me, most wonderful apparatus, the steam-water injector of which I believe that Giffard's is one of the earliest and Koerting's of one of the most efficient specimens. The principle, common to all forms of injector with which I am acquainted, seems to be the production, at a given point, of a vacuum which the liquid, or other material to be operated on, rushes in to fill.

Seeing that the "Injector" plays such an important part in connection with the use of liquid fuel, I desired to learn something about its inception and, for information, I had recourse to the Patent Library, going back in my search as far as the year 1855.

In the prosecution of my enquiry I was struck by the fact that, in spite of the endless and almost indistinguishable variety in details, only two principles were recognizable in all.

1st, the use of two concentric cylindrical or conical tubes with reduced nozzles, the inner tube containing the liquid to be injected while the outer conveyed the operating fluid; this principle is found, with some modifications, in most of the liquid fuel burners of the present day.

2nd.—In the second form of injector two tubes are placed at a right angle, their ends meeting. The horizontal member supplies steam or compressed air at a high velocity across the open end of the vertical tube. In some cases the vertical tube connects upwards with an overhead tank of oil which flows downwards by gravitation, in others, but less frequently, the fuel supply pipe rises vertically from a lower level and the oil is sucked upwards, by the current of steam or air after the manner of the spray perfume apparatus with which we are all familiar. A form somewhat akin to this is still to be found in operation in many automobile carburettors.

I have referred to Giffard's injector as being, to my mind, the parent of the whole family of liquid fuel burners and carburettors. It may, therefore, interest you if I mention that

Giffard's first patent was taken out on 23rd July, 1858 (which was before the discovery of petroleum) and is described as "applied to feeding a steam boiler and for raising and forcing fluids."

Hancock, whose name is familiar to all users of steam, appeals to us with peculiar interest, as his first patent, 17th December, 1864, is for "a blast apparatus for furnaces" and for "promoting the evaporation of liquids." Combine the two purposes and you have something very like an oil burner.

Koerting makes his first appearance on the patent register with a "provisional" on 18th November, 1869, and claims, like Giffard, "feeding boilers and raising water."

In the course of my "Patent Search" I found a large number from 1860 to the present date, dealing directly with liquid fuel.

I enumerate a few of the more important—

A. E. Berard. 4th April, 1862. Berard's is the first patent, of which I find any record, for liquid fuel. He describes his apparatus as an "Injector for air and gas for gas-fired furnaces used in making steel."

Valentine & Levick. 6th August, 1862 These gentlemen describe their apparatus as one for burning "Poor Gas" produced by passing a blast of steam or hot air through incandescent coal or carbonaceous material. Surely, to all intents and purposes, the prototype of all carburettors if not also of the modern "Gas Producer," Dowson's included.

Wise, Field & Aydon. 16th October, 1865. The first direct reference to liquid fuel occurs in the patent granted to Wise, Field & Aydon. Their specification and drawings show a horizontal pipe with restricted opening through which steam is forced, meeting a stream of oil and air from a vertical pipe delivering immediately above the nozzle of the steam pipe.

Aydon & Field. 29th March, 1867. These gentlemen, whose names were mentioned in connection with the patent just referred to, make their appearance again with another invention for the use of "liquid, gaseous and pulverulent fuel fittings for furnaces." The drawings show a horizontal pipe conducting steam and a vertical pipe from an overhead tank which delivers the fuel in front of the steam jet by which it is sprayed into the furnace. The curious thing about this patent is the reference to "pulverulent" fuel by which coal or coke in the form of powder is understood. Evidently Dr. Diesel was not the first to appreciate the value of coal in a pulverized condition as a fuel.

B. F. STEVENS. 29th July, 1867. Steam is supplied through a pipe terminating in a nozzle, within and concentric with which is a tube through which petroleum or other liquid hydrocarbon is supplied. This patent is interesting as being the first in which special reference is made to the use of petroleum as fuel for furnaces, just eight years after the discovery of that article. In subsequent patents frequent references are made to petroleum, paraffin, naphtha, tar, creosote, and other residual products.

NORTON & HAWKSLEY. 22nd August, 1867. The patentees describe their invention as for "liquid fuel fittings and blast apparatus" specially adapted for the use of petroleum. The interesting thing about this patent is that the patentees recommend the use of "helical internal ribs to direct the air current." The arrangement is, I understand, common in modern practice.

In 1868 half-a-dozen patents were taken out for apparatus for burning liquid fuel, and in subsequent years the number of patents steadily increased as the production of oil in the world extended in respect to both quantity and area.

Having thus shown you that, within ten years after the discovery of petroleum, its value as a fuel had been recognized and apparatus for its use designed, I shall not continue my account of these earlier burners.

Before leaving this subject I should, however, like to refer to another invention which, not of immediate interest to marine engineers, is of general interest in these days of motor cars and motor cycles, which we are apt to claim as wholly modern products. It is, therefore, curious to find that letters patent were granted to Mr. E. Butler on 15th November, 1887, for what he describes as "Ejectors for carburetting air for use in petroleum engines for driving tricycles and other vehicles," so that motor cars and motor cycles are not quite such novelties as we are fondly disposed to regard them.

But while, from the hasty account which I have given you of these early devices for using liquid fuel, it will be apparent to you that its value had been realized and various methods for its utilization had been suggested, its general adoption was for many years barred by the high price of oil which rendered it much more expensive than coal.

Modern Practice.

I propose now to devote a little attention to the modern methods of utilizing liquid fuels and to the fuels available for that purpose.

The first instance with which I am acquainted of the practical use of liquid fuel occurred at the Broxburn Oil Works, near Edinburgh. One of the difficulties which the Scottish Oil Refiners had to face was that of disposing of the acid tar from their refining operations for which no market could be found. One common practice was to discharge it on the Spent Shale heaps, while these were still glowing hot, and allow the tar to burn away. Another practice was to construct small brick furnaces in which the stuff was burned to waste. In both cases huge volumes of black smoke were liberated which destroyed the farmers' crops and involved heavy claims for damage.

I shall now let Mr. Norman Henderson, the inventor of the apparatus and, I believe, one of, if not absolutely the first man in this country to utilize liquid fuel, speak for himself in the extract from his letter which I shall read to you. He says:—

> "When I entered the service of the Oakbank Oil Co. in 1869, to erect and manage their works, I took the opportunity of constructing the Still furnaces in such a way as to burn the tar and get what heat we could out of it. This was simply done by forming a $4\frac{1}{2}$in. brick arch in the front end over the furnace, about two-thirds the length of the bars, and the arch levelled up to form a bed on the top for the tar. The tar was allowed to run in a continuous stream on the hot bed, sufficient to feed it. The tar burned readily on the hot brick bed and gave off a good deal of heat which assisted materially the coal furnace in heating the Still. Any coke that was formed on the bottom of the bed was pushed over, from time to time, at the back into the open space of the furnace, where it burned along with the other fuel.
>
> By working the tars in this manner I found that we got considerable heat, one ton of tar being equal to one ton

of coal, but a good deal of labour was involved in working this process and it also had the objection that it produced much smoke.

On joining the Broxburn Oil Co. in 1878, I took the opportunity, in erecting the new works, of making an improvement for the burning of the tars, by fitting the Stills with injectors, instead of the old system as above described. The new arrangement proved a great success, and I found that one ton of tar was about equal to two tons of coal when atomised by the injector with steam. By this system the waste tars became an important saving, doing away with most of the coal used at the Stills. It was also a saving of labour, and produced very little smoke, a very important matter. I enclose a sketch showing, on a small scale, the Still furnace, fitted with injector; and a full-sized sketch of the furnace tar injector itself, as used at present by us*. The ashpit front openings are closed by a sliding door, and in that door is a small aperture for regulating the air supply. I have tried both air and steam for the injector, and find that steam gives the best results, especially with a little superheat."

It is interesting, incidentally, to find that, although Mr. Henderson has every reason to congratulate himself on the success of his arrangements for burning oil in furnaces, he does not expect to see it generally adopted in this country. In his letter, from which I have just quoted, he goes on to say:—

"My personal opinion is that the cost of oil fuel for the raising of steam is out of the question in the United Kingdom where coal is, relatively, so much cheaper. No doubt large quantities of oil fuel are used to great advantage, as against coal, in many of the processes of our manufacturers as well as in the Navy, where cost is a secondary matter, while the Marine Engineers are now giving more attention to the use of oil in internal combustion engines."

Of course, you are aware, he adds that

"the latest practice in the Navy in burning liquid fuel, is by heating the oil and then forcing it into the furnace under pressure by a pump, which gives better results than the injector and is more easily controlled."

* See page 107

Mr. Henderson's success with liquid fuel induced a friend of his and mine, Mr. William McLaren, manager of the Ardan

HENDERSON'S LIQUID FUEL BURNER.

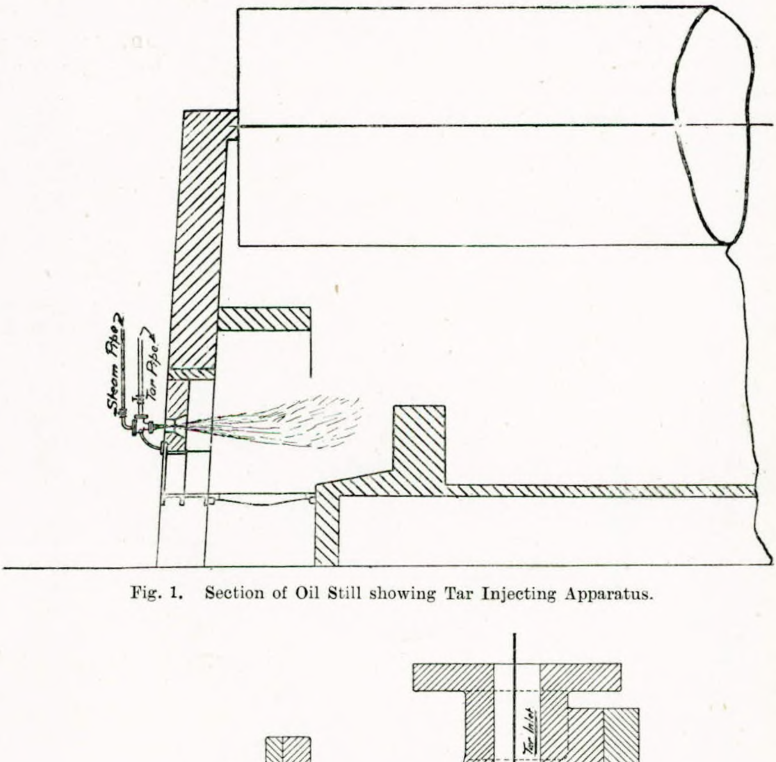

Fig. 1. Section of Oil Still showing Tar Injecting Apparatus.

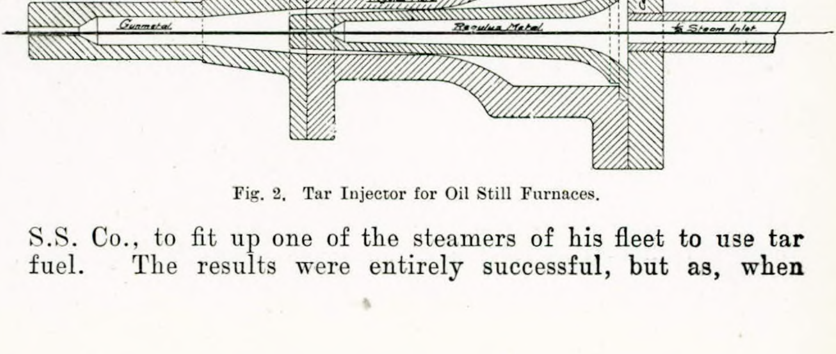

Fig. 2. Tar Injector for Oil Still Furnaces.

S.S. Co., to fit up one of the steamers of his fleet to use tar fuel. The results were entirely successful, but as, when greater supplies were required, the price advanced from about 30s. to between 40s. and 50s. per ton, the cost was found to be too great, and Mr. McLaren reverted to coal.

It is interesting also to notice that the next practical and successful attempt to utilize liquid fuel was due to difficulties similar to those which confronted Mr. Henderson, viz., the necessity for disposing of residual by-products for which no market was available. I refer now to the system, introduced by Mr. J. Holden, for burning, in locomotive furnaces, the tarry residues produced in the manufacture of Pinch gas for lighting railway carriages.

Mr. Holden's first patent was taken out in June, 1886, and shows two conical concentric tubes, the inner containing oil, the outer, steam. These tubes are surrounded by an annular pipe conveying steam which, through inwardly inclined orifices, delivers steam at the point at which the mixture of steam and oil emerges from the injector proper, this supplementary supply of steam also induces a current of air through the small annular space which occurs between the injector and the annular steam pipe. Mr. Holden took out subsequent patents for modification of his burner in 1891 and in 1899.

The records of the Patent Office during the last twenty years are full of specifications of oil burners. To deal with even a selection of these would require more time than we have now at our disposal, and as, moreover, the task is one rather for an engineer than for an oilman, and, having further regard to the fact that I have undertaken to speak of oil fuel itself, rather than with the means of using it, I shall not further pursue the latter aspect of the subject.

In order, however, to afford you some information regarding modern "Liquid fuel burners," I have pleasure in handing you each a copy of two pamphlets, published respectively by the Anglo-American Oil Co., Ltd., and the British Petroleum Co., Ltd., in which you will find a good account of the principal burners now on the market.

Internal Combustion Engines.

I have hitherto been discussing the history, properties and uses of liquid fuels, which properly fall within the sphere of my own observation, but, as a mere layman, the guest of a highly technical society, addressing an audience of practical engineers, I confess that I feel considerable hesitation in approaching the subject which I have next set down for consideration. But, as my business and interests are closely related to yours, and as, moreover, mechanical questions have always had a peculiar fascination for me, I hope that you will forgive me for venturing to express my views upon matters regarding which you are all better qualified to form an opinion than I can be, viz., the relative efficiency of coal and oil as fuel.

The point which I wish to make is that the full benefit to be derived from the substitution of oil for coal as fuel is not to be attained from the substitution of the former for the latter for steam raising, but from the general adoption of the "Internal combustion" instead of the steam engine. The present tendency seems to be in favour of the use of oil instead of coal for raising steam, but while by this change much space may be released for cargo and economy effected in "bunkering" and in the wages bill for stokers, it is evident that the great space required for boilers is still unprofitably occupied while all the troubles and dangers incidental to these remain.

We can readily recognize that there are serious difficulties in the way of the drastic change which is involved in the latter proposition. In the first place it is not to be wondered at that steamship owners should hesitate to "scrap" the engines and boilers upon which they have hitherto depended for power, although they may be prepared to adopt the middle course of converting their boilers from coal to oil firing. In the second place there exists the still greater difficulty regarding an adequate supply of the new fuel. Granting, however, that this latter difficulty has been removed, and that adequate supplies of liquid fuel have been assured, there still remain other important questions to be settled.

For, great as have been the advances which have been effected with the last few years, and excellent as modern types may be, there is no assurance that anything like finality has been attained while there are constant rumours of other forms, the gas turbine has long been adumbrated, which may relagate all modern engines to the scrap heap. Cost, too, is an important consideration, for I understand that, power for power, the internal combustion engine is much more expensive than its precursor, the steam engine, so much so that I have been told that a modern oil engine costs as much as a steam engine and boiler of the same efficiency. Nor is this to be wondered at when we contrast the comparative simplicity of the steam engine with the complications of the oil engine. Compare, if you please, the three or four cylinders and the few moving parts of the former with the more numerous cylinders of the latter with its array of inlet and outlet valves and all their countless spindles, cams and tappets, and elaborate reversing gear. Still, no one who has had, as I have had, the good fortune to see the magnificent productions of Sulser Brothers, Burmeister & Wain, Bolinders or Mirlees, Bickerton & Day, can fail to realise that, even in their present stage, these engines mark the advent of a new motive power in the history of the world.

Nature and Properties of Liquid Fuel.

Earlier in my present paper I endeavoured to give you some account of the geological origin of liquid fuel and I have several times referred to "Combustibles" and to "Supporters of Combustion." Let us now consider, for a few minutes the various articles which may be included under the comprehensive title "Liquid Fuel" with regard to the nature, properties and potential value of each.

The efficiency of fuel, of any kind, depends upon its elementary composition, and, as the calorific value of each element as well as the volume of air with its oxygen content required for complete combustion has been determined by many investigators, the value of the fuel may be calculated from these data.

I therefore submit two tables showing the elementary composition of various materials commonly recognized as "combustibles."

The first table is taken from an excellent little work entitled: "A Practical Treatise on Heat," by Mr. Thomas Box. The second was prepared specially for me by the chemists in the Belmont Laboratory.

Should you find any apparent discrepancies between my authorities, I ask you to remember that doctors claim the right to differ.

TABLE II.—(BOX) THE CHEMICAL COMPOSITION OF COMBUSTIBLES, ACCORDING TO PECLET, ETC.

Elements.	Carbon.	Hydrogen.	Oxygen.	Nitrogen and Sulphur	Water.	Ashes.	Total.
Coal, mean 97 kinds	·804	·0519	·0787	·0216	—	·0408	1·000
Coke	·850	—	—	—	—	·150	,,
Wood, perfectly dry	·510	·053	·417	—	—	·020	,,
,, ordinary state	·408	·042	·334	—	·200	·016	,,
,, charcoal	·930	—	—	—	—	·070	,,
Peat, perfectly dry	·580	·060	·310	—	—	·050	,,
,, ordinary state	·464	·048	·248	—	·200	·040	,,
Oil of Turpentine	·884	·116	—	—	—	—	,,
Alcohol	·5198	·1370	·3432	—	—	—	,,
Olive Oil	·7721	·1336	·0943	—	—	—	,,
Sperm Oil	·789	·1097	·1013	—	—	—	,,
Beeswax	·816	·139	·045	—	—	—	,,
Spermaceti	·816	·128	·056	—	—	—	,,
Tallow	·790	·117	·093	—	—	—	,,
Paraffin Oil	·8522	·1478	—	—	—	—	,,
Resin	·7927	·1015	·1058	—	—	—	,,
Sulphuric Ether	·6531	·1333	·2136	—	—	—	,,

Still quoting from Box, we learn that, according to Dulong, the heat evolved by combination with oxygen is 12,906 units per pound of carbon, and 62,535 units per pound of hydrogen.

The presence of oxygen in a combustible containing hydrogen has the effect of reducing its heating power, as the oxygen to the extent that it is present, combines with the hydrogen to form water, but without evolution of useful heat, whereas, if hydrogen alone be present it yields the full amount of heat due to it.

Let us apply these rules, taking (1st) paraffin oil, which has special interest for us, as a material entirely free from oxygen, and (2nd) alcohol, as containing the highest percentage of hydrogen.

Taking round figures for paraffin oil we have:—

Carbon ...	$\cdot 852 \times 12906 =$	10,996	units
Hydrogen	$\cdot 148 \times 62535 =$	9,255	,,
	1·000	20,251	,,

Turning next to alcohol, we find that it contains ·5198 parts of carbon, ·3432 of oxygen, and ·1370 of Hydrogen, but, as oxygen requires one-eighth part of its weight to form water, the oxygen in alcohol will require $\cdot 3432 \div 8 = \cdot 0429$ hydrogen; whereas alcohol contains ·137 of hydrogen: there remains therefore, $\cdot 137 - \cdot 0429 = \cdot 0941$ hydrogen in excess to develop its heat, and we have:—

Carbon	$\cdot 5198 \times 12906 =$	6,708 units
Hydrogen in excess	$\cdot 0941 \times 62535 =$	5,885 ,,
		12,593 ,,

Let us next deal with olive oil which consists of Carbon, 0·7721 × Hydrogen, 0·1336 × Oxygen, 0·0943, in a similar manner, and we find:—

Carbon	$\cdot 7721 \times 12906 =$	9,965 units
Hydrogen $\left(\cdot 1336 - \frac{\cdot 0943}{8} \right) =$	$\cdot 1218 \times 62535 =$	7,517 ,,
		17,482 ,,

But while it is apparent from these figures, that the presence of oxygen reduces the calorific value of oils as fuels, it must be equally recognised that its presence promotes combustion and reduces the tendency to smoke with production of soot or carbon. We all know that many vegetable and some animal oils may be burned in open lamps without smoke, *e.g.* colza or rape, olive, coco-nut, even castor and sperm and seal oils, while it is impossible to burn paraffin or petroleum under such conditions of account of the dense volumes of smoke which they give off. In evidence of this statement I now draw you attention to the lamps on the table which are trimmed with the oils which I have mentioned*.

From these facts which I have quoted and from this little demonstration which I have given you, I think that I am justified in saying that those engineers are in error who object to the use of vegetable oils, pure or mixed with mineral oil, as lubricants for internal combustion engines for fear of the carbon-

* Mr. Wilson exhibited three open Miller's Lamps which burn without chimneys. Two of the lamps, filled respectively with Olive and Rape Oil, burned during the whole evening against a white background without showing any trace of smoke. The third lamp, containing Mineral Lubricating Oil, was lighted during the evening, but had to be extinguished after a few minutes burning on account of the dense volumes of black smoke which it emitted.

aceous deposits which, they say, these oils are liable to produce. Such is not, I am in a position to assure you, the opinion of some of the leading makers of oil engines in this country, among whom I may mention Crossleys, Tangyes, Hornsbys, Petters, the "Trusty" Engine Co., and others, who use either rich compound or pure vegetable oils.

TABLE III.—(BELMONT) ELEMENTARY COMPOSITION OF VARIOUS OILS.

Material.	Carbon.	Hydrogen.	Oxygen.
Motor Spirit	82·99	16·08	0·93
Royal Daylight	85·00	14·45	0·55
Alcohol, Ethyl	52·17	13·04	34·79
Refined Distillate, .905	87·05	12·56	0·39
,, ,, .910	84·55	12·87	2·58
Cylinder Oil, Natural	84·02	13·05	2·93
,, ,, Charcoal Refined ..	85·43	13·17	1·40
Huile D., French Motor Oil	86·02	13·33	0·65
Gas Engine Oil, Light—Price's ..	85·66	12·53	1·81
,, ,, ,, Heavy—Price's ..	83·79	12·86	3·35
Motorine A.—Price's	84·45	13·04	2·51
Tallow Oil..	77·4	11·8	10·8
Cocoanut Oil	75·4	11·7	12·9
Rape Oil	78·0	12·0	10·0
Castor Oil	74·0	11·4	14·6
Olive Oil	77·2	13·3	9·5

Finally, I show in a simple manner, the volume of oxygen required for complete combustion and the quantity of air necessary to provide the oxygen required.

For this table I am also indebted to the chemists of the Belmont Laboratory:—

TABLE IV.—(BELMONT) APPROXIMATE OXYGEN AND AIR REQUIRED FOR COMBUSTION.

1-lb. Carbon requires 2.66 lbs. Oxygen } For Combustion.
1-lb. Hydrogen ,, 8.00 ,, ,, }

Air by weight = 23 Oxygen + 77 Nitrogen.

,, volume = 21 ,, + 79 ,,

13 Cubic feet of Air = 1 lb. by weight.

1 lb. of Oxygen in $4\frac{1}{2}$ lbs. of air.

Material.	1 lb. Requires.		
	Oxygen. lbs.	Air. lbs.	Air. Cubic ft.
MOTOR SPIRIT.			
Carbon ·84 × 2·66	2·24		
Hydrogen = ·16 × 8·00	1·28		
	$3{\cdot}52 \times 4\frac{1}{2}$ =	15·84	206
ROYAL DAYLIGHT.			
Carbon = ·85 × 2·66	2·26		
Hydrogen ·15 × 8·00	1·20		
	$3{\cdot}46 \times 4\frac{1}{2}$ =	15·57	202
LUBRICATING OIL.			
Carbon = ·85 × 2·66	2·26		
Hydrogen = ·13 × 8·00	1·04		
	3·30		
Oxygen = ·02 (deduct)	·02		
	$3{\cdot}28 \times 4\frac{1}{2}$ =	14·76	192
FATTY OILS.			
Carbon = ·76 × 2·66	2·02		
Hydrogen = ·12 × 8·00	·96		
	2·98		
Oxygen = ·12 (deduct)	·12		
	$2{\cdot}86 \times 4\frac{1}{2}$ =	12·87	167
ALCOHOL.			
Carbon = ·52 × 2·66	1·38		
Hydrogen = ·13 × 8·00	1·04		
	2·42		
Oxygen = ·35 (deduct)	·35		
	$2{\cdot}07 \times 4\frac{1}{2}$ =	9·31	121

Oils Available as Fuel.

Petroleum.—Had I written this paper a few years earlier I should probably have endeavoured to present you with a list of the countries in which petroleum had been found, but as it is now known to all readers of the newspapers that oil has been found in every part of the civilized globe, and in some parts which have not yet come within the pale of civilization, such a geographical enumeration is unnecessary.

From petroleum we obtain the greatest variety of products suitable for as many different types of engine.

(1) Spirit, or "petrol," ranging in regard to specific gravity, from 670 to 760. This is adapted for use in motor and some launch engines.

(2) Kerosene, paraffin or lamp oil, having specific gravity from 800 to 825. This is used in commercial, stationary and portable engines of the Premier, Hornsby, Tangye, National, Gardner, Kelvin, and similar types.

(3) Solar oil of about 840 to 850 specific gravity is also used in engines of the preceding types, and is likely to give more power per gallon than the lighter oil although it may be more difficult to volatilize.

The preceding are refined oils, those which follow are unrefined, or "semi" refined.

(4) Heavy oil, semi-refined, of red colour, varying from 850 to 950 in specific gravity according to country of origin.

(5) Crude Oil. Judging from various conversations which I have had with internal combustion engineers, at home and abroad, I am led to think that these gentlemen generally have a very vague and indefinite idea of what is implied by the words "crude oil." In the oil trade "crude oil" is understood to mean and is applied only to the oil as it leaves the retorts in which it has been produced from coal or shale, or to petroleum in its natural condition in which it issues from the wells. But, as the oil, at this stage, contains all its more valuable constituents, *e.g.*, spirit, lamp oil, lubricating oil, and, perhaps, paraffin wax, it is more profitable, if means are available, to extract these products and to sell the residue as fuel. In my own experience I have found in use under this name, dark coloured distillates, such as we should describe as "gas oil;" heavy

dark oils, probably crude oil with the lighter fractions removed; genuine crude oil, as one may say "entire" and residues from petroleum, coal or shale oils and gas tars.

(6) The residues to which I referred in the last paragraph ought to form a group by themselves. Mr. Wm. H. Booth, in his excellent work on "Liquid Fuel" describes them as follows:—

(A) Natural oils which have parted with their volatile portions under the influence of sun and air and become natural "Mazut."

Borneo oil which flashes at 100°C (212°F) is directly employed as fuel, and Texas oil, which appears to possess little other value than as fuel.

(B) Distillation residues, or Mazut, which result from boiling off all the more volatile portions.

(7) Animal and Vegetable Oils. Finally, the late Dr. Diesel, in his last lecture in this country, that delivered before the Institution of Mechanical Engineers, in March, 1912, enumerates, as oils suitable as fuels for his engine, "fat oils from vegetable or animal sources, such as earthnut oil, castor oil, fish oils, etc." He adds in a footnote, "This class of oil has been added by the author from his own investigation of earthnut oil." Elsewhere, in the same paper and speaking of earthnut oil, he says, "This oil is almost as effective as the natural mineral oils, and, as it can also be used for lubricating oil, the whole work can be carried on with a single kind of oil produced directly on the spot. Thus this engine becomes a really independent engine for the tropics." The curious thing is that, when, in my remarks upon his paper, I recommended compound lubricants, *i.e.*, oils containing a small percentage of vegetable oil, as lubricants for Diesel engines, the good Doctor scouted my suggestion, saying that "unfortunately vegetable oils seemed so liable to form acids when they become warm, that great precaution was required in their application for lubricating purposes. This formation of acid did not originate, as Mr. Wilson thought, from the oxygen of the surrounding air, but from the strong contents of chemically bound oxygen in the vegetable oil itself, so that acid was also formed when the oil was warmed in close vessels."* But, if this is the case,

* The oxygen contents in oils are shown on table of page 113 and the effects of its presence is discussed on page 112.

why should it happen when only a small percentage of vegetable oil is used as a lubricant and not when vegetable oil is used, pure and simple, as fuel?

Before I leave this subject, let me call attention to a serious danger inherent in the equivocal or ambiguous use of the expression, "Crude Oil," which, as I have shown above, may denote either oil containing all its dangerous fractions, or oil from which these have been removed by distillation. If an engineer who has been using the latter, which we may call "reduced crude," with comfort and satisfaction, is, without notice, supplied with natural crude oil retaining all its volatile contents and proceeds to use it without the precautions which its use involves, it is inevitable that danger, possibly culminating in disaster, may ensue.

This aspect of the question was referred to by Mr. R. J. N. Willcox in his remarks in the discussion upon Dr. Diesel's paper.

Mr. Willcox specified these dangers as

(1) "The risk of explosion or fire on board the ship carrying the crude oil.

(2) The risk of damage by fire to other ships and to the warehouses and goods stored therein.

(3) The risk of a conflagration arising from the presence of oil floating over the surface of the water in a crowded dock. The presence of this oil might be due to leakage from the oil ship, from defect in construction, or from accident, such as collision, or from the oil being pumped overboard with bilge-water."

The chief danger would arise from the liberation from the oil of inflammable gases which, accumulating, in imperfectly ventilated apartments, may be ignited by the furnace fire or by an open lamp.

Dr. Diesel replied that the danger was non-existent, and referred to the number of tank ships carrying crude oil and spirit in bulk without accident. It may, however, be pointed out that in such cases, the crew are aware of the dangerous nature of the cargo and take such precautions as may be necessary.

The subject was also referred to by Sir Boverton Redwood, in his presidential address to the Junior Institution of Engineers, on 5th December last, when he said

"Crude Petroleum of a low flash-point is largely used as a fuel in steam raising in the oil fields, but the oil fuel of commerce is usually required to be of a comparatively high flash-point, and is either a distillate or more commonly the residue of crude petroleum from which the more volatile fractions have been removed by distillation. The present and former British Admiralty Specifications for Navy oil fuel have recently been published, and it has thus been made known that the flash-point has been reduced from 200°F to 175°F, close test."

Fuel Values.—Thermal.

I have taken up so much of your time in discussing the matters already referred to that I have left myself little for consideration of "Fuel Values," which should form a fitting conclusion to this paper. Fortunately, the subject has been, of late, so fully debated, alike in technical and in non-technical papers, that it will be sufficient now to put before you a few particulars gleaned from various recognised authorities, regarding the leading fuels under consideration.

The full titles of the books and authors referred to will be found in the Bibliography which is appended to this paper.

Table V. (Booth) shows how Specific Gravity affects the expression of thermal values.

Specification.	Reduced Fuel Oil.	Distilled Fuel Oil.
Spec. Grav. at 60 F.	0·914	0·853
Gravity, Baume..	23	34
Weight per Imp. Gall.	9·14 lbs.	8·53 lbs.
Carbon	87 72	86·19
Hydrogen	11·45	12·51
Calories per Kilo	11·000	11·250
B. Th. U. per lb.	19·800	20·250
B. Th. U. ,, Imp. Gall.	181·340	172·870

The interesting thing about this table is the demonstration which it affords, that although the oil of lower S.G. has the higher thermal value per lb., 20.250 B.T.U., as against 19.800 B.T.U. for the heavier oil, yet the values are reversed when expressed per gallon. This is, of course, due to the fact that a gallon of lighter weighs less than a gallon of the heavier oil.

Table VI. (Bluecher) gives the calorific values, in Calories, of a number of different substances used as fuels:—

Materials.	Units.	Materials.	Units.
Perfectly Dry Wood ..	3750 H.U.	Petroleum Residues ..	11620 H.U.
Air-dried Wood ..	2900 ,,	Hydrogen	29100 ,,
Charcoal	7500 ,,	Methane	12700 ,,
Perfectly Dry Peat ..	5000 ,,	Ethylene	11100 ,,
Air-dried Peat ..	3600 ,,	Coal Gas	10600 ,,
Peat Charcoal ..	6500 ,,	Blast Furnace Gases ..	1070 ,,
Brown Coal	6400 ,,	Carbon Monoxide ..	2403 ,,
Dry Coal	6900 ,,	Alcohol	7183 ,,
Ordinary Coal ..	8100 ,,	Ether	9027 ,,
Bituminous Coal ..	8300 ,,	Methyl Alcohol ..	5310 ,,
Anthracite	8000 ,,	Turpentine Oil ..	10850 ,,
Coke	7100 ,,	Sulphur	2165 ,,
Crude Oil—		Rape Oil	9500 ,,
Heavy Pennsylvania	11520 ,,	Lard	9380 ,,
Heavy Caucasian ..	11188 ,,	Tallow (Beef)	9357 ,,
Light Caucasian ..	12240 ,,		

Table VII. (Redwood) gives the calorific value of various Fuel Oils of different origins:—

Source of Sample.		Calories.	B.T.U.
Lucas Well, Spindle Top, Jefferson County ..		10·874	19·574
Higgins Oil & Fuel Co.		10·992	19·785
Sour Lake, Hardin County		10·201	18·362
Sour Lake, Hardin County		10·305	18·694
North-east of Fort Stockton		9·655	17·387
Near Dunlay, Medina County		9·372	16·807
Dullnig Wells, Bexar Co.		8·531	15·356
Walsh Tract, Bexar Co.		9·177	16·518
Burma Fuel Oil		10·794	
Borneo Fuel Oil		10·371	
Texas Fuel Oil	S.G. 0.919	10·670	
Texas Fuel Oil	,, 0.923	10·755	
Texas Fuel Oil	,, 0.935	10·748	
Texas Fuel Oil	,, 0.941	10·957	
Russian Kerosene	—	11·260	
Russian Solar Oil	,, 0 873	10·920	
American Petroleum ..	—	—	
American Spirit	,, 0.684	12·210	
American Spirit	,, 0.694	12·220	

Corresponding values for coal and for other fuels will be found in the preceding table.

I return now to Mr. Booth, from whom I quote the following paragraph :—

"The B.Th.U. in petroleum vary from 17.000 to 20.000, one experiment giving 20.110. The value taken in Texas is 18.500 B.T.U. or 10.277 calories. The scientific investigation of the coals, etc. used there, with respect to their heat units, has not progressed very far; but it is not thought that, on the average, the B.Th.U. in the coals will be above 12.600, if indeed above 10.800, and are taken, for the present, at 11.700. For the lignites a lower value must be taken, and for the present this will be 9.900."

FUEL VALUES.—COMMERCIAL.

Having now considered the thermal value of various fuels, solid and liquid, it may be interesting to devote attention for a few minutes to the final and most important question of their relative commercial value. I submit this information in the shape of three tables culled from various sources. For the first I am again indebted to Mr. Booth who quotes the following particulars from Professor Denton, one of the most eminent American Authorities upon this subject.

Table VIII. (Denton) showing equivalent values for oil at various prices for coal :—

Price of Coal per Ton of 2,240 lbs.			Equivalent price for Oil per Am. brl. of 42 gals.		
\$ 1·00	..	4/-	\$ 0·29	..	1/2½
1·50	..	6/-	0·43	..	1/9½
2·00	..	8/-	0·56	..	2/4
2·50	..	10/-	0·71	..	2/11½
3·00	..	12/-	0·85	..	3/6½
3·50	..	14/-	0·99	..	4/1½
4·00	..	16/-	1·13	..	4/8½
4·50	..	18/-	1·28	..	5/4

As the Imperial gallon is one-fifth larger than the American gallon, one-fifth must be added to each of these prices to arrive at the value in British measure and price.

I am glad to be able to submit two tables by a British authority upon the cost of fuel. For these I am indebted to Mr. C. E. Stromeyer, Chief Engineer to the Manchester Steam Users' Association, who has kindly furnished me with a copy of his report for 1911, with permission to quote from it.

Table IX. (Stromeyer) showing relative prices of oil and coal if equal economic results are to be obtained:—

Crude Oil, per ton ..	Shillings	35	40	45	50	55	60
Crude Oil, per gallon..	Pence	1·75	2·0	2·25	2·5	2·75	3·0
Good Coal, per ton ..	Shillings	26	30	34	38	41	45

Table X. (Stromeyer) showing relative prices of oil and coal used in various engines:—

Fuel.	Per ton.					
Crude Oil for Diesel engine ..	35/-	40/-	45/-	50/-	55/-	60/-
Petrol ,, ,, ,,	44/-	50/-	56/-	62/-	69/-	75/-
Coal for producer gas engine..	11/6	13/6	15/-	16/-	18/6	20/-
Coal for gas-fired boiler ..	8/6	9/6	10/6	12/-	13/-	14/-
Coal for steam engine . ..	10/-	12/-	13/6	15/-	16/6	18/-

The following particulars of a twenty-four hours' trial and of the first voyage from Hamburg to Havana of the Diesel Engine ship, *Christian X.*, are taken from "Engineering" of 3rd January, 1913.

Table XI. Fuel Consumption of Diesel Engine ship, *Christian X.*:—

Details.	Trial, 24 hours.	Voyage of 4,627 nautical miles occupying 17½ days.
Power of main engines	2,383 I.H.P.	2,390 I.H.P.
Fuel used in 24 hours	8·545 tons	9·732 tons
,, per I.H.P. per hour	0·149 Kilos	0·168 Kilos
,, ,, ,, ...	0·338 lbs.	0·370 lbs.
Power of Auxiliary Compressors ..	216 I.H.P.	
Fuel per 24 hours	840 Kilos	
,, ,, I.H.P.	0·162 Kilos	
,, ,, ,, ...	0·365 lbs.	

The *Christian X.* was built and engined by Messrs. Burmeister and Wain, of Copenhagen, and is a sister ship to the *Selandia*, built and engined by the same firm, which many of us in this room had an opportunity of visiting when she was in the London Docks.

The main dimensions of both ships are:—Length, 386ft.; beam, 53ft.; depth, 30ft.; draught, 23½ft. at 7,400 tons displacement; gross tonnage, 4,900 tons. Two Diesel Main Engines, 1250 H.P. each = 2500 total, and two propellers give a speed of $11\frac{1}{4}$ knots.

The main engines are four cycle motors having eight cylinders, each $20\frac{7}{8}$ inches in diameter and $28\frac{3}{4}$ inches in stroke; they run normally at 140 revolutions; the main engines also drive the compressed-air service high pressure pumps.

The auxiliary engine equipment comprises a pair of 200 Horse Power Diesel engines, driving dynamos and compressors, sanitary cooling and lubricating pumps, winches, steering engines, etc.

In my earlier remarks I called attention to the fact that the best results in comparing oil with coal were not to be obtained by using oil instead of coal in furnaces for raising steam, but by utilizing oil in internal combustion engines, and while, from the data scattered throughout my paper, it appears that the effective value of oil for steam raising may still be taken as from fifty to one hundred per cent. greater than coal, its value in an internal combustion engine may be from three to four times that of coal.

Gentlemen,—Many years ago a good old friend of mine, a genial Irishman, sent me a New Year card wishing me—"a long life, an easy death, and a merciful judgment." I have enjoyed the first, I hope for the second, and I now throw myself on your charity for the last.

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DISCUSSION.

Chairman: I think we have enjoyed listening to Mr. Wilson's paper on Liquid Fuel as much as we did to that which he read on the former occasion when he appeared before us. The subject is now open for discussion. Emphasis is laid upon the question as to the lubricating oil which is suitable for an internal combustion engine, a point which should provoke a good deal of discussion.

Mr. F. M. Timpson: We must all agree with Mr. Adamson's remark that Mr. Veitch Wilson has given another very useful and valuable paper to the Institute. As the Chairman remarked, there is a good deal of discussion on this question of lubricating oils for internal combustion engines, and I think I am correct in saying that more mineral than vegetable oil is used for that purpose. It is therefore peculiar that this should be the case if, as Mr. Veitch Wilson states, the conditions are similar inside a cylinder as in the open air. I raised the question with a large firm of internal combustion engineers, who are makers of light engines, and they said their general practice was to use mineral oils which they had found to be extremely satisfactory. These good results have been obtained, not only in light, but also in heavy engines. In connection with the use of liquid fuel, I think it is beyond doubt that to burn liquid fuel in the open furnace is out of the question at the present prices, and the only method of using it with greater economy than coal is by means of the internal combustion engine. Mr. Wilson's remarks on the use of the word "crude" are very necessary, as the term is used by many without knowledge of facts. Crude oil as such is too valuable a product to the oil producer to come on the market for fuel. A more correct term is the "residue," and as chemistry advances the supply of residue decreases materially. In fact when one sees the large tank vessels discharging crude oil and filling up the bunkers from the various coal tips there does not seem to be much prospect of ever getting sufficient supplies of liquid fuel. It is largely the question of supply of fuel oil which has prevented the greater adoption of the internal combustion engine in large sizes, and no doubt all pioneers have to pay heavily for their experience. Certainly progress is being made, and in this country alone there is a fair proportion of large size engines under construction, and, generally sneaking, internal combustion engines for the heavier oils, such as solar, are being manufactured in greater numbers year by year. I should like to express my appreciation of the facts given by Mr. Veitch Wilson and of the valuable items, both historical and commercial, brought to our notice.

Mr. J. H. Williams: I agree that we have had a very interesting paper. The point I am chiefly interested in is the matter of the introduction of the lubricating oils. I do not quite see the point the author makes regarding the unsuitability of the mineral oils or the vegetable oils. I think the trouble found with lubricating oils inside the internal combustion engine is largely due to the manner in which they are introduced. The fuel is introduced into the cylinders under the conditions almost in which they are going to burn. The lubricating oil is put in neither heated nor under pressure. It is put in as a lubricant, therefore it remains as a lubricant and does not burn as quickly as fuel, with the result that it carbonises and is not consumed. Any oil introduced under those conditions would give the same results—there would be a deposit. Mr. Timpson remarked upon tank steamers bringing in oil and then taking coal for the bunkers. Most of those vessels come from countries where they cannot get oil for fuel in any quantity. The northern states of America, for instance, do not produce much fuel oil.

Mr. J. Clark: The author gives a table, prepared by the Belmont chemists, showing the amount of air required for combustion of the various fuels. This is an admirable table; I have never seen one prepared in such a way before, and it gives at a glance all that is wanted. There is another extremely important statement made: "The presence of oxygen in a combustible containing hydrogen has the effect of reducing its heating power, as the oxygen, to the extent that it is present, combines with the hydrogen to form water, but without evolution of useful heat." It is astonishing how great a number of furnace improvers—I was going to call them furnace engineers, but I am not sure if that is the proper title—get round the theory of this question of hydrogen. They do not bring it forward that there is not useful heat except there is no moisture present. The experiments Mr. Veitch Wilson carried out did not allow for the factor of the amount of air brought in contact with the fuel. Without a doubt you can make smoke at any time if the air supply is not properly mixed. In the pamphlet which has been handed to us an illustration is given of H.M.S. *Indomitable* going at full speed with coal fuel, showing clouds of smoke coming from the funnels, and on the next page is shown H.M.S. *Vanguard* steaming on liquid fuel, with complete absence of smoke. I suppose it is claimed that liquid fuel does not make smoke; but many fuels do make smoke, and make it badly unless they are carefully watched. With regard to lubrication, Mr. Wilson confined his remarks entirely to the lubrication of internal combustion engines; but there is also the lubrication of steam engines to be considered, and I gather from Mr. Wilson's remarks that he considers the compound oils to be more suitable than the hydro-carbons. That may be, so far as lubrication is concerned; but with the use of superheated steam, what is the effect of the separation in the water of condensation? Superheated steam, I believe I am right in saying, splits up the constituents of animal or vegetable oils, whereas in pure hydro-carbons it has no effect. Perhaps Mr. Wilson would refer to that in his reply.

Mr. F. O. Beckett: Mention has been made about the petroleum or gas turbine. I am inclined to think that the metallurgists will have to make a metal that will withstand the great heat of the internal combustion engine on the turbine principle before it will be a commercial success. The author also referred to the Bonecourt boiler, working under blue flame conditions. I had the pleasure of examining one of these some time ago at an exhibition, and it appeared to give very good results; far better results than are obtained with the gas or coal fired boilers. This surface combustion is certainly to be commended to anyone who desires to prevent smoking. It produced sufficient steam to keep two engines going on a much reduced heating surface area as compared with the ordinary marine boiler. The only drawback was the increased use of the air pump or gas pump necessary to pass the air through the tubes containing the refractory material.

Mr. Duncan Barr: We are all much indebted to Mr. Veitch Wilson for his paper to-night; there was one point that interested me particularly, and that was the extract from Mr. Norman Henderson's letter, as I am experiencing the same trouble in getting rid of the tarry residue of a gas producing plant running on waste wood. I think Mr. Wilson promised us a sketch of a burner which was used in that instance. It is a subject of great importance to myself, and perhaps there are some others who would like to see it.

Mr. Veitch Wilson: Is there much tar?

Mr. Barr: Not very much.

Mr. Veitch Wilson: We have a 100 h.p. engine running on sawdust.

Mr. Barr: This is one of 400 h.p. Mr. Henderson had to get rid of the waste tar by running it on to the shale heaps, but, unfortunately, in the centre of London one cannot do that.

Mr. Timpson: There is a good deal in Mr. Clark's remark on the proper mixture entering the cylinders for complete combustion of the oil, and a great deal depends on the manner in which the oil is injected.

Mr. G. Adams: I should like to ask Mr. Veitch Wilson how he arrives at the results of his investigations with regard to ascertaining the calorific value of these oils. We carry out some experiments here in the Institute with coal samples, but we have not got the length of testing oil, and in view of future possibilities a hint from Mr. Veitch Wilson might be of value to us.

Mr. J. Williams: With regard to the question I raised of the introduction of lubricating oils, I think it is a fact that many makers of internal combustion engines—those not of a high pressure type—recommend that the lubricating oil should be introduced with the fuel. Is not that so?

Mr. Timpson: I know of several motors where they mix the oil and petrol, and that performs the lubrication of the whole motor.

Mr. J. Shanks: I am not an expert on either the burning of oil fuel or the internal combustion engine. At the same time all marine engineers are interested in them, and this question of lubricating oils is of special interest to me. I would like to know from Mr. Veitch Wilson with regard to the vegetable oils and mineral oils shown burning, if the one smoking most, which he calls a lubricating oil, is a pure hydrocarbon.

Mr. Veitch Wilson: It is a pure hydrocarbon; of the other two, one is olive and the other is rape.

Mr. Shanks: I consider that to be an important demonstration. In the Diesel engine, so far as I understand, it is not possible to introduce a lubricating oil with the combustible. It must be introduced separately and it must be a special oil, and the manner in which it is introduced must have a great deal to do with whether it carbonises or not. I was very pleased to hear Mr. Clark refer to the lubrication of the steam engine. At the present day we are making rapid advances in the steam engine. With geared turbines and superheaters we are approaching a degree of efficiency never dreamt of four or five years ago, and with the attainment of this efficiency, on the present market prices of oil there is absolutely no chance of the oil engine coming in as a competitor with the steam engine on the commercial basis. If that difficulty is overcome I am perfectly well aware that the internal combustion engine can be made a success. There are a great many difficulties to be overcome, but on the day when oil becomes cheaper we, as marine engineers, are prepared to take charge of the internal combustion engine and run it as successfully as we have the steam engine. Mr. Veitch Wilson refers in his paper to the safety with which oil can be carried. I think I was one of the first engineers who ever went to sea in an oil tanker. I was in the second German ship built 27 years ago, and I was chief engineer in the first English oil ship in this country. We carried crude oil from the Black Sea and America with the greatest of safety, and at the present day, with the great advances made in the tank ship, there is no danger whatever in carrying the oil all over the world and in using it successfully. If the price of oil goes down we are prepared to take the responsibility of using it successfully.

Mr. J. Veitch Wilson: Mr. Timpson, who speaks as an authority on the internal combustion engine, made the correct statement that mineral oils are preferred as lubricants. I am not alone, I am glad to say, but I am one of very few who recommend fatty oils. I have tried on various occasions at your meetings to establish by these experiments with lamps* the fact that fatty oils are not responsible for the deposits in engines. They may be responsible if the arrangements for combustion are imperfect—any oil in such a case would give deposit. I am struck with the fact that in the internal combustion engine the first recommendation is economy in fuel; people try to get the cheapest fuel available, and they think that if they have that in the engine a similar cheap oil will do for the lubrication. I think that if they save on their fuel they ought to spend a little more on their lubrication. What I now say will apply to the remarks of two or three gentlemen. Mr. Clark pointed out that a deposit is not entirely due to the oil itself, as any oil might, if properly adjusted, be burnt without deposit. Granted; but, of two oils, if one burnt well under normal conditions, while another under normal conditions burnt badly, if the conditions are made more severe I do not think the two oils will change places and the one which was worst under normal conditions will supersede the other. The best argument for the superiority of vegetable oils in the internal combustion engine is that when trouble is experienced in a gas or in an oil engine — and I could give many authorities — be it deposit or gumming, it is generally overcome by the use of a vegetable oil. The late Sir William Crossley, with whom I discussed the subject, said: "I am not a chemist, I am an engineer, and I cannot really offer you a reason for it; but this, undoubtedly, I can tell you, that when trouble arises from sticking pistons or valves in oil engines we generally overcome the trouble by using richer, and if necessary still richer, compound oils." Crossley found this

* See footnote on page 112.

out in a very peculiar way. I once interrogated a gentleman who was then a representative of the firm, but who was once an apprentice, and he said: "I think I can tell you how Crossley's came to use superfatted oils in oil engines. I was serving my time in the shop, and when we were testing a big oil engine we used to find a difficulty in starting it in the morning, and sometimes we had to use the over-head crane to move the piston. One evening I said to my mate, 'Let us try this oil on it,' and poured the contents of a can near at hand on the piston overnight. The next morning the piston came away easily. We did it again and again; the foreman was told about it, he told someone over him, and eventually Mr. Crossley made his appearance on the scene. He asked what oil was used. We said we got it out of the oil-can in the shop, and on examining it he found it to be lard oil. The order was then given by Mr. Crossley to use in such circumstances a compound of 60 per cent. mineral and 40 per cent. fatty oil. As a matter of fact for years afterwards Crossley's used a mixture containing 40 to 50 per cent. of vegetable oils. When trouble does occur, it does not occur often, but when it does we overcome it in that way."

The point seems to me to be that many engines are running satisfactorily on mineral oil, and as they give little trouble the engineer does not think, as he might do after consideration, that the position might be still more improved, and at the expense of a few pence more for oil, he might effect a saving in his fuel bill. I remember one man who found that he could save 3d. to 6d. a gallon on the oil, but when the gas bill came in he found he had spent a good deal more on the extra gas than he had saved on the oil. The ordinary gas engine runs very pleasantly if it is not taxed beyond the normal limits; but when a man like Sir William Crossley finds that if trouble occurs it can be overcome in the way I have mentioned, I think we may take it that under ordinary conditions the richer oil must be better for the engines. In addition to Crossley's I could name four or five firms who use rich fatty oils or compound oils. Tangyes have used compound oils since they started; Hornby's use compound oils; Potter's and the "Trusty" use pure or nearly pure vegetable oil, and I do not think these firms would use these oils and would recommend them to their customers if they did not believe there was some value in them. Mr. Clark puts it that it may be due to imperfect arrangements for combustion; but do not these imperfect arrangements occur almost continually when you have an engine working on a varying load? With regard to the various methods of introducing the oil, I think Mr. Timpson spoke of several engines in which the lubricant is introduced with the fuel. The only engine I know of where this is done is the "Gnome," and from its peculiar construction there is no other means of doing it. Are there any others?

Mr. Timpson: It is common with users of motor boats of small power.

Mr. Williams: Many American boats with low pressure engines adopt this method.

Mr. Veitch Wilson: It has not come to my knowledge before, but I see no objection to it. The oil would be spread over the surface and would distribute itself well. Otherwise my own experience has been with the lubricant introduced by various more or less ingenious mechanical devices. On the larger types the pump is in vogue; as in the steam engine circulation by force pump is in use, and I think one or two engines lubricate on the side of the cylinders. But I think the fault many engineers make is that they use the oil too liberally. I am continually telling friends to be sparing with the oil as if it is used too liberally it brings trouble to the user and discredit to the man who supplies it. With regard to the Diesel engine, Dr. Diesel said that pure mineral oil ought to be used, but against that I put his own argument. He recommends his engine because it can use pure vegetable oils. The position he takes up, therefore, seems to be inconsistent. The question of superheated steam, raised by Mr. Clark, takes us away from the internal combustion engine to the steam engine. The temperature of superheated steam, I understand, is being reduced a good deal now. I believe there are some recent engines which are superheated up to 550°; but there is not much difference between thick and thin oils at that temperature. The viscosity of both thick and thin oils drops and they become very much alike; but I would like to point out to engineers that the craving for a very heavy oil to stand the high temperature invariably brings trouble. Mr. Clark is, however, right in his statement that there are material differences between the conditions which occur in the two types. Even in engines using superheated steam I take it that condensation must occur to some extent, and the combined action of heat and moisture must be to decompose fatty oils which are exposed to these influences. On the other hand, although we know that a gallon of oil produces a gallon of water in the course of combustion, the water produced by each explosion must be so small that it must be completely carried off by the exhaust without depositing any moisture in the cylinder and without exerting any effect upon the small percentage of fatty oil which may be present. The crude oil contains a variety of fractions. As it comes from the ground it carries some proportion of bitumen or tar, from 2 to 5 per cent. The American oils used to give about 5 per cent. of residuum and 95 per cent of distillate. The residuum was re-distilled to produce lubricating oil; but if the distillation had been carried on to dryness that residuum would have resolved itself into dry hard coke, and it is evident, if crude oil contains that dry coke, it must be harmful. To produce a good cylinder oil, 50 per cent. of the original volume may be distilled over and in the remaining oil there is the 2 or 5 per cent. as the case may be of the original volume, or 4 to 10 per cent. tar in the reduced volume, and there is danger in introducing this greater percentage of tar. For cylinders in steam engines I am in the habit of recommending the lightest oils that will do the work. There is another question which I do not think has been decided. What should become of the oil in the cylinder? The position is this. One very highly esteemed competitor of my own recommends the use of a thin light lubricating oil. I discussed the matter with him. His argument is that if you use an oil of a fairly low boiling point, that is one which evaporates fairly easily, you are likely to have a clean cylinder because the oil is all evaporated. But, on the other hand, you do not want to do that; you want the oil to have some permanency, to remain there and perform its function as a lubricant. I cannot say that I endorse the idea of using such a thin oil or of using an oil which will be carried away with the exhaust. Mr. Beckett raises a curious question as to whether a gas turbine can be produced. I am not a metallurgist so I will not attempt to answer, but I remember that the first attempt to produce a gas engine was in turbine form. I have heard from time to time of designs for turbines, and I believe I am right in saying that an attempt is being made to produce one in this City just now. With regard to the question of the power obtained from a sawdust plant, as I have said we have a 100 h.p. engine running on gas produced from sawdust and it is working satisfactorily. In the first instance there was some trouble with tar getting into the cylinder, but that was obviated by using a very rapidly revolving fan.

Mr. Barr: We are using a 400 h.p. engine.

Mr. Veitch Wilson: Of course that is a much bigger job. To Mr. Adams I have to make a confession. I hope I have not put myself in a false position; but in the paper I have been largely dependent on the authorities whose names I have given, and I am sorry I cannot help him in giving particulars of how the tests were made, but illustrations and particulars of many of the leading apparatus and methods will be found in a small pamphlet which I wrote some years ago, "Oil testers and how to use them," of which my principals will be glad to send a copy free to any applicant.

A vote of thanks was accorded to Mr. Veitch Wilson on the proposal of Mr. Adams, seconded by Mr. Clark.

The meeting closed with a vote of thanks to the Chairman.

BOOKS RECOMMENDED TO READERS WHO DESIRE FURTHER INFORMATION UPON THE SUBJECT:—

Baku, an Eventful History, J. D. Henry. A. Constable & Co., Ltd., London.

The Diesel Engine, Dr. Rudolph Diesel of Munich. Transactions of the Institution of Mechanical Engineers, 1912.

Fuel Economy, Wm. H. Booth, F.G.S. S. Rentall & Co., Ltd., London.

The Great Oil Octopus (The Story of the Standard Oil Co.), by "Truth's" Investigator. J. Fisher Unwin, London.

Liquid Fuel & its Apparatus, Wm. H. Booth, F.G.S. A. Constable & Co., Ltd., London.

Liquid Fuels for Internal Combustion Engines, R. W. A. Brewer, A.M.Inst.C.E., A.M.I.M.E., M.I.A.E. Society of Engineers of England, 1907.

Memorandum by the Chief Engineer for the year 1911. Manchester Steam Users' Association. Taylor, Garnett, Evans & Co., Ltd., Manchester.

Oil Shales of the Lothians.—Part I., Geology; II., Method of Working; III., Chemistry. Printed for His Majesty's Stationery Office, by James Hedderwick & Sons, Ltd., Glasgow.

PAMPHLETS by Charles Marvin:—

"Baku, The Petrolia of Europe."

"Moloch of Paraffin."

"Coming Deluge of Russian Petroleum."

"England, a Petroleum Power."

"The Coming Oil Age & the Great Canadian Oil Fields."

R. Anderson & Co., London.

PETROLEUM, the Motive Power of the Future; Walter Seldon Tower, P.L.D., and John Roberts, F.G.S., M.Inst.M.E. Hodder & Stoughton, London.

THE PETROLEUM INDUSTRY, Sir Boverton Redwood, Bart.; Groves & Thorp's Chemical Technology, Vol. II. J. & A. Churchill, London.

THE PRODUCTION OF PETROLEUM IN 1910, 1911, 1912, 1913, by David T. Day, and numerous pamphlets on Petroleum and Natural Gas. Department of the Interior, U.S. Geological Survey, Washington.

THE RELATIONSHIP OF STRUCTURE AND PETROLOGY TO THE OCCURRENCE OF PETROLEUM, A. Beeby Thompson. The Institution of Mining and Metallurgy—1910 1911.

THE SHALE INDUSTRY OF SCOTLAND, R. D. Steuart, F.I.C. Reprinted from Economic Geology, Vol. III., No. 7, 1908.

A TREATISE ON PETROLEUM, Sir Boverton Redwood, Bart, D.Sc., F.R S.E., C. Griffin & Co., Ltd., London.

INVESTIGATIONS AND RESEARCHES for the Construction of my Large Oil Engine. H. Junkers, Aachen, (Aix-la-Chapelle). Vorlag von Fachliteratur, G.M.B.H. (Technical Publishing Co.), Berlin and Vienna, 8, Broad Street Place, London, E.C.

NEUERE ROHÖLMOTOREN, Ch.Pöhlmann, C. J. E. Volckmann, Nachf, G.M.B.H., Berlin-Charlottenburg, 1912.

DIE VERBRENNUNGS MOTOREN, Georg Lange. H. A. Ludwig Degener, Leipsig.

ELECTION OF MEMBERS.

The following were elected at a meeting of Council of the Institute held on Wednesday, July 22nd, 1914:—

As Members.

Reginald W. Coomber, 92, Osborne Road, Jesmond, Newcastle-on-Tyne.

W. L. Curnow, 94, Canton Street, Poplar, London, E.

Alfred J. Harrison, 292, Beverley Road, Hull.

Douglas H. Jackson, Harborough, Milngavie, Scotland.

Edmund J. Platt, Combwell Farm, Thinwell, Hawkhurst, Kent.

E. F. B. Robinson, 1, Castleton Mansions, Riverview Gardens, Barnes, S.W.

Wm. M. Shaw, Messrs. H. & W. Nelson, Ltd., Liverpool.

Transferred from Associate Member to Member.

T. Seabrooke Wallis, A/B Surte-Litjedahl, Surte, Sweden.

LIQUID FUEL.

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